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Standby

Standby Consumption in Private Homes Socio-economic Studies, Mapping and Measuring Reduction? What Works: Campaigns or Hardware Solutions?

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Abstract:

The paper will sum up the findings from a standby project carried out in Denmark over a period of 2 years involving 30 households. The purpose of the project is to verify to what extent standby losses in household consumption could be affected by direct communication and by use of technical equipment to reduce the standby losses. The analysis will include studies on how socio-economic status and life style is affecting the standby consumption.

In Denmark standby losses are estimated to be approximately 970 GWh/year. One consequence of this consumption is emissions to the environment by approximately 821 million tons of CO2. It is estimated that standby power is responsible for 1% of the global CO2-emmisions from end uses including transport, industry, agriculture and waste disposal in general.

Increased use of electronic household devices will also increase standby losses. The average share of household energy consumption related to standby losses has increased over the recent years, and will undoubtedly continue to increase over the forthcoming years. However, when the losses for each single device (TV, video etc.) are considered separately, the standby losses and the savings potential are small. However, all devices collectively contribute a significant proportion to total electricity consumption. Earlier campaigns have all focused on changing behaviour of the customers but this most recent study also examined a range of technical solutions to reduce standby.

This new Danish project focuses on standby losses within a group of households over a period of 12 months. The group, containing of 30 households with 2 adults and 2 children each, has received advice and information on how to change behaviour in order to reduce standby losses. Furthermore the group has been equipped with technical equipment as additional means to reduce losses. This equipment (save-plugs and newly developed equipment with low standby) will be presented as a part of the presentation.

Energy consumption due to standby losses in the 30 households has been measured (on each piece of equipment with standby power, some online and some as spot measurements), and this data has been analysed and is presented on a website where the households can follow their own consumption in real time. From these measurements the paper will also include descriptions and analysis of consumer behaviour related to the appliances and devices.

Introduction

First of all this paper deals only with standby consumption in the household sector, and the kinds of equipment that can be connected with a plug, and primarily entertainment and office equipment (ie equipment that is wired directly to the power system has not been covered).

In 1993 at the ECEEE conference in France, Sandberg presented a paper on standby consumption (which he called “leaking electricity”). Standby consumption was more or less neglected, despite Sandberg'e conclusion that, on the basis of the research he had carried out in Sweden, standby consumption 15 years later would be projected to be about 400 kWh/household per year in Europe. At the ECEEE conferences in 2003 and 2005 several papers were presented on the standby issue by Harrington and Meier, among others Standby consumption has also been discussed in many related reports and projects, there has been a particular focus on how to define standby consumption, how to estimate it, and how to influence the producers to realize the importance of designing equipment with low standby consumption and to produce products with low standby.

The IEA has recommended not putting much effort into discussing definitions, even though they have an important role to play, because they would like to see actions, but rather working for politically initiatives to reduce standby consumption. An example how efficient these can be is the Executive order issued by the President of US (Executive Order 13221), claiming that agencies when buying available off-the-shelf products, shall buy products that cause no more than one Watt when in standby mode. This executive order has had a very high impact on the total office product side.

But it is also important to realize that there is another side of the coin with respect to a lack of commonly agreed definitions. Firstly, where there are no agreed definitions for modes then manufacturers have to cope with a range of different definitions which apply in different countries. This was noted by HP's delegate on the "Action on 1 Watt" conference in Copenhagen, March 2005.

Secondly it has been pointed out that the generic term "standby" can refer to many different modes of the same appliance, therefore it is appropriate to differentiate between different modes for different appliance types. For instance, a VCR can have several modes such as active standby (waiting to play), delay start (VCR programmed to record later) and passive standby (shot down but waiting for a remote signal) (Lane & Wajer 1997). Another example is that computers and printers have a range of different types of sleep modes depending on usage regimes and user programmable features. A general taxonomy of such so called 'lopomo', (so called low-power-modes), has been suggested by several authors including Meier (2005) and another paper at EEDAL (Nordman et al 2006).

There are at least two different ways to determine the total magnitude of standby energy consumption in households. Either through bottom-up models where market statistics on ownership of appliances and equipment are combined assumed usage patterns and known power consumption attributes to provide a model of household standby electricity consumption. This has been done in a US study, which concluded that approximately half of the total electricity consumption from consumer electronics are consumed while the appliances are in standby mode (Sanchez et al. 1998). The other way to determine the size of standby consumption, is to directly measure it. However since there is no common definition of standby consumption, there is no one commonly agreed approach to determine it. Another American study is based on spot measurement of electricity consumption in ten households for all appliances in the mode which the households normally leave the appliances (Ross and Meier, 2002). However, this measurement approach does not really capture the actual behaviour of the households. The most accurate way to measure standby consumption is to have continuously measurements of both in-use and standby consumption of appliances in ordinary households.

The most comprehensive study done so far in this way is probably the EURECO-project including 100 households each in four European countries, the measurements including all appliances and lighting in the households, measured during one month (Sidler, 2003). However, individual meter used for this project were unable to measure power consumption levels less than 3 Watts so limited information on standby can be obtained from this data set for many appliance types. A similar project is currently being carried out in Sweden by the National Energy Authority, including 400 households, where 90% of the households are measured during one month and the remaining 10% of the households will be measured during a period of 12 months (Bennich 2006). The Danish part of the EURECO-project data has been analysed further, and it has been concluded that standby consumption for consumer electronics in the Danish households varies between 0 and 1300 kWh per year , on average 8% of the total household electricity consumption is attributable to standby power . More than 10% of these households had between 15% and 28% of their total electricity consumption as standby (Gram-Hanssen, 2005). A recent review study, including both published and unpublished studies, concludes that standby consumption in developed countries is between 60 and 110 W per household, corresponding to an average of between 4% and 11% of the household total electricity consumption (Meier, 2005). European households are in the lower end with 50 to 70 W/household and year (although many of the preliminary studies in Europe only considered a limited range of appliances and equipment when quantifying total standby), with countries like Denmark in the upper end (Meier, 2005). This suggests that Denmark does not necessarily have an inherently worse standby profile than other countries in Europe, but more likely has more carefully quantified the standby for all appliances and equipment. One of the sources for the conclusion are based on preliminary results from the study presented in this paper.

The question of how to limit standby consumption is an issue raised in most of the reports and articles and many concentrate on how to influence the producers of consumer goods to develop products with low standby consumption attributes. It is generally agreed that there is no technical problems in achieving this, and the question is, which political tools are the most effective (IEA, 2001). However, it might also be

relevant to analyse to what extent it is possible to persuade consumers to turn reduce standby of their existing appliances and equipment, either through the modification of their behaviour or with the help of technical devices.
This project been investigated the extent to which it is possible to limit standby consumption in consumer-oriented approaches, and which of these are the most effective ones: either different types of communication or the installation of technical devices.
The results presented in this paper is based on a project supported by the Danish association utilities, and with participants from Danish Building Research Institute, Keep Focus, The Danish Electricity Saving Trust and Lokalenergi. The project had a total budget of 286 000 Euro.

Method

The overall objective of the project was to monitor the standby electricity consumption in 30 households during a whole year with the help of on-line measurement, while they where exposed to different kinds of program measures aimed at changing their standby consumption. To assess each of the different program measures, 3 phases were monitored during the project:

1 *Reference period*, where the standby consumption is quantified prior to implementation of any measures.
2 *Communication period*, where the families are subjected to different types of communication, including posted leaflets, visits from an energy adviser and the possibility of following their own metered standby power consumption on a webpage.
3 *Technology period*, where different types of technical devices to reduce standby power (eg devices which make it easier to manually turn off products or products are automatically turned off), has been handed out. Technical devices include auto-saver plugs for television and PC, remote control or time switches for power boards.

Due to the limited resources available, the focus has been on the consumption of entertainment and office products. There have also been spot measurements of standby consumption on other products such as cordless phones, touch lamps, cell-phone chargers etc. Through the online measurement of the entertainment and office products it was possible to determine when different groups of appliances were either turned off, in standby or in use. The recorded electricity consumption data has been analysed from the perspective of information about the families such as number of members, age, income etc.
For this project standby been defined as consumption of the appliance when it is not actively used by one or more persons.
The families were selected with a focus on the following characteristics: family living in single-family houses, generally with children still living in the household, families with equipment which have significant standby power. The reason for this decision was that the main target of the project was not to estimate the size and composition of the standby consumption for all households, but to understand what works regarding behaviour and reducing standby losses.
The families were selected with the help of the database of the local utility, in all 270 families were contacted. Among the criteria was a total electricity consumption above 5 000 kWh/year.
One consequence of the selection criteria was that the participating families on average had a higher total income than average families in Denmark. This is not surprising due to the fact that the project only consists of families living in single-family houses. The participating families' electricity consumption is also above average.

The online measurements

The main contractor for the installations of equipment for the on-line measurements has been the company Keep-Focus. Their data server has also served as host for the data collection and for the web page where the participants could follow their own patterns of standby power consumption.
Typically four data loggers where used in each house. Since a large part of the entertainment equipment and office products are used together, the procedure has been to connect all entertainments products in a room to one channel of the data logger, all the office products to another channel, and so on. The data was logged with a time resolution of one hour. Logging data in 30 homes over one year includes challenges; loggers fail, people move there equipment around within the home, they buy new pieces of

equipment and forget to tell the project staff about it. The project staff has tried to "repair" such incidents as soon as they were discovered in order to secure high quality and consistent data.

The phases

The communication phase was designed with the purpose to test different communication measures. The measures that where selected for test were:

Information meeting – cancelled due to the fact that too few people signed up for participation.

Direct mail together with folders on "Efficient use of electricity" and "How to reduce standby consumption"

Home visits from a "standby consultant", with the purpose to visualize the standby consumption, with the help of metering of standby consumption of all products included in the project. The metering results were mailed to the families a few days after the visit together with a list of proposals on how to "kill" standby consumption.

The last activity included access to a personal web page where the families could follow their own standby consumption from all the data loggers installed in their homes.

The technical phase was designed to test how much standby consumption could be reduced with the help of so called "standby killers" such as:

Master – slave auto power saving plug banks, that automatically power down any equipment (VCR, DVD, TV etc) when the unit connected to a master plug is switched off.

USB auto-power saving-plug banks, which automatically power down any connected equipment (monitor, printer, etc.) when the computer is switched off

Remote controlled powerboards

Timer controlled powerborads

Interviews

At the end of the metering phase, 10 families where selected among the 30 for interviews. The criteria for selection were those where standby consumption had been influenced during the communication phase, during the technical phase, or where there was no change of standby consumption at all. The purpose of the interviews was to assess the families' experiences from participating in the standby project and to correlate their standby behaviour and the families' opinions on standby consumption.

Results

This results commence with a description of the standby consumption in the reference period, which was the period before any actions was taken to influence the families in the project. This is followed by an analysis of how the families use there appliances and how the different actions influenced the standby consumption.
The size of the standby consumption can be assessed in relation to the total electricity consumption of the families. The standby consumption can also be related to different types of consumption such as entertainment or office, the age of the families, total income of a family.

When relating standby consumption to the total electricity consumption of the household, it can be concluded that there is no unique relationship. From the available data it can be calculated that on average 9% of the total consumption is standby consumption, covering a spread from as little as 2% to as much as 18%, corresponding to 120 kWh/year to 980 kWh/year or an equivalent continuous load of 17 W to 130 W, with an average of 67 W. This is nearly of the same level as assessed in other projects, such as EURECO. Due to the limited resources available for the project it has only been possible to online meter 65% of the standby consumption from office and entertainment equipment in the private homes, the rest is estimated with help of spot measuring.

There appears to be no clear connection between family type and the magnitude of standby energy consumption. With the help of spot metering on cell-phone chargers, cordless phones etc. together with online metering results, it can be concluded that standby consumption related to home office equipment is on average 37 % of the total standby consumption for the families monitored.

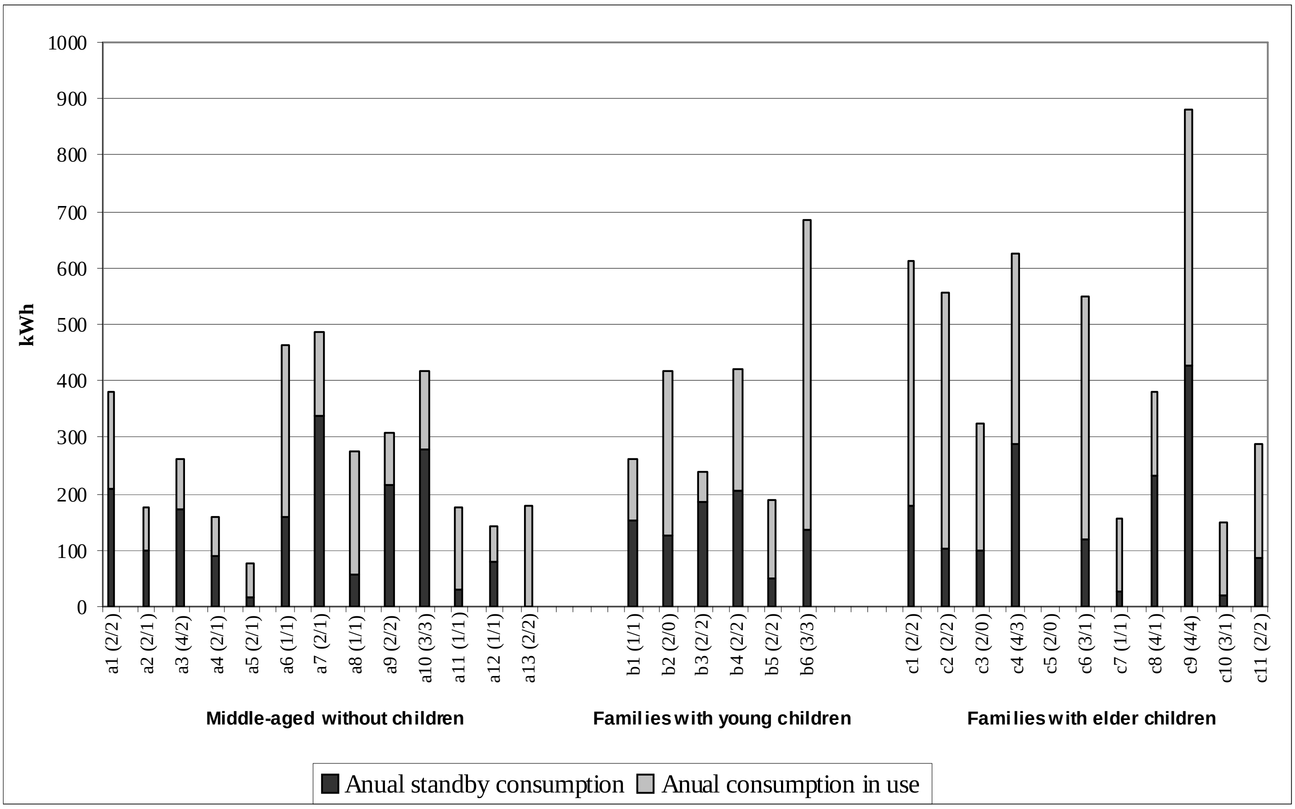
It was found that standby consumption increased with increasing total household income for the families in the study. But because of limited material it is not possible to show any significant results of these types of correlation.

The metering results from the reference period clearly show that the majority of the families have significant standby energy consumption for entertainment equipment. This is generally equal to or larger than the energy consumption in on mode. However, the results show, not surprisingly, that families with teenagers living at home (which tend to have their own entertainment equipment) have higher energy consumption in on mode than in standby mode(s). This is also reflected in the use of office products, where families with teenagers clearly have longer periods and higher energy consumption in on mode than in standby mode(s).

On average for the sample monitored, 42% of the measured electricity consumption for entertainment and office products was in standby mode(s), while 58% was when the equipment was in use.

The following 3 figures illustrate the results for the reference period. Figure 1 shows the consumption as part of total electricity consumption in the 30 households, arranged into three groups; middle aged (older without children living in the household) (to the left in the figure), families with smaller children (in the middle of the figure), and families with teenagers living in the household (to the right in the figure).

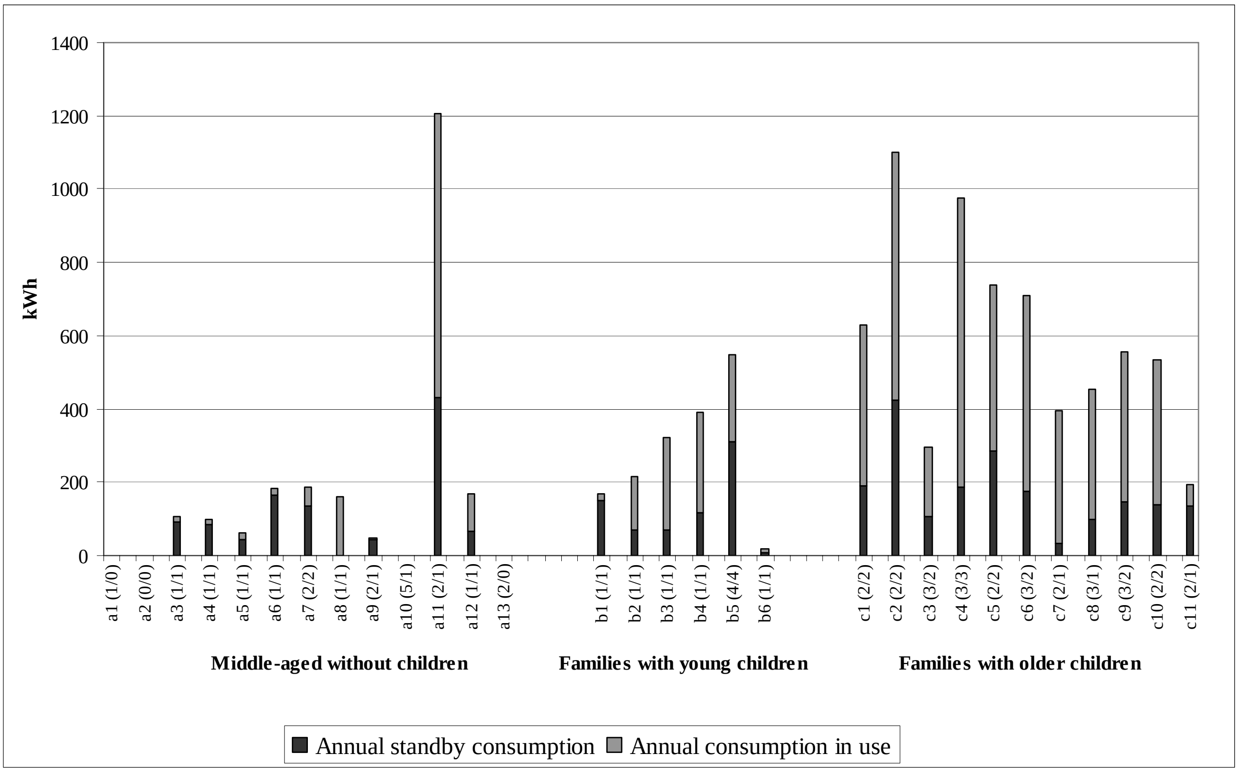
Figure 1 show the electricity consumption pr. year for entertainment equipment, distribution in use and in standby mode.



Numbers in brackets(x,y): x: number of television sets in the household, y: number of television sets measured.

Figure 1: The electricity consumption pr. year for entertainment equipment, distribution in use and in standby mode

Figure 2 shows the annual electricity consumption for office equipment, distribution in use and in standby mode.



Numbers in parentheses (x,y): x: number of computers in the home, y: number of computers measured.

Figure 2: The annually electricity consumption for office equipment, distribution in use and in standby mode.

As described earlier, different actions were taken in the communication phase of the project to trace changes in behavior among the families.

The communication phase was followed by a technology phase, where energy advisers again visited the families to offer them technical devices to reduce standby consumption. The average standby consumption has been calculated in five steps, in order to assess which of the initiatives have measurable effects.

Figure 3 shows that sending out written material and leaflets have almost no effect. Similarly access to a homepage where the families' standby consumption was shown (on the basis of online measurements) also appeared to have little effect. A real change in the behaviour of the families and thereby in the standby consumption was observed when an energy consultant visited the individual families. With the help of a small electronic meter, which was used to take spot measurements on each piece of equipment in the household, the consultant was also able to demonstrate how much electricity is wasted as standby consumption. Among the tools the consultant had at their disposal were samples of “standby killers”, which were used to inform the families of the possibilities to reduce their standby consumption through technology. The visit by the consultant where the standby consumption was visualize together with a presentation of standby killers resulted in a reduction of standby consumption by about one third compared to the reference consumption . The last action was a visit by an energy consultant who installed “standby killers” to make it easier to switch of standby, this resulted in an additional reduction of standby losses to a level that was about one third of the original reference. The conclusions from figure 3 seem rather simple: public campaigns and continuous information on standby consumption are of minor or no use, while individual advice and technical devices result in real reductions in standby. Looking back it is clear that it could have been very interesting to check the effect of standby killers alone.

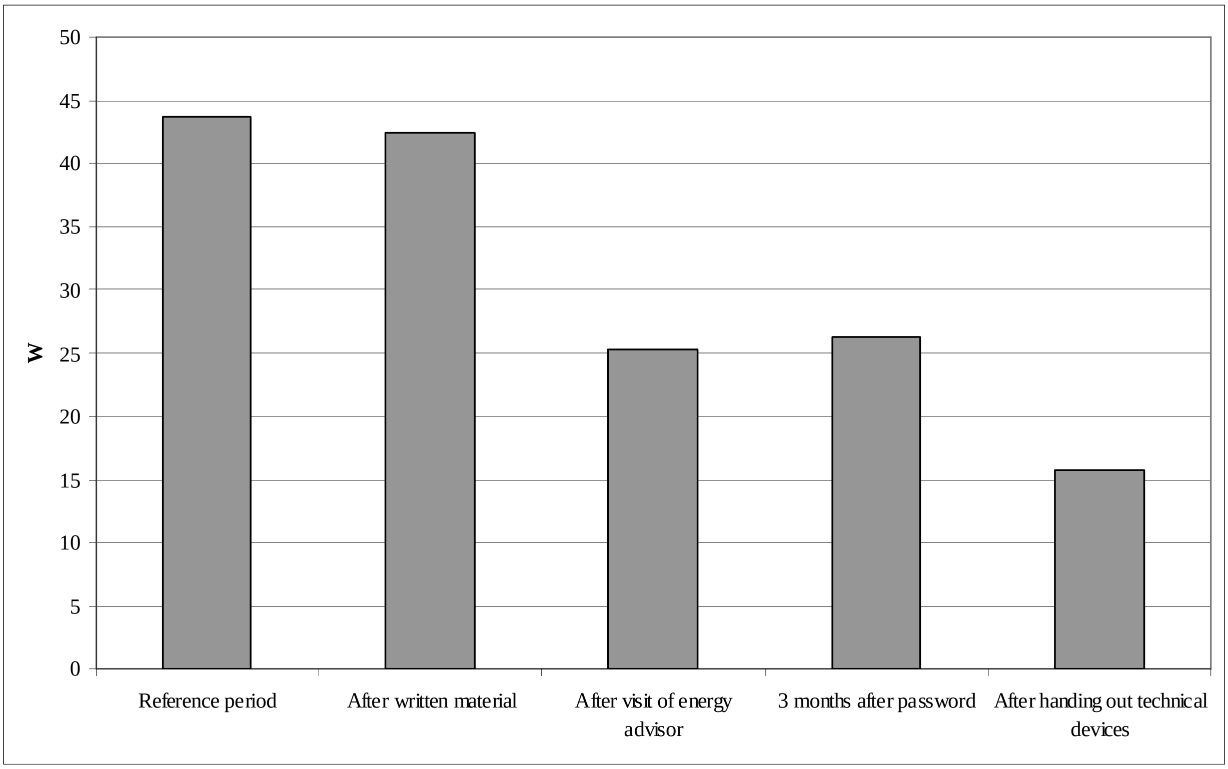


Figure 3. Development in the average (measured) standby consumption in different phases of the project, 3 month after password, means when the families got access to their personal part of the webpage.

But before jumping to conclusions, it is worth looking in more detail at the information collected through the project.
The first question to discuss is to what extent the reference period represents the 'normal' standby consumption or whether the fact that the measurement devices have been installed has altered the user habits. Two things indicate that the reference period is representative of the normal standby consumption levels: first from the interviews it was concluded that many of the families were conscious about not changing their habits initially as they understood that the installation of the meters was to establish their normal behaviour. Secondly, it was observed later in the project that attempts to change the households habits were not very successful, which suggests that just putting measurement devices in the household is not likely to influence their behaviour in any significant way. There where not registered a clear trend in the development of the whole house consumption.
The next question relates to the influence from the written material, including a leaflet sent to the families one to two months after start of project. As seen in figure 4, there is almost no positive effect on standby consumption from this initiative.

From the interviews with the ten families selected for in depth interviews, we learned that some of the families were confused about the material received. For example, some indicated that they did not know whether they were still in the reference period or whether they were supposed to react to the material. Thus in this phase the families' behaviour is clearly influenced by being part of the project. The effect of the written material has been qualitatively evaluated through interviews in the following ways: some of the families considered it to be one of the many small inputs pushing them towards doing something, others (a majority) read the material carefully but only because they where part of the project and others just threw it away without reading. The project thus does not indicate any significant effect of sending out written material.
Figure 3 shows the average of how the families reacted to different initiatives of the project. However, this average includes some major differences between the families. In some families, most of the decrease in

standby consumption occurred immediately after the first visit of the energy adviser, whereas in other families there was almost no reduction in this phase of the project. The families who responded to the first visit, have something in common: they consider standby consumption to be wasteful, mainly of money but for some also of natural recourses, and they also found it very easy to change their behaviour. In some families they simply started to use the on-off button of the appliances instead of the remote control, in some cases they rearranged the cords and plugs making it easier to turn of many appliances on the socket outlet with a single action. In these cases one person appeared to take an "evening walk" through the house, turning of lighting and also equipment with some standby consumption. Some families even bought “standby killers” in order to make it easier to turn of standby consumption.

The families who did not respond to the first visit also have something in common. Typically they did not find the amount of energy or money they use for standby alarming, although it was comparable to those families that found it wasteful. In context, even though the electricity price is high in Denmark (22 Euro cents per kWh) , the cost of an average yearly electricity bill is a small share of the total household budget. Danish families, like the ones in this project, typically spend 1.5 times more money on communication and entertainment such as cable TV and telephone, so raising the relative importance of standby is a challenge, also from the perspective that standby is only “10 %” of the total bill. (They will have an total electricity bill in the size of 1100 Euro and a total “commucation” bill in the size of 1600 Euro)

In the technical phase “standby killers” were handed out to the families half a year later. The delay was intentional, and primarily because we wanted to establish whether communication had a long-time effect or whether it would fade away in time., and due to the fact that there was a summer season to pass, where normally the focus in Denmark are more related to outdoor activities. Assessments of the data clearly indicate that, although small, the changes in the habits resulting from the communication phase were lasting; this was also supported by the interviews. During the interview there was focus on whether the family members thought they would continue their new habits, for instance by turning off standby every evening before going to bed. A typical answer to this question was: 'Of course, because it has become a routine which I just do without thinking about it'.

In the technical phase, an energy adviser walked through the house together with the family members of the household, and proposed different types of “standby killers” for different types of standby consumption. Among the families that did not respond to the actions in the communication phase, the technical phase was more impressive, especially where the energy consultant installed the “standby killers”. Further analysis has shown that standby consumption from entertainment equipment, to a larger extent than from computers, was influenced by communication, whereas standby consumption from office equipment was more influenced by the use of “standby killers”. The unanswered question is: How to get people to buy an install “standby killers” if they are not part of a project. There are also questions about how they could maintain them, because the users may not see if a unit breaks down.

Generally it can be concluded that difficulties in reducing standby consumption primarily occurs in households with older (teenage) children. This may lead to a conclusion that teenagers do not want to save energy, however this might not be quite fair to the teenagers. Other research has shown that teenagers actually do consume more electricity than adults (Gram-Hanssen, Kofod and Petersen 2004). However, this is a result of social pressure from friends as well as from parents who want their children to be up-to date with regard to electronic possessions (Gram-Hanssen 2005).

Another question can be how much is possible to reduce the standby consumption with the existing technology and the modern way of life. Families with older children typically use both television sets and computers independently of each other in both time and space. However, often these appliances are connected with each other for internet access or for satellite television. Since family members use the different appliances in different rooms at different times of the day, it is very difficult to turn off, for instance, routers and satellite dishes. Another challenge to reductions in household electricity consumption is the new fashion with the main entertainment unit in the living room and satellite speakers in other rooms.

Conclusion

The project shows that it is possible to reduce standby consumption in ordinary households to one third of the normal level, by means of communication and help from technical devices. This is valid for an average of the thirty households participating in the project. However, analysis also show that some households rather easily could reduce all their standby consumption just by becoming aware of it, whereas others households mainly reduce their standby consumption by means of technical devices.

Whether a family finds it easy to reduce standby consumption or not depends on on the one hand whether the family in general is interested in energy savings, and on the other hand whether technical details, such as how easy it is to turn of the standby either at the appliance or by reaching the socket outlet in the wall.

One third of the standby consumption of the 30 households was not affected by any of the project efforts. This was primarily a result of different appliances being connected to each other and used by different persons at different times. These results emphasize first of all the need for improved pressure on the producers to develop electronics with much lower standby consumption, for the kinds of appliances which may be difficult to turn on and off. Secondly it also reveals that many people would like to turn off the appliance, should it be possible to do so. This is often hindered by the fact that both socket outlet and appliances not being equipped with a switch, which seams very inconvenient. It is a problem for the producers to solve.
In all you may say that this project only deals with the top of the standby "iceberg" because the focus is on office and entertainment, there are also all the white goods in the homes and other products. Another thing that need to be addressed is the way the products are used the way they power down and so on.
A new test on SetTop-boxes for digital TV, carried out by the Danish Electricity Saving Trust indicates that there are still a great need for for focus on standby consumption, the standby consumption varies from 4.4 watt (Grundig) to 14.4 watt (Digiality) for products that delivers the same thing.

Even though the production side may look as the most promising and obvious way to solve the standby consumptions problem, this is a long term solution. However, even progress towards such long term goals should be started as soon as possible. Until this has been achieved, households have to be considered as relevant actors too. This project suggests a continued effort by raising awareness of the public together with development and marketing of "standby killers" will have some impact. Even though the same success rate achieved in this project can not be expected for a wider program with lower resources per household, still it has been shown that parts of the standby consumption quite easily can be reduced.

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Standby: The Next Generation

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Abstract

Measurements reveal that about 4% to 11% of residential electricity consumption is due to standby. Organised efforts to measure and reduce standby power consumption have been under way for more than a decade. However, the nature of standby and the policies to address standby power consumption need to change. With regard to policies, it has been the assumption for many years that a voluntary approach is faster, more flexible and less costly than a regulatory approach. However, experiences with voluntary agreements have not always lived up to expectations and revealed drawbacks with voluntary agreements which aim to reduce standby power. Regarding the nature of standby, fewer products now have a single simple standby mode, (e.g. the remote control of a TV) as the advent of advanced electronics and complex control systems now means that there are often several more complex modes where the functionality can change in real time.

This paper describes the next generation of approaches to deal with standby power: on one hand the horizontal approach, which targets the simple standby mode for as many products as possible. On the other hand the power management approach tries to deal with complex standby situations to ensure that the product moves into the lowest power consumption state possible for the required task.

Both approaches will be illustrated with examples, from the EU ecodesign framework directive, which is being considered for use as a regulatory framework for a horizontal measure on standby, and from the EU Code of Conduct for Digital TV Services Systems which is a voluntary measure for a more complex product.

Introduction

It is well known that standby power consumption in European homes is about 60 W per home [1], which corresponds to about 10% of residential electricity use. Although a qualifying caveat should be noted in that such estimates tend to be based on the measured standby power requirement of household appliances and generalized usage pattern surveys. Large scale, pan European surveys measuring the actual duty cycle of each household appliance are rare. Estimates of household standby power consumption tend to assume that the appliances are selected to standby or off by the user when the main function is finished. Ad hoc surveys on specific devices such as set top boxes, DVD players, washing machines, dishwashers etc. show that this assumption may be very misleading in the context of estimates of energy wasted when appliances are not performing their main function.

In this paper we will present and discuss three issues that are important for keeping a grip on standby consumption;

- The first issue is the nature of standby. The nature of standby has evolved from one simple standby mode, e.g. the remote control of a television, to the very complex standby modes of e.g. personal computers and set-top boxes. In more complex products the focus needs to be on reducing duty cycle power consumption through power management mechanisms that automatically control device power to the minimum needed to sustain the functions required at a given time. This discussion also puts various definitions of standby, e.g. by IEC62301, in perspective.
- The second is the issue of the approaches needed to address standby. It will be argued that for the simple standby mode a horizontal approach targeting as many products as possible is appropriate, whereas the power management approach should mainly deal with complex standby situations, but may also have an essential basic application in ensuring that simple standby is automatically achieved wherever possible.
- The third issue builds on the foregoing items and discusses which policy approach is appropriate: mandatory or voluntary. Both policies will be illustrated with examples. Finally conclusions and recommendations are presented.

The evolving nature of standby; or why standby consumption will increase

In order to illustrate the evolving nature of standby the following simple typology of products is used [2]: the "on/off" product, the "standby" product and the "networked" product.

The "on/off" product

The "on/off" product is the most simple case: either the product is off (performing no function except for being there and heating the room if energy is dissipated) or the product is on (performing one of the main functions). However, even this simple case immediately raises one of the pitfalls for policy makers: the description of the states "off" and "on" in general does not indicate anything about whether a specific product has an off mode (e.g. hardwired smoke detectors do not have an off mode), nor the time that a product spends in the on mode (e.g. electrical (alarm) clocks in the on-mode all the time)[1].

Despite the trends identified in the next sections, a significant number of household products can be classified as on/off products: vacuum cleaners, lighting, cold appliances, storage water heaters. Furthermore, products with a standby mode and even networked products can have an off mode. From an energy saving perspective these products are interesting for policy makers if they spend time in the off mode and if the off mode has a power consumption > 0 Watt. An example are halogen lamps with a transformer where the on/off switch is on the secondary side. On the other hand, cold appliances and storage water heaters are always on[2] and do not spend time in the off mode.

The "standby" product

The "standby" product denotes the classical standby situation, where the product is performing some function(s) not being one of the main functions of the product, e.g. enabling (remote) control, waiting for a user command, internal timer/clock, clock display or other indicator. Also in this situation the "functionality" perspective offers guidance to distinguish whether a product is in standby or in on mode. Compare e.g. an alarm system with a garage door opener. At a first glance it would seem that both products are most of the time in standby because they are waiting for "input", e.g. from a motion detector, respective a user command to open the garage door. However, in case of the alarm system providing security is the main function and therefore the system is always on, whereas in case of the garage door opener the main function is opening the door and therefore the product is mostly in standby, waiting for a user command[3].

Sometimes the "standby" products may also have an off switch, i.e. meaning that they can be switched into the off mode (performing no function). The classical example is the (European) CRT television which has both a remote control and an on/off switch. However there are few products with these three simple modes these days.

This type of standby could be denoted as "simple" standby, because the procedure to enter (one of) the standby mode(s) or to switch the product from (one of) the standby mode(s) to the on mode is simple, i.e. can be determined internally and needs only recognize one type of (user) input.

This type of standby has evolved from a few products in the 80s to many products nowadays. Not only consumer electronics, office equipment and microwave ovens, but also washing machines, driers, dishwashers, rice cookers, garage door openers, etc.

The "networked" product

The "networked" product could be called an extension[4] of the standby product, because:

a) the product not only can be controlled by the user, but also by other external sources, e.g. a service provider of other products in the network, and
b) the product can communicate with external sources, e.g. a central heating boiler calling a repair service.

Because this type of product is – by definition – connected to a network, the network protocol is an important technical issue.

The consequences of the network connection is that the product becomes more complex in several ways. Firstly, networked products can be controlled from various sources, not only the user but also

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[1] Not to mention the philosophical debate whether a product should do something "useful" in the on-mode; and that if a product is not used by anybody it is not on and therefore it's power consumption should be (near) zero.

[2] Since we have defined "on" in a functional way, i.e. providing one of the main services that the product is acquired for, cold appliances and storage water heaters are always on, even though their power consumption in on mode will vary greatly because of components (compressor, heating element) are turned off and on as a result of temperature controls.

[3] From this example it does not follow that efficiency improvement in alarm systems are not useful.

[4] And as such it *can* also have an off mode and/or simple standby mode(s).

other appliances and network providers. Secondly, the software can be upgraded through the network which means that the functionality of the product can change during product life. New hardware architectures take full advantage of these features. Thirdly, data needed for the functioning of the product can be updated through the network or is not stored at the product at all but in a network attached storage.
This complexity also strengthens the dependency upon the network connection, which in turn focuses the attention of appliance and network manufacturers and service providers to provide faster and more reliable network connections. In the case of PCs this has lead to the concept of “server based computing” where the PC can’t function (i.e. provide functions like word processing, spreadsheets and e-mail) without a network connection. This concept was established for a long time, but the practical application depended on the availability of network connections with sufficient speed, e.g. DSL.
While these products are still limited in number in the typical household at this stage, this is certainly a trend that is likely to be ubiquitous in the future and hence it is critical to set up measures to ensure that energy management becomes an integral part of these products in the future.

Overview of products and consequences
The table below provides some examples of products in the 3 categories and some trends.

Overview of products (examples and trends)

on/off	standby	networked
external power supply		
lighting	lighting with remote control	
white goods	white goods with remote control	cold appliances with display and network connection
vacuum cleaners	robotized vacuum cleaners	
	televisions	televisions with integrated set-top boxes (decoders)
	VCR, DVD recorders	DVD recorders with internet connection
	digital television adapters	set-top boxes
	personal computers	
	stereo equipment	streaming clients (internet)
	printers	
	monitors	
	stoves with clock	
	cordless phones	
	garage door openers	

From the table above it can be concluded that the classical standby product is going to disappear from the market, or at least will become of less importance, because these products will be replaced by networked products. Networked products are the next generation products. However, traditional policy instruments fail with these type of products. Firstly because a single standby mode cannot be defined and if it could be defined, it is doubtful whether the product will spend any time in it. Finally, these products might not have a standby mode at all and they may be in on mode all the time. More probably there will be a sliding scale from off to fully-functional on where it is a question of definition when the appliance is going from a standby to on mode. I.e. how much “on” should the appliance be before it is defined as “on”. The target is to have the minimum energy consumption possible in all the modes as a result of good power management.
Finally the discussion in this section provides clearance on the ongoing discussion on the definition of standby. First it is clear from the foregoing that no single definition of standby mode exists that captures all the modes discussed in the typology above. Second, the definition of standby in IEC62301[5] is ambiguous. For some products it will be the off mode, whereas for other products it will be the stanby mode (with the lowest power consumption). Furthermore, this definion captures – deliberately – only one mode, whereas we have seen that several modes can be important. Third,

[5] Clause 3.1: Standby mode: lowest power consumption mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when an appliance is connected to the main electricity supply and used in accordance with the manufacturer’s instructions.

from an energy efficiency policy perspective it is important that all modes (off, standby and on) are covered and that policy is not restricted by definitions.

Approaches to deal with standby

From the analysis in the foregoing section we conclude that approaches to deal with standby need to match the type of product. In this section we present approaches to deal with the different product types. The emphasis in this section will be on technical solutions regarding the product. It is our opinion that behavioral solutions to the standby problem, e.g. asking consumers to switch off the appliance, are at least less effective than technical solutions. The reasons for the product types are the following.

For those on/off products where switching off is an option, the off mode power consumption can not be influenced by the user unless the user unplugs the external power source of the product or an (extra) hard switch is added which performs the same function. Given the fact that this applies to many dozens of products in the home (e.g. all products with external power supplies), it is in our opinion too optimistic to expect users to users to unplug all devices when not in use. Moreover, technical solutions are possible that reduce off mode consumption to 0.1 W or lower and therefore the behaviour of the user is irrelevant from an energy efficiency point of view.

For classical standby products which can be switched off by the user, it has already been remarked that this action negates the standby function. Although some consumers may not mind this, it is not an acceptable option in terms of functionality in some cases. Furthermore, if such products are (gradually) disappearing from the market, a behavioral solution will become less important.

Because the networked product is dependant on the network connection and given that the network connection is lost when switching off the product, a behavioral approach for networked products is not a viable solution. Furthermore, the consumer does not always know whether a product can be switched off or to standby, because other products might need the services of the product.

Dealing with the off mode

For products that have an off mode, the off mode power consumption should be minimized and close to 0 W. The rationale for this goal is simple: avoid wasting energy. If the product is in the off mode and – by definition – is performing no function, it should also use no energy. Note that this does not indicate anything about how long the product is in the off mode, nor that the product should have an off mode.

From a technical point of view, the reason for power consumption in the off mode is the on/off switch of the product being on the secondary side of the power supply, or the product having an external power supply that can be disconnected from the product while the power supply is still connected to the mains (e.g. mobile phones). In both cases the off mode consumption consists of losses in the power supply. Technical solutions exist to reduce the off mode power consumption to 0.1 W or less.

Minimal standby power consumption

First it should be noted that "standby" mode generally offers some level of functionality to the user. So equipping a product with an on/off switch is not considered to be a solution towards minimal standby power consumption because in the off mode the standby functionality is lost. This does not mean that “standby” products could not have an on/off switch, but with a standby power consumption of 1 W or less, the rationale for having an on/off switch is less clear.

Solutions for standby mode should minimize standby power consumption. In general the following options exist: decrease the number of components that are powered, increase the efficiency of the components that are needed for the standby function(s), and add special “standby” components, e.g. a small efficient standby power supply for sensors or clock functions.

For simple standby functionality that applies to the typical “standby” product, e.g. a clock display or waiting for a signal from the remote control, solutions that require 1 W or less are available (technical solutions to less than 0.1W are available in many cases). However, this depends on the level of functionality required and whether there are other functions such as battery charging etc.

Power management for the networked product

For the networked product the goal is to optimize/minimize total energy consumption. In many cases the solution is to introduce one or several modes (with different levels of functionality) and power management. Like the standby product, equipping a networked product with an on/off switch is not considered to be a acceptable solution for the users, because in the off mode the standby functionality (including network connection) is lost. However, if the lowest level of standby power for

networked products that is likely to persist for long periods is going to be higher than the 1 Watt level, an on/off switch may be a good option for those consumers that do not always need the functionality of the networked product and therefore want to switch off the product at their discretion (although in reality this may be rarely used in many installations).
Power management is the key feature to optimize total energy consumption of networked products. Power management can be defined as a function of a product that ensures – without user interference – that the product is always in the state with the lowest power consumption related to the required functionality[6]. Technically speaking this means that if the product is not or only partly used, unused parts are powered down as far as possible, and only those parts are powered that are needed to detect the need for an increased level of functionality for the product. This requires the following activities from the product:

- monitoring activity levels of parts of the equipment (devices)
- decision rules to enter a certain state: demands for a higher state, falling to a lower state where current level of functionality is not required
- execute state transitions and monitor the result

Power management is a concept that is broader than standby, because also in the on mode power management can be beneficial. Examples of power management are the cd-player that switches into standby after the disc is finished (and unless the user has activated a repeat function) or the digital television that switches from a low standby mode to a mode where it can update electronic programme guide data and switches back afterwards.

Standby: the next generation policies are needed

In this section we will translate the approaches of the foregoing section into policies. In general, a variety of policies exist for increasing energy efficiency of appliances: financial instruments (subsidies, tax rebates), informational instruments (labelling, product information via internet) and “product” instruments (e.g. minimum efficiency standards). Regarding standby we will focus in this paper on product instruments, where – either voluntary or mandatory – products that do not meet certain standards or rules are not brought on the market. The reason for this restriction is the following. In general standby consumption of a single product is relatively low compared to the total energy consumption of a television or washing machine. The impact of standby originates from the total *volume* of products that have standby consumption. An example: 45 million DECT cordless phone kits with on average 2 handsets per kit in Europe have an associated 90 million linear external power supplies. One power supply uses more than 1.5W in standby, this could viably be less than 0.3W, so cumulatively more than 1TWh of energy is wasted per annum. This means that informational instruments (directed at the buyers/consumers) will have only limited impact, while bearing the full cost of them. A typical home may have 50 to 100 products which may potentially have some power consumption in other than on mode - in most cases the amounts of power are small and the transaction costs of obtaining comparative information on differences in standby and taking this into account during the product purchase is not viable. Also financial instruments targeted at buyers would be restricted to relatively small amounts (because relative to the savings) and therefore have little effect. An alternative could be financial instruments targeted at manufacturers, which may be a problem when manufacture also or mainly occurs outside the territory which is financing the measure. Therefore in this section we will consider only (voluntary and mandatory) product instruments.

Voluntary versus mandatory instruments
To date in Europe a voluntary approach has been implemented to reduce off mode and standby mode power consumption of selected products, starting with the official communication from the Commission in 1999 [4]. It was assumed that a voluntary approach was faster, more flexible and less costly. In previous years several voluntary agreements have been negotiated with industry, most notably on consumer electronics and external power supplies[7]. Furthermore, the ecodesign directive which was passed in 2005 [3] now explicitly opens the future possibility for voluntary initiatives as an option to forestall (mandatory) implementing measures.

[6] Although power management is discussed here with regard to networked products, it can be also useful to optimize energy consumption of other types of products.
[7] Energy Star programme for office equipment.

Experiences so far with self-regulation regarding energy efficiency of products in Europe reveal that the advantages mentioned above need to be put into perspective. The following table describes a number of self-regulation initiatives.

Overview of self-regulation in Europe

Self-regulation	Products covered	Level 2008 (lowest standby mode)	Representativeness (market coverage)
Code of conduct external power supplies	Single (output) voltage external ac-dc and ac-ac power supplies in the range between 0.3 W and 150 W.	0.3 W – 0.5 W	< 50 % (coverage is good for mobile telephones and laptop computers)
Code of conduct Digital TV Service Systems	Set-top boxes, adapter boxes, IDTV	2 W – 6 W	?
Code of conduct broadband equipment (planned)	Broadband equipment	not yet decided	n.a.
Industry Self-Commitment to improve the energy performance of household consumer electronic products sold in the EU (EICTA)	CRT-TVs non CRT-TVs DVD-players	1 W 1 W 1 W	70 % 50 % 50 %
Energy Star (* planned in new specifications)	System units (PCs)* monitors printers* copiers*	2 W 1 W 1 W 1 W	currently > 80 % new specifications: > 60 %
CECED Unilateral Industry Commitments	cold appliances washing machines dishwashers	covered by duty cycle not covered not covered	> 80 % n.a. n.a.

From this table we draw the following conclusions.

- Not all products groups are covered by self-regulation.
- For those products where a voluntary agreement has been developed, market coverage is generally much less then 100 %. A reason for the incomplete market coverage is that for some products (most) manufacturers are outside the EU; these manufacturers might be not aware of the voluntary agreements or might not care. If the share of manufacturers outside the agreement is (too) large, then other manufacturers are less or not willing to sign up because it provides them a small disadvantage, which is relevant for products where every € cent counts. Thus, voluntary measures do not create a “level playing field”.
- Finally, voluntary initiatives are re-active, i.e. negotiations only start when the new product variant has been on the market for some time.

Regarding the on/off product and the standby type of product mandatory measures are preferable. Learning from the experience with current voluntary agreements, a pro-active and horizontal mandatory approach should be followed, meaning that a measure should include as many product groups as possible. Since standby is a basic feature and independent of the functionality of the product in other modes, mandatory measures can be pro-active. This means that the measures should also apply to product variations that at the time of the measure coming into force were not (yet) on the market. TVs provide a good example: a mandatory standby level for CRT TVs can also be used for LCD and Plasma TVs. A pro-active approach provides a clear guideline for product development at manufacturers, because whatever product they develop it should comply with the standard.
However such an approach can not yet be used for networked products. The two main reasons are that no general applicable standby modes can be defined for these type of products, or the (simple) standby mode that could be defined is not relevant[8]. Secondly, the concept of power management as

[8] However, because of the horizontal approach mandatory measures will also cover networked products. So in case (some of) these products have a simple standby mode they should comply with these measures.

such is still too general to be put into law. In the next sections the mandatory approach is elaborated upon by the example of a horizontal implementing measure for standby in the framework of the ecodesign directive [3], whereas the voluntary approach for networked products is illustrated by the EU Code of Conduct for Digital TV Service Systems [5].

Simple standby and off: a horizontal implementing measure

Standby is one of the priority items regarding energy efficiency and explicitly mentioned in the ecodesign directive, to be covered by an implementing measure. However, an implementing measure on standby differs in a number of aspects from an implementing measure on a specific product. In this section first several specific aspects regarding standby related to the ecodesign directive will be discussed. Then will follow considerations in preparing a draft implementing measure and criteria for an implementing measure.

Specific aspects regarding standby

Standby consumption is a specific ecodesign requirement. Standby consumption is not an Energy using Product (EuP) itself, but a characteristic of an EuP. In relation to an implementing measure for standby, two questions have to be answered:

a) Is a horizontal implementing measure, i.e. an implementing measure covering one (or more) requirement(s) for – in principle – all EuPs, possible within the current framework directive?
b) Once a horizontal implementing measure is adopted, are other (horizontal) implementing measures allowed for the EuPs for which the horizontal measure is adopted?

re a): According to Annex VII, article 1, the implementing measure can specify more than one type of EuP. Article 2 of the Annex VII leaves the choice to specify one or more specific ecodesign requirements. However, the criteria for EuP, the considerations whether to prepare a draft implementing measure, the rules for preparing a draft implementing measure and criteria for implementing measures require analysis per EuP.

re b): The framework directive does not forbid several implementing measures for the same EuP, so we assume that other implementing measures are allowed.

The purpose of having a horizontal measure on standby is to reduce the energy input in the standby mode. However, product definition plays an important in various criteria, e.g. the volume of sales and trade. Annex VII, article 1, requires the exact definition of the types of EuPs covered. How exactly should this be defined? For a horizontal measure on standby it seems reasonable that the definition only discriminates between product types where different standby behaviour is defined.

So, in principle the products covered are defined by the type of standby consumption they have (ie the functionality of the modes). A horizontal implementing measure on standby should cover both the following modes[9]:

- the “off” mode (the product is connected to the mains, no user function is fulfilled)
- the simple or lowest power “standby” mode (product is connected to the mains, is not in the off mode and not in a main functional mode)

Criteria Energy using Products; preparing a draft.

A horizontal measure on standby could cover in principle all electrical products in homes and offices that have standby consumption. Article 15(2) provides the criteria that have to be met for an EuP to be covered by an implementing measure:

a) volume of sales and trade of more than 200 000 units a year
b) significant environmental impact, considering the quantities placed on the market
c) significant potential for improvement without entailing excessive costs; subcriteria:
    - absence of other relevant EU legislation
    - failure of market forces to address the issue
    - a wide disparity in the environmental performance of EuP available on the market

In conclusion this means that implementing measures will be put in place for mass produced energy using products that have a significant environmental impact and a significant potential for improvement not yet targeted by other measures.

Both environmental issues and current relevant self-regulation lead to the conclusion that an implementing measure is needed. The environmental argument points to standby as one of the

[9] If applicable. As indicated before not all products have both an off mode and a standby mode. The definition of the “lowest power standby” is inspired by IEC63201 and provides a solution for products that have more than 1 standby mode.

priorities to deal with. Analysing current self-regulation reveals that the estimated market coverage is on average roughly 50% and therefore is not complying with the criterion of representativeness as specified in Annex VIII of the Ecodesign directive. The wide disparity must be seen in the perspective of the low power levels of standby consumption: from 2 W to 1 W is a 50% improvement. The impact results from the large quantity of products on the market, not from the absolute value of the savings per product.
Since the implementing measure on reduction of standby power consumption is a specific ecodesign requirement (and a horizontal program measure), a general life cycle analysis would be sufficient. The rationale for having a horizontal measure for standby power consumption results from the possible improvements in energy efficiency for this mode in general, and not on decisions regarding each product based on an life cycle analysis.
It might be sufficient here to state that standby consumption in general can be reduced while other environmental aspects are not affected – or even improved (e.g. less material use in case of switch mode power supplies).
Criteria for an implementing measure (Article 15(5))
Implementing measures shall meet all the following criteria:

a) there shall be no significant negative impact on the functionality of the product, from the perspective of the user;
b) health, safety and the environment shall not be adversely affected;
c) there shall be no significant negative impact on consumers in particular as regards the affordability and the life cycle cost of the product;
d) there shall be no significant negative impact on industry's competitiveness;
e) in principle, the setting of an ecodesign requirement shall not have the consequence of imposing proprietary technology on manufacturers;
f) no excessive administrative burden shall be imposed on manufacturers.

In general the environment and consumers benefit from lower power consumption and thus lower energy consumption and – in most cases – lower carbon dioxide emissions. Studies show that reduction of standby power in general can be achieved at no or little extra costs, e.g. a maximum of € 1 per product (consumer price). With a reduction of 0.5 W to 1 W in standby power consumption, these costs can be recovered 2 to 4 years (assuming an average electricity price of 0,10 €/kWh). In practice the costs for consumers will be (near) zero, since they will be "absorbed" in the redesign of the product.
The impact on competitiveness requires special attention. In the foregoing section a remark was made on impact on costs. Many – or maybe most – of the products or components (e.g. power supplies) that would be affected by a horizontal implementing measure on standby are produced outside the EU. In that case the factor of competitiveness is less of a problem for EU industry because only a small number of manufacturers may be involved. Because an implementing measure is mandatory for every product, it creates a level playing field; in fact minimum efficiency levels could foster innovation and provide competitive advantages for those manufacturers that find clever ways to meet the criteria with less costs.
Since for the EU a level playing field would be created, the question of competitiveness is related to the question whether other parts of the world have mandatory measures for standby. In several other parts of the world (Australia, Korea) mandatory measure are in place or planned. If other parts in the world do not have mandatory measures, either – depending on the costs – manufacturers will run specific lines for products that meet the EU implementing measure (and which may cost slightly more) or manufacturers will change all of their production. In the first situation Europe will benefit from the efficient products, where other parts of the world may get the balance of non-complying (cheaper) products. In the other case – when other parts in the world have mandatory measures – it could be the other way around: Europe will get the less efficient (cheaper) products. Therefore, where other parts of the world have mandatory measures, an EU implementing measure is an important protective measure.
Several techniques exist to achieve a one Watt standby solution, so no proprietary technology is imposed on manufacturers. For power supplies see e.g. the websites of several manufacturers of (components of) power supplies. In fact, in most cases technical solutions to reduce standby to a fraction of a Watt are possible.
The administrative burden for manufacturers depends on the way the conformity check is organized. Since the ecodesign requirements are integrated into the CE marking process, the administrative burden should be minimal.

Conclusion
The ecodesign directive can be used to make an implementing measure on standby (and off mode) mode consumption for various product groups of energy using products.

Networked products: EU Code of Conduct for Digital TV Service Systems

The Television Broadcasting sector of consumer electronics is currently undergoing radical changes. The rapid development of a major communication network to support digital television is complemented by continuous developments in the functionality of the reception hardware, giving the consumer:

- Major improvements in the quality of the audiovisual presentation of broadcast services.
- For the first time, full interactivity with the content and source of the signals.
- A combined entertainment and communication platform with access to the full Internet or to "walled garden" information services. So digital television finally closes the perceived gap between the "lean forward" solo-working tool of the PC and the "lean back" group entertainment device of the TV. This convergence will be the catalyst for significant lifestyle changes in all levels of society, not just the information rich.

The technology supporting these changes is developing at an unprecedented rate. One consequence of this is that the relatively slow and costly, manufacturing and marketing cycle of the mass-produced TV cannot viably accommodate the accompanying rapid changes in the technical specification of the hardware. An independent signal interface and data processing platform, the STB (Set Top Box) has been the preferred manufacturing and market distribution solution. This device readily interfaces with existing and developing TVs and display systems and allows the rapid modification of functionality specifications in high volume production. The STB is an good example of a networked product because it is connected to a network and not only the user but also the service provider need to control the box, e.g. for software updates and security reasons.
The downside of this solution is that the existing voluntary agreement and labelling mechanisms for energy efficient domestic electronic products are too slow to keep up with STB development and could potentially hamper that development. In 1997 a European Commission working group identified the digital service system STB as the domestic electronic device with the largest potential to increase the energy consumption requirements of European Households [6]. Research into proposed development showed that by 2010, the STB could push domestic electronic energy consumption in Europe above that of fridges and freezers (especially as these are decreasing over time as a result of energy labelling and efficiency standards programs). With 150 million of these boxes across the EU - equivalent to one per household – the annual electricity requirement for digital service systems could be around 60 TWh (close to the total electricity consumption of Denmark for all sectors). This electricity would also release 24 $MtCO_2$, which would have a significant impact on the EU's ability to meet its overall Kyoto CO_2 reduction target.
To challenge and resolve this problem the European Commission set up a working group of the key stakeholders in digital service system development – manufacturers, silicon providers, service providers – and energy agency specialists to discuss and specify a (voluntary) Code of Conduct that, amongst others, contains power consumption targets for various types of STB.
This activity has become an excellent example of a product policy initiative that united stakeholders early enough to impact the design process *before* the product became ubiquitous. Furthermore the Code of Conduct has inspired other parts of the world to set efficiency standards for STB; to support international cooperation a "community of practice" has been set up by the Australian Greenhouse Office.
The Content of the Code of Conduct
The principal aim of the working group is to reduce the energy consumption of the STB through the setting of agreed, practicable power requirement targets in a defined development timescale. To that end, a voluntary agreement or Code of Conduct was devised which Europe's principal STB and TV manufacturers and a major Service Provider, B-Sky-B currently support[10].
The Signatories of this Code of Conduct would make all reasonable efforts to:

- Achieve the power consumption targets set out in bi-annualy reviewed tables for new stand-alone products and for digital TVs with built-in IRD placed on the market after agreed dates.

[10] For a full list of signatories see: http://energyefficiency.jrc.cec.eu.int/html/standby_initiative.htm

- Support and contribute to the development and acceptance through an ad-hoc Task Force of the Common Power Management Guidelines.
- Co-operate with the European Commission and Member State authorities in an annual review of the scope of the Code of Conduct and the power consumption targets for two years ahead.
- Facilitate and encourage consumers to adopt energy efficient practices in connection with the use of digital TV services.
- Co-operate with the European Commission and Member States in monitoring the effectiveness of this Code of Conduct.
- Ensure that procurement specifications for digital TV services, systems, equipment and components are compliant with this Code of Conduct.

In this context, the Code of Conduct identifies a key tool to the achievement of significant energy efficiency targets in digital service system platforms: the development of effective power management in the silicon for the principal functional blocks.

Service Provider Needs and STB Power Architecture; Power Management

Effective power management to maximise energy efficiency can only be achieved after consideration of the permitted operating modes. The user may only be aware of the states on and standby but the functionality in these states may vary greatly depending on the requirements of the service provider and the delivery medium - cable, satellite, terrestrial or DSL.

In the on state, digital set top boxes provide the basic function of decoding of television pictures and many have on-screen, interactive information services. Other services such as electronic shopping, e-mail delivery, Internet access, games and software download may also be available. As the digital TV market develops, service providers are keen to offer further premium services which place additional demands on the hardware and increase power consumption. These services could include TV recording, video on demand, telephony, home networking and automation with wireless interface to peripheral devices. Broadband platforms for new broadcast and communication networks based on wired and wireless LAN (Local Area Network) will add to this energy requirement load. To counteract the resulting increased energy demand and follow the Code of Conduct, close attention needs to be given to efficient power conversion, distribution and the management of power usage depending on the function required. More specific designers and stakeholders should:

- Choose the lowest power standby mode consistent with service provider requirements. Decide whether adequate power management of each circuit block can be achieved by control of the silicon/software itself or if switching of power rails is needed.
- Consider power consumption and in-built power management features when choosing silicon. Involve software designers from the outset so that energy efficient software architecture and power management are incorporated in the early design. Check if any third-party software, which may be used for the operating system or conditional access, supports power management.
- Ensure that power to peripheral ports and devices can be turned off when not required.
- Encourage the rapid standardisation of “intelligent” interconnectivity to ensure that any component in the home entertainment and communication network automatically adopts the lowest power requirement for the level of activity required.

Results of the Code of Conduct; relation with ecodesign

The EU Code of Conduct is an important platform for promoting energy efficiency in digital TV services in Europe. The Code of Conduct has already reduced the energy consumption of STBs, even if these offer many more features and services. (see figure 1).

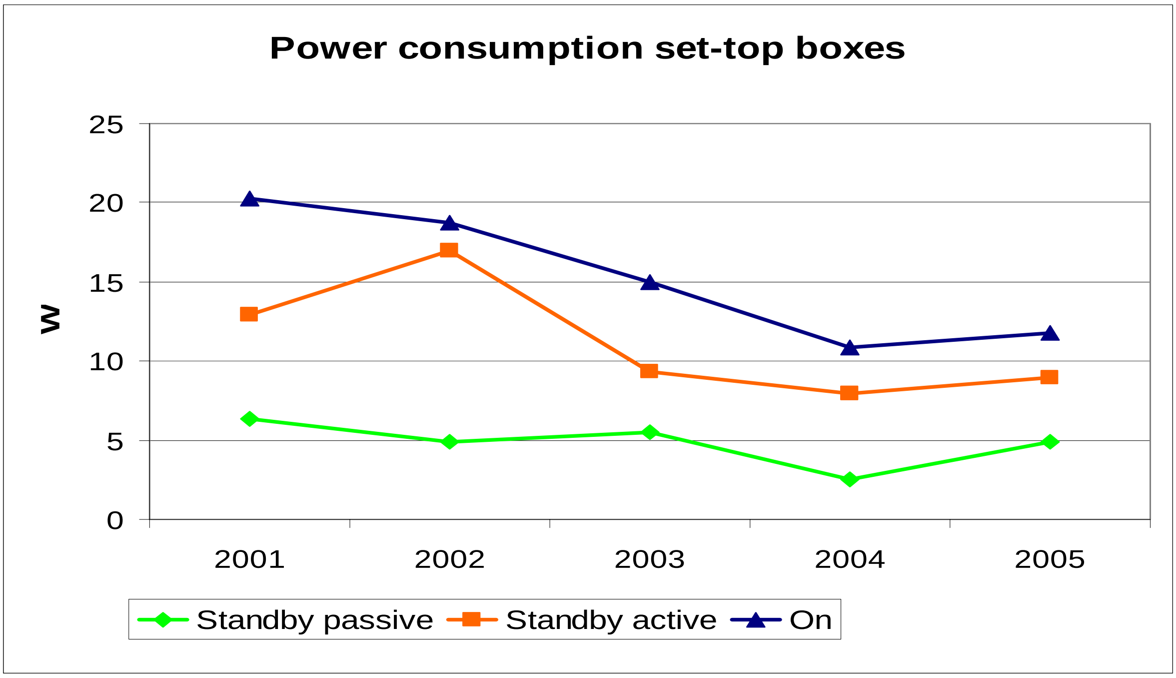

Figure 1: Power consumption STB (as reported by signatories of the Code of Conduct)

However, up to now the Code of Conduct fails to address manufacturers of simple, low cost STB, so called digital TV adapters for legacy analogue TVs and VCRs. In many cases there products do not have an off mode and the power consumption in the standby mode is almost equal to the power consumption in the on mode, due to poor power management. Since the standby mode in these adapters is of the simple type, a mandatory implementing measure within the framework of the ecodesign directive could be used to regulate the digital TV adapter. The same measure should also target the on mode consumption, since it can be expected that in many cases the adapter is left on, e.g. because it is also needed when recording programmed broadcasts with a VCR.

Conclusions and discussion

In this paper we have argued why standby consumption is no longer a simple issue for many products and will become even more complex in the (near) future where more products will evolve into networked products. In our opinion this will be the case for many of the current "classical" standby products, e.g. televisions, video recording appliances, but also for new standby products, e.g. fridges with a screen and internet connection, central heating boilers that call the service centre if maintenance is needed. On the other hand simple standby products, including products with off mode (mostly with external power supplies), are also expected to grow in number, although in practice these products might never be in the off mode.
The current generation of policies, which mostly deal with the simple type of standby (i.e. what we have called the on/off products and the standby products) on a voluntary basis, are not adequate to solve the standby problem for many current product types and perhaps the majority of future products. We have suggested that for the simple type of standby a mandatory horizontal approach should be followed, whereas for the complex standby (found in networked products) voluntary policies targeted at power management should be followed (see table below).

Policy options for reducing standby consumption

Policies	voluntary	X	**X** (power management)
	mandatory	**X** (horizontal)	
		simple (including off) **Type of standby**	complex

X: current prevailing policy
X: suggested policies

A horizontal measure should cover both off mode (product connected to the mains, no function fulfilled) and the simple standby mode (product connected to the mains, not in off mode and no main function fulfilled). The maximum power level for off mode could be set at < 0.3 W and the maximum level for the standby mode at 1 W. The ecodesign directive could be used for such a mandatory horizontal measure. Such a measure would cover also the off mode and the simple standby mode of networked products, if applicable.

Effective power management in complex products or where a product function is shared with other products, will demand the unprecedented involvement of a wide cross section of world-wide manufacturing industry. The object will be to establish basic protocols for all energy using products to automatically communicate their function and required status in a network or chain of products. The translation of this work into standards that are dynamically reviewed with product development is, from experience to date, impracticable in a mandatory regime.

An aspect of power management that may perhaps be mandated in the support of the simple standby state would simply be the requirement that when a product recognizes that its primary function is complete and no other subsidiary functions are essential, it automatically goes to the lowest (simple standby) power state.

From the foregoing conclusions, the following items remain open. Firstly, a horizontal measure that covers off and standby mode does not automatically mean that products covered *should* have an off and/or standby mode. For many product types, several modes may be present (and which ones are covered?) and similar products have different configurations. Care is required to ensure that elimination of a particular mode for a product is not an option to avoid regulatory requirements.

Secondly, extrapolating from the discussion on the voluntary approach regarding the simple standby, it is likely that a voluntary approach regarding the complex standby will not cover all of the market. Thus, the question arises whether in due time power management should and can be made mandatory.

Acknowledgement

The authors thank Lloyd Harrington for his comments on the first draft of this paper.

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Quantification of Standby in Australia and Trends in Standby for New Products

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Abstract

Standby power consumption of household products in a range of low power modes has been on the policy agenda for around 10 years and is an area of growing concern. Australia has been active in both national policy development issues and in the development of an international test method for the measurement of standby power.

To support the development of sound long term policies, a range of data collection efforts have been commissioned, including the measurement of all products present in a sample of Australian households in 2000 and 2005. The low power attributes of a wide range of products have also been measured in retail outlets.

Data from a range of sources suggests that the trend in standby power consumption for some products is improving over time. However, there are a number of products that have very poor standby attributes such as set-top boxes and hard drive DVD recorders, integrated stereos computers and telephony equipment. Major appliances of course are of interest but their total contribution to household standby is only very modest.

One of the most alarming findings was that the number of devices connected to the mains and which used some power when not performing its main function climbed from 21 in 2000 to 27 in 2005 – this is an increase of 35%.

Background

The issue of standby power has been discussed in energy policy circles now for nearly 10 years. Interestingly, the power consumption of appliances and equipment when not in use (i.e. while NOT performing a primary function[1]) was not a policy consideration in the early 1990s, probably in part because few products used power in these modes at the time, but also due to ignorance. It was not until some laboratories noticed in the mid 1990's that some products were in fact using small amounts of power when off or in "standby mode" that the issue was canvassed more widely and further investigations were undertaken. Through the late 1990's the issue was raised within the IEA and a series of three international workshops were held up to 2001. This culminated with the publication of the report Things That Go Blip In The Night [1].

In the late 1990's only anecdotal information was available on the likely magnitude of standby power – almost no data from the wide range of equipment installed in households had been collected in any country. Theoretical estimates ranged from a few percent of household electricity consumption to 10% or more. There were growing concerns about the issue but there was little data on which to base firm policy actions.

Policy Development is Australia

In order to provide a sound basis for future policy decisions, Australian state and federal governments commissioned a survey in 2000 of some 64 households to establish the magnitude of standby power in Australia and to help identify key products and potential problems. The survey measured every plug load present and documented the attributes of some 2400 products actually installed in these homes. The report, which was published in early 2001 [2], found that "standby" (in a very broad sense) accounted for around 11% of residential electricity consumption in Australia or an average of about 90 Watts. While this figure included a number of end uses and low power modes that were not

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[1] Many products, particularly those with electronic controls, have a number of possible states other than the primary function and some have several primary functions.

traditionally regarded as "standby" by some commentators, it was clear that the issue was of significant concern and required a coordinated government response.
In August 2000, the Council of Commonwealth, State and Territory Ministers in charge of energy matters, endorsed a program of work to lead Australia towards achieving the goal of "One Watt" for all consumer appliances and office equipment[2]. They agreed to develop policies designed to ensure the maximum standby power of all household products manufactured in or imported into Australia is One Watt. Australia was the first national government to agree to this formal target. This statement of principle sent a clear message to industry and provided a coherent structure for a diverse range of policies designed to combat excessive standby energy consumption. In 2005 Korea also announced mandatory 1 Watt targets for a wide range of products [3]. 1 Watt targets are now common in many programs that cover standby like the Energy Star program.
The Commonwealth Government in Australia went further and announced in October 2001 a policy to purchase only equipment that complies with the US Environmental Protection "ENERGY STAR" standard, where it is available and fit for the purpose.
International work on a test method for the measurement of standby power progressed within the IEC which culminated in the publication of the test procedure IEC 62301 Household electrical appliances - Measurement of standby power in mid 2005 [4]. This test method provides general approaches, methodology and equipment required to measure power consumption for a range of low power modes for most product types. Australia contributed to this work through the provision of the Convener of the IEC TC59 working group and active participation at all stages of the project. The IEC test procedure does not define relevant low power modes for any equipment types – this is a task for the relevant product committees. While there has been some progress in this area, some manufacturers are resisting further developments at the product level which will hamper the development of uniform product mode definitions into the future.
The development of a ten-year strategy is another key element of the 2000 commitment by the Australian Government to stamp out unnecessary standby power. The document titled Money isn't all you're Saving – Australia's standby power strategy 2002 – 2012 [5] is the culmination of considerable industry and community consultation and the plan:

- sets out a long-term plan for the measures to combat excessive standby consumption;
- identifies some 40 product types initially targeted in period 2003 and 2004 and the process for identifying future products;
- develops the procedures for setting standby targets; and
- outlines the potential sanctions that could be applied should suppliers not meet targets.

Some 30 product profiles have now been publicly released. These profiles identify a range of potential standby program measures for each product type and set voluntary standby targets. Many product types are to be assessed against their voluntary standby target in the period 2006 to 2008. The profiles can be found on www.energyrating.gov.au
The balance of this paper documents the efforts to date to quantify standby energy consumption of products already installed in residential homes as well as the attributes of new products offered for sale in Australia. This data is crucial in the assessment of whether products have achieved the voluntary targets set by government and whether more stringent actions (such as regulation) are warranted for some products.

Data Collection Efforts in Australia

As noted above, the first intrusive survey of Australian homes was conducted in 2000. The survey covered 64 homes and involved direct power measurements of some 2,400 products in a range of modes using a power meter that was accurate down to 0.1 Watt. A second intrusive survey was conducted in late 2005 and the sample was expanded to cover 120 houses and data on 8,000 individual products in various modes was recorded and measured [6].
From 2001, Australia has been tracking the low power mode power consumption of new products on display in retailers. The aim of this work is to benchmark standby performance and trend for each of the major product types which can be used to assess progress by manufacturers towards voluntary standby targets that have been set by governments in Australia. A database of some 5,500 products has been accumulated over the years, with measurements in up to 4 different modes for some product types. This dataset now one of the most comprehensive sets of standby measurements in the world [7].

[2] While a notional target of 1 Watt across the board has been adopted, actual targets vary by product and mode, depending on what is technically feasible based on good design practices.

The key results from these two data collection methodologies is presented below. In the context of this paper, the term standby power is intended to be very broad and covers the energy consumption of a wide range of products in a wide range of low power modes.

Intrusive Surveys 2000 & 2005

The intrusive residential surveys were undertaken to quantify the standby power of products in Australian households. Several modes were measured for most products. This survey was primarily concerned with quantification of the stock of products currently installed in households. The general objective was to quantify the magnitude of standby power used by all appliances and equipment found in Australian residential households in 2000 & 2005, in their applicable low power modes.

The average standby consumption for 2005 was found to be 92.2 Watts per household, or some 807 kWh per year. This is around 10.7% of Australia's residential electricity consumption in 2005. This level of residential standby power consumption was estimated to cost Australian consumers approximately AU $950 million (at an average retail tariff of 15c/kWh) which will result in nearly 6.5 million tonnes of carbon dioxide in 2005.

The total number of products that run on mains power in a typical house in 2005 was found to be 67 (although this ranged from as few as 16 to as many as 136 items per house). During the survey, about 28% (19) of all products were in fact found to be unplugged at the time of the survey. These products were assumed to contribute no power to the total average standby power estimated for all households.

Of the 48 or so products that were found to be plugged in at the time of the survey in 2005, on average around 56% (27) used some low mode power when plugged in and not performing their main function. This is an increase from 21 in 2000. More discussion on usage is included below.

The figure of 92.2 Watts per house could be seen as alarming. However, this is comparable to a study of homes in California which found 108 Watts (but used a different methodology) [8]. However, if all products were in fact plugged in and left in their highest recorded non operating mode, then this power consumption would be as high as 178.3 Watts per household. If all products found had a maximum non operating mode power consumption of 1 Watt or less, then this power consumption would fall to 32.3 Watts per household.

The most important product groups in terms of their total contribution to standby are computers and peripherals, home entertainment equipment (including televisions and set-top boxes), major appliances and other office equipment. An important issue not addressed by this study is the need for a consistent classification of modes and product types to enable comparison between different studies in different countries. This issue is discussed by Nordman et al. [9].

Table 1: Contribution to Total Household Standby from Major Product Groups

Product Group	**Contribution to Total Standby W**	**Number of Items per Household**	**Average Watts per Item**
Major Appliances	11.8	8.5	1.4
Telephones other office equipment	7.1	2.0	3.6
Other home entertainment	19.6	5.0	3.9
Set-top boxes	3.5	0.3	12.1
Televisions	6.2	1.7	3.6
Computer and peripherals	28.1	5.4	5.2
Monitoring and continuous appliances	8.7	7.6	1.1
External power supplies	3.4	4.7	0.7
Other items with a standby mode	3.9	9.7	0.4
Products unplugged	0	18.7	N/A
Products with no standby mode	0	3.1	N/A
Total	**92.2**	**67.7**	

Source: [6]. In this context, total standby takes into account the number of products and the modes in which these products were found or are normally left. 20% of computers are left on continuously.

The expected contribution to the total standby power for each of the major product groups is illustrated in Table 1. Other important parameters such as the number of items per household for each of the main product groups and the average standby power consumption per item within the product groups is also shown. When these parameters are considered, the power consumed per item and the number of items is quite critical for computers and home entertainment equipment. Set-top boxes also have a large power consumption per item, even though the total contribution to overall standby is still low due to their low penetration. This is a product that is likely to have a rapid growth penetration over the next 5 years. The average power per item is also reasonably high for televisions and telephones and other office equipment.

More detail is shown in Table 2 including ownership data and age of selected items. The mode in which the product was found is not reported here as this can be one of several modes (see below).

Based on current information, the growth of standby is of the order of 3% per annum, although there is some uncertainty surrounding this estimate.

Assumed Usage Patterns

The intrusive surveys assumed a simplistic usage pattern for standby modes – the mode in which the product was actually found was recorded and used for analysis purposes and this was confirmed with the house owner whether this was the normal state in which the product was left. Where a product was found in "on mode" at the time of the survey, the householder was questioned on the normal state or mode when not in use. The detailed survey report gives information about each product and the modes in which products were found. About 28% of products were found to be off at the mains[3] or unplugged.

Many products have several possible non use modes and these are fully documented in the study. A simplistic assumption is that the hours of active use for most products is relatively small. One of the main exceptions is televisions, where viewing hours range from 20 to 40 hours per week and computers – many appear to be left on for very long hours even if not in active use (about 20% are left running continuously). Many home entertainment products were left in active standby mode in the 2005 survey, indicating the potential value of power management or auto-off functions for these products.

[3] Unlike the USA and Europe, Australian power outlets have a switch which controls power to each product which is plugged in.

Table 2: Summary of Key Standby Attributes – 2005 Intrusive Survey, Australia

Product Type	On Mode (Watts)	Active Standby (Watts)	Passive Standby (Watts)	Off Mode (Watts)	Ownership (items/ household)	Age (Years)
Amplifiers	NA	22.4	3.4	0.2	0.36	8.7
Answering Machines	NA	3.1	NA	NA	0.17	NA
AV Receivers	NA	65.3	3.1	0.3	0.13	3.2
Breadmakers	NA	1.7	NA	NA	0.18	NA
Clock Radios	NA	2.1	NA	NA	1.33	NA
Clothes Dryers	NA	3.3	NA	0.2	0.63	10.3
Clothes Washers	NA	5.8	NA	1.9	0.95	7.0
Computer Speakers	NA	4.1	6.0	2.2	0.83	3.9
Computers	82.2	NA	35.5	3.5	1.25	3.5
Cordless Phone Base Stations	NA	3.3	2.4	NA	0.98	NA
CRT Monitors	61.7	NA	8.2	1.9	0.86	4.6
CRT Televisions	66.9	NA	7.4	0.1	2.07	7.7
Set-Top Boxes	13.3	NA	10.7	0.0	0.32	1.8
Dishwashers	NA	2.8	NA	0.8	0.57	6.6
DVD Players	NA	9.0	2.6	0.0	0.82	1.8
DVD Recorders	NA	26.5	4.9	NA	0.08	0.7
External Power Supplies	NA	NA	1.2	NA	6.86	NA
Facsimiles	NA	5.9	NA	NA	0.26	NA
Game Consoles	NA	26.7	1.9	1.4	0.33	3.7
Inkjet Printers	NA	4.6	NA	1.9	0.89	4.4
Integrated Stereos	NA	18.1	6.5	1.8	0.97	5.9
Laptops	34.1	NA	16.5	9.2	0.54	2.8
LCD Monitors	29.3	NA	2.6	1.0	0.37	1.4
Modems	NA	5.9	4.4	2.4	0.68	NA
Multifunction Devices	NA	11.2	NA	5.5	0.23	2.3
Non Convection Microwaves	NA	NA	3.0	NA	0.77	NA
Portable Stereos	NA	5.8	2.2	2.3	0.63	5.3
Radios	NA	NA	1.5	NA	0.46	NA
Remote Garage Door Openers	NA	4.1	NA	NA	0.30	NA
Scanners	NA	8.3	NA	0.9	0.25	4.5
Smoke Alarms	NA	0.4	NA	NA	1.23	NA
VCRs	NA	10.5	5.1	1.7	1.11	6.7

Source: [6]

If total annual energy consumption was to be accurately estimated, much more detail on the possible modes and length of time in these modes would need to be collected for each product. Surveys using diaries are notoriously unreliable and there is likely to be limited value in this approach (it is also very onerous on the participant). A more valuable approach would be to use individual end use meters to track mode usage for different products. If this approach is adopted, it is important to measure the power consumption of each mode prior to monitoring as it can be difficult to surmise behaviour from power data where information is not known about the product or its possible modes. Special meters which are capable of measuring low power modes also need to be used in this case.

Store Surveys 2001-2006

The methodology used has been to visit a number of large retail outlets and measure the relevant modes for all products that are on display for sale. Measurements are made on 500 to 1,000 new products during each survey. Data is recorded on brand, model, price, details of any energy labels or markings, features, product type and any other relevant features. Power consumption in defined modes is recorded, mostly passive standby and off modes, but also active standby and on mode in some cases.

Initially, the surveys were conducted once annually, but since 2003, two to three surveys have been conducted per year. This has resulted in a database of more than 5,500 new products offered for sale in the period.

When all products considered together, each of the modes measured has remained fairly stable over the period. The results are summarised in Table 3. It should be noted that the number and mix of products measured in each year of the survey were somewhat different so the results need to be taken as indicative and trends within each product need to be examined separately. So while this is a very coarse measure, it does show some interesting overall trends.

Table 3: Summary of average consumption across all products

Mode/Survey	2001	2002	Jan 2003	2003/04	2004/05	Nov 2005
Total readings off	258	380	330	925	782	296
Average off	1.3W	0.8W	0.9W	0.8W	0.7W	1.1W
Total readings passive	440	397	325	682	737	295
Average passive	5.8W	4.1W	3.4W	3.6W	3.7W	3.9W
Total readings active	101	210	216	527	665	333
Average active	11.4W	15.6W	13.9W	14.3W	15.2W	14.7W
Total readings delay start				71	51	28
Average delay start				4.1W	3.5W	4.1W

Source: [7]

Figure 1 shows the distribution of measurements taken for all products in passive standby mode. All six years of data are presented on the graph. The graph clearly shows that the distribution of measurements since 2001 has shifted from the higher end (greater than 3W) to measurements less than 3W. In 2001, 35% of all measurements taken in passive standby were less than 3W, while in November 2005, 55% of measurements were recorded under 3W. The latest results show 23% of products are now less than 1W in passive standby compared with only 8% in 2001. The change in distribution further supports that passive standby has declined in the products measured since 2001.

The other findings of interest were that off mode power consumption continues to persist at a significant level (of the order of 1 Watt) and that that fewer and fewer products appear to have an off mode present over time.

Results indicate that there is an opportunity for many products to improve energy consumption in low power modes within product groups. For the products measured, there was generally a wide variance in power consumption in off mode and passive standby mode without any difference in performance or functionality between these products. This tends to suggest that there are substantial opportunities for manufacturers to reduce low power mode consumption, probably at low marginal cost. Details on the findings of the surveys can be found in EnergyConsult 2005 [7].

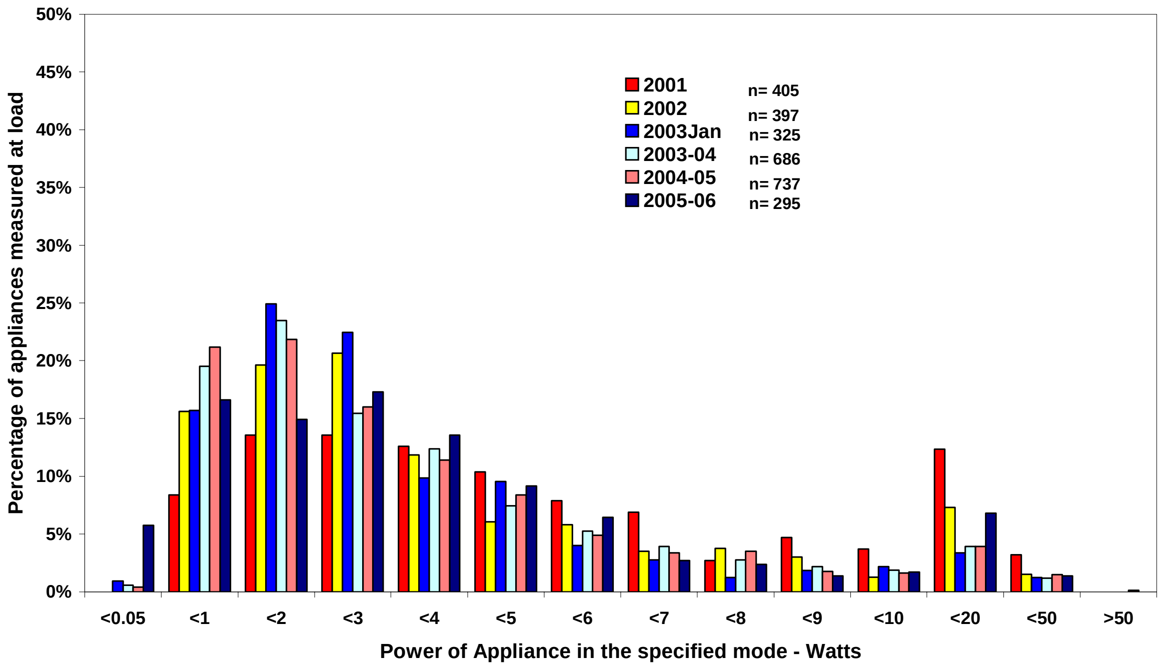

Figure 1: Distribution of "passive standby mode" power – all products
Source: [7]

Trends in Standby for Key Products

The following section analyses the data trends on standby for selected products and modes combining data from the 2000 [2] and 2005 [6] intrusive surveys and the store surveys conducted from 2001 to 2005 [7]. This draws on a database of more than 16,000 products. It is important to note that the attributes of the older stock (say pre 1995) as recorded in 2000 may be different to the attributes recorded in 2005. For some product types, the sample is quite small so these need to be seen as indicative. Generally, data from the store survey is the most reliable trend line as each point consists of a large number of readings taken in store for that year.

Desktop Computers – Off Mode

Personal computers primarily had what appeared to be hard off switches installed in most products up until the mid 1990's so they had effectively zero energy consumption when off. By 2001 virtually no computers had zero power consumption in off mode. Data suggests that power consumption in off mode peaked at 4 Watts and is now declining to around 2 Watts in 2005. The sample of houses in the intrusive survey found 1.25 desktop computers per house. It is important to note that this trend is more a function of the design of the power supplies now commonly used in desktop computers that than the computers themselves. The other issue is that in Australia, there are a large number of small companies that assemble computers using parts from a wide range of OEM suppliers. This makes dealing with this particular product difficult in terms of any voluntary or mandatory industry based commitments.

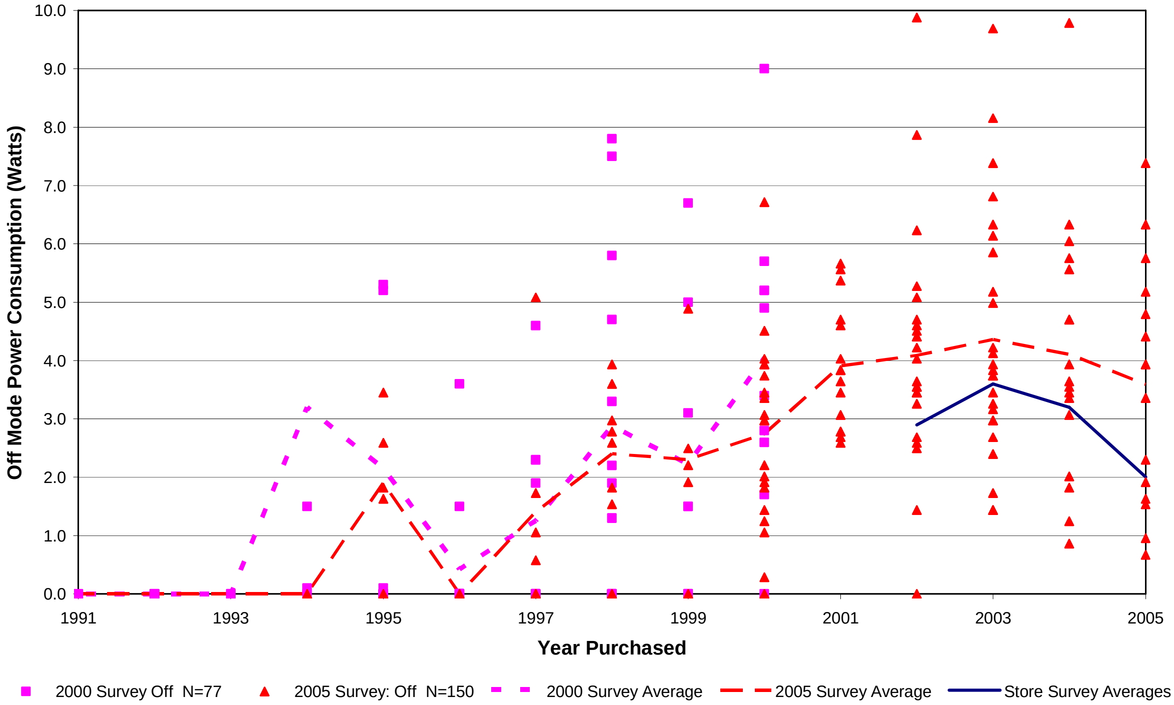

Figure 2: Trends in Computer Off Mode

VCRs – passive standby mode

While VCRs are perhaps an obsolete technology, they are ubiquitous and ownership levels in Australia are around 1.11 per household. Greatly reduced prices mean that the product is likely to linger for many years.

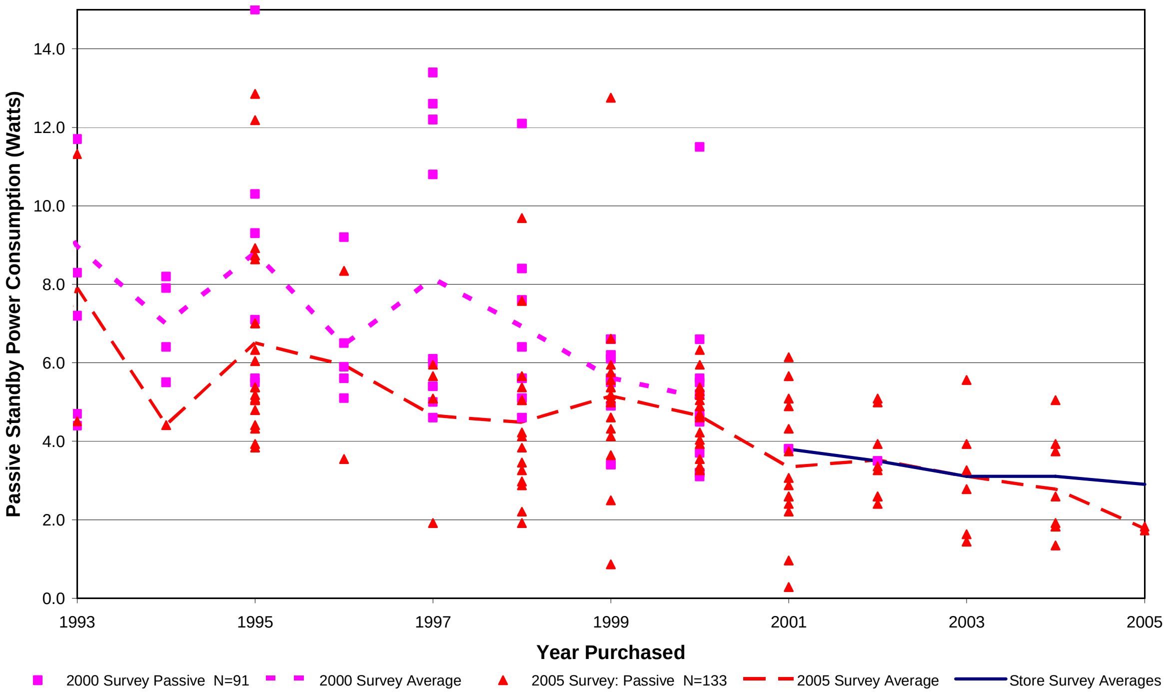

Figure 3: Trends in VCR Passive Standby Mode

Passive standby mode is the most important for a VCR – this allows activation by remote control and clock circuits are active. Virtually no models have an option for off mode. In the mid 1990's passive standby mode was around 8W and this has declined to about 3 Watts in 2005 (based on the store survey data).

Integrated Stereos – Passive Standby Mode

Integrated stereos are common devices with an ownership of around 0.97 per household in Australia. These are products with a single power cord that provide functions such as radio, tape player and CD player and are not designed to be portable. They usually have separate speakers. In the mid to late 1990's passive standby for many of these products averaged around 10 Watts. This has declined to around 4 Watts in 2005.

Despite improvements in the average passive standby mode power, there is still a very wide distribution on the power consumption in this mode – the distribution is almost bi-modal and split into high and low power products – the data below is from store surveys 2001 to 2005 for integrated stereos. The improvement in average power has been a result of an increase in products < 1 Watt and a decline in products over 10 Watts. So while the improvement over time is to be applauded, there are still many products on that have very poor passive standby attributes.

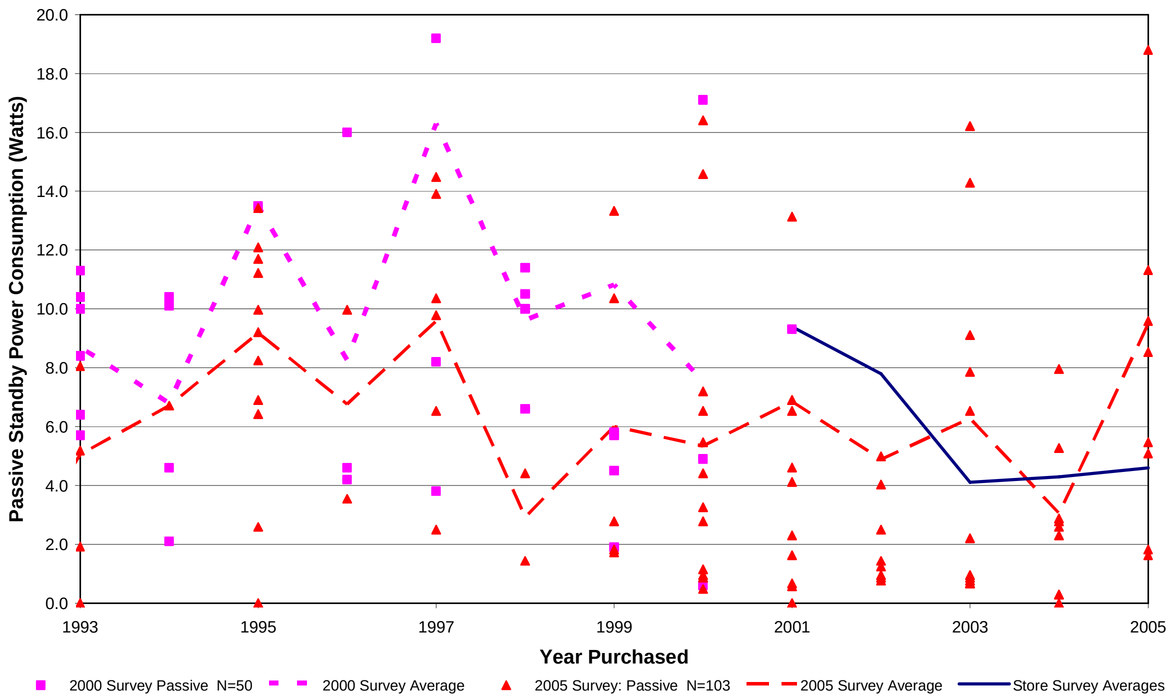

Figure 4: Trends in Integrated Stereo Passive Standby Mode

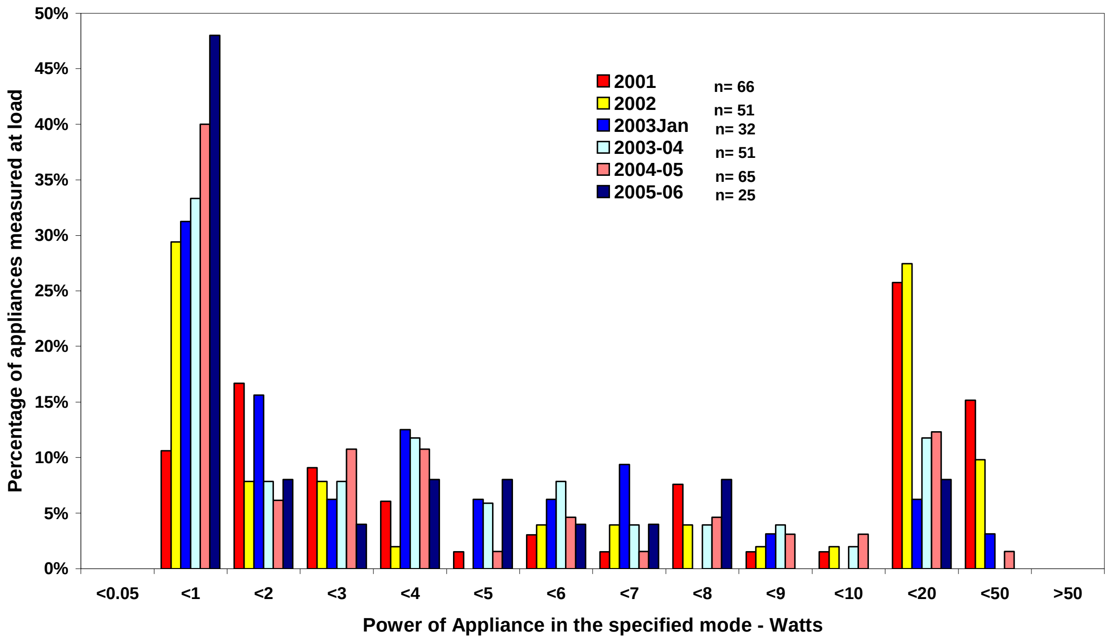

Figure 5: Distribution of Integrated Stereo Passive Standby Mode Power

Televisions – Passive Standby Mode

Televisions are common devices with an ownership of around 2.0 per household in Australia. In the mid to late 1990's passive standby for many products averaged around 14 Watts. This has declined to around 4 Watts in 2005. Average new products in Europe are somewhat better than this (less than 2 Watts). Many new products still consume more than 6 Watts in passive standby mode. Most televisions in Australia have an off switch and most use 0.0 Watts when off.

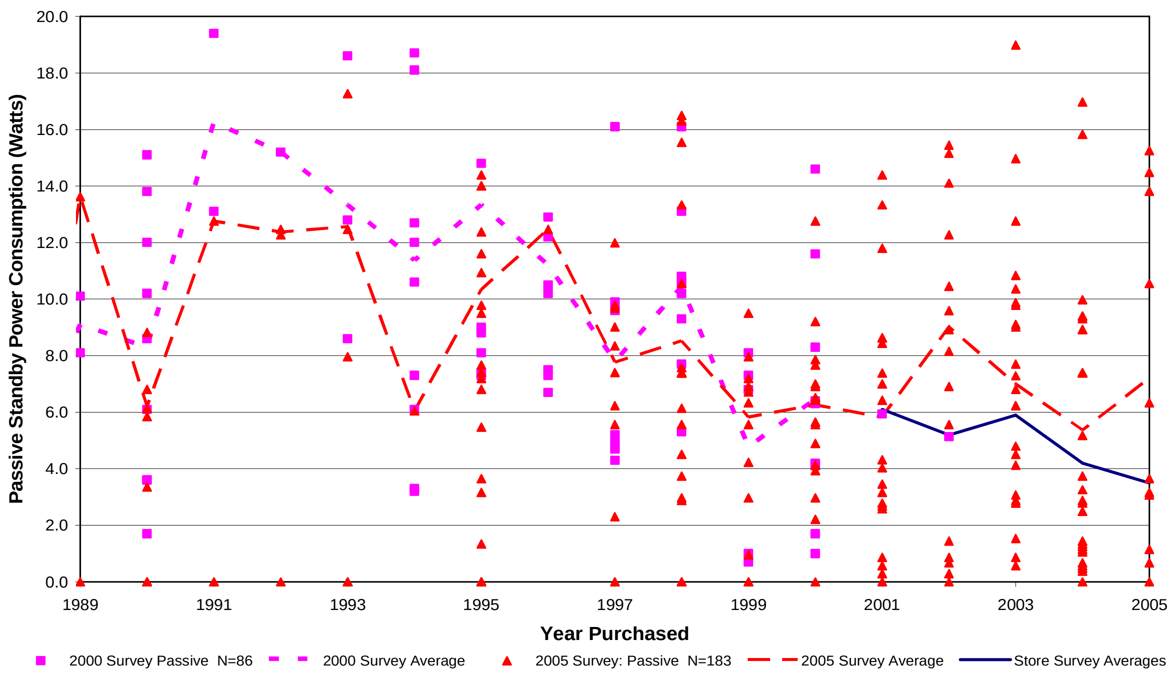

Figure 6: Trends in Television Passive Standby Mode

Clothes Washers – Off Mode

Prior to the mid 1990, few if any clothes washers used any power when off as most had electro-mechanical controls and switches. From the mid 1990's machines with electronic controls appeared in the stock. The average power consumed up to around 2001 was about 2.5 Watts in off mode. Since

2003 there has been a marked decline in average power to below 1 Watt in off mode. It is interesting to note that while the average off mode power from 1990 to 2002 was probably 2 to 3 Watts, there were a lot of machines that used 0.0 Watts and a lot of machines that used 5 to 10 Watts. The worst machines were removed in about 2002, possibly in response to the Australian government's targets for clothes washers that were announced in 2003.

There is an important issue regarding clothes washers and dishwashers. Most European products have an off switch, which usually disconnects power to most parts of the machines and drops the power consumption close to zero Watts. However to achieve this, the consumer must manually turn the machine off when the cycle has been completed and the load removed. Disturbingly, during the intrusive survey in 2005 around 40% of the European front loading machines were found left in active standby mode when not in use (ie the users did not manually turn the machines off when the washing cycle was completed). These machines persist in active standby mode indefinitely with the current machine designs. This means that the off mode power consumption for many European machines is probably not all that relevant. A more relevant figure is the active standby power consumption (which in many cases is likely to be similar to end of cycle mode). In 2005 this averaged about 4 Watts, although individual values varied from 1 Watt to 7 Watts in this mode. This is an example of a mode which is impossible to accurately determine from store or house measurements.

All non European machines automatically revert to off mode automatically at the end of the cycle, so only off mode measurements for these machines are relevant.

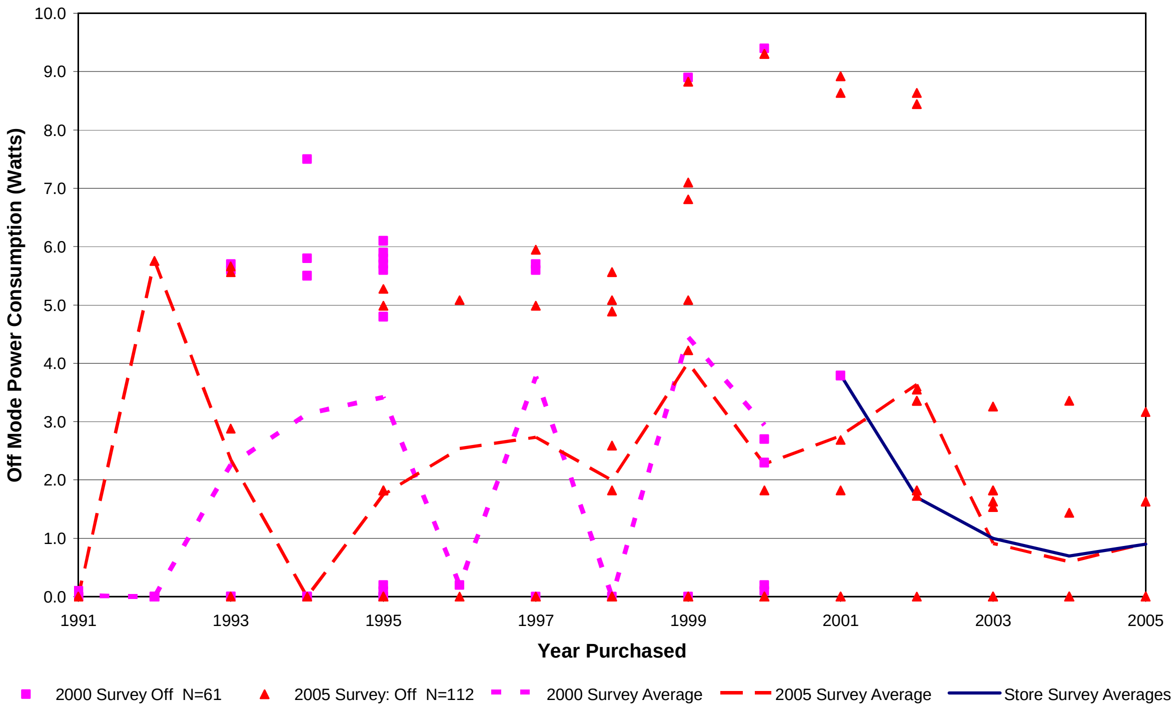

Figure 7: Trends in Clothes Washer Off Mode

Other Products of Particular Concern

The 2005 intrusive survey identified a number of other products that are of concern with respect to standby. The are summarised below:

- Clock radios: 2.1 Watts, ownership 1.33, trend: no changes expected.
- Computer peripherals: range from 2 Watts to 6 Watts, multiple items per house (printers modems, speakers, switches/hubs, scanners etc.).
- Digital set-top boxes: 13.3 Watts, ownership 0.32, trend: ownership likely to soar.
- DVD recorders: 4.9 Watts, ownership 0.08, trend: ownership increasing as they replace VCRs, much higher power with hard drives (more common) – blurred divide with set-top boxes and DVD burners as digital tuners become available.
- External power supplies: 1.2 Watts (no load), ownership around 7 per house (3 as separate devices not always connected to a product – usually battery charging – e.g. mobile phone).
- Laptop computers: unclear standby measurements (measurements confounded by battery charge state, probably in the range 2 Watts to 6 Watts when fully charged), ownership 0.54 and set to increase.

- Multi-function devices: 11.2 Watts (active mode), ownership 0.23 and increasing.
- Remote control garage door openers: 4.1 Watts, ownership 0.30 and increasing.
- Smoke alarms: 0.4 Watts, ownership 1.23 and increasing rapidly.

Conclusions and Lessons Learned

Data from a range of sources suggests that the trend in standby power consumption for some products is improving over time. This partly due to natural improvements in technology (availability of low power components and modules) but also in part due to increasing pressure from a range of government programs around the world. Many of the products with standby attributes can be considered global commodities and as such, pressure in one or markets will have impacts elsewhere. So there is some good news.

Australia has initiated a multi-pronged strategy for data collection. This is necessary given the diverse range of products found in homes. Store surveys provide a record of the types of new products offered for sale over time and the distribution of standby attributes for these products. It also allows accurate estimates of year to year trends in standby attributes which are important for modeling and impact evaluation. However, store surveys have some limitations – there are some products which cannot be measured in store (most notably devices which are hard wired) and some modes which cannot be reached in a store environment (eg end of cycle mode for clothes washers or dishwashers or modes that take some time to reach – eg auto power-down modes). Consequently, an alternative data collection approach needs to be adopted for such products and modes where these are important. Typically laboratory measurements are necessary, which can be slow and expensive. For ubiquitous products, an alternative strategy is to mandate declaration of the relevant standby values as part of the regulation of products for energy labelling and/or MEPS.

The inclusion of surveys of real houses from time to time is seen as a critical part of the data collection process as it provides information on the range and type of equipment actually installed and used in typical houses. Importantly, it can provide warning of products with high standby power that have not identified in other processes. Household surveys also provide the opportunity to record the age distribution of products (this is usually only indicative) and the modes in which products are left when not in use. However, household surveys also have limitations on the measurement of hard wired devices. Also, there are always some devices that are hidden or inaccessible, so while the data collection for household surveys can be comprehensive, it is rarely complete. Such surveys are also quite an imposition on the household owners (it can take more than 3 hours per house), so good communication with potential survey households with regard to expectations is important.

The data from Australia data suggests that there are a number of products that have very poor standby attributes (particularly in the home entertainment area). Some devices such as set-top boxes and hard drive DVD recorders with a digital tuner have quite high power consumption in most modes and ownership for these products are set to grow rapidly (particularly as analogue television broadcasts are phased out and VCRs disappear). Some integrated stereos have also been very poor, but the worst products are being removed from the market. There also a multiplicity of other devices in the home entertainment area (around 5 per house) which contribute on average 4 Watts each.

The other product of some concern are computers. The increase in ownership is extraordinary (with about than 1.8 per house in the 2005 survey sample, although recent national surveys suggest a lower figure) and this is set to increase. Presumably similar trends are being experienced in other countries. There are several aspects of concern. Firstly, the survey participants indicated that around 20% of the desktop computers included in the survey were never switched off (they were operating as home servers or network points). This has a substantial energy impact as the on mode energy consumption for an average desktop computer is more than 80 Watts (compared to an average of 3.5 Watts in off mode), assuming the screen goes into passive standby mode (2.6 Watts for LCD screen, 8.2 Watts for CRT monitors). The second issue of concern is the number of associated computer peripherals. Items such as modems, routers, switches/hubs, inkjet and laser printers, scanners and speakers are all common (average of 5.4 devices per house, at an average of 5.2 Watts per device). There is also an increasing blur between computers and entertainment devices.

Telephony equipment is also of some concern – cordless phones are now found in nearly every home and the power consumption of this equipment is typically 3 Watts per device (average of 2 devices per house).

Major appliances of course have some standby attributes of concern but their total contribution to household standby is generally only very modest. The user behaviour with respect to European dishwashers and clothes washers will have an impact on the household standby (whether or not the user manually switches the products off when not in use). Also, there is very little data on air conditioners available from the surveys in Australia – the most common products are split systems which are hard wired in the household supply so standby measurements are not possible in most situations. Australia has recently regulated to mandate the supply of data on power consumption in passive standby and off modes and crankcase heaters for air conditioners as part of the energy labelling and MEPS program, so more data should be available in the coming years.

One of the most alarming findings was that the number of devices connected to the mains and which used some power when not performing its main function climbed from 21 in 2000 to 27 in 2005 – this is an increase of 35%.

Some countries have undertaken limited surveys of households to determine standby power consumption. Many of these have concluded that standby is lower than the values determined for Australia (around 11% of residential electricity consumption). Perhaps this is because there are fewer device installed in such countries or their standby attributes are better. However a more likely explanation is that such surveys have concentrated on major appliances which are the obvious initial focus for standby power while ignoring the rapid increase in products that are associated with digital age. Appliances and home entertainment are only part of the total standby story, so it is important to recognize contributions from a wide range of products.

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Electronics Come of Age: A Taxonomy for Miscellaneous and Low Power Products

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Abstract

Most energy end uses such as space conditioning or water heating are apparently well-defined in what is included, and have terminology that derives from the professionals who work in the relevant field. The topic of "miscellaneous" consumption lacks such clarity for historical and practical reasons. As this end use grows in size and interest for the energy community, the confusion and ambiguity around the topic is an increasing barrier to progress. This paper provides definitions for key terms and concepts with the intent that that future work can be more correctly and consistently reported and interpreted. In addition, it provides a taxonomy of product types and categories, which covers both residential and commercial miscellaneous consumption. A key element is identification of "electronics" as a distinct energy end use. Finally, products are identified as to whether they commonly have a low-power mode, and product types that have such modes within the traditional end uses are also listed.

Introduction

Background

When building energy efficiency science emerged in the 1970s, attention was naturally drawn to the end uses that were the largest, most closely related to building services, potentially interactive with the building shell, and most easily characterized in traditional physics efficiency terms. These were climate control (HVAC), lighting, water heating, and major appliances (esp. refrigerators); we call these the "traditional" end uses. Other consumption was typically relegated to "Miscellaneous" or "Other". In monitoring projects, it was common to meter the whole building and the traditional end uses, then calculate the residual for the miscellaneous loads.

Over the last 30 years, the traditional end uses have become more efficient (at least per unit floor area and service delivered) and the absolute amount of miscellaneous electricity consumption has risen. The number and types of miscellaneous products found in buildings has also increased. The result is a significant increase in the percent of electricity use in the "other" category. For highly efficient new houses, it can exceed 50%. There is increasing interest in this topic area, but no consistent set of terminology on which to base policy and analysis. Since so many product types are covered, definitions are sorely needed to avoid confusion.

Scope

This taxonomy covers only electricity used by mains-voltage (115 and 230 V for the U.S.) AC products. It does not include any gas consumption (standby or otherwise), but does include the electricity consumption of primarily gas products. It addresses primarily residential and commercial buildings[1], but not exclusively. It does not cover low-voltage DC-powered products (e.g. USB or Power Over Ethernet), though the consumption of the latter are included in the products that provide the low-voltage DC such as computers and powered USB hubs.

Approach

In this project we surveyed current taxonomies of miscellaneous or low power products to draw inspiration for the approach and specific naming and categorization. We had previously reviewed issues related to power modes [1] and brought the results of that analysis to the taxonomy. We

[1] One of the principal sources for miscellaneous products, [4], included educational buildings in addition to strictly commercial ones. Most of the sources used are residential, so that our coverage of commercial miscellaneous products is considerably less comprehensive.

combined the past approaches with knowledge of how this taxonomy could be used in the future to craft a system with the primary goals of consistency and clarity[2].

Sources for the taxonomy included studies that focused on measurement methods ([1] and [2]), particular types of electronic devices ([3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], and [14]), standby power ([5], [15], [16], [17], [18], [19], and [20]), appliances ([15], [21], [22], and [23]), miscellaneous products ([1], [4], [24], [25], and [26]), and energy consumption in buildings generally ([27], [28], [29], and [30]).

Key Terms

Definitions

Following are proposed definitions ("low power", "product", and "product type" taken or adapted from that specified in [1]).

Low Power Mode[3]. Any mode in which a product is not performing any of its principal functions. Some products have more than one principal function. When feasible, low-power modes shall be categorized into on, sleep, and off modes. Disconnected is not a low power mode.

Standby. The minimum power mode of a product, or more formally, "the lowest power consumption mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when an appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions." [2].

Product. A piece of equipment that can be powered directly from mains power. This covers a specific instance or model number.

Product Type[4]. A general category of product within which there is a sufficient amount of common functionality, modes, and behavior.

Electronics. Devices whose primary function is Information (obtaining, storing, managing, or presenting).

Traditional End Uses. HVAC, Lighting, Water Heating, and Major Appliances.

Major End Use. The Traditional end uses plus Electronics.

Miscellaneous. Any product type not included in any of the major end uses. "Other" should be taken as a synonym for Miscellaneous.

Overlooked Products. Devices that perform the function of a traditional end use but are not usually included in that end use's total. We have these included in the Miscellaneous end use.

Plug Loads[5]. A product powered by means of an ordinary AC plug (e.g. 100 V, 115 V or 230 V).

Hard-Wired Loads. A product with a direct-wired connection to an AC source. These can have switches or timers between the product and the AC source.

Category. A group of product types within a single end use that share common functionality or are otherwise logically related.

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[2] The full version of the paper includes an appendix with additional information including a description of each of the source taxonomies. A spreadsheet of all of the raw data is also available.

[3] This definition is expansive as it includes "ready" modes that are forms of "on". It also is intended to include the powered mode of single-mode products.

[4] This is the core term of interest to energy professionals, e.g. "dishwasher" or "TV, CRT". Product types are differentiated "by capacity or other performance-related features that provide utility to the consumer and affect efficiency." (U.S. Department of Energy (DOE). 1991. Energy Conservation Program for Consumer Products: Final Rule Regarding Energy Conservation Standards for Three Types of Consumer Products. Code of Federal Regulations, Title 10 Part 430, Vol. 56, No. 93, May 14, 1991. Docket No. CE-RM-88-101).

[5] This is often understood to exclude product types included in major end uses.

Key Topics

Electronics. In future building science policy and analysis, there should always be a separate end use of "Electronics" [3] — covering products "… whose primary function is Information". Most products in this end use were previously categorized as consumer electronics or office equipment. The electronics end use does not include electronic components of principally non-electronic devices (e.g. dishwasher controls) unless it is a separately powered device (powered from mains AC or from DC other than from the non-electronic device[6]). Electronic products can have significant non-electronic components. For example, a laser printer contains large heating loads but retains information presentation as the principal function. Electronics were formally part of miscellaneous but the magnitude of electronics consumption in both the residential and commercial sectors and consistency of function (information) across electronics makes it logical to recognize it as a distinct major end use[7].

There are some products that can be reasonably argued to be within or outside of the electronics category, e.g. smoke and CO detectors (which provide information about potential fire status), and exit signs (which provide directional information rather than illumination in the usual sense). In both of these cases we did not include the product type in the electronics end use as their status in the infrastructure and lighting categories (respectively) seemed clearly established. In addition, at least at present, they do not usually connect to other electronic devices. By contrast, we have included the entire security category in electronics as the amount of information is larger and increasing and the security devices are also increasingly linked to clearly electronic devices.

Miscellaneous. Miscellaneous is taken to be all building energy consumption (on the load side of the utility meter) that is not covered by any of the major end uses. This includes "overlooked" products — those that serve the broad functions of the major end uses but are not usually included in estimates (e.g. ceiling fans, humidifiers, space heaters). Per above, electronic products as a whole comprise a distinct end use and can no longer be mixed in with miscellaneous products.

Miscellaneous products span the range from the very small to the very large, both in electricity consumption and physical size. Examples range from staplers to pool pumps.

Low Power Modes. Low power mode consumption was reviewed in great detail in [1]. That paper took an expansive view of the concept, including "ready" modes and consumption of single-mode products. It is useful to look at these modes collectively across many product types. The purpose and potential efficiency, of low power mode consumption is often similar across products whose active functions are quite different. Note that per IEC 62301, "standby" is defined with respect to is power level and in practice can occur in any operating mode (On, Sleep, or Off).

The Taxonomy

Naming and Categorization

Traditional energy analysis deals with a small number of end uses with a modest number of product types within each end use. Allocation of product types to end uses is almost always obvious. Naming and categories are by no means trivial but are clearly driven by functional and capacity factors. By contrast, miscellaneous products lack clarity in categories, product types, and naming.

The number of different miscellaneous product types is large. For example, an assessment of just eight California houses, [1] found 108 different product types among only products with low power modes (that is, not including miscellaneous products without low power modes). An audit of 16 commercial buildings [4] found 321 different product types without even assessing closets, plenums, basements, or attics.

Many past studies have listed and categorized product types, but the naming and grouping has generally been *ad hoc*. We reviewed the listing and naming of products in 28 different studies (listed in the References), each of which offered a system of product grouping that was typically secondary to the study scope.

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[6] For example, a 24 VAC thermostat powered from a furnace is not considered electronics, but an electronic HVAC control powered by mains AC or by USB would be considered to be electronics.

[7] "Office equipment" is now better characterized as IT as those products can and often are used for non-office purposes, particularly as used in the home.

Structure

This **taxonomy** covers two distinct but significantly overlapping topics: **miscellaneous** and **low-power mode** product types. Miscellaneous is the electricity end use which includes all products not included in other end uses (including arcane uses such as utility meter and wire resistance losses[8]). The other end uses are the **traditional** ones — HVAC, lighting, water heating, major appliances — plus the new end use of **electronics**.

For each of the traditional end uses, there are products that are usually not counted as part of them but are performing the end use's function. Examples are portable fans, task lights, point of use water heaters, and wine refrigerators (for HVAC, lighting, water heating, and major appliances respectively).

The overall structure is shown in Table 1. The taxonomy is divided into two major end uses plus the traditional end uses. Each end use is divided into a number of **categories**. There is one category for each traditional end use to accommodate low power mode consumption of these products — products without low power mode consumption in the traditional end uses are not included. There is also a category within miscellaneous corresponding to each traditional end use for the overlooked products. Most electronics are in categories that were formerly consumer electronics or information technology. Everything else is truly miscellaneous.

Table 1: Overall structure of the taxonomy

End Use	Categories
Electronics	Audio, *Cash exchange,* Computer, Display, Imaging, Networking, Peripherals, Security, Set-top, Telephony, Video
Miscellaneous	Business equipment, <u>HVAC</u>, *Commercial kitchen equipment,* Electric housewares, Hobby/leisure, Infrastructure, <u>Lighting</u>, <u>Major Appliances</u>, *Medical (lab, exam, and specialty)*, Other, Outdoor Appliances, Personal Care, Power, Transportation, Utility, <u>Water heating</u>
Traditional	HVAC, Lighting, Major Appliance, Water heating

Note. Italicized categories occur rarely if ever in residential buildings. Overlooked categories are underlined.

The degree to which product types are comprehensive or split into many pieces is a combination of a number of factors, including the similarity of the ultimate function provided, the key technology employed (e.g. inkjet vs. laser printers), capacity/size, power levels, usage patterns, stock-wide consumption, and ease of disaggregation. Some studies will find it useful or necessary to split some product types or to combine several. Over time, this taxonomy will change, as technologies and the stock of products evolve. The taxonomy reflects products in use rather than for sale.

In our review of relevant literature, we encountered numerous taxonomies of product categories. Table 2 provides an overview of some categorizations we found during our review. The order of the categories has been changed to provide some correspondence across these examples.

The variety and scope of the categories included varied widely. For example, office and consumer electronics were treated in many different ways, with office equipment variously characterized as IT, treated as a separate equipment category, or wrapped into the consumer electronics category as a whole. Different studies included or dropped entire categories, and the naming showed wide variation. The current version of the taxonomy is presented in Table 3.

[8] The loss from electrical resistance of wiring within buildings is not due to the use of a "product" *per se*, but accounting for it as such is the best way to include it in total building consumption.

Table 2: Product categories used in five sample studies

Australia	Lebot	Sanchez	Rosen	Ross
IT	IT	Electronics	Office	Computer
Entertainment	Video		Video	Entertainment
	Hi-Fi		Set-top	
			Audio	
	Telephone Systems		Telephony	Communication
Major Appliances	Cooking	Motor		Miscellaneous
Small Appliances	Miscellaneous	Heating		
		Lighting		

Australia: Ministerial Council on Energy Forming Part of the National Greenhouse Strategy. Money Isn't All You're Saving. Australia's Standby Power Strategy 2002-2012. **Lebot**: Lebot, Benoit et al. Global Implications of Standby Energy Use. **Sanchez**: Sanchez, M. et al. Miscellaneous Electricity Use in the U.S. Residential Sector. **Rosen** Rosen, K. et al. National Energy Use of Consumer Electronics in at the end of the Twentieth Century. **Ross**: Ross, JP and A. Meier. Whole House Measurements of Standby Consumption.

Table 3: The Miscellaneous and Low Power Taxonomy: May 10, 2006 version (Residential) Electronics

Audio

- Amplifier
- Audio minisystem
- Cassette deck
- CD player
- CD player, portable
- Charger, digital music player
- Equalizer (audio)
- Home theatre system
- Karaoke machine
- Musical keyboard
- Radio, table
- Receiver (audio)
- Speakers, powered
- Speakers, wireless (base station)
- Speakers, wireless (speakers)
- Stereo, portable
- Subwoofer
- Tuner
- Turntable (audio)

Computer

- Computer, desktop
- Computer, integrated-CRT
- Computer, integrated-LCD
- Computer, notebook
- Dock, notebook
- Game console
- Game console with internet connectivity

Display

- Computer display, CRT
- Computer display, LCD
- Computer display, plasma screen
- Game console, portable
- Projector, slide
- Projector, video
- Television, large CRT
- Television, LCD
- Television, plasma
- Television, rear projection
- Television, standard CRT
- Television/VCR

Imaging

- Copier
- Fax, inkjet
- Fax, laser
- Fax, thermal
- Multi-function device, inkjet
- Multi-function device, laser
- Printer, inkjet
- Printer, laser
- Printer, photo
- Scanner, flatbed

Networking

- Hub, ethernet
- Hub, USB
- Modem, cable
- Modem, DSL
- Modem, POTS
- PVR
- Router, ethernet
- Wireless access point

Peripherals

- CD recorder
- Dock, PDA
- External drive
- Speakers, computer

Security

- Security system

Set-top

- Set-top box, analog cable
- Set-top box, digital cable
- Set-top box, digital cable with PVR
- Set-top box, internet
- Set-top box, satellite
- Set-top box, satellite with PVR

Telephony

- Answering machine
- Caller ID unit
- Charger, mobile phone
- Phone
- Phone, conference
- Phone, corded
- Phone, cordless
- Phone, cordless with answering machine

Video

- Charger, still camera
- Charger, video camera
- DVD player
- DVD recorder
- VCR
- VCR/DVD
- Videocassette rewinder

Miscellaneous

Business equipment

- Adding machine
- Pencil sharpener
- Shredder
- Stapler
- Typewriter

Electric housewares

- Automatic griddles
- Blanket
- Blender
- Bread maker
- Broiler
- Clock
- Clock, radio
- Coffee grinder
- Coffee maker, residential
- Corn popper, air
- Corn popper, hot oil
- Deep fryer, residential
- Espresso maker, residential
- Food processor
- Food slicer
- Frying pan
- Hand mixer
- Heating pad
- Hot plate (kitchen)
- Iron
- Juicer
- Kettle
- Knife
- Mug warmer
- Oven, microwave
- Pasta maker
- Rice maker
- Sewing machine
- Slow cooker
- Stand mixer
- Toaster
- Toaster oven
- Vacuum, central
- Vacuum, rechargeable
- Vacuum, standard
- Waffle iron

Hobby/leisure

- Aquarium
- Kiln
- Pool
- Sauna, electric
- Spa/hot tub

HVAC

- Air cleaner, mounted
- Air cleaner, portable
- Air conditioning, evaporative cooler
- Ceiling fan
- Dehumidifier
- Exhaust fan
- Fan, portable
- Fan, rangehood
- Fan, whole house
- Fan, window
- Furnace fans
- Heating, fireplace electric
- Humidifier
- Space heater, portable (electric)
- Space heater, portable (non-electric)

Infrastructure

- Breaker, AFI
- Breaker, GFCI
- Detector, carbon monoxide
- Detector, smoke
- Doorbell
- Garage door opener
- GFCI outlet
- Infant monitor, receiver
- Infant monitor, transmitter
- Utility meter
- Wire losses

Lighting

- Dimming switch
- Emergency light, interior (commercial)
- Grow lamps
- Lamp, decorative
- Lights, holiday
- Low voltage landscape
- Motion sensor, exterior
- Motion sensor, interior
- Night light, interior
- Photosensors, exterior
- Timer, exterior
- Timer, interior

Major Appliance

- Garbage disposal
- Refrigerator, wine cooler
- Trash compactor
- Water dispenser, bottled

Other

- Fountain, indoor
- Waterbed

Outdoor Appliances

- Charger, hedge trimmer
- Charger, weed trimmer
- Coil, snow melting
- Grill, outdoor
- Lawn mower
- Timer, irrigation

Personal Care

- Air freshener
- Curling iron
- Hair dryer
- Heat lamp
- Home medical equipment
- Massager
- Shaver
- Toothbrush
- Water softener

Power

- External power supply
- Power strip
- Power supply
- Surge protector
- Timer
- Uninterruptible power supply

Transportation

- Auto engine heater
- Car, wheelchair or golf cart

Utility

- Bicycle light
- Charger, battery
- Floor polisher
- Pet fence
- Power tool
- Power tool, cordless
- Pump, sump
- Pump, well

Water heating

- Water heating, instantaneous single point of use
- Water heating, point of use tank

Traditional End Uses

HVAC

- Air conditioning, central
- Air conditioning, heat pump
- Air conditioning, room/wall
- Heating, boiler
- Heating, furnace baseboard, floor or wall unit
- Heating, furnace central
- Heating, heat pump

Lighting

- Lighting, residential

Major Appliance

- Clothes dryer, electric
- Clothes dryer, gas
- Clothes washer, horizontal axis
- Clothes washer, standard
- Cooktop, electric
- Cooktop, gas
- Dishwasher
- Freezer
- Oven, electric
- Oven, gas
- Refrigerator

Water heating

- Water heating, electric
- Water heating, gas
- Water heating, heat pump
- Water heating, other

Product Type Naming

We brought a variety of principles to the process of selecting names for product types.

- Strive for brevity, e.g. dropping “electric” from “electric knife” since non-powered knives would obviously not have energy consumption. Also use common acronyms like “TV”, “CD”.
- Give preference to names used in ordinary language. Avoid brand names.
- Use commas to distinguish related types of products, e.g. “TV, CRT” and “TV, LCD” or “Clothes dryer, electric” and “Clothes dryer, gas”. Related types need not be in the same category.
- Use “/” within lists rather than commas. Use only one comma; if more needed use parentheses and “/”s).
- Use parentheses to denote product types that share a common name, e.g. “Amplifier (network)” and “Amplifier (audio)”.
- Distinguish between products that can be run off of integral rechargeable batteries (“rechargeable products”) from those that cannot (“non-rechargeable products”). Non-rechargeable products includes both those that can be run from AC or generic batteries and those that can only be powered by AC (e.g. some audio minisystems); this distinction is not considered significant for the purposes of the taxonomy. It is not considered significant whether a battery powerable product can be used while being AC powered (e.g. many shavers, mobile phones) from those that can’t (e.g. power tools, some vacuums).
- “Portable” as a suffix is to indicate if something can be easily moved, not whether it can be powered by batteries.

Product Types in the Traditional End Uses

We relied primarily on RECS category definitions to determine which products were grouped into the traditional end uses, though we have modified these, and will be seeking clarification on how the RECS definitions are applied. Our lists are shown in Table 4.

For HVAC and Water heating, we used the RECS definitions directly. RECS includes many products in “appliances” that seem to not merit the “major” name and are not likely included in most energy analysis estimates of appliances. Examples include: evaporative coolers, spas, and waterbed heaters. For lighting, RECS includes “Energy used to supply electricity to light bulbs inside and outside of the housing unit. All types of light bulbs are included: incandescent, fluorescent, compact fluorescent, halogen, and high-intensity-discharge (HID),” and includes lighting in the general “appliance” category. We use a narrower definition. “permanently installed” includes products that are hardwired as well as those that have plugs but are screwed down or otherwise firmly attached.

Table 4: Products Types included in the Traditional End Uses

End Use	Included
HVAC	Boiler, heat pump, central furnace, heater (baseboard, floor, or wall unit —any fuel type), central air conditioning, heat pump and air conditioner (room or wall unit)
Water heating	Tank units (electric, gas, heat pump, and other fuel types, such as LPG)
Major appliances	Clothes dryer, clothes washer, dishwasher, refrigerator, freezer, oven, and cooktops
Lighting	Permanently installed fixtures (interior), permanently installed fixtures (exterior), floor lamps, table lamps

Product Type Attributes

In [1], products types were categorized as one of four types for the likelihood of having low-power modes as defined in Table 5 (from [1]). Estimates of energy consumption need to take into account the fraction of the time that examples of each product type actually have a low power mode at all. This affects understandings of power levels and usage patterns. The taxonomy spreadsheet indicates which product types sometimes or always have low power modes.

Table 5: Attributes of Product Types

Product Type Classification	Characteristic	Examples
Always	Always (or nearly always) have low-power modes.	Cordless telephone
Sometimes	Some examples have low-power modes; others do not.	Ceiling fan, radio, toaster
Never	Never [or rarely] have low-power modes	Corded power tools
Excluded	Not included in this measurement procedure, regardless of whether or not they have low-power mode consumption.	Refrigerator

Note: The concept of an excluded product type does not apply to the taxonomy.

Details

In some cases the principal function is not absolutely clear. For example, is a clock radio mainly a clock or mainly a radio? While the energy use, cost, and physical size may be driven more by the radio feature, we judged that these are foremost used as clocks and only secondarily as radios. This does not preclude an audio system from having a clock on its display; these will be judged to be principally audio devices with the clock only incidental.

For audio equipment, an “Audio minisystem” (or compact audio system) is one in which the speakers sold with the product can be physically detached from the main electronics. This is in contrast to a “Stereo, portable” which has integral non-detachable speakers. In the comments, a “Rack” system is a set of separately-powered components that are often sold as a unit that match and readily stack. This provides the equivalent of separately purchased independent components.

Future Development

We have included commercial products found in studies we reviewed, though few of the studies had the commercial sector as a focus. At present, only the Roberson report and Energy Star commercial kitchen products are included. A key missing area is much of commercial building infrastructure.

As the taxonomy evolves over time, it should be republished with dated versions and clear differences identified from previous ones (this version is dated May 10, 2006).

Conclusions

A major result of this taxonomy is that electronics should be considered a major end use on its own, distinct from miscellaneous products. While products in the traditional end uses are not a particular focus of this project, it is necessary to know what precisely is in them to know what is or is not in the miscellaneous category. Products can be named in a reasonably consistent manner and put into categories that well serve many purposes — no taxonomy is ideal for all purposes (for example, hardwired products are not a distinct category as the fact of being hardwired is not related to the function which is our criteria for assigning to categories). This taxonomy is not the ultimate — and it will always evolve over time — but this should get the energy efficiency community most of the way towards a consistent framework for naming and categorizing these products.

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Smart IC
and Power Supplies

Active and Passive Harmonic Compensation in Household Appliances

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Abstract
This paper points to the possible energy efficiency improvement in the electrical power distribution grid due to the necessity of applying compensation in consumer electronic equipments. This “necessity” has arisen as a consequence of distortions in the mains supply that triggered the compensation strategies to force compliance with power quality standards. Technically, power quality is the term used to encompass overall concerns about distortions in the mains supply. Taking power quality issues into consideration, ordinary figures of merit are the measurement of the power factor (PF) and the total harmonic distortion (THD) and, therefore, are focus in this paper. To improve the power quality indexes active and passive compensation have currently been used. It is shown that the passive, which is the conventional approach, presents drawbacks that may fall it into disuse. As a result, an active compensation strategy is investigated for comparing purposes. The employment of an active compensation strategy implies that an electronic converter should be used to drive the household appliance. In fact, on driving a compressor used in refrigeration its efficiency may be improved in the range of 30% to 40%. In the other hand, it is quite important to limit the harmonic emissions of the electronic converter as it amounts to losses in the power line, transformers, and cables are reduced since they are proportional to the square of the current. In this article a popular (low cost) one-door model refrigerator was chosen as the base-case for analysis purpose. It has been one of the most sold models and receives the one-star classification according to technical standard ISO7371.

I. Introduction

The improvement of electrical appliances in general concentrates industry-wide efforts to deal with the worldwide tendency to seek efficiency in energy consumption. Evidently, it should be mandatory in the future while natural resources have in recent years been noticeably decreasing.
Higher efficiency may be achieved in household appliances by electronic control, based on feedback from appropriate sensors of crucial variables such as temperature in refrigerators, motor speed in washing machines and so on. While embedded electronic is actually an inherent characteristic, for example in audio and video equipments, it has been emerging in recent years in HVAC (heating, ventilation, and air conditioning) applications. HVAC accounts for significant percentage of electric energy consumed in residential areas. Most of these applications utilize single-phase induction machines for driving fans and compressors. Increase in the energy efficiency of these devices of up to 30% could be achieved by introduction of adjustable or multi-speed electronic drives [1]. In refrigeration segment specifically, the variable speed compressors serve the possibility to adjust the refrigeration capacity according to the load by controlling the motor speed.
However, not only to the appliance itself the increase in efficiency also has impact on the public low voltage supply (i.e. the public 230V ac mains supply) due to the embedded electronic. A ‘public’ supply is one that is shared between more than one organization or household [2].
This paper focuses on the impact on the mains supply due to refrigerators with compressors driven by power electronic converters (adjustable speed drives).
The aforementioned impact arises from the voltage distortions in the public voltage supply as a consequence of the harmonic currents generated by the front-end stage of the power converters. The harmonic currents are power quality-related problems, which may be minimized by using active and passive compensation strategies.

The objective of this article is also to thoroughly analyze these compensation strategies faced with power quality requirements. A popular (low cost) one-door model refrigerator was chosen as the base-case for analysis purpose, i.e., it is active and passive compensated. It has been one of the most sold models and receives the one-star classification according to technical standard ISO7371.
This article is organized in the following way. Initially, a concise introduction of voltage distortions related to power quality issues, namely total harmonic distortion and reactive power, is given. Section III presents the electric characteristics of the original refrigerator, i.e. without applying power electronic apparatus for speed control. Section IV deals with the non-linear load models and discusses passive compensation and its drawbacks, section V discuss the alternative active compensation, which give possible way to improve the refrigerator energetic efficiency without depreciating mains supply distribution network efficiency and finally section VI presents some details about the current emissions technical standard IEC61000-3-2.
One should keep on mind that active compensation minimizes THD (total harmonic distortion) and Q (reactive power) quantities and therefore, increases the energetic efficiency of the mains supply distribution network due to the reduction in the drawn currents.

II. Voltage distortions – power quality issues

Conventional power converters with rectifier-capacitor front-end have distorted input current waveform with high harmonic content. Harmonic is defined as “sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency” [3]. Therefore, harmonic is the presence of current with the frequency of a multiple of fundamental current in the current of the system [3]. For example, Figure 1 (bottom) shows a waveform with 60Hz fundamental frequency and third (180Hz), fifth (300Hz), seventh (420Hz) and nineteenth (540Hz) harmonics.
For reference purposes, a pure sinusoidal waveform with only fundamental frequency of 60Hz, therefore free of harmonics, is shown in Figure 1 (top). The current waveform rich in harmonics shown in Figure 1 (bottom) has been recorded in the variable speed drive with typical rectifier-capacitor front-end stage shown in Figure 2 [2].

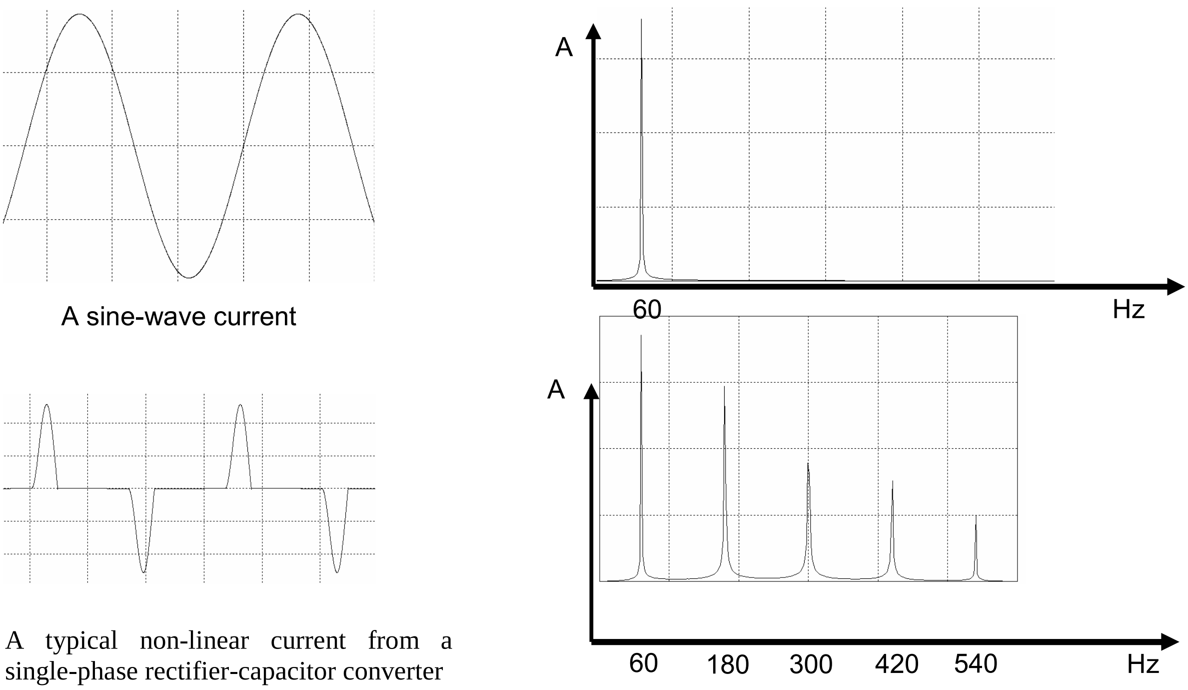


Figure 1: Comparison of two waveforms and the corresponding spectral content

The rectifier provides unregulated dc voltage rails to the adjustable speed drive. Since the dc storage capacitor is loaded at the peaks of the ac supply waveform the current consumption is discontinuous and non sinusoidal as seen in Figure 1 (bottom). For this reasons these load type has a nonlinear behavior.
The Figure 2 sketches out an approach to voltage distortions in the mains supply network at the point of common coupling (PCC) due to harmonics drawn by the rectifier. PCC is the site at which other

costumer's loads are connected to and, therefore, may be affected by the voltage distortions. It is quite fair to infer from Figure 2 that the "flat-topped" voltage waveform at the PCC is polluted by harmonics. This distortion ("flat-top") is consequence of the harmonic currents flow through the unavoidable impedances associated with the mains supply. As the harmonics currents flow through the mains supply impedance, they give rise potential differences that distort the waveshape of the supply voltage at PCC.

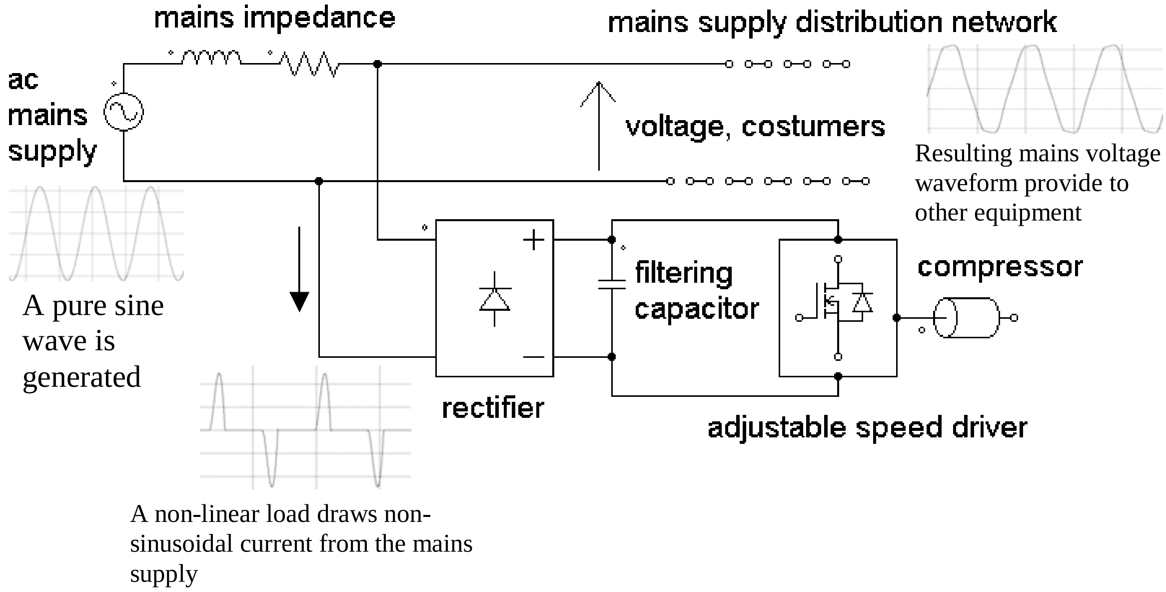


Figure 2: Voltage distortion at PCC due to current harmonics flow through mains impedance.

Typical harmonics quantities in single-phase rectifiers are illustrated in Figure 3, where they are expressed as a percent ratio of the fundamental current [4]. Third harmonic is 73.2%, fifth harmonic is 36.6% of the fundamental one and so on. A particular problem with single-phase rectifier-capacitor power converters is that they emit significant levels of "triplen" harmonics (i.e. 3rd, 9th, 15th, etc.), which are a particular nuisance because they add linearly in neutral conductors (no phase cancellation) and in zero-phase transformer flux, and they cause additional (and sometimes unexpected) heating of cables and transformers [2].

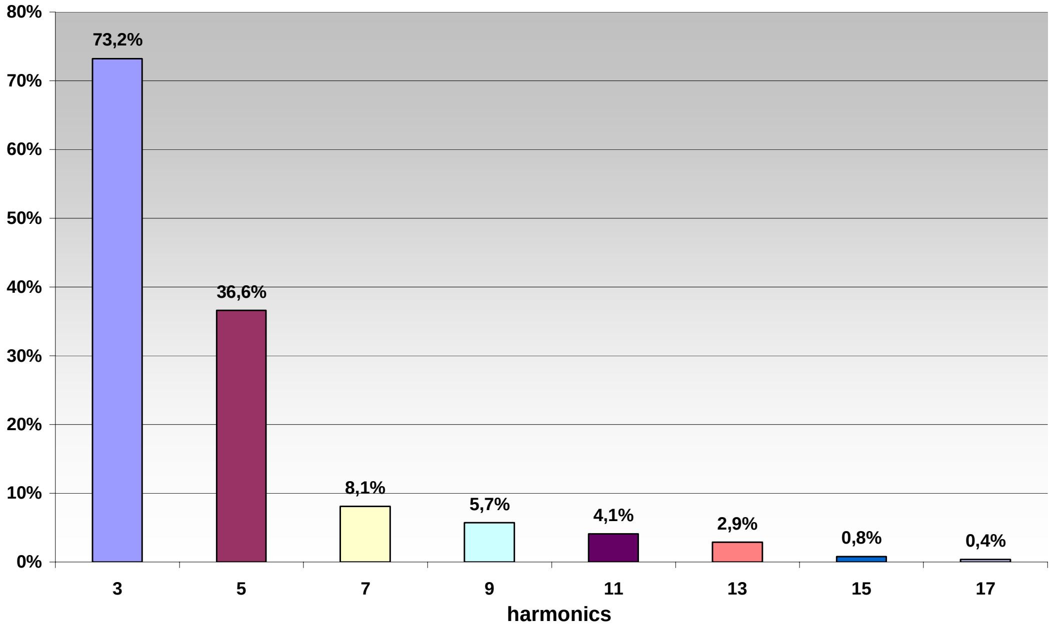


Figure 3: Typical current harmonics in single-phase rectifier with capacitive filtering.

For the metering and comparison of harmonic contents of waveforms, a parameter has been defined as a total harmonic distortion (THD). THD has been defined for both current and voltage as follows [3]:

$$THD_x = 100\frac{\sqrt{\sum X_h^2}}{X_1} \tag{1}$$

where $\boldsymbol{x}$ is the current (i) or voltage (v) quantities and $\mathbf{X_h}$ is the current (I_h) or voltage (V_h) harmonics. The subscript character **1** indicates the fundamental component, i.e., the pure sinusoidal component.

Thus, it is now possible to calculate the THD_i by (1) to be 82.59% for the harmonic spectrum in Figure 3. To put it simply, the voltage distortion at PCC (THD_v) could be taken into account only to the rectifier current flow. However, it is a tricky question because there is no certainty about the mains impedance value. As a consequence it is usually considered that a THD_v that exceeds 4% is a cause of concern, and one that exceeds 8% is cause of alarm as it is likely to cause significant problems [2].

Note that the current components at harmonic frequencies do not contribute to the average (real) power (P) drawn from the sinusoidal ac mains supply in Figure 2. In fact the THD_i is related to the power factor (PF) as follow:

$$PF = \frac{1}{\sqrt{1+THD_i^2}}\cos\phi_1 \tag{2}$$

The dimensionless power factor is a measure of how effectively the load draws the real power (P), which represents the rate of useful work being performed. The harmonic currents drawn from equipment's ac mains supply have a negligible effect on its power consumption, measured in Watts, and contribute to the power factor decreasing. Typically single-phase rectifier-capacitor has a power factor lower than 0.65, i.e., quite far from the ideal of 1.0. As a consequence it's assumed that there is a reactive power (Q) flow in the network. Reactive power is energy produced for maintenance of the network and is not produced for end-use consumption. The cos ϕ_1 factor in (2) quantifies the displacement between the voltage at PCC and the current fundamental component. Power converters have a nearly unity displacement factor.

The power quality problems related with Q and THD may be kept to a minimum by using active and passive compensation strategies.

In addition to the voltage distortions, the effect of harmonics can be noticeable in many ways such as low voltage notching, communication systems (telephone) interference and high voltages and currents in case of resonance. Further, harmonics may cause relay protection misoperations, equipment failures and high overall system losses [5].

Regard to energy efficiency, the harmonics give rise to overall losses due to the "skin effect" in copper and the increased eddy current losses in silicon steel used in mains distribution transformers at frequencies above 50/60Hz, the thermal losses in conductors and transformers that carry harmonic currents increase and they run hotter. In a larger installation with a lot of single-phase electronic loads the excessive harmonic currents (hence overheating) can be as much as 1.7 times greater than the highest phase current, due to the "triplen" harmonics that flow uncancelled in the neutral conductor [2].

III. Base-Case Refrigerator with no Variable Capacity

Energy efficient motors in the past were designed to reduce internal losses, which in turn reduce energy use. Enhanced engineering design and improved materials used in the manufacturing of motors have resulted in energy efficient motors that generate less heat, use fewer lubricants and last longer. However, it is shown in Figure 4 that current harmonics and reactive power were inherent due nonlinear electromagnetic characteristic of the motor/compressor. In this case, the current distortion depends on the design of the motor and varies with the voltage level [6].

Fig. 4 shows the measured current, voltage and power of the base-case refrigerator. The refrigerator manufacturer's assures a target consumption of 26.6 kWh/month in order to pay attention to the PROCEL[1] energetic efficiency labeling requirements. Experimental results concerning power quality issues are the measured reactive power (Q) of 131VAr and the power factor (PF) of 0,64. These

[1] With regards to refrigerators the National Institute of Metrology, Standards and Industry Quality (INMETRO) holds a labeling program in partnership with the National Energy Conservation Program (PROCEL). Information to consumers on the energy consumption of household refrigerators is provided through two labels displayed on refrigerators available at the retail market. The Brazilian energy-efficiency label follows the European design showing energy efficiency class on a scale from A to G, for A being the best performing appliances. Every appliance achieving class A efficiency level fits in PROCEL and is endorsed by means of the specific label.

results point to a non-energetic efficient appliance regard to the mains supply distribution network since it draws 131VAr of reactive power to 108.5W of active (real) power. Figure 4 highlights the reactive characteristic in the perceptive displacement between voltage and current waveforms which is cos ϕ_1= 0.58, i.e. the waveforms are not in phase (see displacement factor considerations in section II). Based on the low distortion in the current waveform (low THD_i), the low power factor (PF) of 0.65 in equation (2) is essentially linked to the high cos ϕ_1. This conclusion is corroborated by current spectrum in Figure 5 where the low amplitude of harmonics 3_{rd} (6,2%), 5_{th} (5%) e 7_{th} (1,5%) may be compared to the fundamental 60Hz.
Further, the voltage waveform at PCC in Figure 4 is with a minor distortion, i.e. THD_v< 0.5% since in this case the current harmonics do not have a prominent content.
If controlling techniques based on electronic resources are to be used for achieving higher energy efficiency the use of rectifiers with dc smoothing filters (capacitors) become a common feature. As a consequence the impact on mains supply distribution network changes from reactive power, for original refrigerator, to the prevailing current harmonic components. Figure 6 shows the expected current at input of the rectifier as discussed in section II.
The current is strongly distorted reaching the as high as THD_i=108%. The factor power remains around 0.66 and displacement factor of 0.97 is closer to unity, therefore, reducing reactive power demand. On the other hand, the increases of the current harmonics cause voltage distortions at PCC, which is THD_v=3.2%. Accordingly, passive or active compensation should be applied to mitigate harmonics. So, load models are evaluated providing insight into the requirements for the compensator design.

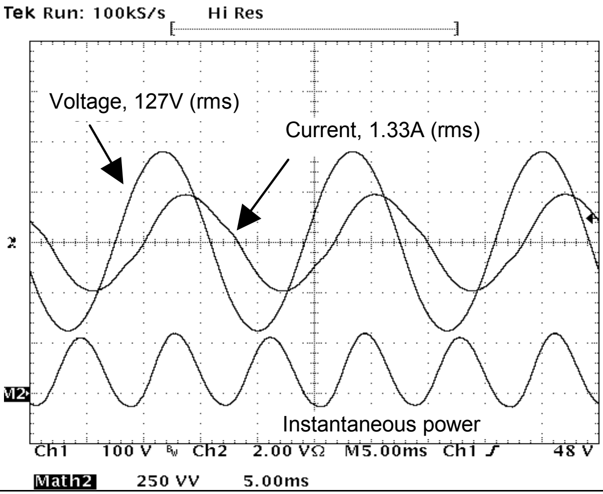


Figure 4: Voltage, current and instantaneous power of a refrigerator with no variable capacity. Horizontal scale: 5ms/div. Vertical scale: current, 2A/div; voltage, 100V/div and power, 250W/div.

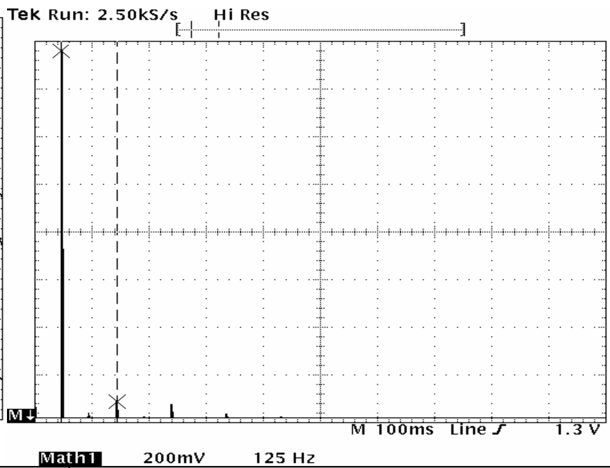


Figure 5: Current spectrum. Horizontal scale: 125Hz/div. Vertical scale:0.2A/div.

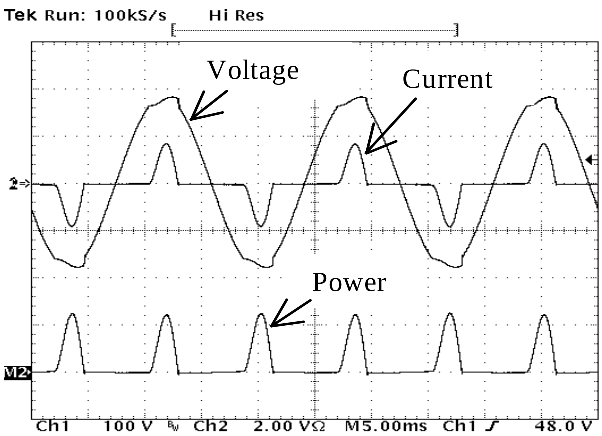
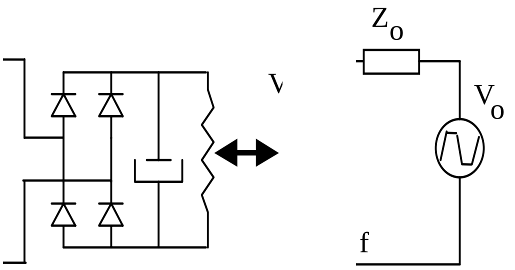


Figure 6: Mains voltage, current and instantaneous power in a rectifier-capacitor front-end power converter.

IV. Nonlinear Load-Type and Passive Compensation

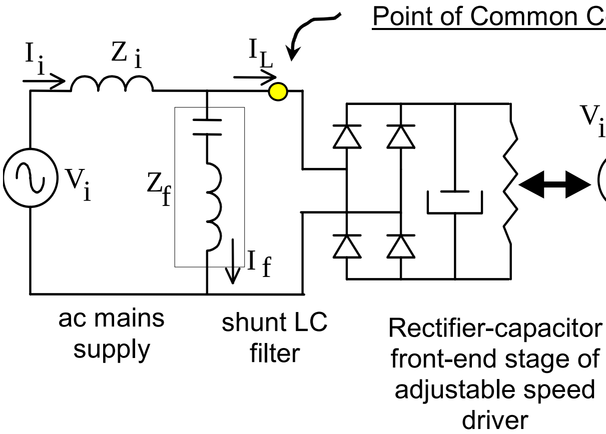
The power quality problems are primarily due to voltage distortion caused by nonlinear behavior of the loads as seen in Figure 6. Simulation models have represented two types of nonlinear load, i.e, current harmonic source and voltage harmonic source. The models differ in the rectifier-filtering element, which changes from a capacitor in the voltage source to an inductor in the current source, respectively connected in parallel and series with the load. A rectifier with smoothing dc capacitors behaves like a harmonic voltage source, rather than a harmonic current source [7]. Accordingly, this type of nonlinear load has to be characterized as a harmonic voltage source and, therefore, the current source is out of interest in this article. Figure 7 shows the rectifier and its equivalent model, which has been used for analysis purposes.



Harmonic source

Figure 7: Rectifier-capacitor power converter (left) and its harmonic equivalent circuit (right)

The conventional approach to passive harmonic compensation has been the parallel (or shunt) LC filter in which shunt low impedance branches traditionally consisting of 5^{th} and 7^{th} tuned LC series-resonant filters are connected in parallel to a nonlinear load [7]. The Figures 8 and 9 shows respectively the shunt LC filter connected at PCC and its equivalent circuit.



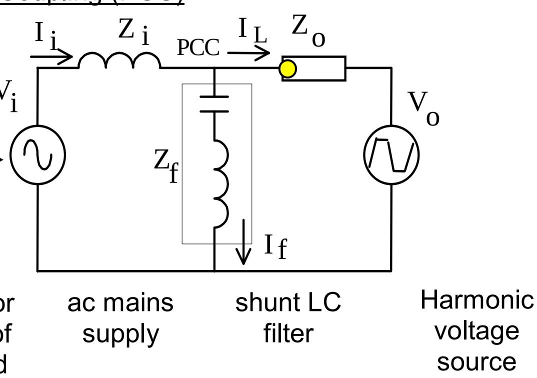


Figure 8: Basic principles of shunt LC filter for harmonic voltage source compensation.	**Figure 9: Equivalent circuit**

The compensation performance of a shunt LC filter for a harmonic voltage source load can be expressed as:

$$\frac{I_i}{V_o} = \frac{Z_f}{Z_o Z_i + Z_o Z_f + Z_i Z_f} \tag{3}$$

It is clear from Fig. 9 and (3) that the compensation characteristics depend on the load impedance Z_o as well as the source impedance Z_i. If Z_o is zero, then (3) is reduced to =1/Z_i, which means the parallel filter is useless. On the other hand, if Z_i is zero, then (3) is reduced to $I_i/V_o = 1/Z_o$, which means the parallel filter is useless as well.

Experimental results of a circuit including a linear (inductive-resistive) and a nonlinear load (rectifier-capacitor) connected at PCC are shown in Figure 10. In this case the former demands reactive power and the latter is a harmonic-rich load. A 5^{th} harmonic tuned LC filter is connected at the PCC, consequently there is no phase shift between current and voltage. At this point the displacement factor is close to “1” and the LC filter capacitance compensates the reactive power. However, the current is noticeably distorted (has harmonics).

Table I indicates the PCC voltage harmonics. As expected, the shunt filter reduces de 5th component (and also the 7th) but increases the 3rd and 9rd harmonics. This unexpected effect can be understood by taking into account the non-linear behavior of the load, i.e., the load reacts to changes in the voltage waveform. The voltage THD_v is decreased from 4.46% to 4.05% mainly due to the 5th harmonic reduction. The harmonics amplitude and THD_i at the mains supply current (I_i in Figure 9) are listed in the Table II. Likewise, the 5th tuned harmonic filter reduces this component but increases the 3rd harmonic and consequently the THD_i as well. The fundamental component is reduced due to the reactive power compensation.

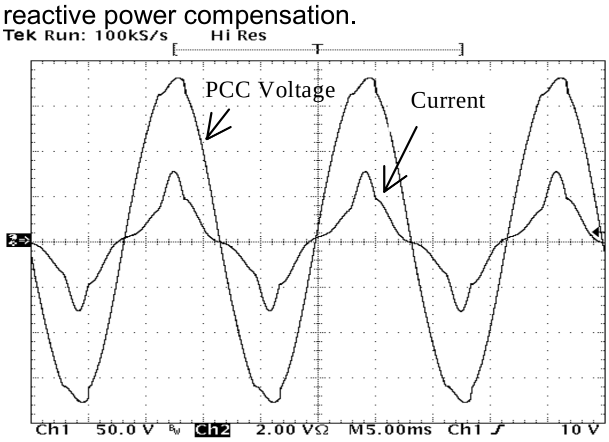


Figure 10: Voltage and current distortions at the PCC caused by reactive and harmonic-rich loads with passive compensation (5th tuned LC shunt passive filter). Horizontal scale: 5ms/div. Vertical scale: current, 2A/div and voltage, 50V/div.

Table 1: Voltage harmonics (peak value) at the point of common coupling (PCC)

Harmonic order	With 5th harmonic filter [%]	Without the filter [%]
3	2.92	2.2
5	0.83	2.58
7	1.73	2.03
9	1.27	1.08
11	0.66	0.69
THD (%)	4.05	4.46

Table 2: Harmonics (peak value) of the ac mains supply current

Harmonic order	With 5th harmonic filter [A]	Without the filter [A]
1	2.2	2.68
3	0.904	0.671
5	0.157	0.477
7	0.232	0.268
9	0.132	0.11
11	0.056	0.058
THD (%)	43.7	32.8

Review of these results shows that the passive compensation does not avoid the mains supply distribution system of carrying harmonic currents and, therefore, decrease its energy efficiency (discussed in item II). It is quite clear that the improvement of the energy efficiency is closely linked to the power quality of the system.

V. Active Compensation

An active front-end stage should be used in order to reduce harmonic currents of adjustable speed drives. Accordingly, power switches (transistors) must be used rather than diode rectifiers or semiconductor-controlled rectifiers (usually termed thyristor) since transistors allow full controlling of the current. Most common switches are insulated gate bipolar transistors (IGBT) due to its high range of application and as a consequence low cost.
In this article two, a high and a low switching frequency, active front-end stages are evaluated.

1) High switching frequency active front-end stage
Figure 11 illustrates an alternative to a high frequency active front-end stage for adjustable speed drives [8]. A split capacitor bank forms the dc link. The switches Ta and Tb form the front-end rectifier. The inverter to convert the dc-link voltage to a balanced two-phase output with adjustable voltage and frequency features is configured with four switches Tc to Tf, respectively.

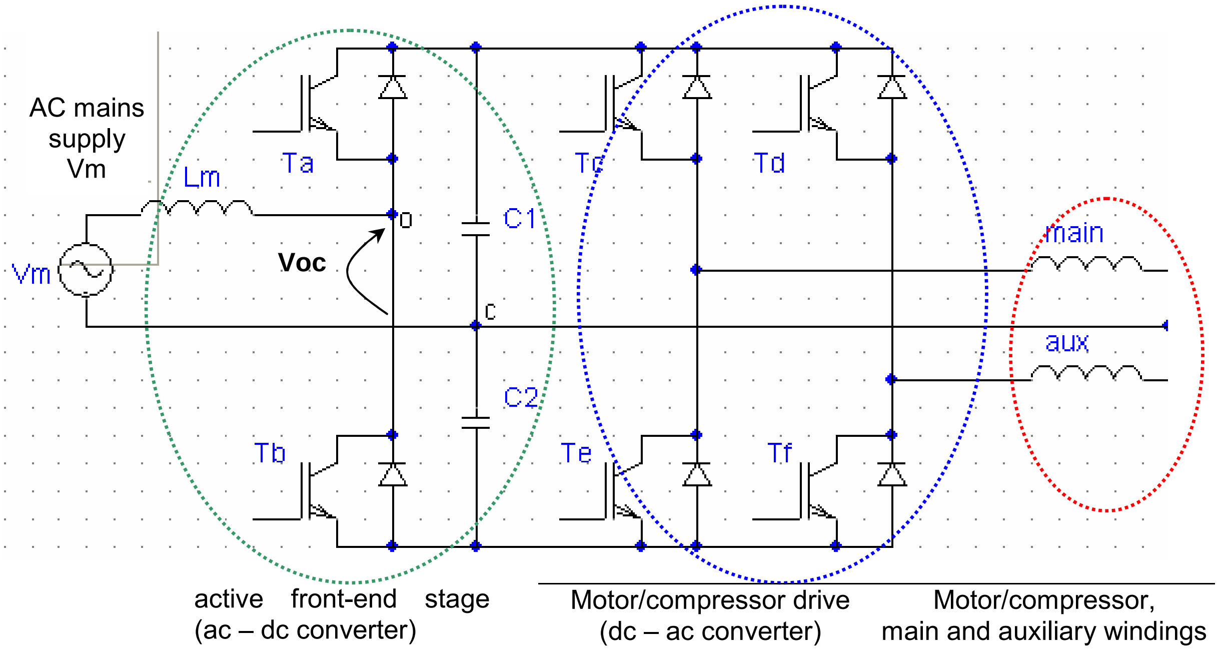
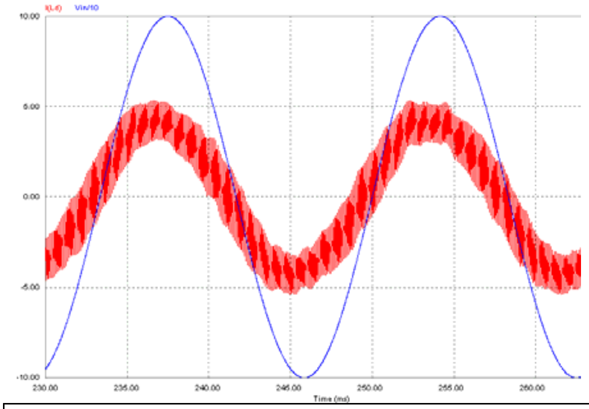


Figure 11: Active front-end stage applied to adjustable speed drive.

The single-phase AC supply is rectified by the front-end rectifier switches Ta and Tb. The split capacitor bank (C1 and C2) in the dc link is charged through the diodes present in Ta and Tb. The switches Ta and Tb are operated on a PWM pattern synchronized to the ac mains to shape the input current to provide a unity power factor. The filter inductor L_m aids in filtering higher order current harmonics.
The fundamental component of the voltage at points “0” and “c” is V0c,1, which is essentially the reflected voltage due to the PWM operation of Ta and Tb. A sinusoidal PWM technique or an advanced PWM technique that selectively eliminates several lower order harmonics may be used to control Ta and Tb. In this article the former has been evaluated and therefore the harmonic spectrum has only high harmonic frequencies, which would be mitigated through (electromagnectic interference) EMI filters[2].
Results from simulation in PSIM/SIMCAD software are following shown. Current in such a front-end stage is shown in Figure 12 to its respective spectrum in Figure 13. The 3rd harmonic (180Hz) is thirtieth times lower than the fundamental at 60Hz, which is sufficient to comply with harmonic current standards such as IEC 61000-3-2.
Since harmonic current and reactive power are the main focus in this article only concise information about control is provided as follow: two nested control loops are used, the inner guarantees the sinusoidal current shape and the high power factor, and the outer keeps the total dc voltage with a

[2] EMI filters are designed for complying with technical standards that limits frequencies amplitude in the range of 150kHz up to higher frequencies.

stable value. An equalization loop may be also needed to equally share the voltage in the split capacitors C1 and C2.



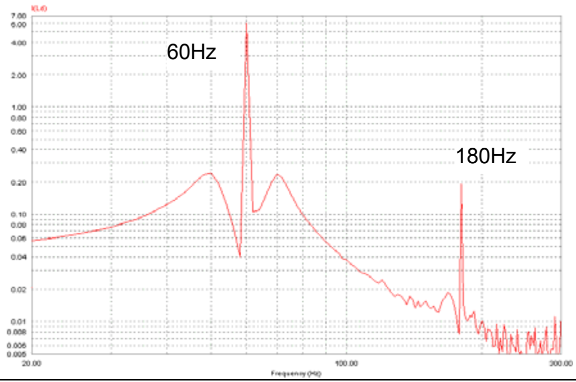


Figure 12: Simulated voltage and current in the ac mains supply. Switching frequency of 10kHz

Figure 13: Ac mains supply current spectrum. Horizontal scale range: 20 to 300Hz.Vertical scale in dB.

Results from an experimental prototype under test are shown in Figure 14, designed for output power of 220W, total dc voltage of 300V, C1=C2=450μF and L_m=2mH. Although the voltage distortion looks satisfactory a closer examination reveals that control design could be improved in order to phase voltage and current. The voltage in capacitors could be better balanced through applying an equalization loop.

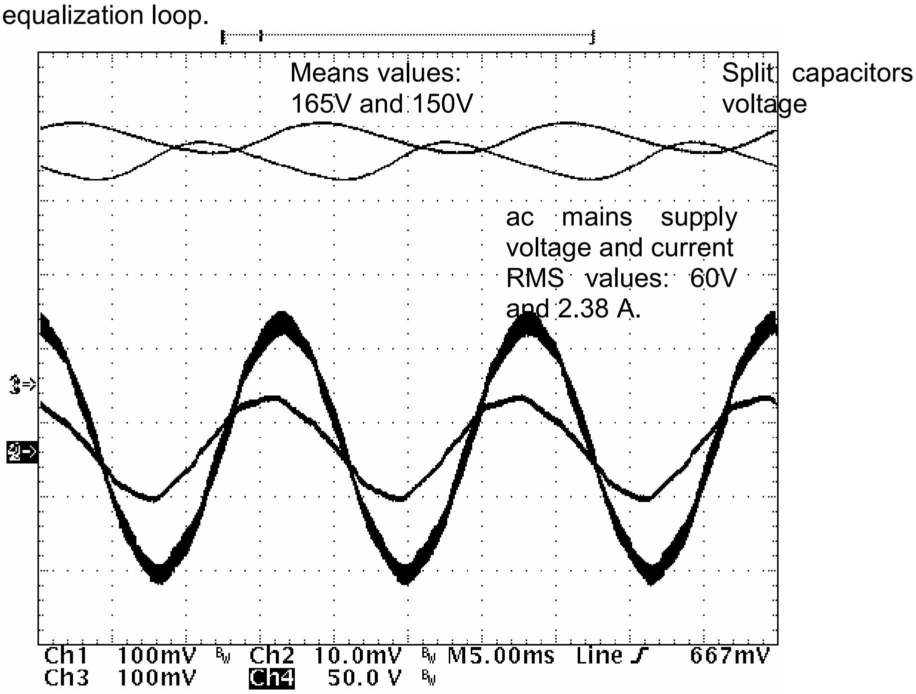


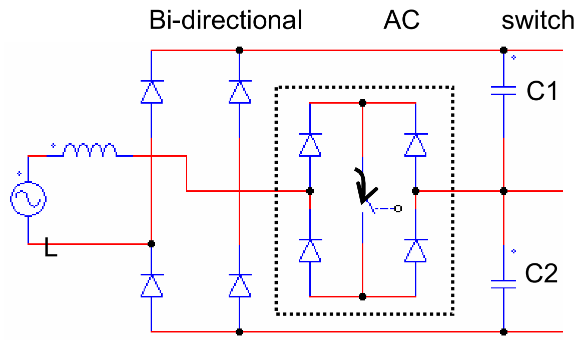
Figure 14: Experimental results. Vertical scale: voltage (50V/div) and current (5A/div). Horizontal scale: 5ms/div.

Even though, the active high-frequency front-end rectifier satisfactory raises the energy efficiency at PCC, due to the fast switching inside the drive, there's a risk of electromagnetic emissions, which can take the form of conductive and radiating interference. It does not overall affect efficiency but, in turn, interfere in other appliances work. International regulations set limits on both low- and high-frequency emissions. With the use of filters, screening, and suitable mechanical construction inside the drive cabinet, it's possible to meet the electromagnetic compatibility (EMC) standards. Other suitable alternative is to use line-frequency commutated auxiliary AC switch in traditional passive rectifiers as is going to be discussed below.

b) Front-end stage coupled to line-frequency commutated AC switch

The line-frequency commutated AC switch coupled to split capacitors shown in Figure 15 is able to greatly improve both power factor and output voltage regulation of rectifiers with passive L-C filters [9]. As seen the AC switch has bi-directional current flow capability. It is getting through the arrangement of the diodes and the uni-directional switch.

The switch is turned on with some delay regard to the line voltage zero crossing. It allows having current flow start close to the voltage zero crossing and therefore reducing the displacement between voltage and current as illustrated in Figure 16. This auxiliary switch starts a resonance phenomenon between inductor L and both capacitors C1 and C2. During the resonant interval the input current splits almost equally between the capacitors. This circuit has a boost action introduced by the commutation cell, which through compensation of the voltage drop across the input filter inductor allows the achievement of dc voltages higher than the peak of the ac mains supply voltage.



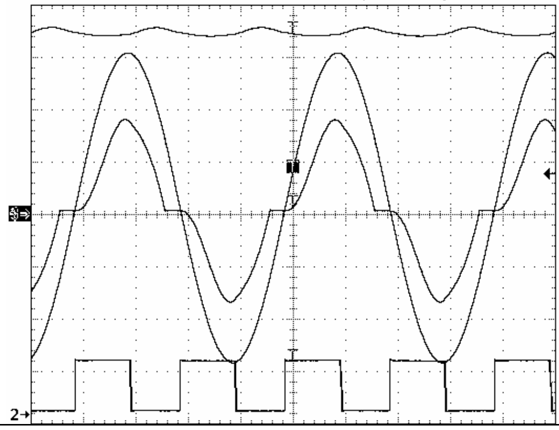


Figure 15: Line-frequency commutated front-end rectifier	Figure 16: AC mains supply voltage and current waveform. Total link CC voltage and switch pulses.

Despite of its slightly distortion the current waveform in Figure 16 comply with the limits for harmonic current emissions set by IEC 61000-3-2 technical standard.

VI. Current emissions technical standard (IEC 61000-3-2)

Compliance with IEC61000-3-2 is now a requirement (for all equipment within its scope) for conformity with the Electromagnetic Compatibility Directive [10].

The standard establishes four classes of equipment, each with their own harmonic emissions limit.

- Class B for portable equipments
- Class C for lighting equipment, including dimmers
- Class D for Personal Computers (and their display monitors) and TV receivers, with a "specified power" less than or equal to 600W.
- Class A for everything else, particularly balanced three-phase equipment.

Adjustable speed drives for compressors/motors in refrigerators are class A limited due to the front-end rectifier. The emissions limits EN61000-3-2 Ed.2:2000 for each class are listed in Table III.

Table 3: EN61000-3-2 current harmonics limits

Harmonic order 'n'	**Max current Class A**	**Max current Class B**	**Max current** (% of fundamental current**)**	**Max current Class D** **(**but no more than Class A**)**
2	1.08 Amps	1.62A	2%	Not specified
3	2.30A	3.45A	30λ%	3.4mA/Watt
4	0.43A	0.645A	Not specified	Not specified
5	1.14A	1.71A	10%	1.9mA/Watt
6	0.30A	0.45A	Not specified	Not specified
7	0.77A	1.155A	7%	1.0mA/Watt
8 ≤ n ≤ 40 (even)	0.23 (8/n) A	0.345 (8/n) A	Not specified	Not specified
9	0.40A	0.6A	5%	0.5mA/Watt
11	0.33A	0.495A	3%	Not specified
13	0.21A	0.315A	3%	0.35mA/Watt
15 ≤ n ≤ 39 (odd)	0.15 (15/n) A	0.225 (15/n) A	3%	(3.85/n) mA/Watt

where λ is the circuit power factor and *n* is the harmonic order.

The harmonic limits are absolute values for Classes A and B, whatever the input power. The Class C limits are expressed as percentages of the 60Hz current consumed, and for Class D they are a set of sliding values proportional to the mains power consumed. For equipment with an input rating greater than 600W the Class A and Class B limits, being fixed, become proportionately more difficult to meet as the mains input power increases.
Compared to the Class A the current draw by the line-frequency commutated front-end rectifier is within the current emissions limits as shown in Figure 17.

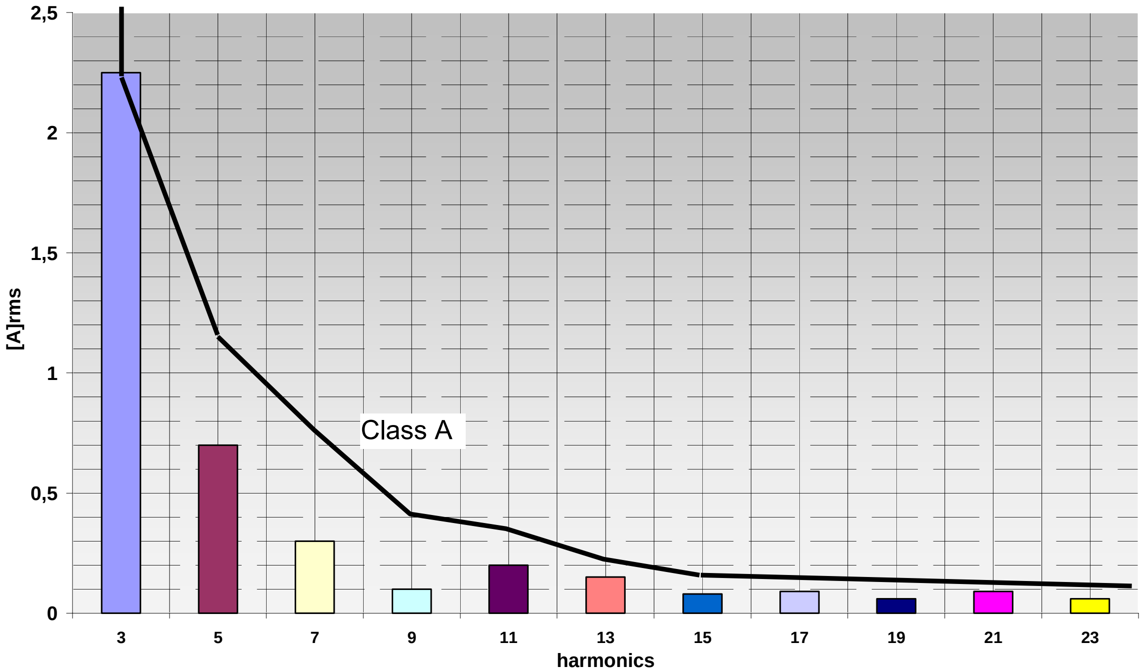


Figure 17: Line-commutated rectifier complies with IEC 61000-3-2 technical standard.

VII. Conclusions

It has been shown that power quality indexes, such as Q and THD, and the energy efficiency of the mains supply distribution network are closely linked. Thus, a design concerning with these indexes avoids depreciating the network overall efficiency while improves the energy efficiency of household appliances.

Power converters with rectifier-capacitor front-end stages are usually embedded in household appliances for achieving higher energy efficiency since electronic resources allow implementing control techniques.
Nevertheless rectifiers do not determine the current drawn from network, otherwise, it imposes the voltage at the PCC. As a consequence, the conventional approach to passive harmonic compensation, i.e. shunt filters, cannot effectively filter out the resulting current harmonics.
If one is interested in reducing current harmonics at PCC, the best alternative according to (3), is to increase both, the series impedances to the mains supply (Z_i) and the load series impedance (Z_o). In conclusion the individual compensation is unfeasible for rectifier type loads because they already have a capacitive fundamental displacement factor. Thus, active solutions considering high and low switching frequency have been investigated for applying in an adjustable speed drive.
The presented results showed that both active solutions comply with technical standards, although the line-frequency commuted converter is very close to the limits of the standard. It helps to choose better solution, however a more careful analysis should be done taking into account the performance, cost and volume of a prototype. It would also be interesting to note that the solution based in the line-frequency commutation complies with IEC61000-3-2 despite of drawing low amplitude 3th, 5th, 7th, and other harmonics. That is quite different from the high switching frequency based solution, which essentially transfers energy at the high switching frequency.So, strictly taking into consideration the power quality indexes the high-frequency based solution will not significantly decrease the energy efficiency of the mains supply distribution network.

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Increasing Efficiency in Appliances, Office Equipment and LED Lighting

Douglas Bailey

Power Integrations

Abstract

New energy efficiency regulations with tight standards are driving original equipment manufacturers (OEMs) to make their products operate more efficiently. Markets such as domestic appliances, small office/home office equipment and consumer electronics are very cost competitive, so the means used to increase the efficiency of the products sold in those markets must be affordable for OEMs to implement. Highly integrated power conversion ICs already exist, making it relatively painless for OEMs to quickly, easily, and cost effectively design energy-efficient power supplies for their products. When this fact is understood, many OEMs are motivated to bring their products into compliance since that can give them a distinct advantage over other manufacturers who's products do not yet comply with the new standards.

This paper looks at some power budget aspects of power supplies for products that range from washing machines and LED lighting to ink-jet printers, and shows how their power supplies can be radically simplified and made compliant to all of the current (and proposed) worldwide energy efficiency standards, by redesigning them around highly integrated power conversion ICs.

Introduction

Various governmental and standardization bodies around the world, committed to protecting our dwindling energy resources, have enacted power supply regulations to help save energy and further minimize power supply costs. However, if the power supply efficiency regulations focus on making power conversion more efficient, but the system-level product misuses the converted power, any potential energy savings may be lost. For this reason, new regulations are emerging—such as the ENERGY STAR "imaging products" and "computing equipment" specifications—that define the number of watts required to power standard system-level functions. This presents the designer with more design-for-efficiency decisions and choices. The designer can choose whether to derive energy savings from the power supply, from the functional system, or from a combination of both. Applying this "power budget" approach to standby power usage has resulted in the introduction of many efficient products (popularized by the *1-Watt Standby* movement). This paper looks at a few of the more common applications where a power budget approach was used to reduce power consumption in standby modes and shows how the derived savings can be applied to other modes.

White Goods

Washing machines and white goods, in general, require small amounts of low-voltage DC power to operate their controls and status displays. Typically, the physical enclosure of the machine provides sufficient isolation, enabling the use of a non-isolated type of power supply that is both easy-to-implement and inexpensive. One of the most popular types is the post-regulated capacitor-dropper (see Figure 1), which uses a minimum number of discrete components to provide the small amounts of current needed to drive the system's electronics. However, the efficiency of a cap-dropper is about 30 percent at the full load of 50 mA, making the conversion of power for the control systems extremely inefficient. In standby, the efficiency drops to 18 percent. In the example shown in Figure 1, the 360 mW of power absorbed by the microcontroller and other electronics was costing a continuous 2 W of power drain. This equates to the energy of one wash cycle every two weeks, or about 10 percent of the total energy usage of the washer over a one-year period. To achieve a 1 W power budget on the standby power of this same appliance, the designer would have to redesign with a more efficient power supply technology. The use of a non-isolated buck (see Figure 2) can provide 720 mW of power for just 1W of input power (see Figure 3), and free 360 mW of power for use in driving the electronics. Put in practical terms, the benefit of using the non-isolated buck in the redesign is this:

any consumer wishing to use less power in standby than in wash mode can limit laundry days to a bachelor-approved “once-a-month.”

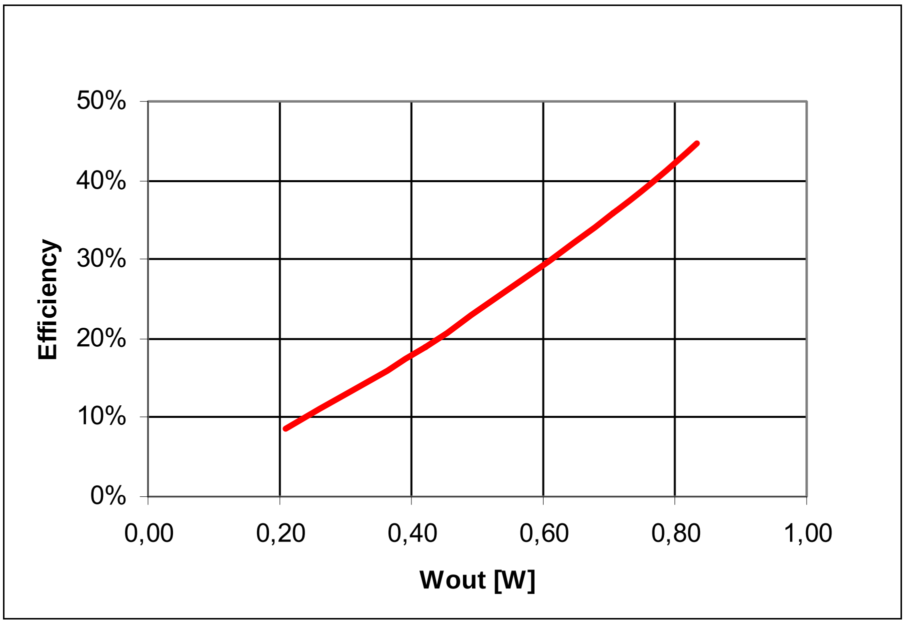


Figure 1: Efficiency curve of a typical, post-regulated, capacitor-dropper power supply.

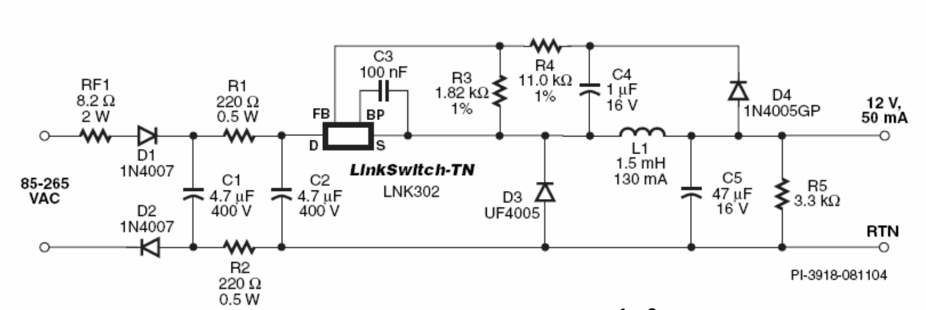


Figure 2: A non-isolated, buck power supply[1, 2] designed to replace capacitor-dropper supplies.

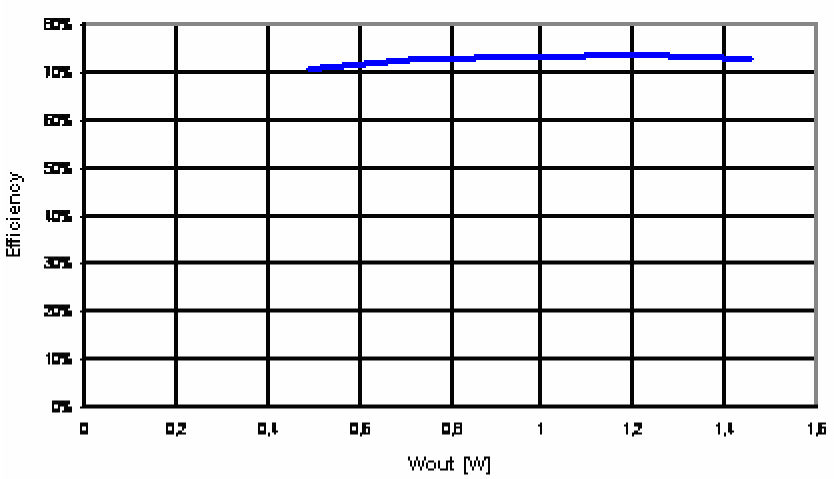


Figure 3: Efficiency curve of the non-isolated buck power supply.

[1] See LinkSwitch-TN datasheet.
[2] See LinkSwitch-TN Design Example Report 92.

Printers

The power used in inkjet printers varies from ≤ 1 W in standby mode to 70-to-80 W in peak-power mode (generally when the paper feed motors are engaged). Given this large dynamic range, the power budget for a printer is best viewed as the average of operation over a substantial period. Figure 3 shows the power usage of a typical inkjet printer. The standby-mode functions are well defined, and can be generally summarized as follows: check the "ON" switch for activity, and keep the "Power Connected" LED illuminated. However, printers also have a sleep mode that permits fast power-up when a print-job is issued: this mode needs to be considered when using a power-budget approach to design. To maximize the use of available power across the printer's entire power range, the power supply needs to deliver efficient power from standby to full peak-power modes. Figure 4 is the block diagram of such a power supply, designed using an integrated switched-mode IC with peak-power capability. Figure 5 is the efficiency curve of the supply depicted in Figure 4.

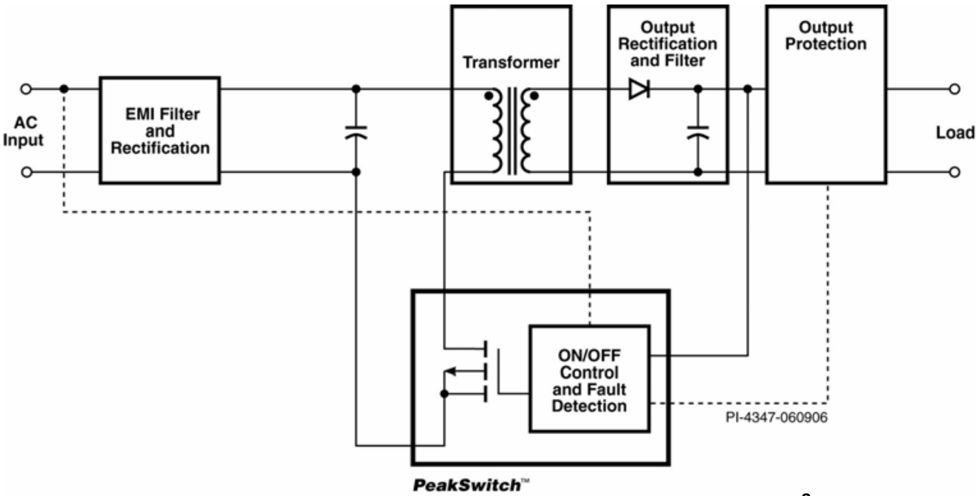


Figure 4: A power supply designed around a switched-mode IC[3] with peak-power capability.

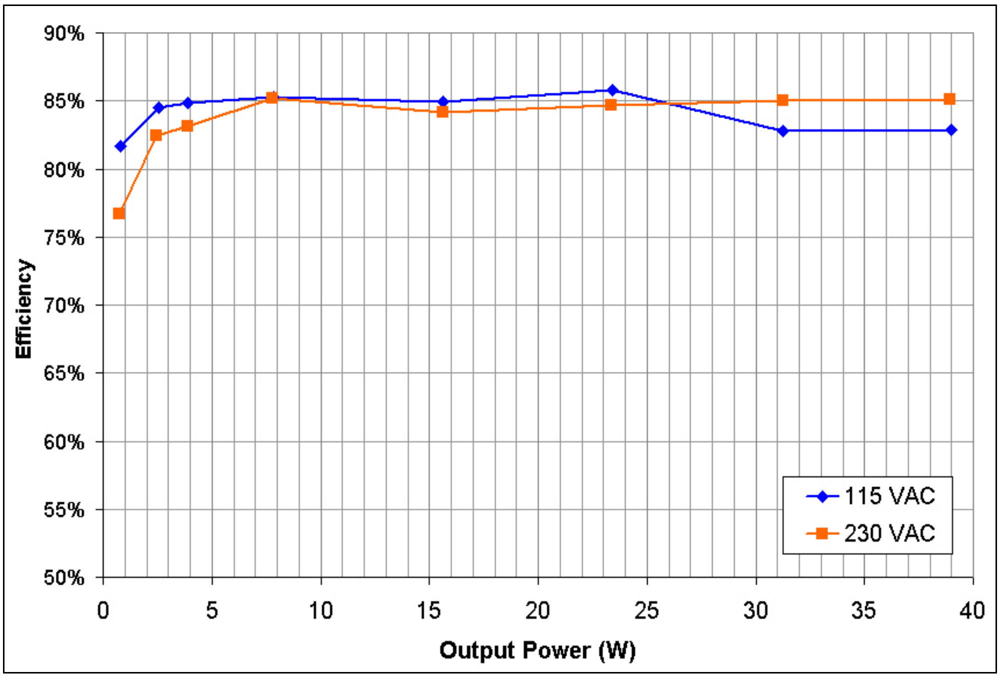
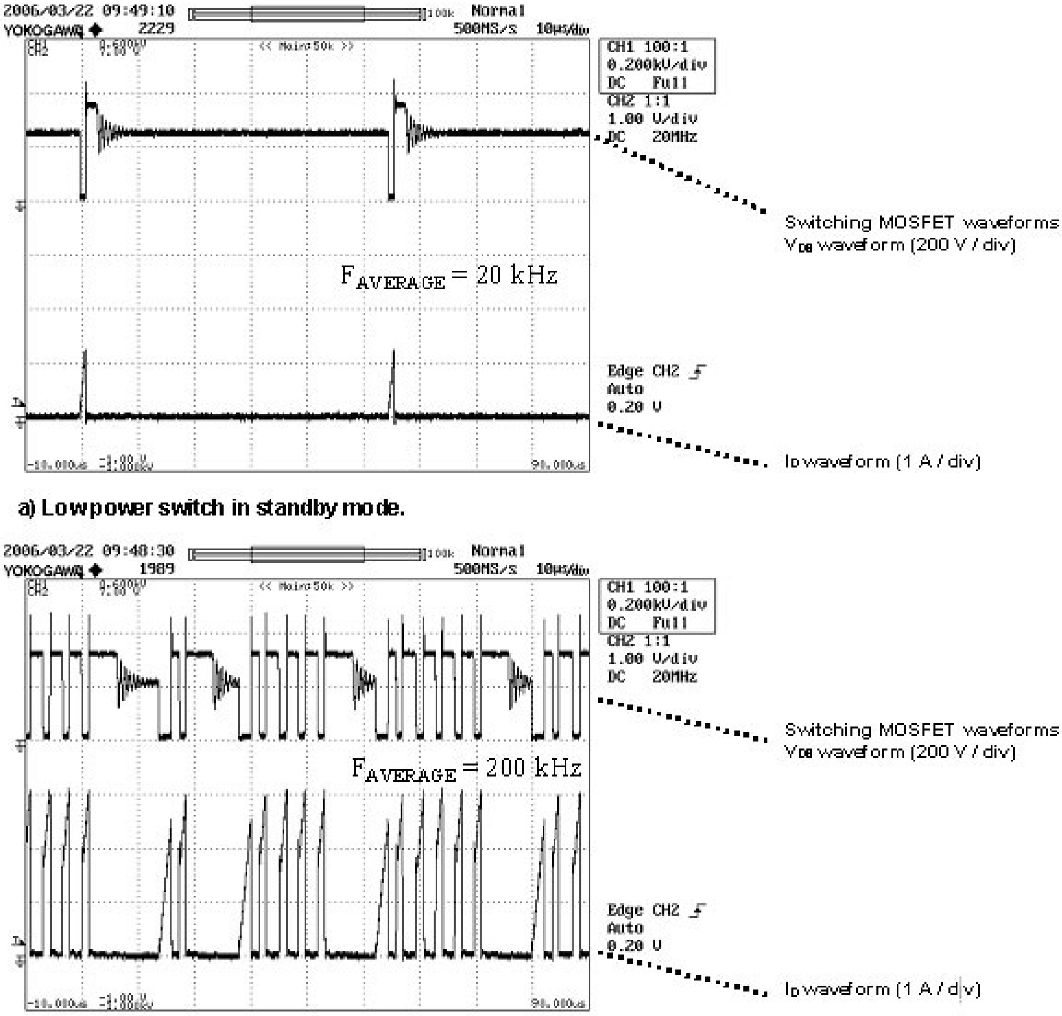


Figure 5: Efficiency obtainable using a switched-mode IC with peak-power capability.

[3] See PeakSwitch datasheet.

Power delivery, proportional to $P = 0.5 \cdot LI^2f$, where L = transformer inductance, I = current limit, f = frequency), is predefined for the design. The current limit, which is defined in the ON/OFF control scheme, is also predefined to one of 4 levels. The integrated switch-mode IC with peak-power capability changes average switching frequency to provide variable amounts of power across the range required by the printer, as shown in Figures 5 and 6.



a) Low power switch in standby mode.

b) Low power switch in peak mode.

Figure 6: Peak-power management using intelligent, switched-mode IC.

LED Lighting

California's new *Title 24* brought advancements in efficiency to residential lighting installations. The regulation requires that, under most circumstances, high-efficiency lighting be installed on the hard switch points in every room. The target for lighting efficiency is 40 lumens per watt, which is out of the range of most incandescent technologies, making fluorescent or LED lighting a necessity. The current standard, which ignores the ballast losses of the incandescent light, is likely to change to address the need to manage these losses. LED use in general lighting is beginning to gain momentum, and can achieve 40 lumens per watt when a highly efficient power conversion technology is used. A luminaire using LED sources with a conversion efficiency of 50 lumens per watt requires a power conversion efficiency of at least 80 percent to deliver 40 lumens per watt (input power to output light). For a 15 W luminaire, this requires losses in the luminaire to remain at or below 3.75 W. Figure 7 shows an example of an LED lighting source designed using this power budget approach.

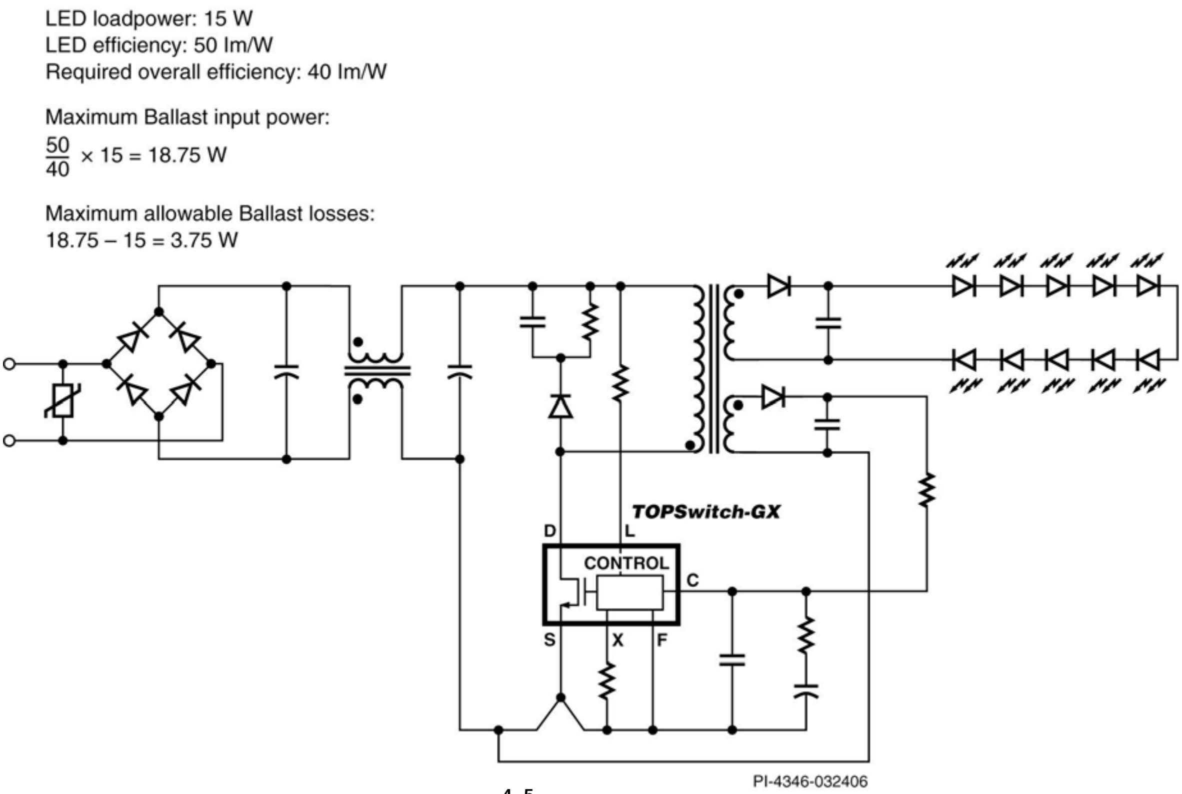


Figure 7: Energy efficient power supply[4, 5] for an LED lighting source.

Summary

New regulations are forcing engineers to apply pre-defined power budgets to their design. Optimizing for power conversion efficiency in the supply unit is no longer regarded as the only means to reduced energy usage. Given the tighter regulations governing system-level power usage, the designer must now look at ways to derive energy savings from the power supply, from the functional system, and from a combination of both. Taking a power budget approach to design results in more power-efficient products in standby mode and can lead to new orders of efficiency in no-load and peak-power modes, as well.

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Monitoring and Control Systems to Manage Energy Use in US Homes

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Abstract

Energy use in homes represents 21% of US total energy demand in 2004. Managing this sector is an important priority for addressing global warming, conserving resources and improving energy security. Much energy is wasted in delivering energy services not actually used by residents. IT-enabled monitoring and control technologies have played an important role in eliminating similar inefficiencies in other sectors, they could have an important role in the home as well. The technology level of energy control in most residences is at least 20 years old, with simple programmable thermostats still in only about a quarter of US homes. Networked thermostats, power meters and switches, and zone heating are technologies that can that can monitor energy and enable control for delivery only where and when needed. In addition to direct energy savings, there is also the potential to reduce indirect needs for energy infrastructure through peak shifting, or redistributing of electricity demand more evenly throughout the day. In addition to surveying these energy management issues, this article also relates the experience of a pilot project setting up monitoring/control systems in three Sacramento homes. The design specifications of these systems combine capabilities for web-based monitoring and control and peak shifting via pre-cooling, and load shedding. The pilot has shown that such a monitoring and control system satisfying the design parameters can be implemented via mainly off-the-shelf parts. Much work remains to be done however, to develop low-cost user friendly systems attractive to typical homeowners.

Introduction

Mitigating energy use in homes is an important challenge. Residential energy use accounted for 21% of US total energy demand in 2004, and grew a total of 16% over the last 10 years [1]. Improvements in residential energy efficiency have been offset by the growth in average home size, rising from 1400 ft^2 ($130m^2$) in 1970 to 2200 ft^2 ($204m^2$) today, as well the proliferation of additional electrical appliances [2]. Considering growth in telecommuting, the use of e-commerce, and digital home entertainment, it is likely that time spent at home (and thus energy use) is increasing, making the residential sector an even more important target to mitigate demand. In addition, housing is one of the more inefficient energy sectors both in terms of technology and management.

On the technology side, while there have been improvements in areas such as insulation and furnace efficiency, major innovations such as heat pumps and solar/wind generation remain at the fringes. Inefficient transformers and power supplies continue to cause significant losses in small appliances.

While there is clearly much to be done to improve these “hard” technologies, there are also vast opportunities to lower energy use through better energy monitoring and control, and increased awareness. A typical example of the former is heating and cooling residences when no one is at home. Improved control and management of energy use at home using information technology has great potential to reduce residential energy consumption. Networkable sensors, meters, and switches continue to decline in price and improve in sophistication. These elements can be integrated into energy monitoring and control systems that inform residents of how and where energy is being used and provide automation of many actions to mitigate consumption.

Energy use in residences

To set the context for the discussion and analysis, in this section we review the structure of energy use in US homes. Table 1 shows average use in space heating, air conditioning (AC), water heating and appliances in US residences [2]. This data comes from the Residential Energy Consumption

Survey (RECS) of the US Department of Energy (DOE), which is the central source of such information. Energy use in column 1 is what DOE terms as “primary energy”, which adds the direct energy of fossil fuels and the secondary energy needed to produce electricity (a factor of 3.03 megajoules (MJ = 10^6 Joules) of input energy per MJ of electricity). Energy use per household is obtained by dividing total energy use in each category by the total number of households, 107 million. Note that not all homes have air conditioners (26 million do not), the average energy per household with an air-conditioner is 24,500 MJ, considerably higher than the figure in Table I.
The share that appliances account for in total energy use continues to increase over time, and indeed the rise in total energy demand in residences is largely driven by the use of more appliances. We also mention that yearly expenditures on utilities are increasing rapidly due to rises in natural gas and electricity prices.

Table 1: 2001 average energy use in a US residence [2]

	Energy use per household (MJ)	**Energy Share**	**Expenditures per household ($)**
Space heating	53,000	29%	480
AC	19,000	10%	197
Water heating	23,000	13%	203
Appliances	88,000	48%	670
Total	183,000		1,550

Applications of monitoring and control systems for managing residential energy use

In this section we overview major aspects of residential energy use which can be addressed through monitoring and control technologies.

A. Delivering heating/cooling when and where needed

A substantial amount of energy is used for heating and cooling residences in unoccupied homes and rooms, and to a lesser degree, lighting. RECS data on heating suggests that on average thermostat settings when people are not at home are nearly the same as when they are. This suggests that the practice of leaving heating (and presumably cooling as well) full on when not at home is common.
Also, most homes in the US have central heating/cooling, systems that make it difficult, if not impossible, to differentially climate control in different areas of the home. Thus substantial energy is used to heat and cool unoccupied rooms. For example, keeping an entire home climate controlled at night when only bedrooms are occupied represents an obvious opportunity for energy savings.
Space heating, and to a lesser extent air conditioning, are usually controlled from one central thermostat. This often leads to substantial temperature variations through different parts of the house. In particular, the common placement of the central thermostat on the first floor results in upstairs temperatures that will generally be higher than the downstairs setting. These area variations in temperature lead to inefficient use of energy due to “oversetting” of thermostats.

B. Enhanced awareness of energy use leading to behavioral shifts

Energy monitoring systems can influence behavior by making residents more aware of the economic and environmental implications of their home energy decisions. Given that the only information source on energy use in the home for most people are monthly utility bills, its structure remains a black box. This makes choices of actions to mitigate energy use difficult. Imagine a system in which the breakdown of real-time electricity use of heating/cooling equipment, water heaters, and a variety of appliances are viewable through via computer or television with an easily understood graphical interface. Armed with such information, consumers could make much better choices in decisions of what equipment to purchase and how to use it. In terms of purchase decisions, if consumers know how much electricity is being used by different equipment as well the possibility to reduce this use by opting with a different model, this information could influence purchase decisions. Also, there are a variety of energy-related behaviors, some discussed earlier such as leaving heating and cooling on when not at home, that consumers might reconsider given knowledge of the cost implications.
There are pilot projects examining the effect on behavioral changes induced by a monitoring system. For example, a recent Japanese study found that energy savings of up to 10% per household were achieved with a monitoring system providing real-time information on heating, cooling and select appliances [3]. While we know of no equivalent trial in the US, there is a pilot project in California

which explores residential response to increases in the peak price of electricity, to be discussed in the next section.

C. Peak shifting: precooling and load shedding

There is also the possibility to use monitoring and control systems to mitigate peak-time electricity use. Demand for electricity varies substantially on daily and seasonal time scales, peaking during the afternoon of summer days. In warmer climates, the peak can be twice higher than the typical baseline. The need to provide additional electricity during this peak makes utility construct a power generation and distribution infrastructure larger than what is generally needed. There are environmental impacts associated with building and maintaining this additional infrastructure. For example, for a typical nuclear plant, the energy embodied in construction, operation and management of the plant is about 0.2 megajoules per kWh of electricity generated [4,5]. In addition, high peak demand makes it more difficult for utilities to maintain stability, increasing risks of brownouts and blackouts.

One strategy to manage peak demand is known as peak shifting, which involves redistributing the time an energy service is delivered away from the time of peak demand. For the nuclear plant above, the energy investment required implies that one can spend up to an additional 5% of electricity on peak shifting, and still realize a net energy benefit due to the reduced need for power infrastructure.

One way to peak shift is through precooling, which involves overcooling a building before the heat of the day, thus reducing AC electricity use during the peak period. While peak use goes down, precooling is expected to increase total electricity use [6]. This is because temperature differentials inside and outside are higher for precooling, increasing the rate of heat leaking into the house and lowering the coefficient of performance for A/C. However, given the secondary energy use and other environmental impacts associated with the infrastructure to deliver peak electricity, there clearly exists a crossover point where the energy saved through avoided infrastructure exceeds the additional electricity demand.

In additional to environmental considerations, pre-cooling presents significant cost savings opportunities to the consumer. Many utilities offer rate-saving plans to encourage consumers to more energy during off-peak times and use less energy during peak periods. This is because the incremental cost to the utility of electricity only needed at peak times is relatively high. Dependent on the size of the home and climate, these savings can run from $10-$100 each month.

Another strategy for peak shifting is known as load shedding. This refers to the capacity for utilities to restrict electricity use during peak times. There are a variety of schemes to implement this idea, clearly they all depend on the utility being able to remotely control some aspect of resident's energy system. Another strategy is to substantially increase the price electricity during critical peak hours to motivate consumers to reduce energy use during those times. [

A recent case study in California explores both automated load shedding and shifts in behavior of residents in response to peak pricing [7]. One group of residences were equipped with automation that shut off HVAC systems during peak times, while another was left to manually change behavior given prior information on what days peak pricing would be implemented. Both groups displayed reductions in peak use, -4% to -13% for the manual group and -25% to -41% for the automatic group. However, there was no clear pattern of reduction of total electricity use, with net use increasing in some cases and decreasing in others. This is despite the fact that 5-20% of residents reported taking actions that would reduce overall energy consumption, such as turning off lights, and reduced laundry water temperature) [8]. It is possible that the additional electricity burden of precooling tended to cancel these beneficial actions.

The adoption of monitoring and control system in homes remains limited. The mainstay control system currently used in homes is the programmable thermostat, but only 27% of residences have these [2]. RECS survey results also indicate little difference between thermostat settings during day when occupied, unoccupied, and during sleeping hours. This suggests that most programmable thermostats are not actually being used. In terms of monitoring, homeowners generally have no information on energy use beyond the monthly utility bill. To sum up, it would seem that the last several decades of progress in information technology has yet to be applied in the monitoring and control of home energy.

Overview of residential monitoring and control systems

There are many possible monitoring and control systems that could be built for residential energy consumers with current technology. The structural elements of such a system are:

a. Wired (especially through power line) and wireless network architecture/protocols

b. Programmable and networked thermostats
c. PC/input-output device hub
d. Controllable/networked vents (zone heating/cooling)
e. Sensors (temperature, flows (e.g. of natural gas))
f. Software systems to monitor and control home utilities via hub

However, while there are products available on the market in each of these areas, it is fair to say that the challenge of how to optimize each component and integrate into a system attractive to a typical homeowner has yet to be achieved. Working towards such a system is the objective of the case study described in following sections.

System overview

From here we introduce a pilot project initiated in February 2005 between the Intel Folsom Innovation Centre and the Sacramento Municipal Utilities District (SMUD). Three equivalent monitoring and control systems were developed and deployed in Sacramento, California, USA. These systems were designed to combine capabilities for web-based monitoring and control, offpeak pre-cooling, and load shedding. In all three homes gas is only used for heat and hot water. Heat in not used over the summer months of the pilot period. Major electric users are A/C, dryer, and a home pool pump for one home.

The target of the web-based monitoring and control system is to allow users to view and control energy data via a home URL with a graphical user interface. The off-peak precooling system is essentially a programmed thermostat schedule implemented on days when peak demand is expected to be high. The load shedding system target is an implementation of On Demand Load Shedding, in which the utility would publish (on the internet) a request to shed load. The automation system in the digital home periodically checks and based on the utilities demand notice, notifies the homeowner (email, SMS message to their cell phone, or voice in the home) that it is responding to the utilities request and then "up-tick" the home's thermostat by 2-4 degrees. The homeowner could override if desired. When the demand period has ended, the automation system would set the thermostat back to its normal set point. Participation in the program would result in lower energy costs for the consumer.

The central platform consisted of a computer connected to the home's primary entertainment display (TV) for viewing purposes. Home Automation and other specialized software were installed to collect, normalize, store, and display information from temperature sensing devices, as well as a whole house energy meter. Interfaces included radio frequency reading of the whole house energy meter and a command and control interface for HVAC. Internet access was used to transfer data to centralized project owners as well as to provide remote access to data and control systems. Wireless and powerline technologies were used for meter and control system communications.

The systems used in this study used Intel-based PCs running Windows Media Center edition. This operating system (OS) was chosen due to its built in navigation, user interface, and display technologies. This same OS supports advanced features such as personal video recordings, home music and video playback. However the programs used would run on any Windows-equipped PC. In general, though, a goal of the project was to demonstrate how energy awareness and home automation features could be added to existing home computer systems. Since Windows Media Center computers are specifically designed to already be "always on", e.g., to make personal television broadcast recordings on demand, we did not consider the electricity burden of the central computing system in this analysis. In reality, the marginal electricity use of any of the home automation or control subsystems would be relevant, but we perceive these marginal burdens to be small.

The system is composed of several key components, which are summarized below.

A. Energy Meters

The existing traditional analog meters for residences were replaced with wireless digital meters attached to each home's electrical panel and are of a type now commonly used in new homes in the Sacramento area. A major motivation for utilities to switch to wireless meters is that monthly use for billing purposes can be collected remotely, realizing significant savings in labor costs. The specific type of meter used broadcasts its reading every 2-3 minutes and can be received via a special wireless reader attached to the PC. The reader connects via a standard USB port and is accessed via terminal emulation software.

B. Temperature Sensing

In the scope of this project, only one device type was needed in the home control space, HVAC. HVAC was controlled with Residential Control Systems thermostats using the X10 protocol for powerline communications. Typical X10 reliability issues such as low signal strength and failures due to noise on the powerline were encountered and resolved by installing phase couplers and noise filters. Next generation networking technologies such as Universal Powerline Bus or Z-Wave would have prevented these communication issues, but such devices were not commercially available when the project started. We expect that networking capabilities enabled by such technologies will be needed to implement the kinds of advanced features desired in next generation monitoring and control systems. Inside the home, on wall thermostat displays showed unit status and allowed for manual control. A separate thermostat was used to record outdoor temperature. At the PC, a USB based X10 interface was used to communicate with the thermostats over the powerline.

C. Software

Several commercial and custom software packages were used to build out the entire system.

- HAL2000 from Home Automated Living (HAL) was used to provide the core home automation solution. This system provides voice, web, PDA, touch screen and Media Center interfaces into all aspects of home control. In the case of this project, it was used to record temperate data from all thermostats in the home, including outside temperature, as well as to control the set points and modes of the cooling system, and was specifically used for implementation of the pre-cooling schedules in the home.
- To gather data, a custom application was written to log temperature data from the thermostats in the home every 15 minutes.
- A terminal emulator was used to communicate with the digital meter reader. This application also records date and time of the meter reads as they were written to the text file.
- For the On Utility Demand Load Shedding scenario, a custom application using freeware components and the HAL interface was used to demonstrate how HAL could “watch” a utility’s website for critical load condition notification and then take load shedding action.
- Additionally, custom web pages were developed for display within Media Center using the Media Center 2005 SDK and a 3rd party XML based Flash charting system (FusionCharts) to create the “My Energy” portal providing current and historical views in to the homes energy consumption, cost, and temperatures

Figure 1 shows the resulting interface showing results for hour by hour electricity use for one home on August 23, 2005, which had a peak outside temperature of 93degrees C. The steep increase in use after 10A.M. reflects electricity use for A/C.

D. Hardware and Software Costs

This section summarizes the costs of the system deployed in the homes in the case study testbed. Each home used a Windows Media Center-equipped PC ($1500), one x-10 interface ($40), two $250 thermostats, automation software ($400), and $50 of miscellaneous costs, totaling slightly less than $2,500 per house. As mentioned previously, although a Windows Media Center PC was used in this pilot, the software suite would run on most Windows XP desktop computers, commonly found in homes today, albeit with less of an integrated experience. Doing so would reduce the cost to less than $1000 per home. It is important to note that the project goal was to build prototypes with off-the shelf technology rather than to find components and technology at scale or minimum costs. In reality, the costs at large-scale adoption could likely be in the $200 or less range (excluding PC).

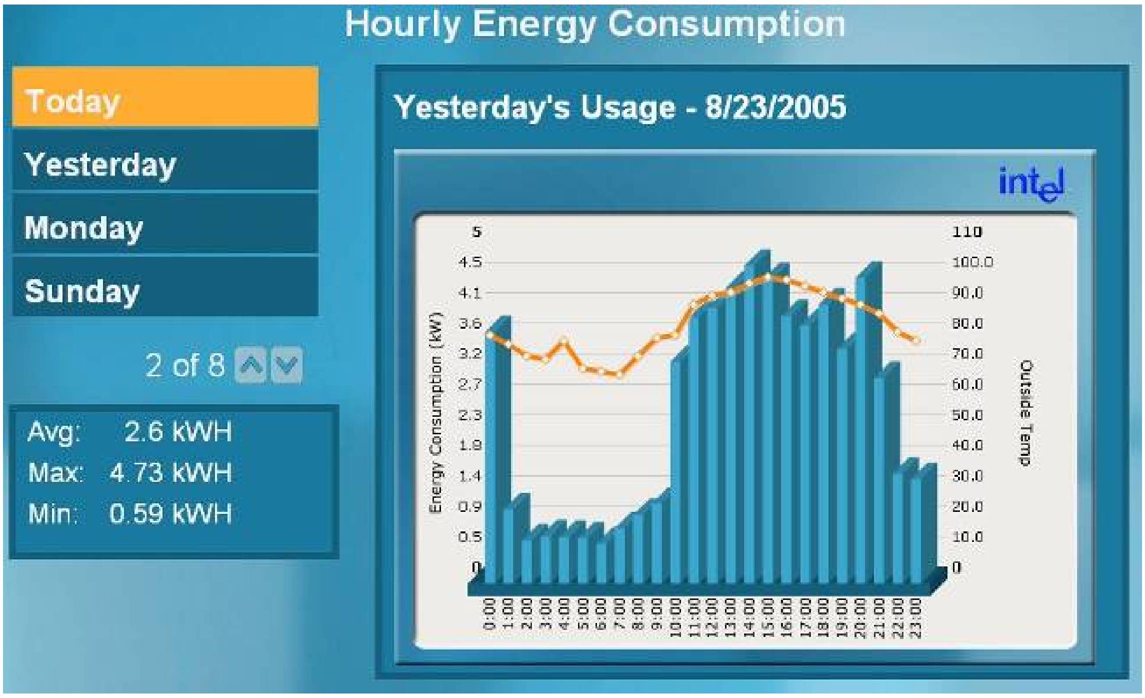

Figure 1: Screenshot of "MyEnergy": thermostat set at 78 degrees F (26C), max outdoor temperature 95 degrees F (35C)

Results

Functionality of the web-based monitoring and control, pre-cooling and load shedding were established. Test runs on the energy effects of precooling were carried out for several summer weeks. The precooling schedule was as follows:

- 8am - set both thermostats to 73 degrees
- 2pm - set upstairs to 85 degrees & downstairs 78 degrees
- 8pm - set upstairs to 78 degrees

A. Precooling Results

Precooling results for the residences studied showed that overcooling the house during 8-12:00 effectively shifted the peak of AC electricity use to that period. This can be seen from Figure 2, which displays electricity use for one home on August 24, 2005, which had a maximum outside temperature of 90 degrees F. Consumers would save on electricity expenditures because they would be purchasing it at a less expensive time. In terms of energy use, it seems that the net increase in electricity use for precooling is small to at least up to the 90 degree range for outdoor temperature. These results are tentative, however, and it must be emphasized that insulation, windows and other aspects of the residence likely cause strong variation in the degree of extra energy needed for precooling. Also, if precooling can be at least partly achieved through passive means, the energy balance could become positive.

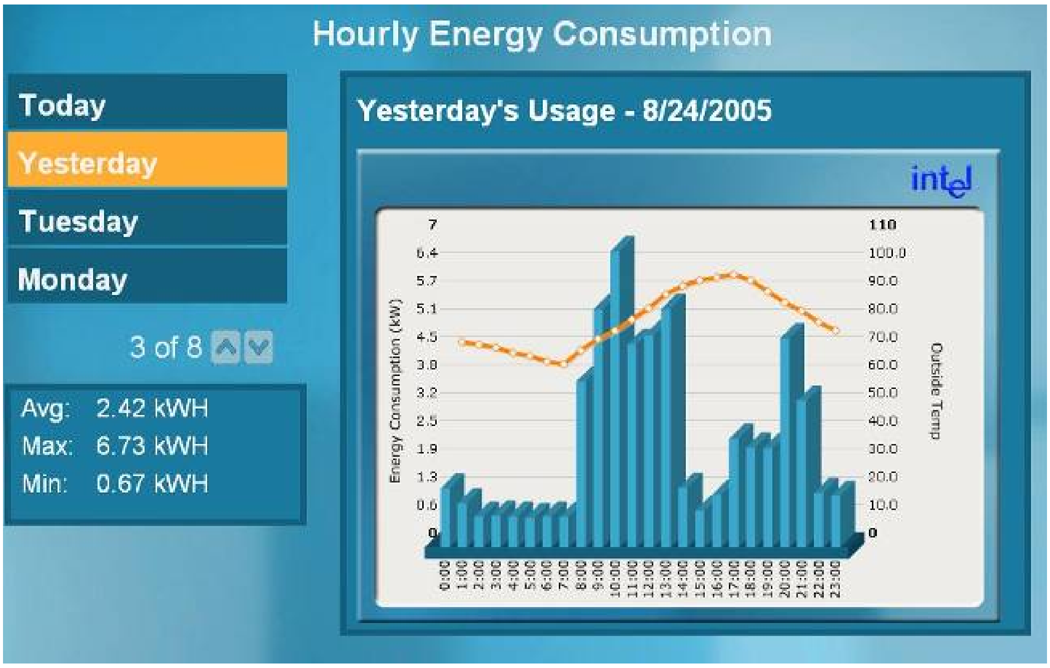

Figure 2: Screenshot of "MyEnergy": precooling schedule, max outdoor temperature 90 degrees F (32 C)

Overall, the pilot has shown that such a monitoring and control system satisfying the design parameters is viable via mostly off-the-shelf parts. Non-PC costs for each house were approximately $1000 using off the shelf components. As previously stated, the project goal was to build prototypes with off-the shelf technology rather than to find components and technology at scale or minimum costs. In reality, the costs at large-scale adoption could likely be in the $200 or less range (not including PC). Given possible energy savings, this presents a significant business opportunity Thus there is possibly a market for IT solutions that have the added benefit of managing household energy consumption (and the associated environmental benefits). Intel and SMUD both have interest in continuing the pilot for additional summer months, as well in adding more participating households. In addition it is desired to add the capacity to monitor end-loads of major appliances as well as non-electricity loads, such as natural gas consumption.

B. PC Energy Usage

Although not the focus of this study, the energy consumption of the PC itself should not be ignored. A PC with limited or no power management can consume a considerable amount of power by itself. In this study, it is not expected that the additional functionality of home control will significantly increase electricity use by the PC. This is because the system used is compatible with the power standby mode. Also, PC electricity use is already included in the measurement of the home's overall energy usage. With this said, future work should assess the life cycle energy footprint of an entire home control system, including additional control and networking equipment. Also, as mentioned above, Media Center edition PCs are already in wide use due to their media management capabilities. When setting up a PC-based home control system, power consumption may be minimized by choosing an energy efficient PC and by enabling power management (sleep, stand-by) of the device. The US Energy Star program is in the process of updating its specifications for computers. In the future, computers carrying the Energy Star label will be required to consume less power when on, asleep and in stand-by power configurations.

Looking ahead

There is a growing trend toward integrating computers and related IT equipment into the home, particularly for home entertainment purposes. As such, the opportunity exists to expand the features of these products to include home management, including the optimization of heating, cooling and lighting. Such integration offers the possibility of future benefits to the consumer in terms of convenience, cost savings, and reductions in energy use at a reasonable incremental cost. As part of ongoing R&D research in this area, Intel and other IT manufacturers are continuing to explore such possibilities.

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How Small Devices are Having a Big Impact on U.S. Utility Bills

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Abstract

Energy consumption attributed to electronic devices in the typical U.S. home has more than doubled since 1980 and is expected to continue to grow at a rate nearly double the forecasted growth rate for residential electricity end use.[1] The breadth of these devices also grows continuously, driven by technological innovation designed to meet surging consumer demand and changing lifestyles.

While the traditional sources behind this increasing energy consumption trend are office equipment and consumer electronics, other miscellaneous devices, such as power tools, portable appliances, and personal care products contribute as well.

The growth in electricity consumption within the typical home from miscellaneous end uses is in addition to the rising costs of fuel, such as gasoline for automobiles and oil for home heating. These costs are intensifying, straining consumer budgets while adding to the climate change burden. To address these concerns, consumers, more than ever, need relevant information about the growing array of miscellaneous products and their energy consumption in order to make smart buying decisions.

As a result, new opportunities exist for ENERGY STAR to highlight existing electronics products that are efficient across multiple modes of operation, including "active" or "on" mode, and to address non-traditional miscellaneous products. As each opportunity to address multiple modes of operation and product types presents itself, it brings with it the need to overcome a variety of technical challenges while designing relevant policy options that will benefit consumers.

Introduction

The energy consumed by the typical U.S. home has more than doubled since 1980, according to the U.S. Department of Energy's (DOE) Energy Information Administration (EIA), and it is expected to continue to increase. The growing quantity of electrical products found in homes contributes significantly to this growth of energy consumption. While this trend is due in part to the proliferation of home computer equipment and consumer electronics, other devices, such as power tools, portable appliances, and personal care products, contribute as well. The individual and collective energy consumed by miscellaneous devices are worthy of scrutiny as consumer appetites for these devices drive their quantity, quality and usage patterns.

The growth in residential electricity consumption comes at a time when the United States is experiencing rising prices for electricity, natural gas, and heating oil, used primarily in the densely populated northeastern United States. Along with utility bills, car centric homeowners also feel the pain from spiking gasoline prices. In the short run, many home owners find these times confusing and frustrating, as they search for a way to lessen the bulging energy bills that have cut into discretionary spending. Neil Elliott of the American Council for an Energy Efficiency Economy likens the situation to being in an energy *straitjacket*. Few options for the nation as a whole exist in the short run, especially for people who have awakened to find they are vulnerable to rising energy prices. Adding to their anxiety is a growing awareness of the connection between the energy they use to support their lifestyle and global climate change, over which they feel they have little control.[2]

Sustainable pathways forward to break out of the *straitjacket* have been identified, but they will unfold over many years. In the short run however, consumers can begin to reduce their energy bills by understanding and managing the amount of energy consumed by miscellaneous devices.[3] This paper will provide data and background information to define and substantiate the emergence of

[1] Per the Annual Energy Outlook 2005, the growth rate for residential miscellaneous electricity consumption is 3.7% for 2005 – 2010 while the growth rate for residential electricity consumption is 2%.

[2] Despite rising gas prices, according to the U.S. Bureau of Economic Analysis, the total percentage of personal income spent on gasoline today is 3%, as opposed to 5% in 1981.

[3] In the California Independent System Operator area, for example, efficiency measures reduced energy consumption by 6.7% from 2000 to 2001.

miscellaneous products as a new major category of residential end-use energy consumption. The miscellaneous category will be compared to other major end-uses in terms of their characteristics in the typical residential setting. Lastly, the paper will identify available policy options which are being pursued by governments looking to address the growing energy demand from miscellaneous products.

Background

What are the "Miscellaneous" Products?

EIA has traditionally tracked five main sources of energy consumption in the residential sector:

- Lighting;
- Major appliances (white goods);
- Water heating;
- Air conditioning; and,
- Space heating.

Miscellaneous electricity consumption constitutes all the energy consumed that is not directly a result of the use of the above sources. Examples of these miscellaneous products are extremely varied and include televisions, computers, mobile phones, small home appliances, such as toasters, coffee makers, baby monitors, and home security systems to name a few.

For the better part of the last 50 years, the utility bills for the typical U.S. home were dominated by the energy consumed by key products representing the five major categories listed above. Collective ownership of these products were hallmarks of growing economic prosperity, both at a national level and for individual households. Against the backdrop of abundant and inexpensive energy, homeowners traditionally gave little thought to the energy these products consumed. By the late 1970s, a growing environmental movement and higher energy prices drove several states to launch the first appliance efficiency standards. These were followed by the U.S. government's mandatory standards in 1987, as legislated by the National Appliance Energy Conservation Act. These initial standards took hold as a legitimate and cost effective means to ensure greater efficiency and paved the way for new standards to be developed and implemented for a variety of products such as furnaces and boilers, electric motors, lighting, pool heaters, and water heaters.

How Much Energy is Consumed by "Miscellaneous" Products?

Even as the energy attributed to miscellaneous products continued to grow, it was still outweighed in absolute terms by the five main categories listed above. However, the trend is clear – a plethora of new energy consuming devices now populate the typical home. The collective energy consumed by this new category constitutes a new major source of end-use consumption, and individually, is larger than several of the five major residential end-use categories.

Based on a 1995 EIA report, DOE estimates that in 1980, residential miscellaneous electricity consumption totaled 2.25 quads (Buildings and Energy in the 1980's, EIA). 18% of this consumption, or 0.4 quads, was due to "other" or miscellaneous consumption.[4] Electronics products, grouped into the miscellaneous category, accounted for only about 5% of home electric consumption. Electronics includes products such as consumer electronics and IT equipment, motor includes products such as pool pumps, well pumps, and fans and heating includes products used to heat water-beds, hot-tubs, pools, and other such products. (The breakdown of the miscellaneous category into electronics, motor, and fan consumption was based on an analysis by Marla Sanchez, Lawrence Berkeley National Lab, and John Cymbalsky, EIA.) The remaining 1.85 quads were attributed to the other five main categories. Figures 1 and 2, below, illustrate how the 2.25 quads were divided among the primary categories.

By 2005 total residential electricity consumption doubled to 4.5 quads, according to EIA. Of this, approximately 28%, or 1.3 quads, could be attributed to 'other' or miscellaneous energy consumption. The allocation of the remaining 3.4 quads was: appliances (20%); lighting (18%); air conditioning (15%); space heating (11%); and, water heating (8%). Electronics products accounted for about 13% of total home electric consumption; almost three times the level in 1980 (Building Energy in the 1980's

[4] Lawrence Berkeley National Lab's estimate for miscellaneous consumption in 1980 (as a percentage of EIA's 'appliance' category) is based on the 1980 consumption estimates for the heating, motor and electronics categories in Sanchez et al., 1998.

and Annual Energy Outlook 2005, EIA).[5] Figures 1 and 2, below, illustrate how the 4.5 quads were divided among the primary categories.
By 2015, EIA projects residential electricity consumption to increase 20% from 2005 levels, to 5.4 quads. Lighting will still account for about 18% of the total, but space heating, water heating, air conditioning and appliances will all consume smaller percentages of energy than they did in 2005. On the other hand, the total miscellaneous category is projected to grow to 34%, or 1.8 quads. Electronics products alone will account for 18% of total home electric consumption. Figures 1 and 2, below, illustrate how the 5.4 quads are divided among the primary categories. Other studies, such as a report prepared for DOE entitled *U.S. Residential Information Technology Energy Consumption in 2005 and 2010* (TIAX LLC), have concluded that the major drivers of residential energy consumption growth rates will be IT equipment, much of which has aggressive usage patterns.

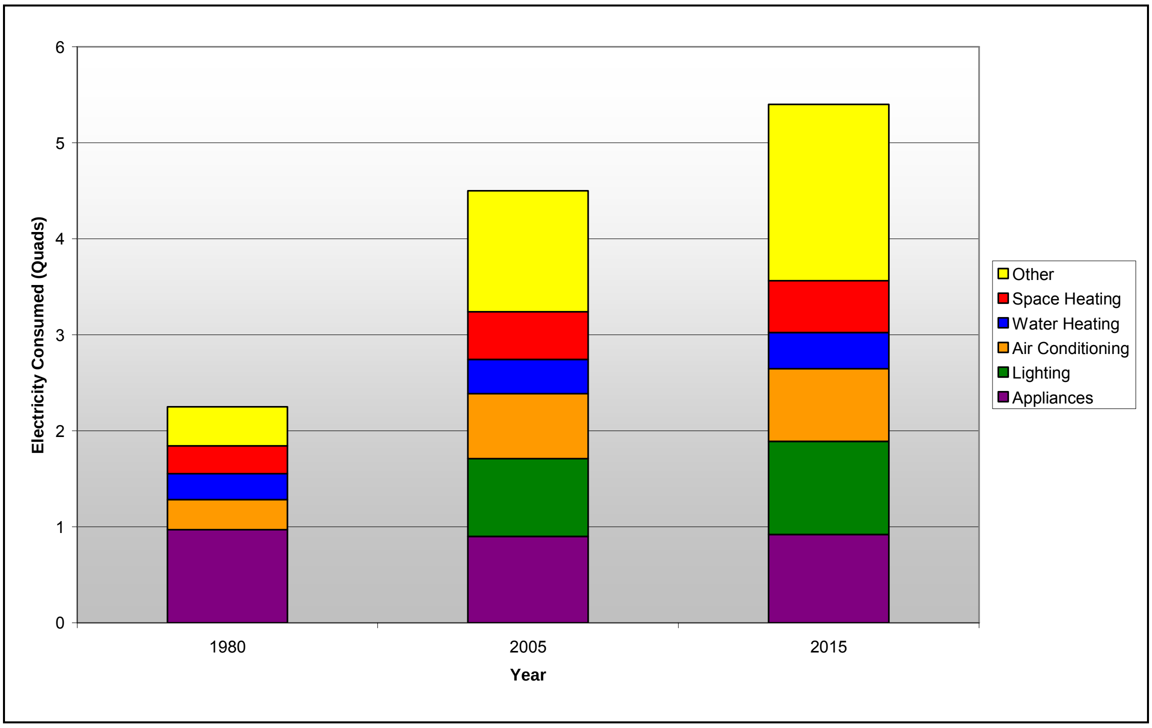

Figure 1: Total Residential Electricity Consumption for 1980, 2005 and 2015 (Projected)
Figure 1 Note: In 1980, EIA grouped lighting into the appliances category. Lighting has since been broken out separately as its own category, as reflected in the data for 2005 and 2015. (Source: EIA's *Building and Energy in the 1980's, June 1995; Sanchez et al,1998*)

[5] LBNL combined certain categories within EIA's 2005 data so comparisons could be drawn to 1980 data: for space heating, EIA's space heating and furnace fans categories were combined; for appliances, EIA's refrigerators, freezers, cooking, dryers, clothes washers and dishwashers categories were combined; for other, EIA's other, TV and PC categories were combined.

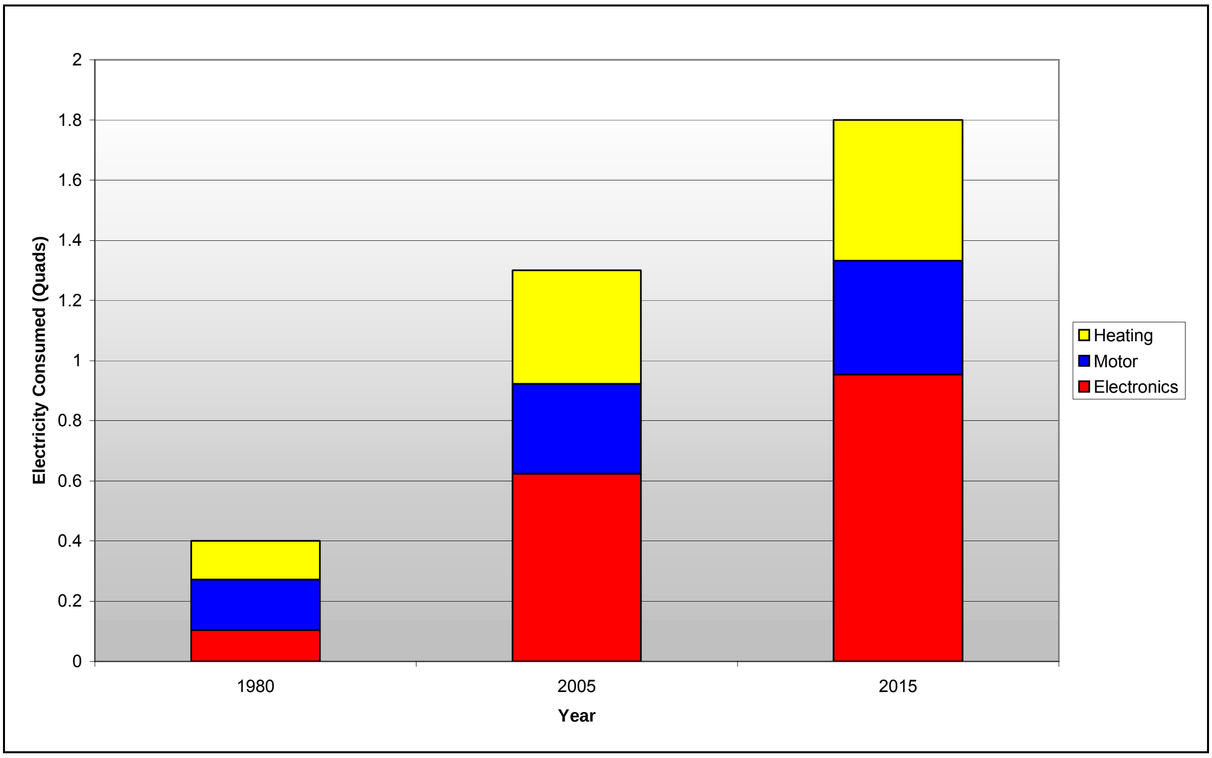

Figure 2: Breakdown of 'Other' Residential Electricity Consumption in 1980, 2005 and 2015 (Projected)

Figure 2 Note: Heating in Figure 2 does not refer to space heating; rather, it reflects heating for water-beds, hot-tubs, pools, and other such products. Motor in Figure 2 refers to fans and pumps. (Source: EIA's *Annual Energy Outlook 2005)*

Several studies, such as W*hole-House Measurements of Standby Power Consumption* (Ross, J.P. and Meier, A.) and *Developing and Testing Low Power Mode Measurement Methods (Nordman, B. and McMahon, J.E.)* have documented the breadth of miscellaneous products in the typical U.S. home. Hundreds of products found in homes (and in some commercial buildings) that use electricity have been identified. Many are commonly recognized such as televisions and coffee-makers, while others are less obvious, such as air cleaners and garage door openers. Often, certain rooms have their own unique devices, such as electric tooth brushes and shavers in bathrooms, coffee-makers and toasters in kitchens, and power tools in basements.

It is unknown how some of the newer miscellaneous products entering the market will affect future energy demands. For example, sales of mobile phones and game consoles are growing quite fast and are quickly becoming modern essentials, but have yet to reach market saturation. According to The NPD Group, mobile phone sales to U.S. consumers reached 34.8 million units in the first quarter of 2006; an increase of more than 11% compared to the same period in 2005. In spite of the growth in sales, U.S. market penetration for mobile phones in mid-2005 was still only at about 65%; nowhere near countries such as Germany and Switzerland, which were at 90% market penetration.[6] The U.S. still has a ways to go before reaching market saturation for these products. Alternatively, the market for products such as dehumidifiers is mature and more regional in nature with significantly fewer units being shipped. According to *Appliance Magazine,* an average of 972,685 units shipped annually from 2000 – 2003 in the U.S. TVs on the other hand, have more than 90% penetration in U.S. homes and shipments are once again growing briskly due to new technologies and features. In fact, according to iSuppli's TV Systems Market Tracker, shipments of TVs to the U.S. in 2005 increased 14% over 2004, going from 25.6 million units to 29.28 million units.

Not surprisingly, sales of consumer and IT electronics have the fastest rates of growth, due in part to their rapid obsolescence. According to the Consumer Electronics Association (CEA), sales of consumer electronics rose 11.5% from 2004 levels to $125.9 billion in 2005. For 2006, CEA expects 7.5% growth and sales of $135.4 billion. Many consumer electronics products such as televisions or cordless telephones have been prevalent for decades, whereas others, such as cable modems, have

[6] Data is from research conducted by Merrill Lynch in June 2005.

only recently emerged in volume. Digital cameras, which are usually plugged in to an electricity source to be recharged, have rapidly displaced their traditional single-lens-reflex (SLR) counterparts, only to now be overtaken in sales by camera phones. iSuppli estimates more than 57 million camera phones were sold in 2005, representing 46% of all handset sales. By 2007, InfoTrends predicts 109 million unit sales of camera phones, or 71% of all cell phone handset sales.

As compared to the other major common household products, miscellaneous products are more diverse and populous. They are also typically designed to perform a unique and sometimes infrequent task. Such a narrow usage pattern contrasts with general purpose lighting and cooling products, for example, which can be used for thousands of hours per year.

Why Care About Miscellaneous Energy Consumption?

As the name implies, the source of *miscellaneous* energy consumption can be nebulous, and its growth and impact on utility bills obscured, given the disproportionate attention paid to white goods, lighting, and the other primary energy usage categories. In some cases, the small physical size of certain miscellaneous devices obscures their importance as a group, making the tracking and inventory of their energy consumption challenging. While this is slowly changing, EIA has wrestled with the means to account for miscellaneous energy consumption in its Residential Energy Consumption (RECs) survey, with the exception of computers.

Slowing the energy consumption growth of miscellaneous products may require a different mix of actions from policy-makers and a persistent commitment to efficiency on the part of manufacturers. Increases in the prices of all forms of energy have begun to raise consumer awareness. In some cases, consumers do a fairly good job of not wasting energy because they understand the connection between a product and the energy it consumes. For example, consumers have become conditioned to flip the lights off when they leave a room. But it is probably unrealistic to expect that most home occupants would unplug a multitude of devices, which they may think are off in the first place since they are not "being used." Nor is central control of these devices an option. While programmable thermostats exist as a controlling device for products in the air conditioning and space heating categories, they have not always been found to save energy; a lack of consumer-friendly programmable thermostats has sometimes perversely caused more energy to be used than saved (Haiah et al, 2004).

Quantifying the size and growth of miscellaneous energy consumption is necessary to understand the impact on the home energy budget. This paper reveals that the energy used by miscellaneous devices is comparable in magnitude to the energy used individually by the five major end-use product categories. The growth of energy attributed to miscellaneous products has expanded the amount of funds families must contribute to their home energy budget. These actions have obvious implications for disposable income, which are well documented. On a positive note, the energy consumed by the major end-use categories has not experienced as much growth due the presence of mandatory standards, which are often coupled with consumer education, mandatory labeling and improved home building codes.[7]

Feature-rich products such as televisions and computers, which serve communication, entertainment and work purposes, have appreciably improved the quality of life to such an extent that many consumers view them as indispensable. Many U.S. consumers would no sooner sacrifice TV or high-speed Internet access, than they would sacrifice hot water and refrigerated food. In fact, as consumers cut back on non-essentials to conserve money, such as dining out and entertainment, they are spending more time at home, which translates into more hours watching television, playing video-games, or using the computer. Homebuilders recognize this trend. According to a 2004 builder survey conducted in the U.S. by Parks Associates, approximately 45% of homebuilders offer built-in home theatres as an option in new, single-family homes.

In 1980, the average U.S. household spent $1,280 on utility bills (adjusted for inflation and not including water usage). Of this amount, approximately $230 was for the electricity to power miscellaneous products. Today, the average household utility bill is approximately $1,500 per year with $420 spent to power miscellaneous products. Add in the average annual household gasoline expenditures of $2,327, and this raises the estimated home energy budget to $3,800. Miscellaneous consumption would still represent 11% of this total.

[7] It should be noted that the intent here is to raise awareness of the unique nature and characteristics of the miscellaneous product category; not discount the importance of efficiency for the other major end-use products.

Miscellaneous plug loads have also emerged in the commercial sector. DOE estimates that for certain types of buildings, such as commercial office-buildings or schools, miscellaneous plug loads are equal to half of lighting levels. Figure 3 shows a breakdown of the electricity consumption attributed to the primary product categories in the U.S. commercial sector for 2005 and projected for 2015 (Annual Energy Outlook 2005, EIA).

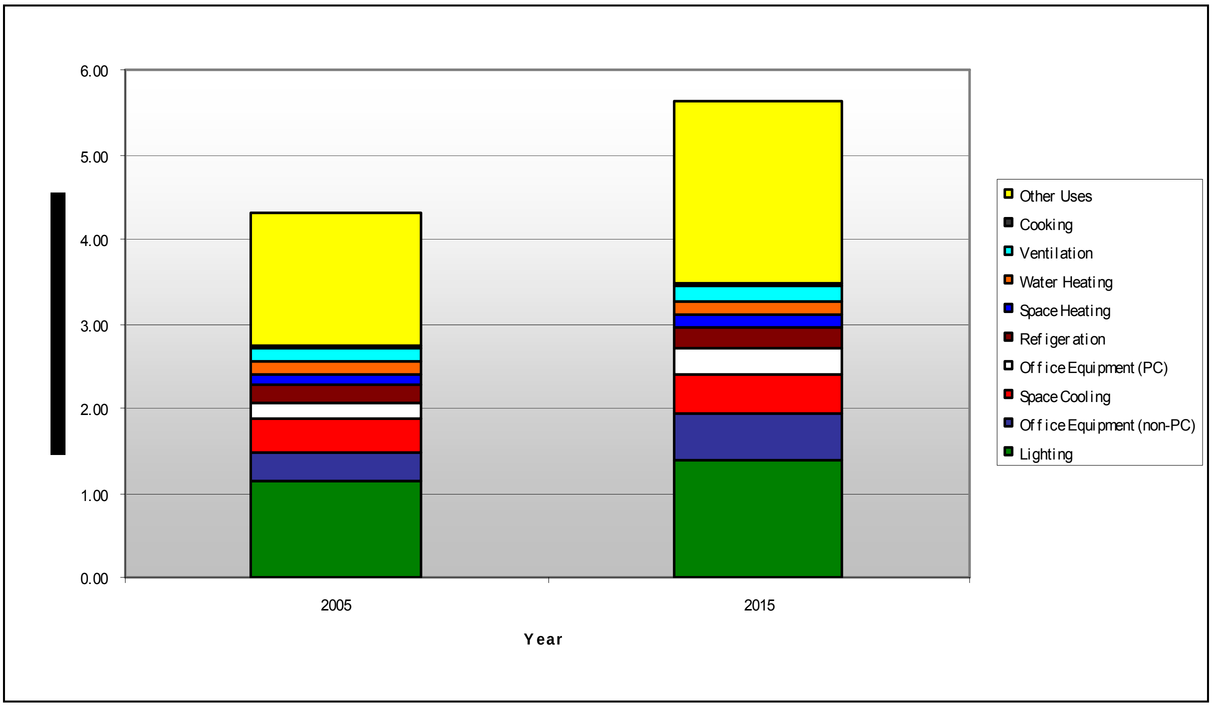

Figure 3: Percentage Breakdown of U.S. Building Sector Energy Consumption
Figure 3 is derived from EIA's *Annual Energy Outlook 2005.*

It should be noted that the building types in the commercial sector are more diverse than the residential sector. Universities, hospitals, industrial sites, etc have different types of functions that may require different levels of miscellaneous plug loads. There are some common miscellaneous devices, however, found in both the residential and commercial building types. But more study is required to determine whether common policies can be used to address the miscellaneous plug loads found in both sectors.
An analysis of projected overall growth of residential electricity consumption from 1980 to 2015 indicates that the miscellaneous category will contribute significantly to this growth. Conversely, the major end-use categories (e.g., heating, cooling, etc.) are mature and there is a greater probability that their energy consumption will be kept in check due in large part to mandatory minimum efficiency standards.[8] Products within the major end-use categories have also been through many design cycles, and so their efficiency has increased over time as technological advancements are made. For example, although the number of lighting fixtures per American home has increased along with the size of the typical home, several technical advancements and market efforts are minimizing the overall growth in energy use. The improved quality of compact fluorescent lamps in recent years has increased consumer adoption of screw-in lamps and fixtures that use fluorescent technology. In addition, residential fixture manufacturers are more accepting of the technology and most major manufacturers are offering decorative fluorescent lines (Vrabel, 2006). Use of high quality fluorescent lighting in a new home is an emerging trend due to efforts by EPA, electric utilities, and the adoption of state energy codes in California, such as Title 24. Additionally, the average new home in the U.S. is being built to the International Energy Conservation Code building code, which ensures greater efficiency compared to homes from a decade ago. An improved building envelope will use energy for heating and cooling more optimally.

[8] These standards are even more important given that the average total square footage of the typical U.S. home expanded to approximately 2,527 feet in 2001, from 2,278 feet in 1993, per DOE's 2001 Residential Energy Consumption Survey.

What is Being Done to Address the Energy Use of Miscellaneous Products?

Miscellaneous products, as with most products, have not ordinarily been designed to save energy as a primary function. Where a product incorporates energy management, action has been needed by the user to initiate this feature or it has been included as a safety precaution. In the case of programmable thermostats, they are marketed primarily to provide comfort and convenience, and secondarily to reduce energy cost. For most miscellaneous products, the options to control energy consumption range from the non-existent to intelligent engineering designs for 'smarter' operation.

Some miscellaneous devices allow for passive or active means to manage energy use. Televisions, for example, are easily put into standby mode via a remote control. Computers, on the other hand, offer several means to implement power management. Other products, such as air cleaners or dehumidifiers provide occupancy or other sensors to manage energy. Products utilizing lithium ion battery chemistry have intelligence designed into the product circuitry to prevent over-charging, but this is primarily a safety feature that has a side benefit of energy management.

Given the diversity of energy management features found in miscellaneous products, policymakers face a challenge to find a common thread upon which to base uniform requirements to reduce energy waste. In many cases, policies can be devised to encourage greater energy efficiency in these miscellaneous products, but the greater challenge is ensuring that they remain relevant given the changing mix of technology, consumer lifestyles, and the need to be cost effective.

Policy Pathways for Miscellaneous Products

As indicated earlier in the paper, standard making organizations have focused on more traditional and high profile energy consuming products over the last few decades (e.g., lighting, water heating, etc.). Products in these categories offer significant savings per unit and are relatively simple to characterize with little variance from one model to the next in terms of key components. As a result, standards for products in these areas have been embraced and implemented across the U.S. and globally.

Meanwhile, the miscellaneous category has been growing, in both numbers and energy consumption, and slipping under the radar screen of energy modelers. These products have either been left out of the energy consumption equation completely or not addressed in their entirety (i.e., only low power mode requirements have been addressed). At the same time that consumers are being educated about the range of efficiencies and opportunities presented by more traditional products, and thus associating them with rising energy costs and high utility bills, we as consumers and policymakers are missing a growing contributor to the energy used in the home.

Over the last decade, the ENERGY STAR voluntary labeling program has sought out these miscellaneous products and taken a number of different approaches to developing specifications to address this category. Efforts began in the early- to mid-1990s with the more visible electronics products such as TVs and computers. These products represented large and widespread markets that were ripe for the type of market differentiation that the ENERGY STAR mark provides. More recently, however, EPA wanted to both expand the scope of products covered by these specifications and address additional operational modes. To conserve limited resources and maximize the energy savings potential, EPA identified three approaches, which are described in further detail below. The first approach was to address the energy being consumed by numerous miscellaneous products through a common thread: the power supply. A second approach, designed for those products where it was not feasible to isolate or appropriate to focus solely on the power supply, was to develop specific metrics to directly address Active mode for the entire product system. And finally, a third approach was to work with international stakeholders to harmonize test procedures and specifications as much as possible, given that a number of products in the miscellaneous category are globally manufactured and sold.

Power Supplies: The Common Thread

Focusing on the power supply provides enormous energy savings potential because:

- They have broad application in finished electronic products. EPA estimates there are more than 10 billion power supplies are in use worldwide.
- Many current power supply designs are only 30-60 percent efficient, but efficiencies of 90 percent or more are feasible.

The following is a brief discussion of EPA's three-pronged strategy to transform the power supply market.

Phase I: External Power Supplies (EPSs)

The first step in EPA's power supply strategy was to provide market-based incentives to improve the efficiency of EPSs. EPSs represented the best near term opportunity because 1) they are physically separate from their end-use devices and thus easier to measure, and 2) more research has been devoted to understanding their current and potential efficiencies. By pairing an end-use device with a highly efficient EPS, one can significantly reduce the energy consumption of the end-use device without investing in costly or time consuming product redesigns.

To prepare an EPS specification, EPA supported the development of one internationally recognized test procedure and then compiled a data set with over 600 EPS models tested in Australia, China, and the United States. Figure 4, below, illustrates the wide range of Active Mode efficiencies found in EPSs with a nameplate output power of 10 watts or less within EPA's data set. For example, within EPA's data set, EPSs with a nameplate output power of 3 watts had average Active efficiencies of 31.9 percent to 67.8 percent and No-Load consumption of 1.9 to 0.2 watts.

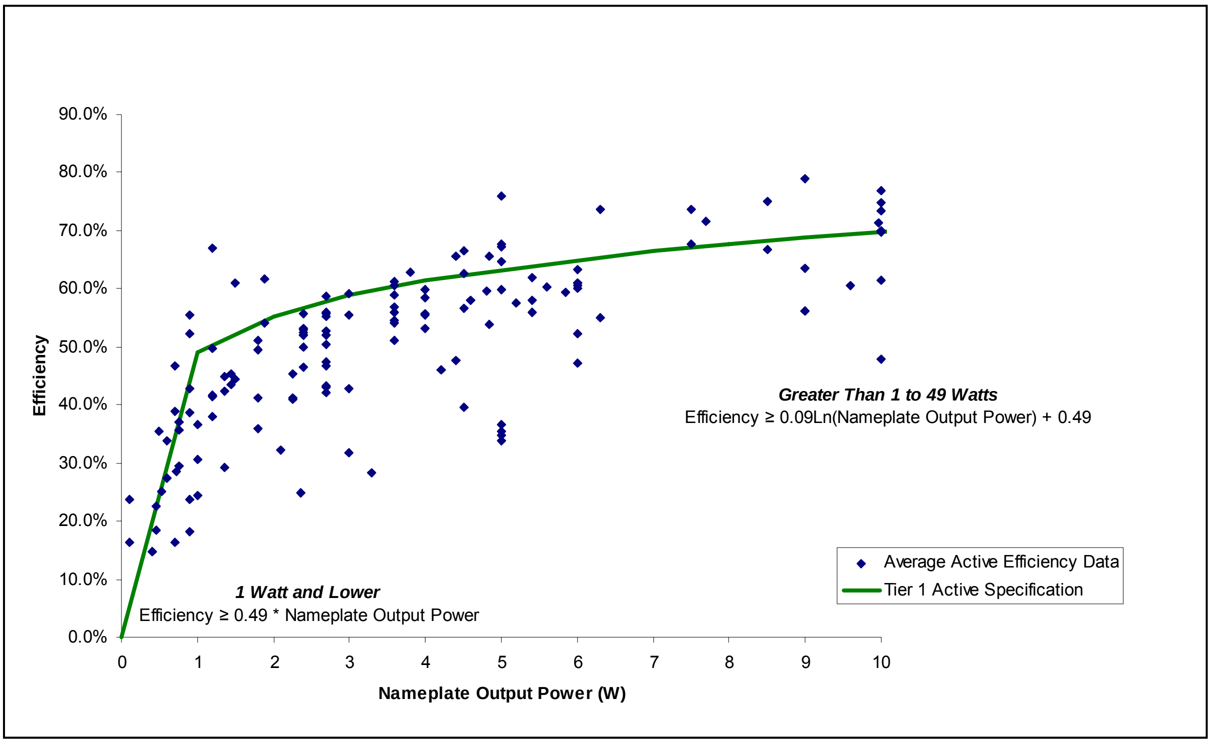

Figure 4: Range of Active Mode Efficiencies in EPA's Data Set

Figure 4 is derived from data collected during the development of EPA's Version 1.0 ENERGY STAR specification for external power supplies. A point above the line denotes an EPS model that exceeds minimum efficiency levels.

Figure 5, below, illustrates the wide range of No Load efficiencies found in EPSs within EPA's data set. The final ENERGY STAR specification for EPSs, which took effect in January 2005, includes requirements for both Active (tested at 100 percent, 75 percent, 50 percent, and 25 percent of rated current output) and No-Load Modes and recognizes approximately the top 25 percent of models.

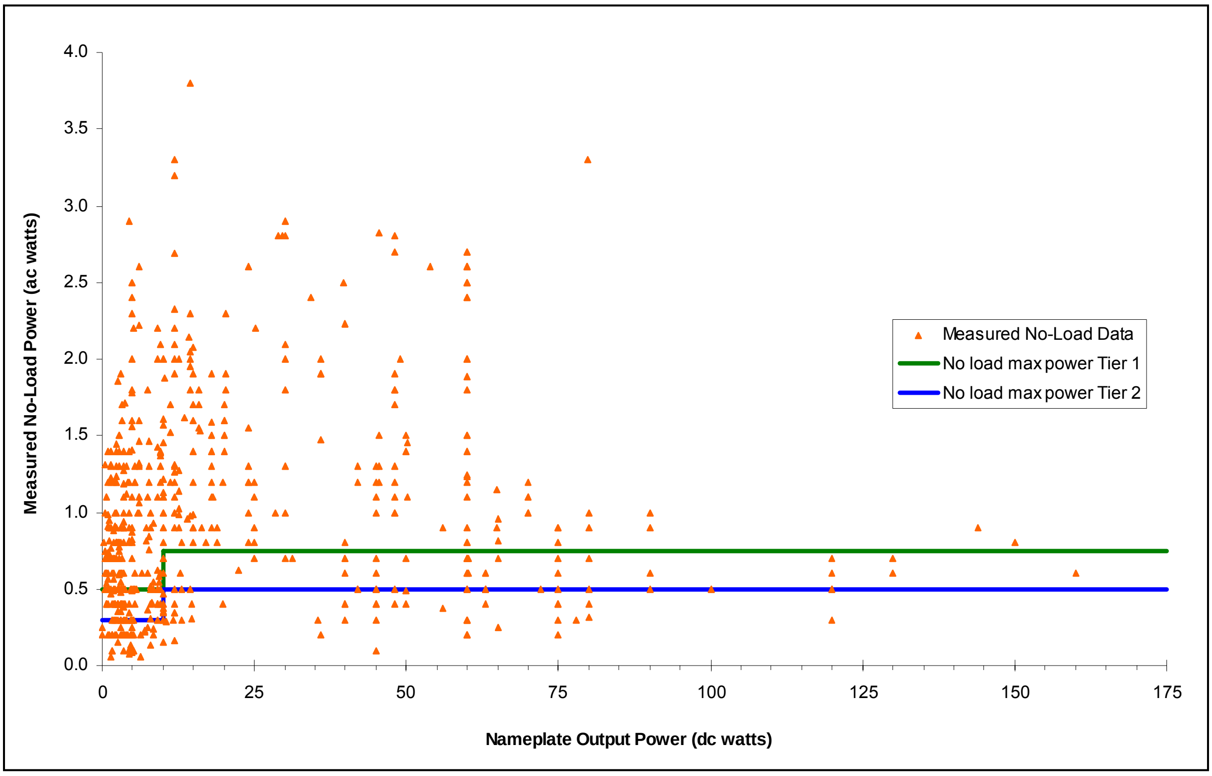

Figure 5: Range of No Load Efficiencies in EPA's Data Set

Figure 5 is derived from data collected during the development of EPA's Version 1.0 ENERGY STAR specification for external power supplies.

The ENERGY STAR specification for EPSs is designed to highlight those models with an efficient ac-dc or ac-ac conversion process. A broad array of single voltage external ac-dc and ac-ac power supplies, including those used to power computer and consumer electronics such as laptops, digital cameras, monitors, CD players, cell phones and cordless phones, are covered by this specification. As of May 2006, 26 manufacturers have joined ENERGY STAR and qualified more than 255 models.

EPSs that earn the ENERGY STAR mark are on average 35 percent more efficient than conventional models. EPA projects a potential U.S. energy bill savings of $636 million, electricity savings of over 9 billion kWh, and prevention of 5.13 million metric tons of carbon dioxide pollution from 2005 to 2015 due to the specification.

In addition to recognizing efficient EPSs, EPA is 1) requiring ENERGY STAR EPSs in its latest electronic product specifications (e.g., ENERGY STAR for telephony, imaging equipment, etc.), and 2) allowing end-use product manufacturers, whose products otherwise might not be eligible for ENERGY STAR, to join the program and promote their end-use devices that use ENERGY STAR qualified EPSs (e.g., digital cameras, wireless routers, etc.). In this way, EPA is not only striving to increase the supply of efficient EPSs, but is also taking steps to stimulate demand for them.

Phase II: Battery Charging Systems (BCSs)

Soon after the launch of the EPS program, EPA began work on another specification to extend the brand to BCSs—the components used to recharge a wide variety of cordless products. BCSs found in small household appliances, personal care products, and power tools were specifically excluded under the EPS specification in order to allow time for the development of an appropriate test procedure and efficiency metric.

Based on a careful review of the energy used in more than 100 BCSs, EPA decided to focus on Nonactive modes (i.e., Battery Maintenance and Standby) because these modes offer significant potential for energy savings (70-75% of the energy is used after the battery is fully charged) and can be consistently measured through a robust and easy-to-use test method (see "Test Method for Determining the Energy Performance of Battery Charging Systems" on the ENERGY STAR Web site).

The ENERGY STAR specification for BCSs allows models to qualify if they do not exceed a maximum

Nonactive Energy Ratio[9] based on the nominal battery voltage. By avoiding explicit requirements for Battery Maintenance and Standby Modes, EPA allows manufacturers to choose the most efficient design(s) for the overall operation of the product and takes into account products that do not have a Standby Mode.

The ENERGY STAR specification for BCSs took effect in January 2006. Consistent with the ENERGY STAR guiding principles, the final specification represented the top 24.8 percent of data points from EPA's data set. Care was taken to ensure that a wide array of models and manufacturers would be eligible to qualify as ENERGY STAR under the BCS specification, as illustrated in Figure 6 below.

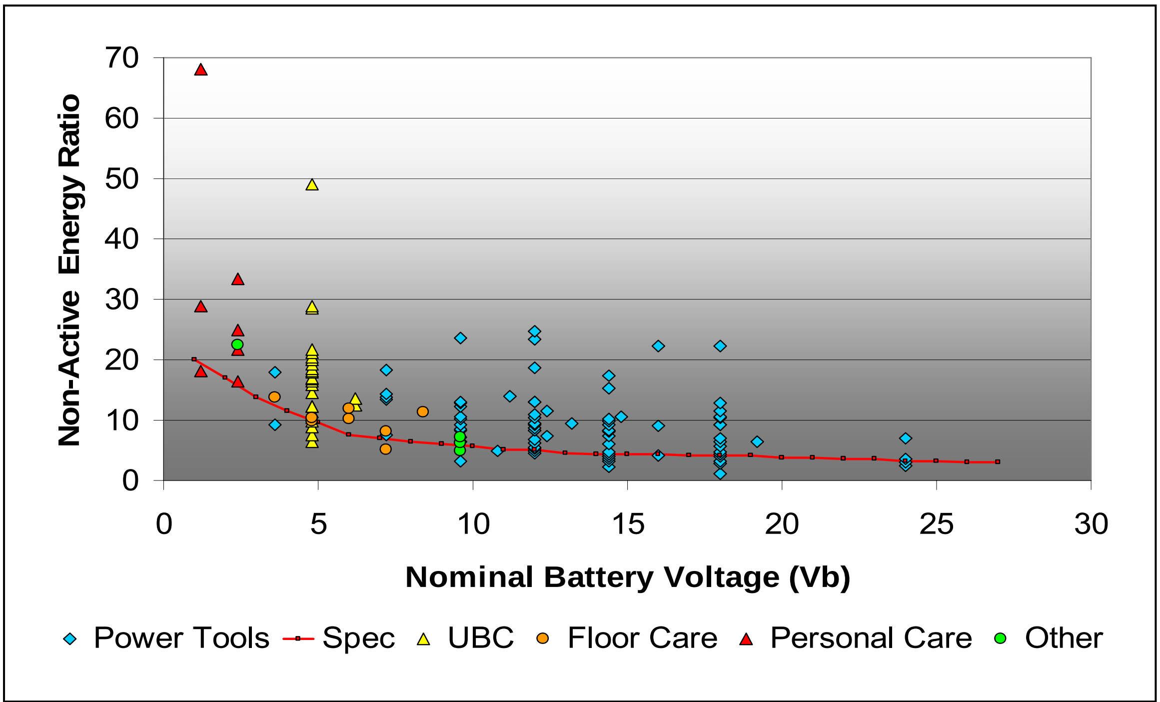

Figure 6: BCS Specification by Product Type
Figure 6 is derived from data collected during the development of EPA's Version 1.0 ENERGY STAR specification for battery charging systems.

In the United States alone, more efficient battery chargers have the potential to cut energy consumption by more than 1 billion kWh per year, saving Americans more than $100 million annually while preventing the release of more than 1 million tons of greenhouse gas emissions.

The BCS specification is intended to complement the EPS specification to comprehensively cover a variety of different miscellaneous products and ultimately impact their power conversion efficiency and standby power consumption. The last phase of the power supply strategy will allow EPA to reap even greater environmental savings.

Phase III: Internal Power Supplies (IPSs)

Following successful development and launch of the EPS and BCS specifications, the U.S. EPA has now shifted focus to the development of a test procedure for IPSs. Given the complex nature of these devices, however, the U.S. EPA recognizes that the same efficiency levels will not work for all IPSs and their end-use products. The U.S. EPA has therefore decided to follow a product-specific approach with IPSs, based on the end-use products for which they are designed. The first end-use product specification that will incorporate an IPS requirement is the new ENERGY STAR specification for computers.

Since its inception in 1994, the ENERGY STAR computer specification has sought to bring energy savings to consumers through low power mode requirements. However, with enabling rates reaching

[9] Nonactive Energy Ratio (ER) is the ratio of the accumulated nonactive energy (Ea) divided by the battery energy (Eb). Accumulated Nonactive Energy (Ea) is the energy, in watt-hours (Wh), consumed by the battery charger in battery maintenance and standby modes of operation over a defined period. Battery Energy (Eb) is the energy, in watt-hours (Wh), deliverable by the battery under known discharge conditions.

only 11% and computers spending most of their time outside of these low power states, EPA realized that to guarantee significant savings, energy consumed during active mode would need to be addressed. One way to reduce active power is through the internal power supply.

While beginning revisions to the ENERGY STAR computer specification in 2004, EPA was also supporting another initiative created to help develop a market for more efficient internal power supplies. The utility-funded 80 PLUS program offers incentives to computer manufacturers that incorporate 80%+ efficient internal power supplies into their computer and server designs. The program also provides power supply manufacturers a vehicle to certify and market their more efficient power supplies to interested buyers. To date, 11 power supply manufacturers, three of which hold a significant share of the market, have certified internal power supply models through the 80 PLUS program.

With a variety of models and brands now available in the marketplace, EPA felt confident that including an internal power supply requirement under the new ENERGY STAR computer specification was both technically feasible and cost effective for manufacturers to incorporate. Therefore, in addition to including more challenging low power mode and power management requirements, EPA is requiring a minimum 80% internal power supply efficiency for ENERGY STAR qualification. Replacing a standard efficiency internal power supply (70% efficient) with an 80% efficient model could save 50 kWh/year for each computer and more than 200 kWh over the expected four-year lifetime of the computer.

In addition to minimum power supply efficiency, EPA is also including a Power Factor (PF) of 0.9. While PF may not contribute to the efficiency of the power supply, studies show that it does help to reduce the overall plug load of the building by minimizing harmonic distortion. Use of high efficiency power supplies will result in direct reduction of energy use, due to lower power consumption. Power factor correction adds another 12 to 21% to the resulting energy savings, based on the cable lengths typically found in residential and commercial buildings (40 feet and 100 feet, respectively). Many power supply manufacturers are designing PF into their high efficiency models already. The new ENERGY STAR computer specification goes into effect on July 1, 2007, which includes the 80% efficiency and 0.9 PF internal power supply requirement.

Other Approaches to Addressing Active Mode

Another approach that EPA is increasingly adopting to address the power consumption of products in the miscellaneous category, particularly when revising existing product specifications, is to set new criteria that focus on reducing the Active Mode power consumption of these products. This approach is more complex than EPA's power supply strategy (and may take more time to design and implement), but allows manufacturers more design flexibility when meeting the energy efficiency criteria.

Computer Monitors

The new ENERGY STAR computer monitor specification, which took effect on January 1, 2005, was EPA's first foray into the development and implementation of an Active Mode specification for a product within the miscellaneous category. In the early part of this decade, market penetration of ENERGY STAR qualified computer monitors exceeded 90% and there were limited additional energy savings to be gained by merely lowering the Sleep Mode levels specified for ENERGY STAR qualification. EPA had to pursue an Active Mode specification for these products in order to both gain additional carbon savings and ensure that the ENERGY STAR continued to be a differentiator in the marketplace for the computer monitor product category.

A primary reason why Active Mode had not been addressed for this category under previous ENERGY STAR specifications was because no test procedure existed to measure the active mode power consumption of computer monitors, irrespective of display technology. As such, EPA worked closely with interested stakeholders to develop a sound test procedure to measure the power consumption of computer monitors in Active, Sleep and Off Modes. Once finalized, manufacturers were requested to test their latest models using this test procedure. EPA received data on approximately 270 monitor models, all of which were available or being introduced to market as the specification was being developed, and only these data points were used when setting the Active, Sleep, and Off Mode levels for the new ENERGY STAR specification. Due to the new specification alone, EPA projects a potential U.S. energy bill savings of almost $590 million, electricity savings of 8 billion kWh, and 1.2 million metric tons of carbon (MMTC) avoided over the time period of 2005 to 2015.

Imaging Equipment

A similar approach was used when developing the new ENERGY STAR specification for imaging equipment, scheduled to take effect on April 1, 2007. When EPA initiated the specification revision cycle for imaging equipment in 2003, the specifications had been in effect for up to seven years and ENERGY STAR qualified printers, copiers, and fax machines accounted for 92 to 99 percent of units sold in 2000 (Gartner 2001). The high market penetration levels alone suggested that a review of ENERGY STAR performance specifications was warranted. Further, as imaging equipment products increased in speed and functionality, Active Mode contributed to a greater portion of total product energy use.

When EPA began to revise the imaging equipment specifications, the need to address Active mode for some products quickly became apparent. This was accomplished with the "typical electricity consumption" (TEC) approach that considers the electricity consumed by imaging equipment during its entire duty cycle. This method for assessing product energy efficiency was received favorably by many stakeholders and at the time, demonstrated a forward-thinking approach to the development of an energy-efficiency specification. The revised imaging equipment specification will save U.S. consumers more than $3 billion over the next five years and avoid greenhouse gas emissions equivalent to taking more than four million cars off the road.

Televisions

EPA is following a similar approach in revising the current ENERGY STAR specification for televisions. When first developed, the ENERGY STAR specification for televisions focused on Standby Mode due to the vast amount of time these products spent in standby mode and the millions of televisions in use in U.S. homes. In 1998 when the specification was introduced, EPA estimated that ENERGY STAR qualified televisions would use about 20 percent less energy in a year than comparable televisions. However, Active power consumption is now becoming increasingly important due to changes in product technology and usage patterns that result in increased energy consumption. Such changes include:

- The advent of new display technologies, some of which *may* use significantly more energy than their traditional counterparts;
- The trend towards larger screen sizes;
- The marketing of televisions as part of "home theater packages," which may be used in conjunction with a variety of audio and video devices, increasing overall system energy consumption;
- The burgeoning availability of new cable and satellite programming content, leading to increased television viewing; and,
- The growth in sales of game consoles, meaning there is an increase in the number of hours a typical television operates each day.

Today, TVs account for about four percent of annual residential electricity use in the U.S. – enough to power all of the homes in New York State for an entire year (Natural Resources Defense Council, February 2006).

EPA is working with stakeholders and a number of key governments, including Australia and the European Union, to develop a single, harmonized global test procedure for televisions. This test procedure, when completed, will be used by each of the government entities to implement policies to encourage the sale of more energy efficient televisions, thereby giving consumers a means to factor power consumption into the purchasing decision.

International Harmonization of Test Procedures and Specifications

As various governments and other entities develop standards for these miscellaneous products, harmonization will be a key element to successful implementation. Manufacturers are designing these products for global distribution and are looking for ways to streamline their certification processes. Through harmonization, countries can combine their resources and technical knowledge to create test procedures and specifications that will be applicable worldwide. For countries that have yet to begin addressing these product types, global test procedures and specifications will provide for ease of adoption and implementation. As an added benefit, countries will have access to a large data set already developed and maintained by those governments that have already made the decision to align their test procedures and specifications. Policymakers representing the European Union, Canada, Australia, Japan, Taiwan, New Zealand and China are considering the inclusion of miscellaneous products such as computers, TVs, EPSs, and BCSs in their voluntary and/or regulatory standards and working very closely with EPA to harmonize their respective approaches. Through initiatives such as the Asia Pacific Partnership, the U.S. is also working with fast-growing markets India and South Korea. This brings the total population that could benefit from harmonization of test procedures and specifications to well over 3 billion.

An important step taken by the U.S. EPA and its country partners towards global harmonization of test procedures is that products are now required to be tested to the appropriate conditions of intended markets where the products are to be sold as ENERGY STAR qualified. EPA has implemented this policy in specifications moving forward, particularly for products in the home electronics and office equipment categories, because energy consumption values may vary according to the input voltage/frequency combination. In some instances, particularly for those product-categories that have a 1-watt Off Mode specification, the variance caused by testing at market-specific input voltage/frequency combinations is enough to qualify products in certain markets and not in others. As the ENERGY STAR program develops an increasingly international scope, EPA has determined that it is important to confirm that products meet specifications at the representative market conditions where the products are sold. This ensures that consumer expectations are satisfied when they purchase products that carry the ENERGY STAR mark.

Conclusions

As illustrated throughout the paper, the energy consumed by miscellaneous products continues to grow. Through their ongoing work to understand and control this energy consumption, U.S. EPA has learned some key lessons. Most importantly, it is possible to develop and implement measures to mitigate the amount of energy consumed by the miscellaneous products category, as many of the products have common elements such as power supplies. However, often a combination of measures works most effectively, such as both voluntary and mandatory standards, as well as Market Transformation tools such as consumer education campaigns, government procurement, rebates, and/or tax incentives. These measures aid in raising awareness of the energy consumed by miscellaneous products, allowing increased information to be shared with consumers and empowering them to make more informed purchasing decisions. There is still a lot of additional work that needs to be done to continue addressing the power consumption of miscellaneous products, especially in terms of increased data collection to better understand this product category. However, due to the global nature of many of the products in this category, international cooperation is vital as it brings together the critical mass needed to effect change.

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IT Equipment

Environmental Impacts of Computers in Belgium

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Abstract:

In the framework of a study focussing on four product categories (namely housing, packaging, cars and computers), we modeled their annual impacts in terms of GHG emissions, raw material use and waste production over their life cycle for the years 1990 – 2010. The results showed that though the impacts of computers in households are small, they are increasing at an amazing pace (+ 150% GHG emissions in 2010 compared to 1990). Moreover, about half of the impacts occur in the production phase, due to the manufacturing of chips.

Different strategies could be envisaged in order to decrease these impacts, in the framework of a product policy. Concerning computers, 5 strategies were identified: stabilising the demand, substituting products, increasing the lifespan of computers, improving consumers' behavior and increasing recycling. The strategy that rises as the most important one is increasing the lifespan of computers, which of course decreases the impacts due to manufacturing. Targeting the demand could also lead to significant improvement.

In a last step, key stakeholders were consulted in order to gain insight on which practical measures could be taken in Belgium. Increasing the lifespan of computers, which appeared as the top option, still has a negative image in the industry, while there are already some initiatives of repairing for reuse in Belgium by the social economy. Targeting the demand is foreseen as extremely difficult by all stakeholders, in particular due to the association between computer ownership and social status. Increasing services is seen as the best possibility.

Introduction

Attention is shifting more towards examining the potential of policies oriented at improving products and consumption patterns. This, because the sector-based, mostly 'process'-oriented environmental policies seem insufficient to reach the objectives of sustainable development. The perspective of "Integrated" in Integrated Product Policy (IPP) is the consideration of the entire product's life cycle chain and the consideration of multiple environmental problems to avoid adverse effects and shifting to other impact types.

Climate change, resources use and waste management are major challenges for policy makers and society in general. These three environmental issues constitute the core issues of the project "Integrating climate, waste and resource policies through a product policy" that started in 2002 and ended in 2004. This project was carried out within the scientific support plan for a sustainable development policy financed by the Belgian Science Policy.

After a first step aimed at the identification of key products for a product policy that would intend to reduce all three impacts simultaneously, the second step of the project studied in detail four product categories (cars, household packaging, housing and computers & paper), with the view to evaluating theoretical potentials of reduction of greenhouse gas emissions, energy use, waste production and material resource use. The last phase of the project aimed at contributing to establish a framework for the evaluation of product policy measures by stakeholders.

For the study of computers, we covered both computers in households and computers in federal administrations (as an example of an office activity). In this paper, we present the results for computers in households only, since the methodology and scope of these two parts were very different.

Methodology

Determination of theoretical impact reduction potentials

Elaboration of an analytical tool

The implementation of product policy requires an appropriate approach to take into account both the different life cycle stages of products with their own environmental impacts, and the different strategies with their ability to tackle one or several life cycle stages. In the framework of this study, we have developed and used an analytical tool that aims at linking product life cycle stages with the emissions, emission reduction potentials and relevant policies and measures. It summarises how different improvement strategies of products can decrease their greenhouse gases emissions, waste production and resource use at different life cycle stages, thus making computers more efficient during their production and use. It resulted in a series of strategies that can have an impact on one or more life cycle stage; for each of these strategies, independent parameters are varied in order to reflect the potential effect of targeted policies and measures on the product characteristics.
For computers, the strategies envisaged were as follows:
Strategy 1 : Changes in final demand for the considered function: This strategy aims at changing the demand of consumers for a particular. It would, of course, influence all life cycle stages, but is not often envisaged in environmental programmes, as it influences consumption and therefore production of goods and is often seen as damaging to the economy and the quality of life.
Strategy 2 : Substitution by products fulfilling the same function: The final function can be fulfilled by different products. The design of the product (shape, material composition) can influence its life cycle impacts. For those products for which the impacts from the use phase are important, the shift from lower to higher energy efficiency or from higher to lower carbon-content fuel can also contribute to reducing the life cycle impacts. In the case of computers, we considered desktop PC with CRT and LCD screens, as well as laptops. Shifting from CRT to LCD , or from desktop to laptop, are two possibilities to fulfil this strategy.
Strategy 3 : Product reuse: Product reuse allows doubling (or more) the product's use phase, thus delaying the time when it will become a final waste. Therefore it mainly influences the waste phase and the production phase (because less new products are consumed), but also the use phase of products if their impacts vary over the time. Product reuse is mostly not considered in actual climate policies, but more in waste policies.
Strategy 5 : Rational use of the product: Properly using a product has a significant influence on its impacts during the use phase and can also extend the product life span. It is only partially considered in the current environmental policies, mainly through information and education measures. However, information is increasingly considered as insufficient to change consumers' behaviours [1]. For example, enabling power management is more likely to be successful if this is a compulsory setting on the equipment than if users are informed and encouraged to enable it. Measures envisaged in this strategy should thus focus also on technology, and not rely on users to voluntarily change their behaviour.
Strategy 7 : Increasing end-of-life products recycling: The increase of product recycling has a mostly beneficial influence on energy used/generated in the waste phase, but also on the material production and product manufacturing through the use of recycled materials or parts. In general, recycled materials need less energy for transformation. Product recycling is not envisaged as such in climate policies, but is mostly implemented through waste policies.
These strategies are product-oriented and do not target the production phase of computers (except the design phase). The improvement of the production phase was included in the business as usual scenario. Scenarios 4 and 6 (namely decreasing the product lifespan and change of composition of the product) were nor relevant in the framework I-of the study of computers. Another strategy had to be left out, though interesting: the decrease of transportation distances. Indeed , in the case of computers, parts are manufactured world-wide and assembled somewhere else, leading to probably important impacts in terms of fuel consumption from transportation. However this production and assembly network is so large and unknown that we could not envisage to quantify this strategy.

Impacts from product consumption

A product-oriented policy would potentially aim at curbing not only impacts from products bought each year, but also impacts from products already used in the country (existing stock).

This means that both the existing stock of products and the products put on the market had to be considered in the study, especially in the development of scenarios on impacts from products, including impacts produced in Belgium but also impacts produced abroad.
As the study aimed at evaluating to what extent a product policy would contribute to the simultaneous fulfilment of the three objectives to reduce GHG emissions, waste and pressure on raw materials, impacts and impact reductions have been calculated in such a way as to fit with the following environmental objectives:

- regarding greenhouse gas emissions, the emission reduction targets agreed in the Kyoto Protocol are expressed as a percentage reduction of the average annual national emissions over the period 2008-2012 compared to the 1990 level.
- regarding waste, several types of objectives are defined in the regional waste policy documents, based on per capita annual emission ceiling and minimum recycling or reuse rates in a year.

As a result, for GHG emissions and for waste, annual emissions need to be estimated and especially "domestic" emissions.
Regarding material resources, there is no quantified objective.
Based on this approach, we calculated the three impacts for each phase:

- GHG emissions, in kg CO2 equivalent
- raw material use. This impact category indicator is related to extraction of scarce minerals and fossil fuels. The Abiotic (= non-organic) Depletion Factor (ADF) is determined for each extraction of minerals and fossil fuels based on the remaining reserves and rate of extraction. It is based on using the equation, Production/(Ultimate Reserve)2 and comparing this to the result for Antimony (Sb), which is used as the reference case. The reference unit for abiotic depletion is therefore kg Sb equivalent.
- waste, in kg of final waste, i.e. waste after treatment of the disposed product, thus going to landfill.

Calculation of annual impacts and scenarios of impacts from products

For all four product groups studied in the project, we have developed a common methodology for the construction of alternative scenarios. The development of this methodology has been guided by two main concerns, which are to:

- reflect the annual environmental impacts from existing and new products used in Belgium from 1990 through 2010, with a clear distinction between impacts from the disposal phase of existing products, the use phase of existing products and the production phase of new products;
- quantify the individual impacts from each general improvement strategy as well as the impacts from the combination of all these general improvement strategies.

It starts with the building of a “business as usual” scenario (BAU) that reflects an evolutionary case where the current policies do not change in the future. The BAU scenario is based on the different data sets and on several assumptions regarding future trends. Alternative scenarios were then built by changing key parameters, following each of the strategies mentioned above.

Stakeholder consultation on possible policies and measures

Once the theoretical improvement potentials were determined, we envisioned how a product policy could help– at least partly – to achieve them. In order to identify measures, the expertise of stakeholders was required. Indeed, existing policies and measures in Belgium are not evaluated after completion (ex-post evaluation) nor beforehand (ex ante evaluation). This gives us very few knowledge on the consequences of these measures.
We reviewed a series of consultation methods based on the following pragmatic criteria:

- Usability for all stakeholders
- Equity between stakeholders
- Amount of time required from stakeholders
- Possibility to express their views
- Quantitative exploitability of the results

We also evaluated cost and total time requirement for the research team.

Following the evaluation of existing methods, we chose to develop a method based on the Delphi principles [2], though not aiming at reaching consensus but rather at mapping opinions. This approach is sometimes referred to as “policy Delphi”[3].
Using quantitative notation ranges allows the determination of mean values for each question, as well as the statistical distribution. The Delphi method has been used for a long time. and allows structured answers and removes traditional bias occurring in interactive settings. Consequently, it is a good method to obtain stakeholders’ views while obtaining quantitative inputs to the model.

First consultation round

A Delphi questionnaire was supplied to the stakeholders willing to cooperate that asked them to evaluate possible measures on a series of criteria:

- Technical feasibility: is technology / knowledge adequately available to implement this measure?
- Political feasibility: is there political willingness (or no political impediments at least) to set up, implement and monitor this measure?
- Effectiveness: can this measure result in a substantial reduction of at least one environmental impact (GHG emissions, resource use, waste production)?
- Acceptance by the stakeholder: would the measure be well accepted by the stakeholder?
- Market acceptance: will the affected market react positively to this measure?
- Cost for industry: will this measure substantially increase the costs in the industry concerned?
- Cost for policy: will this measure require the allocation of a substantial amount of money from the policy level for its implementation and monitoring?
- Cost for users: will this measure substantially increase the total cost of ownership (purchase price + run price) for the user?

The questionnaires were filled in through the Internet. In both rounds, we had to be very careful about the phrasing of questions and of measures. Stakeholders had the opportunity to enter new measures, as well as to rephrase the measures. We also differentiated the criteria to evaluate depending on the stakeholder in order to require less time from them.

Findings from round one : reorientation of round two

We had several findings from the first round on the general methodology for this consultation.
First, although we limited the number of criteria and the number of measures to limit the time requirement from stakeholders, we had several negative reactions to this approach. Indeed, most stakeholders would have preferred to have all measures and all objectives, and select themselves the ones for which they feel they have enough expertise.
Second, the number of criteria was found to be too large to enable an easy assessment; moreover, some criteria were found either to be redundant or to have too broad a definition that would have required to split them up into other criteria. For the second round, we thus reduced the criteria to the following ones: acceptance by users (user perception and user costs); acceptance by industry (costs for industry and social costs), and efficiency.
Last, but not least, we found that the comments given by each stakeholder were more useful than the actual figures of evaluation of the different criteria in order to evaluate measures. However, the results altogether did not enable a common ground required to carry out the identification of priority measures.
Based on these findings, we decided to reorient the second round to deepen the comments from all stakeholders, with the aim to present the variety of opinions of the different stakeholders on the subject of product-oriented policies and measures.

Hypothesis for the modeling of computers

For household computers, the distinction was made between laptops, desktops with CRT monitors and desktops with LCD monitors. The data sources and main hypotheses used for these different products follow.

BAU data

Sales and market shares

We have few data on market shares of these different products. However, we can estimate for 2001 that laptops market share is ca. 20%, desktop with CRT screens, 65% and desktop with LCD screens 15%. These assumptions were used in the DSM study by Fraunhofer Institute [4]. In 2005 we had data from GfK on market shares of laptops [5] (46% in 2005); although we would tend to think that they are more likely to be sold to professional consumers. The rapid decrease of prices encourages the buying of laptops (but probably not always as a replacement of a desktop) and LCD screens. We assumed that after 2005, the sales of computers in Belgium will continue to increase (after the stabilisation of sales for 2003 – 2004), as it seems to be the case already for 2005.

It is very difficult to get reliable data on computer stock in households before that date. Actually, computers were only integrated in the INS annual survey on household consumption in 1995. For that year, the stock of computer is 1,28 million units. The share of the different products is not known, but it is not likely that laptops were often used by households in 1995, and LCD screens for computers were not widespread either. Therefore it will be assumed that in 1995, desktops with CRT screens accounted for 100% of the sales. The stock of computers in 1990 is unknown ; we assumed that the ownership rate was at best 20% (thus 785 722 units).

Production phase

For the composition data, we based our calculations on EPA [6] and Handy and Harman Electronic Materials Corp [7].

Data on impacts from production of materials were extracted from SIMAPRO. However, for computers, the production and assembly stages of chips are of high relevance [8], we thus used data provided by E. Williams.

Use phase

Knowing the power draw of computers is more difficult than it seems. Indeed, on central units, the wattage found in the technical specifications represents the maximum power draw, but by no means the average power draw. The maximum power is reached when all electricity consuming parts of the central units (CPU, hard disk, fan, drivers, etc) run at the same time, which is almost never the case. Therefore, it is necessary to measure the average power draw in use. Variations in power draw between different models also complicates developing an average number for the installed base. It is also more difficult to predict the future power consumption, even if it is assumed that due to higher computing speed and the increasing number of peripherals (CD writer, , etc), this average consumption will increase slightly. The growth in graphic card power draw also contributes, to a large extent, to this increase of average power draw..

For displays, the task is easier since technical specifications mention an average power consumption while in use, although these specifications may not be precise (e.g. depending on the contrast, colour level of the screen etc). In the future, due to the increased size of screens, the energy consumption is likely to increase slightly Although CRT-based monitors' active mode power draw tends to increase moderately as screen size grows, the active mode power draw of LCD monitors increases rapidly with increased screen size. Eichhammer et al [4] estimated some figures from 2000 onwards that we used for our modelling and extrapolated back to 1990. This source of data was also used to derive values on the on and stand-by hours.

Disposal phase

For 2000, OVAM (the competent body for waste in the Flemish region) reported a selective recovery rate of 95 % in 2001. In this value the computers sent abroad are also included (39%). These computers are sent abroad mainly for charity purposes, but may also contain illegal electronic waste. They will be taken into account as other end of life computers afterwards, but it should be noted that the vast majority of these computers, after a possible second use in developing countries, are likely to end up in landfills under very bad conditions.

Scenario assumptions

- Scenario 1 : **change in final demand** for the function: In this scenario, we assume that the penetration rate of computers in households remain constant after 2005.
- Scenario 2 **substitution of products fulfilling the same demand:** In this scenario, we assume an increased market share of LCD screens (to 35% in 2010) and laptops (to 65% in 2010) and a decrease of CRT screens down to 0% in 2010.
- Scenario 3 **product reuse**: Computers can be re-used easily as long as they meet the needs of the customer and as long as they are not too damaged when they are disposed of. Indeed, most computers are replaced because they are outdated, not because they are not working. In these conditions, they can fulfil a second use. We assumed a second life span of the same length as the first one, and these computers are assumed to replace new ones (this is optimistic). Scenario

5 **rational use of the product**: In the BAU scenario, both the time of usage and the time in standby mode are increasing. For this scenario we assumed that they remain constant after 2005, thus 370 hours in on-mode, 12250 hours in stand-by mode.

- Scenario 7 **increasing end-of-life recycling**: We assume 100% selective collection rate and 100% recycling for all materials after 2005.
- Scenario synthesis : this scenario combines the different assumptions made for each scenario.

Results of modeling

In this section, we present the results of the life cycle modelling of computers including monitors in households for the 3 impacts (GHG emissions, raw material use, and waste production) for the period 1990 – 2010.

Greenhouse gas emissions

Greenhouse gas emissions mainly cover CO_2 emissions due to energy use during the whole life cycle. Although semi-conductor manufacturing uses PFCs, HFs and SF_6 as plasma etchers, these emissions are still not well quantified and difficult to link to functional units of computers. GHG emissions presented here include only CO_2 emissions and should thus be seen as minimum values.

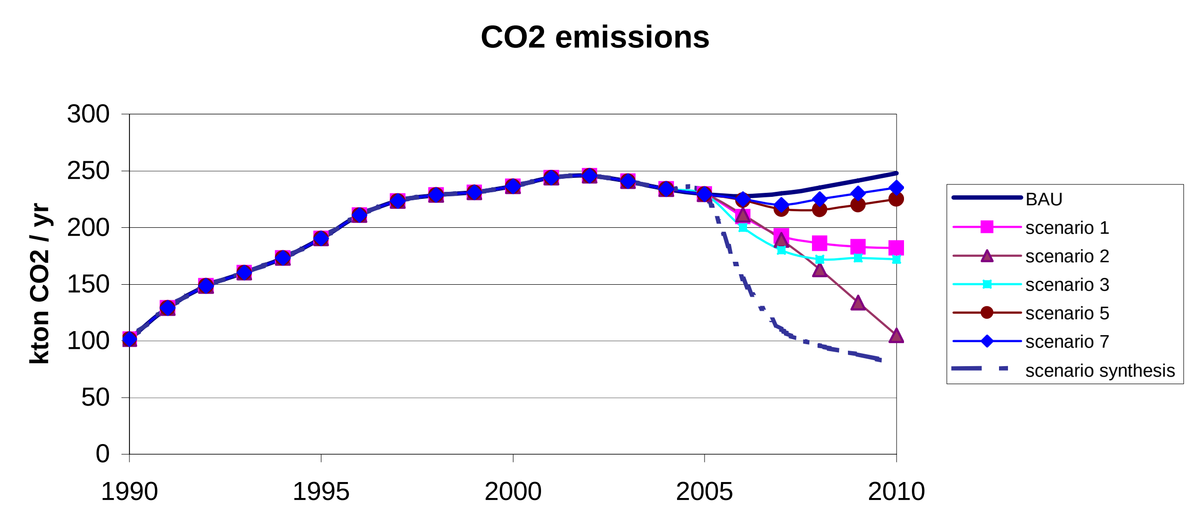

Figure 1: GHG emissions from computers – 1990 to 2010

Figure 1 shows that GHG emissions are expected to level-off for the period 2005 – 2010. Indeed, even though computer sales are increasing again, the rapid shift towards LCD screens and laptops should compensate for this.

CO_2 emissions come in almost equal proportions from the production phase and the use phase. But only the use phase occurs in Belgium because most of the production phase is abroad. Moreover, only half of the emissions from electricity take place in Belgium, since the other half is due to fuel extraction[1]. Thus, only 25% of the CO_2 emissions shown above take place in Belgium.

Figure 2 clearly shows the equal levels of impacts for production and use.

[1] Source : SIMAPRO database, fuel extraction

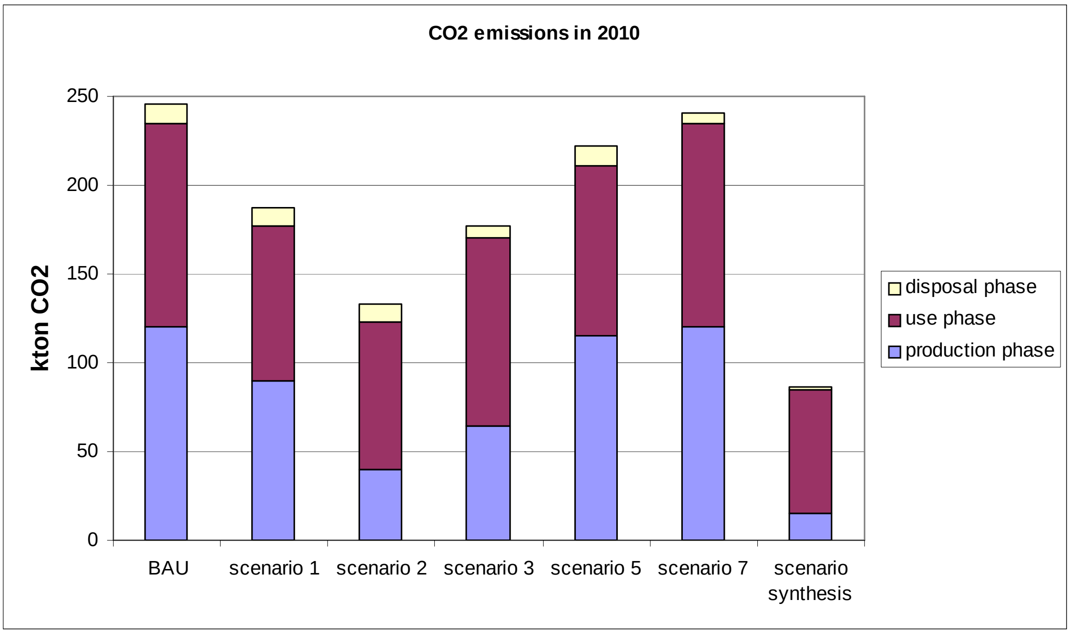

Figure 2: CO2 emissions due to consumption of household computers in Belgium– 2010 : impacts per life cycle stage and per strategy

As can be seen from the figures above, the different strategies could decrease GHG emissions in a very significant way: 64% reduction from the BAU scenario in 2010 for the combination of the different strategies. The main strategies that would be effective are: substituting products i.e. increasing sales of LCD screens and laptops (scenario 2), product reuse (scenario 3) and targeting the demand (scenario 1).

These strategies target different life cycle stages. Increasing the trend towards LCD screens and laptops would thus result in decreased GHG emissions for both the production and the use phase. Indeed, in our model[2], manufacturing laptops and LCD screens require less material, because they are lighter . This also applies to scenario 1.

In contrast, scenario 3 (reuse) only results in a decrease of GHG emissions in the production phase. These correspond to avoided GHG emissions of new computers that would otherwise have been manufactured.

Raw materials

Raw materials used by computers come from two main sources: materials used to manufacture the computer; and energy used both to manufacture and to use the computer. Indeed, about 95% of these impacts come from electricity consumption in the use phase. This is due to the electricity mix of Belgium, which uses about 65% of nuclear energy in its electricity production. Although it does not result in high GHG emissions, it still uses a large amount of raw materials due to the extraction of fuels (including uranium).

Therefore, raw material use is expected to level-off until 2010, showing a similar curve as GHG emissions (also linked to energy).

[2] However, other studies indicate that this hypothesis could be flawed, laptops being much more complicated to manufacture than desktops [9]

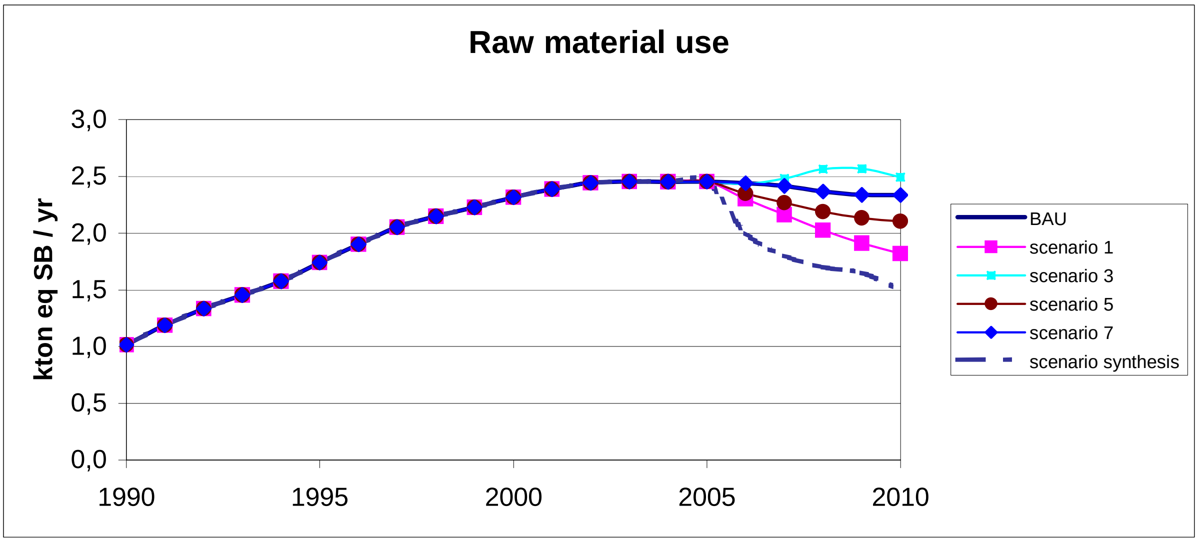

Figure 3: Raw material use of computers – 1990 to 2010

Here the share of the use phase is highly predominant, as is shown in Figure 4, thus encouraging strategies mainly targeting the use phase : scenario 2 (substitution), 1 (targeting the demand) and to a lesser degree scenario 5 (rational use of the product) are the most promising. On the contrary, reusing computers could have an adverse effect on raw material use, since it results in a longer lifespan of old, less effective equipment (mainly due to CRT screens).

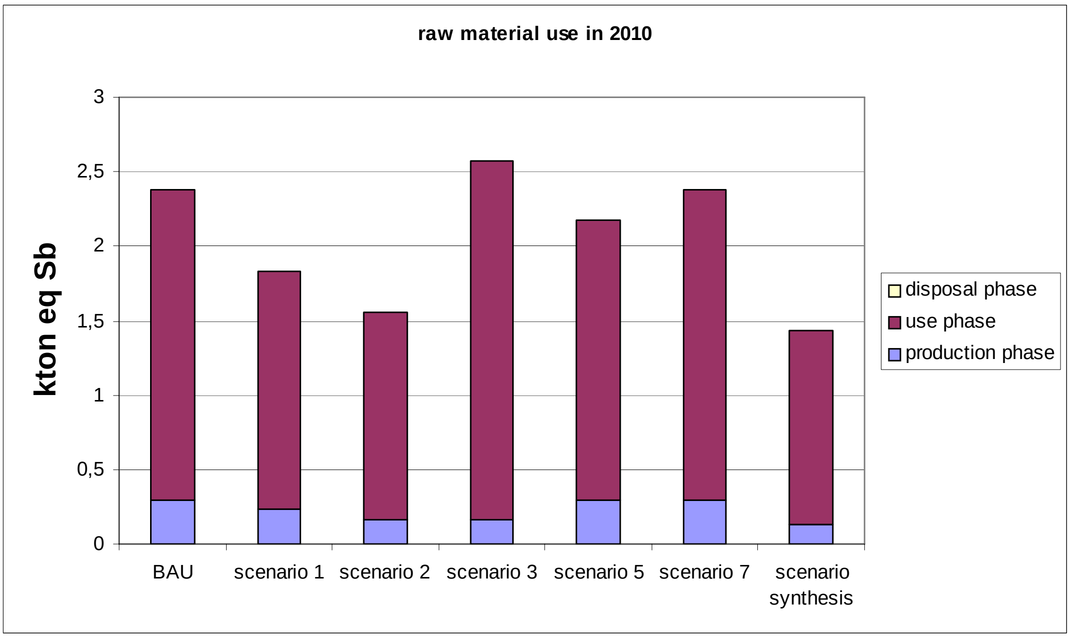

Figure 4: Raw material use of computers in 2010 per life cycle stage and per strategy

Waste production

Belgium is a leading country in Europe in terms of product take-back and recycling. Product take-back was installed through the Recupel taxation scheme that started in beginning 2001, thus 2 years before the European WEEE directive[3].

A computer's average lifespan of 5 years was assumed for the period 1990 - 2005, decreasing to 4 years in 2010. Indeed, most computers are replaced not because they are not working anymore, but because they are obsolete and do not have sufficient capacities to support ever more memory- and speed-demanding applications.

The model used here was a very simple one. The Gaussian distribution of waste production was not taken into account for two reasons: it was difficult to integrate in Excel modelling and, in the case of

[3] Directive 2002/96/CE.

computers, this Gaussian distribution is not very accurate. Indeed, people tend to store their computer, before either reselling it, or finally dispose of it (usually when it is too old) [10].

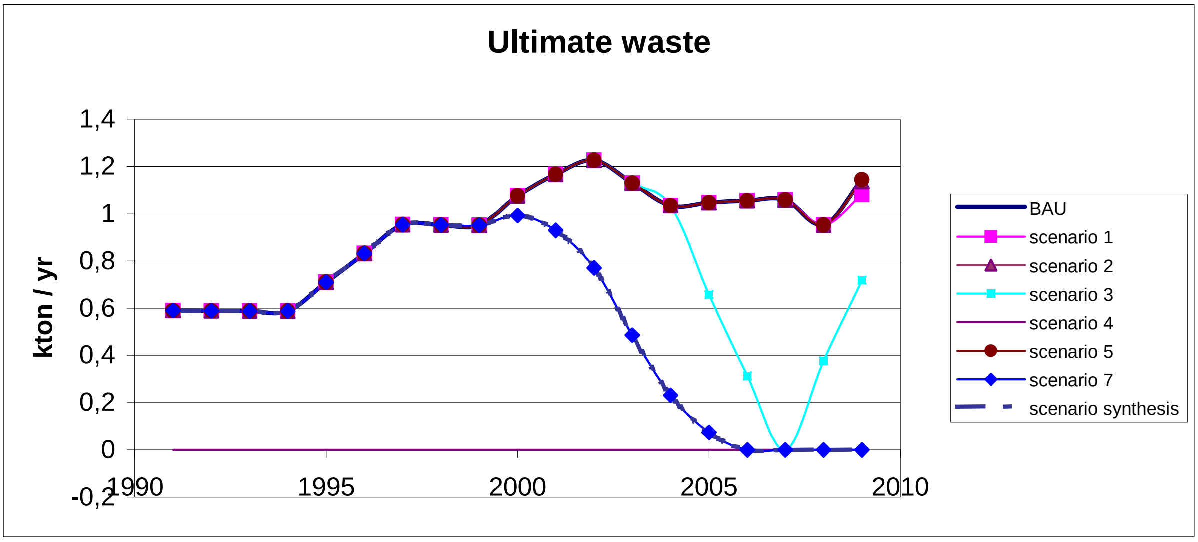

Figure 5: Waste production of computers : 1990 – 2010

Figure 5 shows the waste production calculated in this study. It shows that although Belgium is already doing a lot of efforts, waste from computers could be lowered further, especially by improving the recycling processes. It should be noted that these figures do not account for waste production in the production and distribution phases. This is thus an under-estimation of actual impacts of computers over their life cycle, and will be discussed later on.

Policies and measures

The results of this project underlined the importance of impacts in the production phase. Thus, computers should be considered not only as products that consume energy in the use phase (electricity), but also products resulting from very energy-intensive processes that are thus worthy of careful treatment as a "waste", and where reuse is a policy option that could lead to substantial environmental benefits.
We presented to key stakeholders a list of possible improvement measures taken from literature or foreign experience. The comments from each stakeholder for each strategy are presented hereunder, with a view of showing all opinions on these matters.

Scenario 1 : reduction of final demand

- Industry emphasised the need for a product policy to change consumption patterns, but not consumption levels. The development of services versus computers (e.g., through the increase of computer centres) was not seen as a good option due to possible side-impacts on traffic. However, in order to decrease the "digital gap", the industry is favourable to the presence of free PC access in town halls.
- For the actors from the social economy (non-profit organisations specialised in the collection and reselling of electrical equipment) (selling second-hand computers), it is important to inform consumers about the impacts of computers when they buy one. Especially, information on the cost of upgrading vs. the cost of a new computer.
- For environmental NGOs, decreasing demand would be possible by subsidizing specialised small and medium enterprises (SMEs)which could bring to households the use of software.
- For consumer organisations, the symbolism of computers is now so important that targeting the final demand would be extremely difficult.
- Researchers in sociology also think that the symbolism of computers is now so important that targeting the final demand would be extremely difficult.

<u>Agreements on this strategy</u>
There seems to be an agreement with the difficulty of the task of controlling the demand for computers. Increasing services seems the only possible solution, but a further analysis of the impacts associated with them, as well as the means to promote them, would be necessary.

Scenario 2: product substitution

- Concerning this strategy, the industry underlines the fact that such a substitution must be carried out carefully, taking into account the whole life cycle impacts of the different products as well as a cost / benefit analysis of the change. Attention must also be paid to side-effects of such changes, e.g. concerning the security of the product. Concerning possible measures, ecolabels are not seen as a good measure since it is not a compulsory label, thus disadvantaging other environment friendly products. They also comment that international discussions have already started to develop the Energy Star label.
- For consumer organisations, the promotion of energy efficient computers should preferably take place through compulsory labels rather than ecolabels, because consumers are not receptive to labels. For the same reason, developing existing labels should be preferred to creating new ones.
- For researchers, rather than developing new labels, they prefer field agreements.

<u>Agreements on this strategy</u>

There is a general agreement on the uselessness of promoting ecolabels for computers (they are considered to be ineffective labels). Stakeholders agree that a better solution to promote the use of energy-efficient equipment would be the development of existing compulsory labels, or by field agreements.

Scenario 3: product reuse

- For industry, reuse can be an attractive option if scientific evidence suggests that it is an effective and environmentally friendly solution, and provided that it can be implemented at a reasonable cost, without detracting from the technical characteristics required for the intended application. The limitations with respect to reuse make it very important to continue encouraging research and development (R&D) to improve the eco-efficiency of computers. Industry maintains that the promotion of second-hand computers is not always the best solution, since new PCs are more energy efficient than older ones
- For the actors from the social economy, computers "cost" a lot during their production in terms of environment. Increasing their life span is therefore logical. They are also in favour of open-source software, which enables the consumers to have a flexible system which can evolve as they wish. They also underline that reused computers do not directly compete with new ones on the market; on the contrary, they fulfil different needs (e.g. basic needs in terms of speed and power) in a responsible manner. Finally, they agree with the need to increase the upgradeability of computers, which should be carried out in the assembly phase.
- Consumer organisations warn about a possible rebound effect, where people who cannot afford a new computer could possibly buy a used one, thus increasing the penetration rate of computers in households. Also, the network of second-hand equipment sales should be associated with the new equipment network, so that salesmen can point the consumer towards the best choice depending on needs and constraints. But in this case, second-hand equipment should be interesting to sell for the new equipment distribution network. They also suggest to develop a tool to know the characteristics of the computer fulfilling the consumer's needs. This tool could be supplied through the internet and sales points.
- For environmental NGOs, in order to lengthen the life span of computers, PC design is very important (for maintenance in particular).

<u>Agreements on this strategy</u>

In this strategy there is a clear opposition between the industry and the social economy actors. However, this strategy is particularly important for computers, as about half of their CO_2 emissions occur in the production phase. Further research and market studies would be necessary to determine if second-hand computers compete with new ones on the market place, and if developing them would lead to a rebound effect. It should be emphasised that developing the market for second-hand computers could possibly lead to the creation of new jobs in Belgium.

Scenario 5 : improvement of product use

Many comments from researchers underlined the necessity to help consumers to use computers more efficiently. For example, sociologists believe that stand-by enabling should be set up automatically and less easily changed by users. Also, the benefits for consumers should be clearly stated and given to them, in order to increase the efficiency of communicating.

Scenario 7 : material recycling

- Industry is of the opinion that 1) no measures can be imposed which make the use of recycled material obligatory and 2) market forces themselves must determine where the raw materials yielded via recycling can be most effectively deployed.
- For the social economy actors, this strategy is an "end-of-pipe" measure that is only efficient if accompanied by priority measures linked to prevention and reuse. Experience for white goods

shows that monetarisation of flows inhibits reuse and limits the freedom of stakeholders in terms of private initiatives. Moreover, the IT sector works in a business to business view, thus old equipment often find solutions in the framework of leasing contracts or sales with / without take-back of old equipment.

- In general, environmental NGOs insist on the fact that public authorities must orient industrial policy depending on determined social objectives. It should be remembered that economic instruments would be very useful to send the necessary signals to reorient production and consumption patterns. These instruments are more and more refused by industry delegates. On the contrary, they support awareness measures that have minor impact. Public authorities should overcome these wishes and target public interest.

Agreements on this strategy

For this strategy, it is difficult to make conclusions. The industry is against regulations in the field of recycling, and the social economy thinks this should not be a preferred strategy (but rather reuse).

Discussion

Producing computers

When having a look at the calculations of impacts over the life cycle of computers, we notice that the impacts occurring from the production phase mainly stem from the core process of chip manufacturing. This manufacturing consists in building a series of layers on top of a silicone wafer, therefore laying the network of transistors and diodes that give a chip its functionality. This process requires large amounts of chemicals, water, and energy [8], actually about 500 times the weight of a chip is required in a series of raw materials (including fossil fuels) in order to manufacture it. As a comparison, a car requires twice its weight of fossil fuels to be produced [11].

The GHG emissions estimated by our model is actually an underestimation, since it does not take into account PFCs use as a solvent. In 1993, an estimation of PFC use in the semiconductor industry showed that about as much global warming impact occur due to PFC use as to electricity consumption during the production [8]. PFCs have since been phased out to some extent, but in an un-quantified amount.

Besides waste from end-of-life disposal, waste during production also occurs. In 1997, the Electronics Industry Association of Japan reported 15 kg of waste occurring during the production of a desktop unit [12]. A large majority consists in acid and alkali wastes.

A favoured way of reducing impacts from computer production is to replace part of the production of new computers by the reuse (with possible upgrade) of older ones. This strategy would lead to a decrease of GHG emissions occurring from the production of computers; however, it should be coupled with the replacement of old CRT screens by LCD screens; otherwise, electricity use in the use phase is likely to increase compared to the BAU situation.

This proposition was one of the biggest sources of disagreement in the consultation phase of the study. Industries are reluctant to envisage this strategy that they consider threatening to the economic health of their sector. Open-source software, that can be a good option in order to solve the problem of software equipment on used computers, is also considered with caution. Other actors emphasise the social impacts of reusing computers. One of the main negative effects could be the rebound effect, where used computers would not substitute to new ones but actually increase the penetration rate of computers on the Belgian market. Moreover, given the social status that is linked to owning the latest, most trendy type of computer, this could be hard to achieve.

While reuse thus appears as an approach to be taken cautiously in households, it stills can be a good option in schools and offices, where decisions are taken more rationally than in households.

Concerning the stabilisation of the demand for computers, all stakeholders are doubtful on this possibility. The only way that could possibly work would be to increase the offer of computer as a service, thus developing internet cafés, computer renting etc. How this strategy could be implemented would require a more in-depth analysis of social representations of computers.

Using computers

The trend of GHG emissions and raw material use is to remain level until 2010. Indeed, although an increase of sales of computers in Belgium can be expected and begins to be noticed, the trend towards more “flat screens” (LCD screens) and laptops is decreasing the average consumption per unit. A CRT screen consumes on the average 60W; a LCD screen, 15 W; a laptop, about 20W [4]. The unknown factor in these figures is the market shares of different screen sizes : indeed, the larger the screen, the higher the electricity consumption. 17” screens seem now the largest category of

screens on the market, having largely replaced 15” screens, and even larger screens appear on the market. The trend for the years to come may influence slightly these power consumption figures.
Besides the question of CRT versus LCD screens, the issue of energy efficient equipment should be tackled. Energy efficient equipment can today be identified by either the European Ecolabel, or the Energy Star label. The former is actually not available on the Belgian market; the latter has outdated requirements and does not really identify energy-efficient equipment [13]. Stakeholders are not willing to develop new labels; indeed, there is a general state of confusion on labels in Belgium, consumers generally not recognising them or not knowing what they mean [14]. Creating new labels would only lead to increased confusion. The priority thus seems to update the Energy Star requirements at the international level. This has been undergone at the European level where legislation has been taken for display units (CRT and LCD screens)[4] and criteria are under revision for computers.
Using computers in an efficient manner is also an option. It has small effects on total GHG emissions (electricity being mainly produced from nuclear in Belgium), but higher impacts in terms of raw material use. It requires using the stand-by mode of both the monitor and the central unit, but also shutting down if the equipment is expected to stay unused for a longer period. This would require improving the ergonomics of the stand-by and shut-down management options, which are largely unused by inexperienced users.

End-of-life computers
Belgium is already ahead of existing legislation related to electrical and electronic equipment. This means that additional improvement will be difficult to get. However, several strategies could be beneficial.
First, a “mechanical” decrease of waste production would occur both from the reduction of the demand and from the substitution of products. LCD screens and laptops being much lighter, their development could contribute to waste reduction in terms of quantities.
Second, reusing computers would decrease the production of waste at a significant degree; indeed, if all computers had a second life of the same length as the first one, this would halve yearly waste production from end-of-life products. The feasibility of this option is yet to be assessed, 10 years of working life being considerable for a computer.
Last, increasing recycling targets would enable a further decrease of waste production. This should be envisaged only when reuse is not feasible (not-repairable equipment for instance). However, the network of EEE collection in Belgium (especially for large equipment such as computers) is now well developed; the critical step would therefore be the development of recycling facilities and their treatment capacities.
It should be underlined that this study does not take into consideration a phenomenon that is currently being investigated at the federal level: some computers are exported as second-hand computers to developing countries, but they are actually only EEE waste. Waste treatment in developing countries is of course not as efficient as in Belgium, resulting in very harmful exposure to pollutants for the population [7].

Conclusion

Computers are not often seen as polluting equipment. However, they have non-negligible impacts in terms of GHG emissions, raw material use and waste production. Production in particular is a very polluting phase, and it produces as much greenhouse gas emissions as the CP itself during its whole lifespan; however since it does not occur in Belgium the only possibility to influence this phase is a product-oriented policy aiming at favouring products with the smallest impacts on the environment over their life cycle. A preferred way of doing so is to encourage the reuse of computers; this would require the development of the social economy network, thus also offering the possibility to create jobs. It would also have the benefit of reducing computer waste.
The impacts of the use phase could be mitigated by increasing the proportion of LCD screens and laptops. They could also be addressed by updating the most widely known energy efficiency label to include an active mode power draw component, Energy Star, in order to make it a real commercial incentive for low electricity consumption.
Finally, it is worth underlining the fact that this sector is changing at an increasing pace. Technology developments occur at such a rate that it makes modelling and policy design very difficult. For this reason, it is important to involve the industries manufacturing or reselling computers for reuse (social economy network). Belgium is probably not the best country for this to happen, given its small impact

[4] Commission Decision 2005/42/EC

on the computer production market, but it is necessary to begin raising awareness and finding solutions at a more global level.

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Residential IT Energy Consumption in the U.S.

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[2]Ionary Consulting

Abstract

TIAX carried out a study to quantify the energy consumption of U.S. residential Information Technology (IT) equipment in 2005 and develop scenario-based projections for 2010 [1]. This paper presents the key findings of this study for 2005. The project team identified ten key equipment types and evaluated their energy consumption in 2005. Prior studies suffered from a dearth of data about PC and monitor usage patterns and these devices account for a majority of residential IT energy consumption. Consequently, TIAX independently commissioned a survey to assess residential IT usage patterns in 2005 that posed a dozen questions to people in 1,000 demographically-representative households about the usage patterns for up to three computers per household. This survey yielded more accurate estimates of PC and monitor use than prior studies, which markedly improved the accuracy of the estimate of total residential IT energy consumption. Overall, U.S. residential IT equipment consumed about 42TWh of electricity in 2005, or about 0.46 quads of primary energy. This translates into approximately 3% of residential electricity consumption and 1% of U.S. electricity consumption and about 0.45% and 2.4% of U.S. and residential primary energy consumption, respectively. Desktop PCs and monitors account for about two-thirds of the energy consumed by the key equipment types. The current study's estimate of total residential IT energy consumption is much higher than prior estimates, primarily because the new usage data indicate that PCs and monitors spend much more time in active mode.

Introduction

Over the past decade, the widespread commercialization of the Internet, increased integration of IT in peoples' lives, and consistently large gains in capability and functionality coupled with consistent decreases in equipment costs have resulted in a dramatic increase in the use of information technology (IT). Consequently, residential IT equipment has begun to have an impact on residential electricity and energy consumption. An earlier study estimated that residential IT equipment consumed 16.5TWh of electricity (0.2 quads primary) in the U.S. in 2001 [2]. Desktop PCs and their monitors accounted for more than 75% of the total. In the context of residential buildings, they found that residential IT accounted for approximately 1% of both total electricity and primary energy[1] consumption circa 2001. This suggests that U.S. residential IT energy consumption was about 1/6th of commercial IT energy consumption (based on [3]).

Although the earlier study indicates that residential IT accounted for a relatively small portion of U.S. residential energy consumption in 2001, recent trends suggest that it may have increased substantially since 2001 due to an increased number of PCs and other IT equipment in residences and the possibility of increased utilization (e.g., due to greater deployment of broadband Internet connections and home networks). In addition, the data used to estimate PC and monitor usage patterns had limitations that make estimates based upon the data have a high degree of uncertainty.

To support its strategic planning efforts, the U.S. Department of Energy, Building Technologies Program (DOE/BT), contracted TIAX to develop an estimate of U.S. residential IT equipment energy consumption in 2005 and scenario-based projections for 2010. To realize those goals, TIAX and DOE/BT decided upon the following approach to the project:

1. Generate a list of equipment types and collect existing data from literature.
2. Develop a preliminary estimate of national energy consumption for each equipment type.
3. Select 5 to 10 equipment types for further evaluation, based upon preliminary calculations and perceived growth in future energy consumption.

[1] Primary energy, as opposed to site energy, takes into account the energy consumed at the electric plant to generate the electricity. On average, each kWh of electricity produced in Y2000 consumed 11,030 Btu [4].

4. Develop refined bottom-up estimates of national energy consumption of each selected equipment type, for Y2005 and three scenario-based projections for Y2010.
5. Compare the current results with the results of other studies.
6. Publish the findings in a report, including feedback from government and industry.

This report describes the methodology, results, findings, and recommendations of the evaluation of residential IT energy consumption in 2005.

Approach

Equipment Analyzed

A wide range of energy-consuming IT equipment is found in homes. Moreover, the continued integration of IT into more aspects of home life suggests that the proliferation of new kinds of devices will only continue to grow in the future. The definition of what equipment falls under the scope of this study, i.e., are defined as IT equipment, is somewhat arbitrary. For instance, IT could, potentially, encompass a broad range of different equipment types, ranging from office equipment to telephony to many consumer electronics (e.g., televisions, personal audio products, etc.). Notably, a growing portion of a wide variety of electricity-consuming devices are incorporating IT functionalities, such as on-board computing and networked connectivity. Due to the scope limitations of this study, however, the project team could only consider and model the energy consumption of a limited subset of equipment types. Table 1 shows the equipment considered for evaluation in the current study.

Table 1: Potential and Selected Key Equipment Types

Potential Key Equipment (Key equipment types in **BOLD)**
o **Broadband Access Devices (cable and DSL modems, satellite)**
o Cellular/Wireless Phone
o Copy Machines
o **Desktop PCs**
o **Digital Set-Top Boxes with Personal Video Recorder (PVR)**
o Facsimile Machines
o Fiber Optic Terminal (w/ Fiber to the home [FTTH])
o **Home Routers (wired and wireless)**
o Home Servers
o **Inkjet Printers**
o **Laptop PCs**
o Laser Printers
o **Monitors**
o **Multi-Function Devices (MFDs)**
o Personal Digital Assistants (PDAs)
o Scanners
o **Uninterruptible Power Supplies (UPS)**
o **Voice Over IP Adaptor (VoIP)**

To focus the analysis on the equipment that accounts for most residential IT energy consumption, the team selected up to ten key equipment types for evaluation from many potential equipment types. The selections reflected preliminary estimates of candidate equipment types' energy consumption in 2005, as well their projected impact in 2010. In addition, the selections had a moderate bias for devices that had not been evaluated by prior studies. Subsequently, the team analyzed the energy consumption for each key equipment type in 2005.

Energy Consumption Calculation Methodology

Figure 1 shows the basic methodology used to develop the annual energy consumption (AEC) estimates.

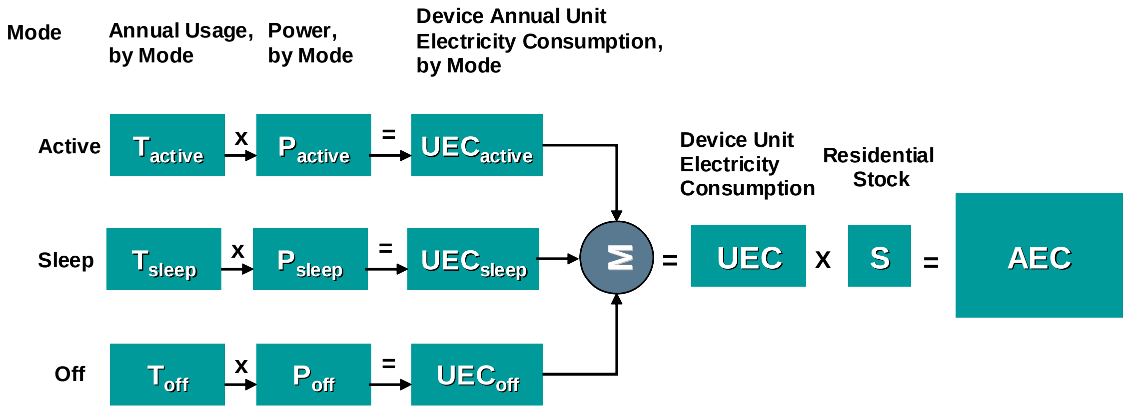


Figure 1: Annual Energy Consumption Methodology Source: [3]

For each equipment type analyzed, the project team calculated the average unit energy consumption (UEC, in kWh) of a single device for an entire year. The UEC equals the sum of the products of the approximate number of hours that each device operates in a residential setting in each power modes and the power draw in each mode. The product of the estimated residential stock (i.e., installed base) and UEC yields the total annual energy consumption (AEC, in TWh) for that equipment type. Reference [3] describes the calculation methodology in greater detail.
The following sections describe our approach to developing values for the different components of AEC calculations.

Residential Equipment Stock
Residential building equipment stock simply means the number of devices in use in residential buildings. Stock estimates primarily came from published estimates, such as industry market reports, the U.S. Department of Energy's Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS[2]), and other research reports. Overall, residential stock estimates appear to have the smallest uncertainty of all three components of device AEC calculations. Table 2 displays the stock estimates for the different key equipment types; the full report [1] provides details about the stock estimates, as well as the sources used to develop each.

Table 2: Residential Stock Estimates in 2005 for Key Equipment Types.
Sources: See [1].

Equipment Type	**Stock Estimate [millions]**
Broadband Access Devices	32
Desktop PCs	85
Inkjet Printers	75
Laptop PCs	36
Monitors	85
Multi-Function Devices (MFDs)	13
Digital Set-Top Boxes with Personal Video Recorder (PVR)	10
Uninterruptible Power Supplies (UPS)	8.5
Voice Over IP Adaptor (VoIP)	1.5
Home Routers (wired and wireless)	15

[2] EIA characterizes the RECS as: "a national statistical survey that collects energy-related data for occupied primary housing units. In the 2001 RECS, data were collected from 4,822 households in housing units statistically selected to represent the 107.0 million housing units in the United States." More information about RECS can be found at: http://www.eia.doe.gov/emeu/recs/ .

Usage Patterns

A device's usage pattern refers to the number of hours per week that, on average, a device operates in a given mode. Most equipment types have several different modes that are typically condensed into three distinct modes (see Table 3). The analysis also uses two other modes for certain equipment types. Inkjet printers and MFDs have a "ready to print" mode instead of an active mode, as printing accounts for a small portion of residential inkjet UEC[3]. In addition, digital set-top boxes with PVR and VoIP adaptors both have an on-ready mode for when the device is on but not providing user functionality in lieu of a sleep mode. In many cases, power management (PM) strategies (such as the voluntary EnergyStar® program operated by the U.S. Department of Energy and the U.S. Environmental Protection Agency) and their degree of implementation have a major impact on the amount of time spent in the active and sleep modes.

Table 3: Office Equipment Usage Modes

Mode Type	**Description**	**Example**
Active	Device carrying out intended operation	• Monitor displays image • Copier printing
Sleep	Device not ready to carry out intended operation, but on	• Monitor powered down but on • Copier powered down but on
Off	Device not turned on but plugged in	• Monitor off, plugged in • Copier off, plugged in

Table 4 displays the usage patterns estimated for the different key equipment types; the full report [1] provides details about the usage patterns, as well as the sources used to develop each estimate.

Table 4: Usage Patterns Estimates in 2005 for Key Equipment Types

Equipment Type	**Average Annual Hours by Mode**		
	Active	**Sleep**	**Off**
Broadband Access Devices	8,760	0	0
Desktop PCs	2950	350	5460
Inkjet Printers	50*	1610	7100
Laptop PCs	2370	930	5460
Monitors	1860	880	6020
Multi-Function Devices (MFDs)	50	1610	7100
Digital Set-Top Boxes with Personal Video Recorder (PVR)	2890	5870* *	0
Uninterruptible Power Supplies (UPS)	2500	1070	5180
Voice Over IP Adaptor (VoIP)	360	8400* *	0
Home Routers (wired and wireless)	8760	0	0

Sources: See [1]. * Ready to print for inkjet printers and MFDs. * * On-ready mode for set-top boxes and VoIP adaptors.

In contrast to commercial building IT equipment, very few measurements exist for residential IT usage. Most prior studies of residential IT energy consumption have used informed estimates for usage by mode ([2], [5]). One survey, the EIA Residential Energy Consumption Survey (RECS), asked respondents to estimate weekly PC usage and reported results in very broad time bands (e.g., 2-15 hours, 16-40 hours, 41+ hours [6]). Although these data were the best available prior to this study, they provide only a general feel for PC active mode usage and do not directly address time spent in off or sleep modes.

Because desktop PCs and monitors appear to dominate residential IT energy consumption (per [2] [5]), TIAX[4] decided to commission a phone survey to develop more refined and up-to-date estimates for PC and monitor usage by mode (henceforth referred to as the "TIAX Survey"). The TIAX survey[5]

[3] Assuming that an inkjet printer consumes an additional 30W while printing (than in ready mode) and prints five pages per minute, printing a single page consumes approximately 0.1W-h. If a residential inkjet printer printed 1,000 pages per year, printing would contribute approximately 1kWh to inkjet printer UEC.
[4] This survey was funded in its entirety by TIAX LLC, i.e., no government funds were used to carry out the survey.
[5] An appendix in the full report [1] contains the complete survey.

posed twelve questions to 1,000 demographically-representative households about the usage patterns of up to three PCs and monitors used most often in each household. The current study uses usage data for PCs and monitors derived from the TIAX survey.

The team developed two models to translate the TIAX survey responses into residential PC and monitor daily weekday and weekend usage patterns. Together, they provide upper and lower bounds for PC and monitor usage. The current usage estimates presented for PCs and monitors use the lower-bound approach (i.e., "OffModel" in Appendix A); applying the upper-bound approach would increase desktop PC and monitor AEC by approximately 30% and 25%, respectively. Appendix A discusses the two models in more detail.

Power management (PM)-enabled rates can have a significant impact on the UEC of a given device, particularly if the device remains on overnight. Consequently, the TIAX survey posed questions to ascertain the PM-enabled rates for PCs and monitors. Based on responses to the question: "If the computer monitor of the computer is left on, after one hour or more of no use, does it continue to display the same image, display a screensaver, or go blank?," residential monitors have a PM-enabled rate of about 60%. This rate is consistent with the estimate of reference [2] and similar to values from surveys of monitors used in commercial buildings [7].

The survey data also suggest that the residential desktop PC power management (PM) enabling rate appears to be about 20%, which is higher than the commercial sector rate (roughly 6% [7]). This estimate has appreciable uncertainty. The project team attempted to develop a meaningful question that users could readily answer to determine the PM-enabled status of PCs and solicited feedback from several people outside of TIAX. Ultimately, PM-enabled rates were derived from respondents' answers to question: "If members of your household leave the computer on and do not use the computer for one or more hours, how long does it take for the computer to respond to moving the mouse or typing on the keyboard?". Potential responses included:

01 Almost instantaneously
02 Within a few seconds
03 In about ten or more seconds
99 DON'T KNOW

The thought was that a PC that took more time to respond to input after a significant period of non-use would have a higher probability of being in sleep mode. Consequently, the analysis assumes that a PC that responded "In about ten or more seconds" had its power management enabled[6]. If, however, "Within a few seconds" and "In about ten or more seconds" both denoted PM-enabled, the PM-enabled rate rises to about 50% and desktop PC AEC decreases by about 20%.

As one researcher points out, responses to the question may correlate more with monitor PM-enabled status, i.e., people are aware if the monitor displays an image or not, and may prevent accurate characterization of the PCs' PM-enabled status. Other measures associated with PM, such as hard drives spun down, do not necessarily mean that the measure that typically achieves the largest reduction in power draw (powering down the CPU) has occurred [8]. On the other hand, it is not clear that most users would be aware of these events and could provide meaningful responses to a telephone survey. Consequently, the approach taken provides a general sense of PM-enabled status but has appreciably more uncertainty than metered data. Overall, device usage patterns have the greatest uncertainty of any component of the AEC calculations.

Power Draw by Mode

The AEC estimates rely upon power draw estimates for all of the relevant operational modes for each equipment type analyzed. For each mode, the power draw value represents the best estimate for the average power draw of all of the different devices included in a single equipment type. This estimate assumes that annual usage by mode does not vary appreciably with power draw by mode, e.g., that desktop PCs draw 120W in active mode do not spend appreciably more hours in active mode per year than desktop PCs that draw 50W in active mode. This simplification is not demonstrably true; however, in general, the magnitude of the error introduced by this assumption is likely on the order of or less than that of the magnitude of other uncertainties in usage patterns.

Whenever possible, the active mode power draw values reflect actual power draw measurements as opposed to the device rated power draw. Rated power draws represent the maximum power that the

[6] All "DON'T KNOW" responses were excluded from the PM-enabled percentage calculation.

device's power supply can handle and often exceed typical active power draw values by at least a factor of three (see, for example, [3]).
Table 5 displays the power draw by mode estimates for the different key equipment types; the full report [1] provides details about estimates, including the sources used to develop each estimate.

Table 5: Power Draw by Mode Estimates in 2005 for Key Equipment Types

Equipment Type	**Average Power Draw by Mode**		
	Active	**Sleep**	**Off**
Broadband Access Devices	6	n/a	n/a
Desktop PCs	75	4	2
Inkjet Printers	13*	5	2
Laptop PCs	25	2	2
Monitors	45[7]	2	1
Multi-Function Devices (MFDs)	19	11	7
Digital Set-Top Boxes with Personal Video Recorder (PVR)	27	25*	n/a
Uninterruptible Power Supplies (UPS)	9	6	6
Voice Over IP Adaptor (VoIP)	6	4	n/a
Home Routers (wired and wireless)	6	n/a	n/a

Sources: See [1]. n/a = not applicable. * Ready to print for inkjet printers and MFDs. * * On-ready mode for set-top boxes and VoIP adaptors.

Unit Energy Consumption
Table 6 summarizes the UEC values for the key equipment types.

Table 6: UEC Values for Key Equipment Types in 2005

Equipment Type	**UEC [kWh]**
Broadband Access Devices	53
Desktop PCs	234
Inkjet Printers	23
Laptop PCs	72
Monitors	91
Multi-Function Devices (MFDs)	68
Digital Set-Top Boxes with Personal Video Recorder (PVR)	225
Uninterruptible Power Supplies (UPS)	60
Voice Over IP Adaptor (VoIP)	36
Home Routers (wired and wireless)	53

Results and Discussion

In 2005, U.S. residential IT equipment was estimated to consume 42TWh (see Figure 2), or about 3% of residential electricity consumption and 1% of U.S. electricity consumption [10]. For comparison sake, residential IT is projected to account for about 1.4%[8] of electricity consumed in Germany in 2005 [11]. Translated into primary energy, residential IT accounts for 0.46 quads, which equals approximately 0.45% of U.S. primary energy consumption in 2005[9] [10].

[7] Monitor average power draw values based on the following installed base distribution: 55% 17-inch CRT, 20% 15-inch LCD, 30% 17-inch LCD [9].
[8] This total includes additional devices not included in this study, including: Mobile phone chargers, personal digital assistants (PDAs), scanners, matrix printers, copiers, "active boxes," ISDN boxes, and assumes that 50% of set-top boxes and satellite receivers are digital devices in 2005.
[9] Assuming that each kWh of electricity requires the consumption of 10,913 Btus on average to generate, transmit, and distribute [4].

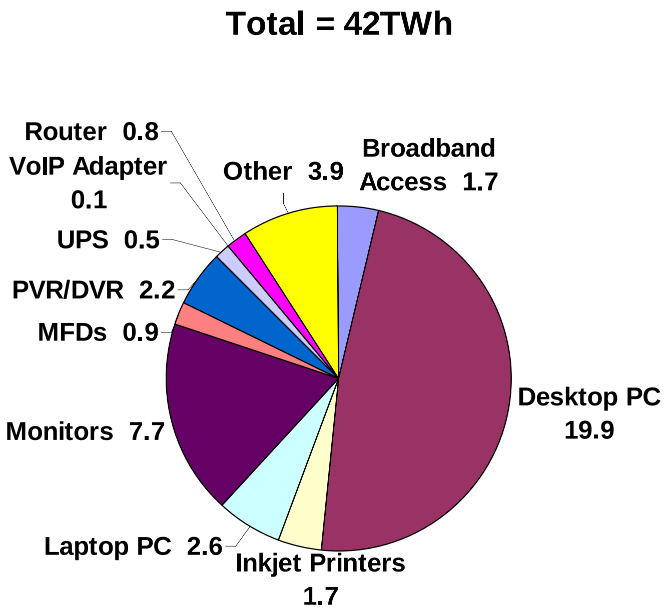


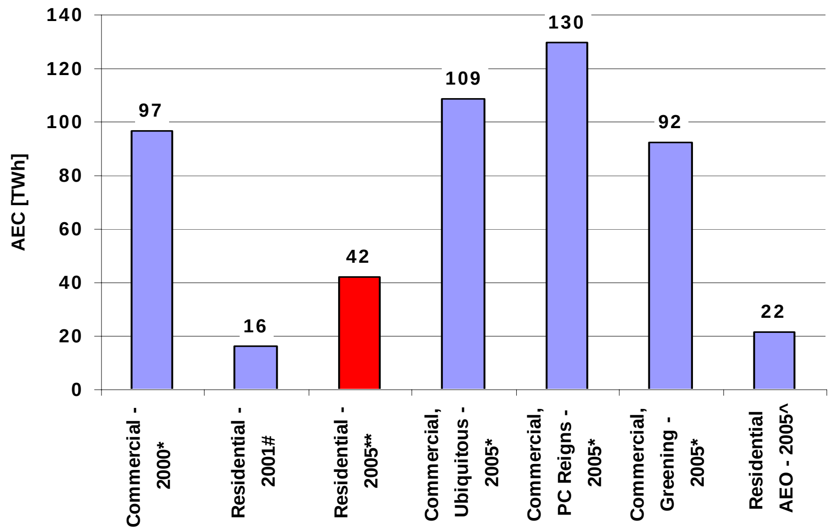
Figure 2: U.S. Residential IT Energy Consumption in 2005 (in TWh)

In 2005, desktop PCs and monitors account for about 65% of residential IT energy consumption. "Other" devices included come from reference [2], with scanners accounting for around ¾ of the total. As the authors of that report note, the value for scanners appears to be quite high. In general, the AEC of at least three of the four "other" devices is probably decreasing as MFDs supplant scanners, facsimile machines, and copy machines.

Comparison to Other Studies

The current estimate of residential IT energy consumption is more than twice as high as the Y2001 estimate of reference [2]. In addition, the current estimate for the sum of desktop PC, laptop PC, and monitor AEC is about 35% greater than that used in the Annual Energy Outlook (AEO [10]; see Figure 3). Overall, increased residential IT usage estimates for both PCs and monitors, based on the TIAX Survey, drive the higher levels of total AEC. Specifically, the TIAX Survey suggests that PCs and monitors spend at least *100% and 60%* more hours, respectively, in active mode than estimated in reference [3] (based on [6][10]). This occurs because approximately 20% of PCs remain on overnight on a given day. On the other hand, the current study finds that 2005 residential IT energy consumption is less than half of projections of commercial IT energy consumption[11] from reference [3].

[10] For comparison sake, the active mode hours per year estimates for desktop PCs and monitors are more than four and five times greater than those projected for Germany in 2005 [11].
[11] The values shown for [3] equal the projections for the key equipment types divided by 0.9 to include energy attributed to other (i.e., non-key) devices.



***Reference [3]**
 # Reference [2]
****Current Study**
^ Reference [9]; includes only PCs and Monitors

Figure 3: Comparison of Current U.S. Residential IT Energy Consumption Estimate with Other Studies

The authors believe that the current study provides a more accurate estimate of residential IT energy consumption than RECS for several reasons. First, the TIAX Survey was carried out in March of 2005, so it provides more recent data than the RECS. Second, the TIAX Survey posed more targeted questions about residential PC and monitor usage than RECS, including questions about individual (versus all) devices' daily usage on both weekdays and weekends, nighttime status, daytime status when not in use, and PM-enabled status. Third, the TIAX Survey elicited information about the usage of up to three computers and their monitors for each household, whereas the RECS poses a single question about the number of hours that all of the PCs are on during day. Fourth, the TIAX Survey allowed a much wider range of responses than the RECS, e.g., respondents provided numerical estimates of both typical weekday and weekend residential IT active use hours instead of the broad ranges used in the RECS, i.e., less than 2 hours, 2 to 15 hours, 16 to 40 hours, 41 to 167 hours, and 168 hours per week [6].

Conclusions and Recommendations

Conclusions

TIAX carried out a study to quantify the energy consumption of Residential Information Technology (IT) equipment in 2005 and develop scenario-based projections for 2010. The study identified ten key equipment types and evaluated their energy consumption in 2005 and for each 2010 scenario. Overall, the key residential IT equipment analyzed consumed about 42TWh of electricity in 2005, or about 0.40 quads of primary energy. This translates into approximately 2.8% of residential electricity consumption and 1% of U.S. electricity consumption and about 0.39% and 2% of U.S. and residential primary energy consumption, respectively. Desktop PCs and monitors account for about two-thirds of the energy consumed by the key equipment types.

This represents a dramatic increase in residential IT energy consumption relative to prior estimates of residential IT energy consumption, i.e., more than twice the 16.5 TWh estimated for 2001 [2] and about 35% greater than the Annual Energy Outlook projection for 2005 for PCs and monitors [10]. Relative to these two prior studies, the current study estimates that PCs and monitors spend much more time per week in active mode, i.e., approximately *100% and 60%* more, respectively. This occurs because a non-trivial minority of PCs remain on overnight at least some portion of the time. The current study uses usage data derived from a survey of 1,000 demographically-representative households of residential PC and monitor usage patterns carried out by TIAX in 2005. This survey yielded much more accurate estimates of PC and monitor usage. Because desktop PCs, laptop PCs, and monitors account for a majority of residential IT energy consumption, this markedly improved the accuracy of the estimate of total residential IT energy consumption.

Recommendations

This study yields two distinct recommendations, one programmatic and the other informational. Programmatically, this study reinforces the strong link between power management (PM)-enabling rates and residential IT energy consumption. The TIAX Survey suggests that residential PCs may have higher PM-enabling rates than commercial PCs (approximately 20% as compared to likely less than 10% [10]), while monitor PM-enabled rates are around 60%. Nonetheless, increasing PM-enabled rates both devices has a large energy saving potential that may well increase in the future as always-on operation of residential IT equipment becomes even more common. Consequently, programmatic actions that can increase the PM-enabled rate of PCs and monitors have a large energy saving potential. This study also points out the need to collect good data about residential PC and monitor usage. To date, almost all usage data have come from survey responses or reflect researchers' rough estimates. The finding of this study that residential IT now accounts for about 3% of residential electricity consumption emphasizes the need to collect representative, high-quality data about IT usage for desktop PCs, preferably via monitoring of equipment power draw for a useful period of time (e.g., two weeks or more).

Acknowledgements

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Appendix A – Usage Models to Interpret the TIAX Survey

The team developed two models to translate the TIAX survey responses into residential PC and monitor daily weekday and weekend usage patterns. Together, they provide upper and lower bounds for PC and monitor usage. The first model, referred to as the OffModel, assumes that the user turns off his/her PC outside the timeframe that the PC has the potential to be routinely used. The second, known as the OnModel, makes the opposite assumption, that is, that the PC is left on. The survey explicitly asked how many hours each PC (and, thus, its monitor) is actively used on both weekdays and weekend days and both models directly incorporate this data. Using the data from the TIAX Survey, each model also calculates the hours each PC and its monitor spend active-unused, sleeping, and off per week based on a used-hours allocation algorithm, model-specific assumptions, and a weighting mechanism that reflects the average likelihood that the PC and its monitor will be turned off during the day when not in use and overnight. Specifically, both models assume that a PC is most likely to be continuously used from 7pm to 10pm during a typical weekday and 3pm to 5pm for weekend days (for the sake of simplicity, the discussion will focus on weekday hours). In all cases, monitors were assumed to have the same basic usage patterns as their PCs, albeit using the monitor PM-enabled and night status information instead of that for the PC.

On Model

The usage pattern for the OnModel first allocates active-used time in the 7pm-10pm window. If additional active-used hours remain, the model subsequently allocates a half hour of usage at 7am, i.e., it assumes that the PC is turned on first thing in the morning. It then allocates remaining active-used hours by adding a 0.5-hour active-unused break (assuming that users often take a break from their PCs instead of continuously using them[12]), followed by up to a 2-hour active-used period. If active-used hours still remain, the algorithm repeats this 0.5-hour active-unused 2-hour active-used pattern as many times as necessary, working back to 7am until all the active-used hours have been allocated (see Figure A-1). If additional hours remain, the algorithm converts the 0.5-hour active-unused periods to active-used to account for the remaining active-used hours (beginning with the half hour closest to the 7pm-10pm time window, i.e., 6:30-7pm). Finally, if yet more time remains, time during the 10-11pm period can be assigned to active-used.

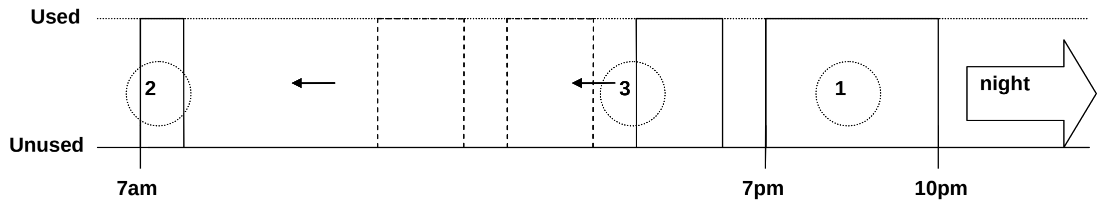

Figure A-1: Illustrative Application of the OnModel for Active-Used Hours

Once turned on in the morning, the model uses the response to the question about how often users leave the PC on during the day if it is not used for more than half an hour to determine its daytime status. If a PC is never left on, the model assumes that the PC is turned off until the additional active-used hours later during the day (case ON_A). If a PC is always left on during the day, the model assumes that the PC remains in active-unused for an hour. Subsequently, any time between that point in time and the time of the later active-used hours begin is allocated to active-unused and sleeping[13] based on the devices PM-enabled status (the ON_B case). The response to the question about how often users leave the PC on during the day if it is not used for more than half an hour is used to calculate the weighting between the ON_A and ON_B cases and calculate the average usage by mode (see Table A-1). For example if the response is that the person "often" leaves their PC on during the day if not used for more than half an hour, the ON_B case would receive a 75% weighting and the ON_A case a 25% weighting.

[12] Implicit in this assumption is that the PC does not have sufficient time during the 0.5-hour breaks to enter sleep mode, an assumption generally consistent with the sleep-mode settings for new desktop PCs.

[13] In essence, the model assumes that a PC spends 1 hour in active-unused before sleeping.

Table A-1: OnModel Weighting Based on Survey Response

Survey Response	OnModel Weighting
Always	100%
Almost always	90%
Often	75%
About half the time	50%
Occasionally	25%
Rarely	10%
Never	0%

Source: Reference [1].

The OnModel also consists of two weighted sub-models based on whether or not the PC is turned off at night. If the PC remains on at night, the hours will either be active-unused or sleep, depending on the PCs PM-enabled status (ON-Night$_A$). If the PC is turned off, it is off[14] (ON-Night$_B$). The weighting assigned to the two night models, ON-Night$_A$ and ON-Night$_B$, is determined by the response to the question about how often users typically turn off their PC at night and used to calculate the average usage by mode.

For weekend usage, the algorithm first allocates time from 3pm to 5pm and then propagates the 0.5-hours active-unused-2-hours used allocation sequence before 3pm. If additional active-used hours still remain, it then begins to convert the ½-hour active-unused periods to active-used (as with the weekday model) and, subsequently, assigns hours *continuously* (i.e., without ½-hour active-unused periods) after 5pm to active-used until all of the active-used hours have been allocated. In the OnModel, the day is assumed to begin at 9am (versus 7am on weekdays). The nighttime calculation procedure does not change.

OffModel

The OffModel uses both the OnModel and another model, depending on the night status of the device. If the device is always turned off at night, the OffModel assumes that the device is **not** turned on at 7am (or 9am on weekends). Instead, it first allocates active-used hours in the 7pm-10pm (or 3pm-5pm) window and any additional active-used hours via the ½-hour active-unused 2-hours active-used allocation sequence described above, followed by conversion of the ½-hour active-unused periods to active-used and, if necessary, addition of the 10-11pm period (case OFF$_A$). That is, all remaining daytime hour are off hours (see Figure A-2). If the device is always left on at night, the OffModel uses the OnModel to calculate the usage pattern (case OFF$_B$). The weighting assigned to cases OFF$_A$ and OFF$_B$ is determined by the response to the question about how often users typically turn off their PC at night and used to calculate the average usage by mode.

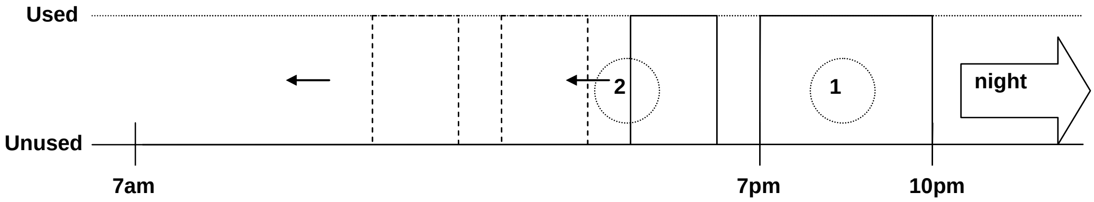

Figure A-2: Illustrative Application of the OFF$_A$ Case of the OffModel for Active-Used Hours

The following example illustrates how the model works. The model allocates hours as follows for a person responding that she typically used her PC four hours a day and always (100% weight to OffModel) turned off her PC at night. First, the OffModel allocates three hours to the 7-10pm period. Next, it allocates one hour to the 5:30pm-6:30pm period, assigning ½ hour to active-unused between 6:30pm and 7pm. Finally, it allocates all remaining hours to off. In total, the model allocates four hours active-used, ½ hour active-unused, and 19.5 hours off per day.

If, however, she responded that she turned off her PC at night occasionally (25%) and rarely (10%) left her PC on after not using the PC for more than half an hour during the day, and her PC was found

[14] It is also worthwhile to point out that in the case where PC usage is less than 3 hours per day, e.g., the active-use hours do not fill the 7pm to 10pm window, is not filled entirely, the algorithms assume that the PC is turned off immediately after the last used hour if the PC is turned off at night. For example, if a PC is used for 1 hour per day and the user turns it off for the night, the PC is off starting at 8pm and remains so throughout the night.

to have PM enabled, the calculation becomes more complex. In that case, the model calculates daily usage in two ways and weights them to derive the usage estimate (see Figure A-3 and Table A-2). For the 25% of the days when the PC is turned off at night, the usage calculation uses the process described in the prior paragraph and receives a 25% weighting (Figure A-3a). For the 75% of the days when the PC remains on at night, the model allocates three active-used hours to the 7-10pm period. Next, it allocates another active-used ½ hour to 7am-7:30am and the remaining active-used ½ hour to 6pm through 6:30pm, with ½ hour spent in active-unused between 6:30pm and 7pm. The PM-enabled response determines whether the nighttime hours are allocated to sleep or active-unused. Since PM was enabled, the model assumes that the PC enters sleep mode after one hour from 10pm to 11pm active-unused and allocates the rest of the time from 11pm to 7am to sleep. The allocation of the daytime hours between 7:30am and 6pm depends on her response as to how often she left her PC on when it had not been used for more than half an hour during the day. Based on her “rarely” response (10%), the model calculates two usage scenarios and weighs each. For the 10% of the time the PC is left on, the model allocates one hour, from 7:30am to 8:30am, to active-unused and the remaining 9.5 hours from 8:30am to 6pm to sleep (because PM was enabled; Figure A-3b). For the 90% of the time that the PC is turned off, the model allocates all 10.5 hours to off (Figure A-3c). Applying the appropriate weightings, the model calculates the following *daily* usage for the 75% of the days that the PC remained on at night: 4 hours active-used, 1.6 hours active-unused, 8.95 hours sleep, and 9.45 hours off.

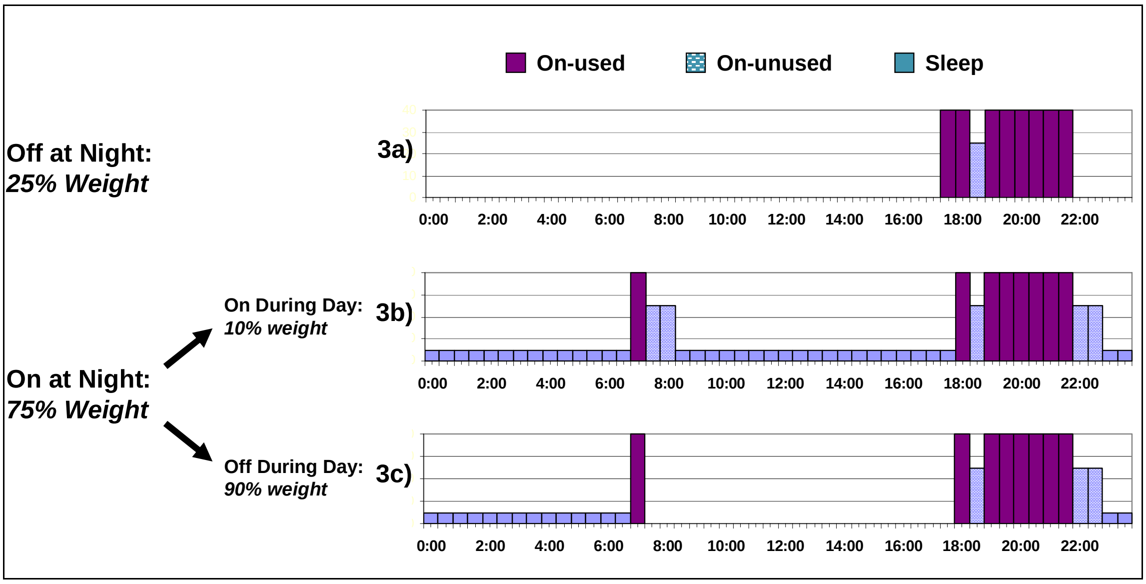

Figure A-3. Example of Usage Hours Allocation Model

Subsequently, the model weights the outputs from those two scenarios appropriately (10% and 90%) and sums them to obtain the average daily usage for the 75% of the days when the PC remains on at night. Finally, the model weights the model usage output for the 75% of the days when the PC remains on at night and that for the 25% of the days when the PC is turned off at night and sums them to obtain the average daily usage estimate for that PC (see Table A-2).

Table A-2. Sample Translation of Survey Responses to a Usage Pattern

<table>
<tr><th colspan="2" rowspan="2">Survey Response</th><th rowspan="2">Total Weighting</th><th colspan="4">Hours per Day</th></tr>
<tr><th>Active-Used</th><th>Active-Unused</th><th>Sleep</th><th>Off</th></tr>
<tr><td colspan="2">Off at Night – 25% of Time</td><td>0.25</td><td>4</td><td>0.5</td><td>0</td><td>19.5</td></tr>
<tr><td rowspan="3">On at Night – 75% of Time</td><td>On During Day – 10%</td><td>0.075 (=0.75* 0.1)</td><td>4</td><td>2.5</td><td>17.5</td><td>0</td></tr>
<tr><td>Off During Day – 90%</td><td>0.675 (=0.75* 0.9)</td><td>4</td><td>1.5</td><td>8</td><td>10.5</td></tr>
<tr><td>TOTAL</td><td>0.75</td><td>4</td><td>1.6</td><td>8.95</td><td>9.45</td></tr>
<tr><td colspan="3">TOTAL</td><td>4</td><td>1.33</td><td>6.71</td><td>11.96</td></tr>
</table>

The Power Challenge - Intel’s Holistic Approach to Power Management

Kevin Fisher, Todd Brady

Intel Corporation

Abstract
Driven by Moore's Law, semiconductor manufacturers such as Intel are able to continually produce new innovative products that deliver increasing levels of performance and other user-valued capabilities. However, as more transistors are packed into a smaller area, power density increases, creating challenges for cooling and thermal management. Efficient power delivery and thermal management are critical as systems become smaller and more capable with every generation of new computing and communication products.
In 1983, the Intel® 286 microprocessor consisted of 134,000 transistors. Intel microprocessors today can contain over 1 Billion transistors (see Figure 1). Similarly, the computing power of the PC has increased by factors far exceeding 1,000X since the early 1980s. If the power consumed by an average PC had increased at the same rate, each one would require a 250-300 kilowatt (kW) power supply. Instead, for an average PC, the power consumed has stayed largely the same over the last 20 years despite dramatic improvements in PC performance and computing ability [1, 2].

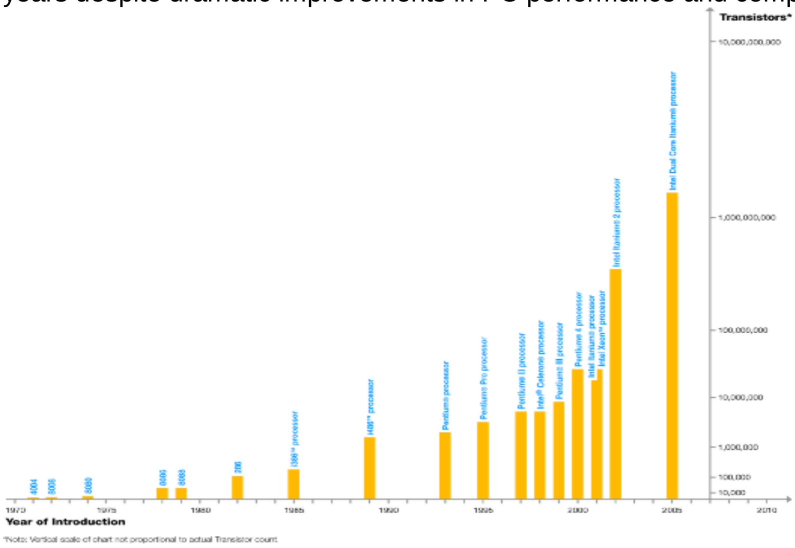

Figure 1: Growth in the number of transistors in an Intel CPU

The active power for a CMOS device is defined as: $P = CV^2f$, where P = active power needed for switching, C = total capacitance being switched, V = operating voltage and f = switching frequency. Although the switching frequency has increased dramatically over the past decade, Intel has focussed on driving both the voltage and capacitance down through improvements in manufacturing technologies. As a result, energy consumed per CMOS logic switching has decreased about 300X since the early 1990s [3].
Intel is a leader in developing innovative solutions to address and resolve power challenges. To be successful, Intel has taken a holistic approach toward power management by tackling the challenge at all levels: micro/macro architecture, silicon and circuit design & manufacturing, packaging, platform design, software optimization, and ecosystem enabling. Building on its past, but further emphasizing the future, in August 2005, Intel’s CEO Paul Otellini announced a new product direction for the company that put even more emphasis on energy efficiency.

1 Intel Power Management achievements: Recent history

1.1 Mobile

In 2003, Intel released its Pentium® M processor which when combined with the Intel® 855 chipset family and the Intel® PRO/Wireless 2100 Network Connection made up the key building blocks of the Intel® Centrino™ mobile technology. Intel® Centrino ™ mobile technology improves both performance and battery life over previous mobile processors. Energy efficiency has improved by over 30% using industry standard benchmarks [11].

In 2005, Intel released mobile processors with Enhanced Intel SpeedStep® technology and Intel® Mobile Voltage Positioning. Both technologies helped to minimize the power consumption of the mobile processor. Enhanced Intel SpeedStep® technology enables real-time dynamic switching of the voltage and frequency between two performance modes based on processor demand. Intel® Mobile Voltage Positioning (Intel® MVP IV) dynamically lowers voltage, based on processor activity.

In partnership with the Mobile PC Extended Battery Life Working Group (www.eblwg.org), Intel led a successful effort to increase the energy efficiency of LCD's by about 40%. LCD screens are the largest source of power consumption in a notebook PC (~30-40% of the total power). This work successfully reduced the energy consumption of the screen from ~5 watts to 3 watts or less.

1.1 Desktop

When evaluating the total system power of a desktop PC, it can be seen that the processor consumes only about 10% of the total power. The video display devices and power supplies tend to dominate. If a CRT monitor is used, the monitor and power supply alone can account for up to 75% of the total desktop system power. If a LCD monitor is used, this value drops to about 50% of total system power [1].

Through research which started in 2000, Intel was able to show that the desktop PC power supply was a major source of energy inefficiencies for the system (some power supplies were as low as 50% efficient and most were designed to give optimum performance at full load). As a result of these findings Intel issued an update to its Power Supply Design Guidelines to include minimum energy efficiency targets for power supplies at 3 loadings – 20%, 50% and full load. As a result of these efforts, typical power supply efficiencies today are of the order of 80%.

Intel has a long history of actively working to improve the power management of PCs through work in industry groups to develop open industry specifications for power management. As an initial founder of Advanced Power Management (APM) and the follow-on Advanced Configuration and Power Interface (ACPI), Intel has helped develop and promote the use of sleep states to reduce overall system power consumption. In September 2004, ACPI version 3.0 was made available to the public.

In 2005, a new feature was introduced into desktop (and server) products as a means of reducing platform idle power consumption. Enhanced autohalt (c1E) is a low power state entered into when the processor executes the HALT instuction. Since introduction, the autohalt feature has been continually optimized to enabling lower power states for the microprocessor.

There are many other examples of contributions from Intel to enable more power efficient desktop system designs such as: Intels integrated graphics chipset product line and the enabling of new form factor standards (actually Intels enabling of new form factors covers many market segments such as: mobile, ultramobile, workstation mobile, desktop, gaming machine, workstation, server, etc).

1.2 Servers

Servers present their own unique challenges for power management integration. Server systems can have multiple processors, significantly large memory, redundancies, multiple networking cards and hard drives. A server architecture, design and usage model is significantly different than a desktop or notebook PC. A server may be used locally or remotely with one or even millions of users. Availability and response time to an uncertain frequency of requests for service is paramount. These requirements pose challenges for energy efficiency of servers and the facilities that host them.

In 2004, Intel launched its first server processor products with Enhanced Intel Speed Step® technology to support Demand Based Switching (DBS). DBS minimizes power consumption of the server system by dynamically changing the processor performance states. The performance states are changed based on demand for computing power and/or utilization. For systems using DBS, energy savings of up to 24% can be realized [12]. As illustrated in Figure 2, energy savings are greatest when processor utilization is less than 50%, decreasing as the processor approaches full utilization. Since most servers are utilized much less than 100% under typical operating conditions, DBS has the potential for significant energy savings.

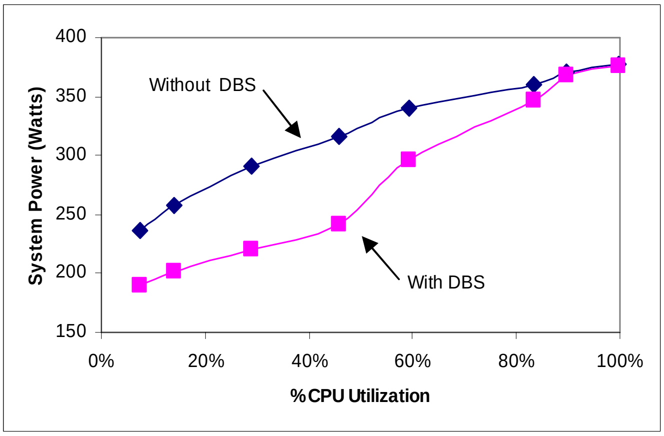

Figure 2: Effect of DBS on System Power Consumption

Intel introduced low voltage versions of its Intel® Xeon® processors in 2005. These processors can be used in server rack and blade designs where space is constrained and power-efficiency is a priority. These processors incorporate Demand Based Switching (DBS) technology.
Technologies such as "autohalt (c1E)" (as mentioned under desktop PC above) and improved power supply efficiencies have also been introduced to server based products.

1.3 Silicon

In August 2005, Intel introduced its 65 nm manufacturing technology. 65 nm technologies allow printing of individual circuit lines on a semiconductor device at widths smaller than that of a virus. The gate within the transistor is even smaller, with a width of 35 nm and a thickness of 1.2 nm or 5 atomic layers [4]. At such small sizes, leaking current, which grows exponentially as the size of the transistor shrinks, becomes a problem. If steps are not taken to control it, leakage current can become a barrier to practical device operation [5].

1.3.1 Strained Silicon

Intel first introduced strained silicon into its 90 nm technology and is now used to manufacture many of Intel's state of the art semiconductor products, such as the Intel® Core™ Duo processor. Strained silicon uses a region of silicon with built in stress, or strain, to increase the speed of the current flow across the transistor. By stressing or straining the silicon crystal lattice, electrons can flow with less resistance. Figure 3 illustrates this point. The result of such a technology is a 5-25X reduction in leakage current and 10-25% improvement in transistor current [5, 6, 7].

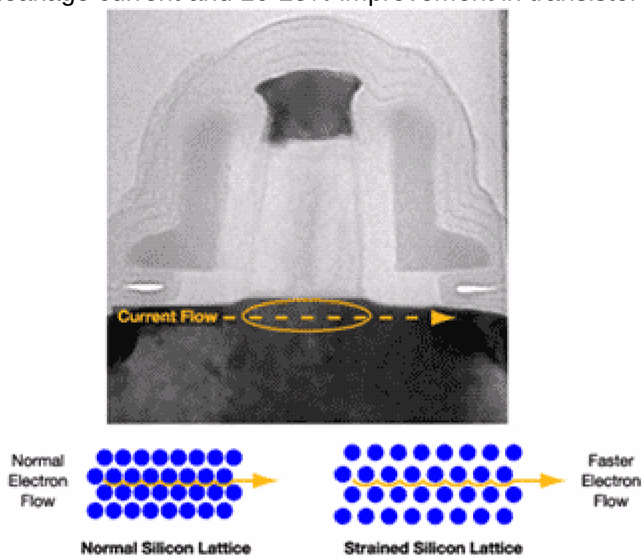

Figure 3: Illustration of Strained Silicon Benefits [8]

1.3.2 Sleep Transistors

Another method for reducing leakage current is to turn off, or put to sleep, the transistors of the silicon device which are idle or not actively in use. For example, Static Random Access Memory (SRAM) makes up a significant portion of Intel 65 nm microprocessors. SRAM is used to cache data and instructions. Sleep transistors can be used to shut off blocks of SRAM that are idle, saving energy by stopping the leakage current in these sections of the microprocessor [9].

1.3.3 High K Dielectric

In order to further reduce leakage at the gate, Intel has developed new thicker gate material termed "high-k dielectric." The high-k material reduces leakage by 100 times over existing silicon dioxide materials [10]. Figure 4 is an image of both the traditional silicon dioxide gate and the new high-k gate material.

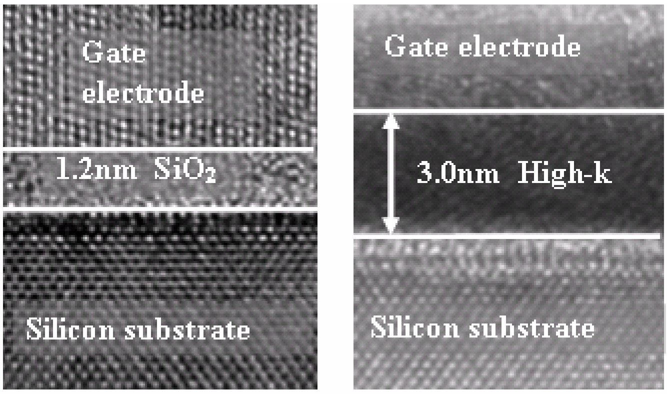

Figure 4: SEM image of existing SiO_2 gate material and new "high-k" gate material.

1.4 Power-Optimized microarchitecture

Intel continually strives to eliminate redundancy at the microarchitecture level by identifying frequent instruction sequences, extensively optimizing them, and storing them for later reuse. For example, Intel® NetBurst® microarchitecture has an advanced form of an instruction cache called the Execution Trace Cache, which stores already-decoded machine instructions or micro-ops for future reuse. Hyper-Threading Technology is another Intel microarchitecture that has been increasing performance without impacting the power envelope.

1.5 Offices and factories

In its offices and factories, Intel completed over 20 energy improvement projects in 2005. These projects resulted in savings of over 20 million kwhrs of electricity and nearly 2 million therms of natural gas. These results have been achieved through the use of improved controls, heat recovery, and other conservation techniques. The 2005 projects are part of an ongoing multi-year effort that has resulted in savings of over 200 million kwhrs of electricity and approximately 5 million therms of natural gas. Due to these projects, Intel's energy used per unit of product manufactured has declined significantly over the last several years, well ahead of our publicly stated goal to reduce normalized consumption 4% per year. Intel has now begun working with the suppliers to drive improved efficiency in the manufacturing tools used in production. We believe progress in this area will complement the work begun on facility systems and continue to drive further improvements in the overall energy efficiency of the manufacturing process. More information is available at:
http://www.intel.com/intel/other/ehs/perform.htm

2 Intel Power Management achievements: Current achievements

In the microprocessor world, performance usually refers to the amount of time it takes to execute a given application or task or the ability to run multiple applications or tasks within a given period of time. However, true performance is a combination of both clock frequency (GHz) and Instructions Executed per Clock Cycle (IPC).

- Performance = Frequency x Instructions per Clock Cycle (IPC)

Therefore it is possible to increase performance by increasing clock frequency or instructions per clock cycle or both. Today, Intel is focusing on delivering optimal performance together with improved

energy efficiency, eg to take into account the amount of power the process will consume to generate the performance needed for a specific task.
As noted in the introduction, power consumption is related to the dynamic capacitance required to maintain IPC efficiency, times the square of the voltage that the transistors and I/O buffers are supplied with, times the frequency that the transistors and signals are switched at

- Power consumed = Capacitance x Voltage x Voltage x Frequency ($P = CV^2f$).

By taking into account both performance and power equations, designers can carefully balanced and therefore optimise performance and power efficiency.

2.1 Intel® Core™ microarchitecture: setting new standards for energy efficient performance

The move to multi-core processing has opened the door to many other micro-architectural innovations that further improve performance and energy efficiency. Intel Core microarchitecture is one such state-of-the-art micro-architectural update that has been designed to deliver increased performance combined with superior energy efficiency. The Intel Core microarchitecture is a new foundation for Intel architecture based desktop, mobile, and mainstream server multi-core processors and is expected to start shipping in Q3 2006.

2.1.1 Intel Wide Dynamic Execution

Intel Wide Dynamic Execution enables delivery of more instructions per clock cycle to improve execution time and energy efficiency. Every execution core is wider allowing each call to fetch, dispatch, execute and return up to four full instructions simultaneously (previous technologies could handle up to three instructions at a time).

2.1.2 Intel Intelligent Power Capability

Intel Intelligent Power Capability is a set of capabilities designed to reduce power consumption and design requirements. This feature manages the runtime power consumption of all the processor’s execution cores. It includes an advanced power gating capability that allows logic control to turn on individual processor logic subsystems only if and when they are needed. Additionally, many buses and arrays are split so that data required in some modes of operation can be put in a low-power state when not needed. In the past implementing power gating has been challenging because of the power consumed in the powering down and ramping back up, as well as the need to maintain system responsiveness when returning to full power. Through Intel Intelligent Power Capability, Intel has been able to satisfy these concerns, ensuring both significant power savings without sacrificing responsiveness.

2.1.3 Intel® Advanced Smart Cache

The Intel® Advanced Smart Cache is a multi-core optimized cache that significantly reduces latency to frequently used data, thus improving performance and efficiency by increasing the probability that each execution core of a dual-core processor can access data from a higher-performance, more efficient cache subsystem.

2.1.4 Intel® Smart Memory Access

Intel® Smart Memory Access improves system performance by optimizing the use of the available data bandwidth from the memory subsystem and hiding the latency of memory accesses. Intel Smart Memory Access includes an important new capability called "memory disambiguation," which increases the efficiency of out-of-order processing by providing the execution cores with the built-in intelligence to speculatively load data for instructions that are about to execute before all previous store instructions are executed.

2.1.5 Intel® Advanced Digital Media Boost

Intel® Advanced Digital Media Boost is a feature that significantly improves performance when executing Streaming SIMD Extension (SSE/SSE2/SSE3) instructions. They accelerate a broad range of applications, including video, speech and image, photo processing, encryption, financial, engineering and scientific applications. The Intel Advanced Digital Media Boost feature enables these 128-bit instructions to be completely executed at a throughput rate of one per clock cycle, effectively doubling, on a per clock basis, the speed of execution for these instructions as compared to previous generations.

2.2 Platform-Scalable Architectures

The new Intel Core microarchitecture will provide a solid foundation for new server, desktop, and mobile platforms.

2.2.1 Server Platforms

Servers can deliver significantly greater compute performance and compute density. Intel is developing a DP Server processor optimized for dual-core based on the new, state of the art, Intel Core microarchitecture, codenamed Woodcrest. The Woodcrest processor is targeted for introduction in the third quarter of 2006 and will work within the Bensley server platform and the Glidewell workstation platform. The Bensley server platform and the Glidewell platform are targeted for introduction in the second quarter of 2006.

Intel will also deliver a quad-core (4 full execution cores) processor to the DP Server segment based upon this new microarchitecture, codenamed Clovertown. Clovertown is targeted for introduction in the first quarter of 2007, on the Bensley and Glidewell platforms.

For the MP server segment, Intel is also developing a MP Server processor optimized for quad-core based on this new microarchitecture, codenamed Tigerton. The Tigerton processor is targeted for introduction in 2007 and will work within the Caneland server platform.

2.2.2 Desktop Platform

Desktops can deliver greater compute performance as well as ultra-quiet, sleek and low-power designs.

Intel is developing a desktop-optimized, dual-core processor based on the new, state of the art, Intel Core microarchitecture, codenamed Conroe. The Conroe processor will work within the 2006 Digital Home platform codenamed Bridge Creek, and the 2006 Digital Office platform, codenamed Averill. Conroe is targeted for introduction in the third quarter of 2006.

Intel will also deliver a quad-core (4 full execution cores) processor to the high-end desktop based upon this new microarchitecture, codenamed Kentsfield. Kentsfield is targeted for introduction in the first quarter of 2007.

Mobile Platform

Laptop users can take advantage of the increased multi-core compute capability within the mobile form factors. Intel is developing a mobility-optimized, dual-core processor based on the new, state of the art, Intel Core microarchitecture, codenamed Merom. The Merom processor will work within the Intel® Centrino Duo® mobile technology-based platform and Merom is targeted for introduction to align with the 2006 holiday buying season.

3 Intel Power Management achievements: Looking further ahead

3.1 Low Power on Intel Architecture Project

In addition to technologies and products on the market today to improve energy efficiency, Intel is actively researching future technologies for possible future applications. For example, in the consumer and business marketplaces, smaller devices are proliferating. Smart phones, notebooks, and micro PCs are the leading edge of a wave of new devices designed for communication and entertainment. As part of Intel's vision of architectural innovation for convergence, the Intel Systems Technology Labs is working to accelerate these next-generation technologies and products.

The Low Power on Intel® Architecture (LPIA) project of STL focuses on researching and developing low-power technology building blocks for future Intel® architecture-based platforms. Key learning’s from this research will lay the groundwork as Intel product development groups move toward low power on Intel architecture.

Using the research platform, the LPIA team is conducting research to better understand and reduce the thermal and physical demands of computing technology. A critical focus area is extending battery life for portable devices. In addition, the team is developing power management polices and metrics for future Intel architecture-based platforms.

Intel is also performing system-level profiling and benchmarking, spanning from the power source to power distribution and on to power consumers. Power-smart platforms will extend battery life and enhance user experiences by applying best-in-class power management technologies. Focused on system software policy management, the STL LPIA project is:

- Researching system-level power states and aggressive power-management policies
- Developing power metrics to calibrate power management in handheld devices
- Focusing future efforts on close cooperation with OS vendors for implementation

3.2 Tri-gate Transistors

Intel has also developed a novel three-dimensional design that helps make transistors that scale, perform, and address the current leakage problem seen in smaller dimension planar transistors. Tri-gate fully depleted substrate transistors have a raised plateau like gate structure with two vertical walls and a horizontal wall of gate electrode. This 3D structure improves the drive current while the depleted substrate reduces the leakage current when the transistor is in the off state. Reducing the leakage current in the off state translates to increased battery life in mobile devices.

Intel believes that these new discoveries can be integrated into an economical and high-volume manufacturing process to address the power and heat increases in increasingly smaller transistors.

3.3 Intel and QinetiQ Collaborate On Transistor Research

Researchers from the two companies have successfully built 'quantum well' transistors by integrating a new transistor material, pioneered by QinetiQ called indium antimonide (InSb). InSb is made up of elements found in the III and V columns of the periodic table. Transistors made of this material enable research devices to operate at very low voltages, while still rapidly switching and consuming little power. The research results obtained from the quantum well transistors research showed a 10x lower power consumption for the same performance, or conversely a 3x improvement in transistor performance for the same power consumption, as compared to today's traditional transistors.

4 Summary

Intels efforts in power management go back more than a decade (though this paper has focused on more recent activities). For example Intel was one of 13 companies to receive the EPA’s first Energy Star Computer Awards back in 1994. Intel is an initial founder of Advanced Power Management (APM) and the follow-on Advanced Configuration and Power Interface (ACPI), Intel helped develop and promote the use of sleep states to reduce overall system power. In response to Energy Star’s computer energy-efficiency specification, Intel developed in 2001 the new Instantly Available PC Power Management to improve sleep-state power management.

Intel today works closely with regulatory bodies such as the US EPA and EU/EC in driving Energy Star and other WW regulatory standards to improve computing platform energy efficiency. Today Intel is one of 20 companies working with the DOE and EPA to help define the new Energy Star specifications.

This paper has described a number of Intels recent past, present and future activities aimed at improving the energy efficiency of computer devices. These efforts can be summarised in the table below:

<table>
<tr><th></th><th>Recent history</th><th>Today</th><th>Future</th></tr>
<tr><td>Servers</td><td>• enhanced autohalt (c1E)
• Enhanced Intel Speed Step® technology
• Demand Based Switching
• low voltage versions of its Intel® Xeon® processors</td><td rowspan="4">• Intel® Core™ microarchitecture
• Intel Wide Dynamic Execution
• Intel Intelligent Power Capability
• Intel® Advanced Smart Cache
• Intel® Smart Memory Access
• Intel® Advanced Digital Media Boost</td><td rowspan="4">• Low Power on Intel® Architecture (LPIA)
• Tri-gate Transistors
• Intel and QinetiQ Collaborate On Transistor Research
• Ever smaller transistors (22nm)
• Etc</td></tr>
<tr><td>Desktop</td><td>• Power Supply Design Guidelines
• Intel® Active Management Technology
• ACPI version 3.0
• New form factors
• Integrated functionality
• enhanced autohalt (c1E)</td></tr>
<tr><td>Mobile</td><td>• Intel® Centrino™ mobile technology
• Enhanced Intel SpeedStep® technology
• Intel® Mobile Voltage Positioning
• Mobile PC Extended Battery Life Working Group</td></tr>
<tr><td>Silicon</td><td>• 65 nm manufacturing technology
• Strained Silicon
• Sleep Transistors
• High K Dielectric
• Intel® NetBurst® microarchitecture
• Hyper-Threading Technology</td></tr>
</table>

"Lead the industry in performance per watt across all market segments" is one of Intels strategies within its 2006 strategic objectives for 2006.
Intel observes that energy efficiency demand from users is most pronounced for notebook and server products. Notebooks, because of battery life demands and servers due to high end data center energy demands. Data centers increasingly want to add more computing performance. Doing so requires more energy efficient products in order to effectively cool and stay within the power budget of the datacenter.
Energy efficiency has not been a major market driver for desktop computers. However, factors such as acoustics and smaller form factors are beginning to drive this market need. Despite this, as can be seen in this paper, Intel is investing heavily in continually improving the energy efficiency of desktop products.

5 Conclusions

Moore's Law will continue to drive advances in semiconductor manufacturing. Intel's manufacturing process roadmap predicts the development and use of 22 nm technology by 2011. Such advancement will continue to make technical challenges such as leakage current even more pronounced. As a result, Intel has made power management a top priority in its technology roadmaps.
To be successful in addressing the power challenges of the PC, one must take a holistic approach toward power management, tackling the challenge at all levels: micro/macro architecture, silicon and circuit design & manufacturing, packaging, platform design, software optimization, and ecosystem enabling. Intel has taken such an approach and has made significant progress toward meeting these challenges.

- The need for raw computing performance has evolved into a drive for energy-efficient performance to meet people's expanding demands for more capabilities and higher performance – whether for smaller devices, longer battery life, or greater power savings. Intel is driving innovations in computing multi-core architectures to deliver new levels of performance, capabilities and energy efficiency.

- The Intel® Core™ microarchitecture, Intel's new foundation for delivering even greater energy efficient performance, is expected to deliver significant performance gains and power reductions in desktop (Conroe) and server (Woodcrest) processors and to extend the strong energy-efficient performance leadership of the Core Duo processor.
- Supporting the new multi-core architecture are Intel's unparalleled manufacturing capacity and the most energy-efficient performance CPU transistors in the world.
- Intel delivers energy-efficient performance advances across its architecture, silicon, platforms and software to help the industry's leading companies create new uses, build new markets, and meet the evolving needs of people and businesses worldwide.

Delivering energy-efficient performance requires a holistic effort across all common platform components – processors, chipsets, hard drives, power supplies, graphics cards, memory subsystems, displays, BIOS, software and more. Intel's manage these components as a collective system. This creates a platform whose components work together to deliver performance when required and to conserve resources when one or more individual resources are not needed.

Building energy efficient products in energy efficient buildings is without question high on Intels agenda. Technology realities and market demand are two of the factors determining our strategic research agenda direction on energy efficiency.

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New Approaches to Energy-Efficiency Specifications: Considering Typical Electricity Consumption

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Abstract
The current ENERGY STAR® specifications for imaging equipment address electricity consumption only in low-power modes. As products increase in functionality and speed, Active mode contributes to a greater portion of total product energy use. Additionally, consumer dissatisfaction with long recovery times can result in decreased use of energy-saving features. When EPA began to revise the imaging equipment specifications, the need to address Active mode for some products quickly became apparent. This was accomplished with the "typical electricity consumption" (TEC) approach that considers the electricity consumed by imaging equipment during its entire duty cycle. This method for assessing product energy efficiency has been received favorably by many stakeholders and demonstrates a forward-thinking approach to the development of an energy-efficiency specification. This paper reviews the process of creating the TEC method and resulting test procedure and specification levels. The authors present the key considerations for developing this innovative approach, including:

- Determining the universe of covered products;
- Harmonizing the approach with international standards;
- Developing the test method;
- Accounting for international usage patterns;
- Collecting new TEC data;
- Setting appropriate specification levels; and
- Securing stakeholder support.

The paper reviews specific lessons learned during this process and includes detailed examples that illustrate the vision for this new method.

The Roots of ENERGY STAR Imaging Equipment

In 1992, EPA introduced the first ENERGY STAR product specification for computers and monitors. The suite of products covered by ENERGY STAR expanded over the next five years to include imaging equipment such as printers, fax machines, copiers, multifunction devices, and scanners. The backbone of these and all ENERGY STAR specifications are performance criteria, which are developed in consultation with industry stakeholders to address a product's energy or power consumption. The early ENERGY STAR imaging equipment specifications were generally characterized by performance criteria that addressed a product's power consumption in low-power modes (e.g. Sleep or Off), and the default time in which the product's low-power modes were activated. For example, the Version 1.0 ENERGY STAR copier specification launched in 1995 required that low-speed copiers enter an Off mode of fewer than five watts within 30 minutes of completing the last copy job.

Targeting low-power mode in imaging equipment was logical for EPA. Manufacturers were eager to participate in ENERGY STAR and there was available technology to employ power-saving modes in imaging products. By the time the copier specification had been in effect for one and one-half years, EPA had signed partnership agreements with copier manufacturers that produced more than 90 percent of the copiers sold in the United States, and had more than 100 models on the list of ENERGY STAR qualified products. Low-power mode consumption was the low hanging fruit that allowed EPA to engage industry enthusiastically in a new voluntary program that had achievable requirements and demonstrated value to partners and consumers.

Developing a New Approach

Factors Suggesting the Need for Change

ENERGY STAR adds value to a product category by assuring consumers that qualified models are more energy efficient than alternatives, allowing them to express a preference. The differentiation allows manufacturers to compete to satisfy consumer demand for efficient products, which will spur long-term market transformation and maximum energy savings over the long term. To achieve market differentiation, EPA sets a specification that not all products in the market can meet. Typically, approximately 25 percent of models will perform at a level sufficient to qualify when the specification is introduced.

In the beginning of 2003, EPA initiated a cycle of specification revision for imaging equipment. At that time, the specifications had been in effect for up to seven years and ENERGY STAR qualified printers, copiers, and fax machines accounted for 92 to 99 percent of units sold in 2000 (Gartner 2001). The high market penetration levels alone suggested that a review of ENERGY STAR performance specifications was warranted. In addition, revising the specifications allowed EPA to consider the following:

- Power and/or energy consumed in active modes;
- New technologies and functionalities that had entered the marketplace or become more prominent (e.g., color, digital, and multifunction capability);
- Consistency in requirements and terminology across imaging equipment and other ENERGY STAR products;
- Harmonization with other domestic and international organizations; and
- Streamlining of the product development process for manufacturers, as they tend to be involved in multiple imaging product categories.

Historically, ENERGY STAR and other international, energy-efficiency programs were focused on power-saving modes, such as Standby. Later, partly due to the success of reducing energy consumption in low-power modes, increased attention was paid to Active and Ready modes. The ENERGY STAR Version 4.0 computer monitor specification is the first set of electronics product criteria to include active mode.

Choosing a New Specification Approach – What Should It Accomplish?

At the outset of the specification revision process, EPA's consultants found a number of factors that shaped the approach: field data indicating long default times to low-power modes in many office equipment products, particularly in copiers and MFDs (Nordman et al. 1998); concerns over low power-management enabling rates (Roberson et al. 2004; Webber et al. 2001); and the apparent opportunity to achieve energy savings beyond that available in low-power modes. These factors prompted EPA to consider a new direction for some imaging equipment products. Information received from some partners and international stakeholders affirmed the importance of addressing the Active and Ready mode consumption of certain products.

Rather than extending the existing system to specific criteria for Active and Ready modes, EPA proposed assessing energy efficiency through a product's entire duty cycle, by covering all states and activities. It was intended that the TEC approach would attain the following objectives:

- Relevance and Longevity - The new specification should resume the differentiation the ENERGY STAR mark brings to the marketplace and the reasonably attainable goal it provides for manufacturers. The TEC approach also provides a general framework that does not impede long-term technical innovation.
- Harmonization - The definitions, measurement methods, and criteria levels should be harmonized with existing international standards and test procedures as much as possible.
- Simplicity - Simplicity in the TEC test procedure makes it less onerous and expensive to conduct and increases the transparency of the process and results.
- Universality - Products should be tested with a similar method where possible, which should result in a clearer, more consistent set of specifications across product types.

The Duty Cycle Approach

The TEC test procedure and calculation method cover all states and activities. TEC continues to provide an incentive to partners to minimize the energy consumption of products in low-power modes while rewarding equivalent progress in Active and Ready. Rather than amending the existing specifications by adding energy efficiency criteria for one or more new modes, the duty cycle approach sums the consumption of all modes. This avoids the need to define multiple power states, particularly as the combination of modes is not consistent across TEC products.

As energy specifications mature, it seems likely that other product types would benefit from a duty cycle approach, particularly if the approach can reasonably reflect typical usage. For computers, the increment of Active energy consumption over Idle levels is quite small; however, the distribution of time spent in Idle, Sleep, and Off could be incorporated into an energy efficiency approach, particularly to the degree that capability while in Sleep (especially network connectivity) will drive how often Sleep is used. Thus, a duty cycle approach could allow for different Sleep capabilities, but require more Idle time to be included in TEC calculations for products with less network connectivity in Sleep. As cars begin to consume increasing amounts of energy while idle, particularly for uses such as air conditioning and electronics, a duty cycle approach could incorporate this in addition to various driving conditions.

Establishing the Universe of Covered Products

An important, initial step in creation of the TEC approach was deciding which products would benefit most from this duty-cycle method. Theoretically, all products could be evaluated to TEC. The use of a single approach for all products could result in more straight forward criteria, and make it easier for consumers to compare the energy efficiency of various products. However, this was a new approach that required development of a test method and collection of data, and the testing and reporting is more burdensome than the existing system. Using TEC is most critical when a significant portion of a product’s energy demand is in Active/Ready modes and users tend to disable or lengthen time to power management settings.

Based on this, EPA determined that standard-size copiers, printers, fax machines, multifunction devices (MFDs), and digital duplicators using electrophotographic (EP), direct thermal, dye sublimation, solid ink, and thermal transfer marking technologies were best suited to the TEC approach. These marking technologies use heat-intensive processes in transferring images to the media, which causes Active and Ready modes to dominate energy consumption and potential savings. Additionally, field data shows that products using these technologies are more subject to power-management disabling due to longer recovery times (Nordman et al. 1998).

The TEC structure is designed for the preceding, standard-size products, both monochrome and color. Small-format products and scanners have different usage patterns, and there is no indication of a recovery time problem. In addition, these differing usage patterns would require a modified test procedure. Ink jet products were not considered for the first iteration of TEC as they use little power in Ready mode and lack long recovery times. Digital duplicators were selected for consideration under the TEC approach based on high productivity and functional similarities to traditional copiers and printers.

Much of the rationale for addressing products by TEC applies to large-format EP products as well. These were not included due to the newness of the approach, the relatively small aggregate energy consumption involved, and the paucity of models and data in this sector. However, at some future time, it may be appropriate to bring these products under the TEC framework. For other product types (most notably the large category of standard-sized inkjet), the additional energy consumption in Active does not seem large enough to merit the additional complexity of the TEC approach.

Test Procedure Creation

Once EPA had established the set of imaging equipment products to be addressed by TEC, the next step was to develop a test procedure. The TEC test procedure would specify a series of events to apply to each piece of equipment as well as the recording of accumulated energy use during each step. As consultants to EPA, ICF and LBNL would then develop a calculation to apply to the results to arrive at a figure of energy use over time (expressed in kWh/week).

The primary purpose of the TEC test procedure is to provide a consistent method of measuring and comparing the relative energy efficiency of similar products. It is important to emphasize that the procedure is not intended to precisely replicate real-life operating patterns, in part, since this will vary by country and specific use. In addition, the procedure is not intended to cover all aspects of product usage, but only those which substantially affect the TEC result.

Review of Existing Test Procedures

ENERGY STAR consultants ICF and LBNL reviewed existing test procedures to identify structure, principles, and components that could be used in or adapted for the TEC test. ASTM's "Standard Test Method for Determining Energy Consumption of Copier and Copier-Duplicating Equipment" provides a procedure by which copiers, copier-duplicators, accessories, and similar office imaging equipment may be rated for energy consumption. The TEC test procedure draws from its overall structure and calculation approach. The International Electrotechnical Commission's IEC 62301 informed the test conditions and parameters of the TEC test. International harmonization reduces the testing burden on manufacturers as well as the time associated with the procedure's design.

Test Parameters

Next, ICF and LBNL proposed parameters to specify how products should be configured and tested. Following are a few key parameters from the TEC test procedure and an examination of how EPA arrived at a conclusion.

Testing in simplex mode

In the initial draft of the procedure, it was specified that the test be performed in duplex mode for machines that are duplex-capable. Several stakeholders expressed concern that performing the test in duplex mode could be problematic. Since not all products that fall under the TEC approach have duplex capability, testing in duplex could mean that products of the same speed would be tested differently. In addition, limited data were obtained that indicated there were not appreciable differences in simplex and duplex imaging energy use for current products, so that no meaningful change in the TEC result was at stake. Allowing simplex output alleviated these concerns and provided for greater consistency across all products tested under the TEC approach.

Testing in monochrome mode

Color-capable products are to be tested making monochrome images, unless they are incapable of doing so. EPA proposed monochrome-only testing on the assumption that energy efficiency of units tested making monochrome images is highly correlated to their efficiency producing color. Some stakeholders argued that color imaging should be part of the test and would affect the results, both in general, and specifically, how serial and parallel color printers appear in comparison to each other.
Disagreement persisted over several meetings and it became clear that only empirical data could resolve the issue. An additional color job was added to a draft of the TEC test procedure, and several stakeholders submitted data, representing 16 products. Making up the dataset were 12 parallel EP color printers and four serial EP color printers, with most in the 30-40 images per minute (ipm) speed range. For the 12 parallel models, the energy consumption for monochrome and color jobs was virtually identical. For the four serial models, color imaging was notably more energy-intensive than monochrome. EPA excluded four models from the 16-model dataset that were only instantaneous power measurements, and ranked the remaining 12 according to the calculated TEC result while printing in monochrome. These printers were then re-ranked according to their TEC result using only color imaging. For three of the serial units, the ranking for color printing as compared to monochrome printing changed slightly. However, a test involving 100% color imaging, as implied through color-only ranking, is not realistic. For example, one proposed ASTM test procedure for color-capable products includes approximately equal rates of monochrome and color imaging in the job tables. When the 12-printer dataset from above was re-ranked with half monochrome and half color imaging, there is only one very small difference from the monochrome-only ranking, resulting from a serial machine. Thus, a monochrome-only ranking essentially provides the same result as a mixed ranking.

Testing as-shipped

The product shall be configured as-shipped and recommended for use, particularly for key parameters such as power-management default-delay times and resolution. Many TEC products have hardware components that can be added or removed, software settings that can be adjusted by users or service technicians, or settings that may be determined by incoming print jobs. The procedure's requirement for testing "as shipped and recommended" ensures transparency in test results and that users can readily achieve them in normal use. Testing a product other than as-shipped would offer the opportunity to "game" the system. This provision reassures manufacturers that other companies are not submitting skewed data.

Testing to the appropriate market conditions

Products are tested to the appropriate conditions of intended markets**.** Product testing should be performed at the relevant market conditions since energy consumption values may vary according to the input voltage/frequency combination and media type. Testing to market-appropriate voltage and frequency conditions has been the general procedure for ENERGY STAR testing in the past. As the ENERGY STAR program develops an increasingly international scope, EPA has determined that it is important to confirm that products meet the new specification at the representative market conditions where the products are sold. Parameters of concern are voltage, frequency, media size, and media basis weight.

Table 1: Testing to Global Conditions

Market	Supply Voltage, Frequency	Media Size	Media Weight
North America/Taiwan	115 V, 60 Hz	8.5" x 11"	75 g/m^2
Europe/Australia/New Zealand	230 V, 50 Hz	A4	80 g/m^2
Japan	100 V, 50 Hz / 60 Hz	A4	64 g/m^2

Testing in print mode

MFDs are tested in print mode, where possible. Users employ the print function on an MFD more often than the copy function, and testing both the print and copy functions of an MFD would complicate and lengthen the testing. If the page rendering process increases consumption, then the procedure should take that into account. EPA has not seen evidence showing that measuring both printing and copying would change the results enough to merit the added complexity of the procedure and calculations. The majority of stakeholders support these conclusions.

Use of a standard test image

EPA did not initially propose a standard test image in the belief that for EP products, any basic image would require the same energy to produce. Even if very complicated images did use more energy, no manufacturer would deliberately choose to disadvantage their product during testing by using these. Some stakeholders felt very strongly about the value of a standard test image, and as there was no detriment to the procedure's development or testing burden, this was accommodated using an existing test image widely used in industry.

Designing the Test

In creating the new TEC test procedure, ICF and LBNL had to assist EPA in determining what actions the product undergoes, the number of images to be made during active imaging, and how the energy measurements from the test would be extrapolated to a weekly TEC figure. Throughout all of this, it was important to address key testing variables that can differ by product speed and/or country/region. This was especially important, given that the specification will be used globally.

The measurement procedure

The TEC test procedure contains two measurement protocols—one for products assumed not to utilize an Auto-off function (printers, fax machines, and digital duplicators and MFDs with print capability), and one for products that do use Auto-off (copiers, and digital duplicators and MFDs without print capability). For all products, the test pattern consists of measuring:

- Off energy for five minutes or longer;
- Sleep energy for one hour;
- Four, 15-minute "job intervals," which capture the energy associated with recovery from Sleep, active imaging, Ready, and possibly Sleep; and
- "Final" energy, which includes energy used from completion of a job interval until the product reaches its final mode (Sleep or Auto-off).

Figure 1 shows a graphic form of the measurement procedure.

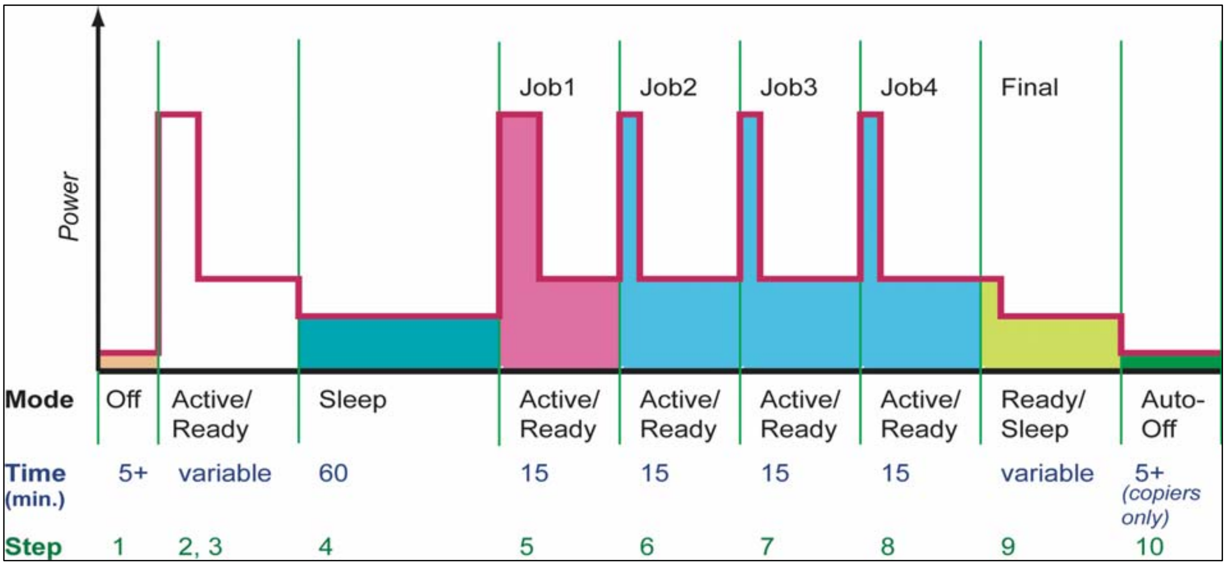

Figure 1: The TEC Measurement Procedure

ICF and LBNL carefully considered what number of jobs was necessary to reliably estimate job energy while not lengthening the test unnecessarily. The first job incorporates recovery from Sleep and so requires more energy than the rest. Job 2 is usually greater than job 3 as the thermal conditions in the fuser have yet to reach a steady state. Examination of early TEC test data made clear that three jobs would be too few, but that four jobs was sufficient. The average of jobs 2, 3, and 4 is taken as the average for all jobs after job 1 in the calculations.

The job interval is 15 minutes for all products tested under TEC. Some stakeholders suggested that the job interval should be greater for lower speed products to better reflect Sleep time during the day. Other stakeholders supported the static 15-minute job interval, noting that for EP products, residual heat from one job reduces the consumption of successive jobs. EPA decided to retain the 15-minute job interval in the final TEC procedure because it seemed to be the best single interval to use across the full range of imaging products.

Defining the job structure

One of the most difficult parts of creating the TEC test procedure was the choice of imaging "job" — how many originals are presented, how many images of each original are made, and how often a job is performed. An example job is three images (duplexed) of five originals, every 15 minutes. This amounts to 15 images per job, 60 per hour, 480 per day, 9,600 per month, and 115,200 per year (based on eight hours per day of active use, and 20 days of use per month). The number of images made over a period of time is the "imaging rate."

The number of images per job is determined by calculations of jobs per day and images per day. The result reflects the assumption that products with greater imaging speeds typically produce greater numbers of jobs per day. The calculation of jobs per day was developed in response to stakeholder comments, which called for the calculated number of jobs per day to increase according to product speed, generally consistent with the ASTM test for copiers (ASTM 1997). The Job Table numbers in the TEC test procedure are based on regressions of manufacturers' monthly rated volumes. EPA took 20% of these figures to be closer to typical usage. In the context of the TEC test procedure, "speed" is the maximum claimed simplex speed making monochrome images.

Weekly extrapolations

The TEC calculation result could be expressed per day, per week, per month, or per year. EPA initially proposed a daily TEC result but changed it to weekly in response to strong stakeholder preference. The energy associated with events in the TEC test procedure is extrapolated to a total TEC value in kWh per week. The TEC calculations embody two clusters of jobs during the day, with the unit going to its lowest power mode in between (as during a lunch break), as illustrated in Figure 2. The "lunch" period was added in direct response to international stakeholders who commented that this slow down time is common. The TEC calculations assume that weekends have no usage and no manual switching-off is done.

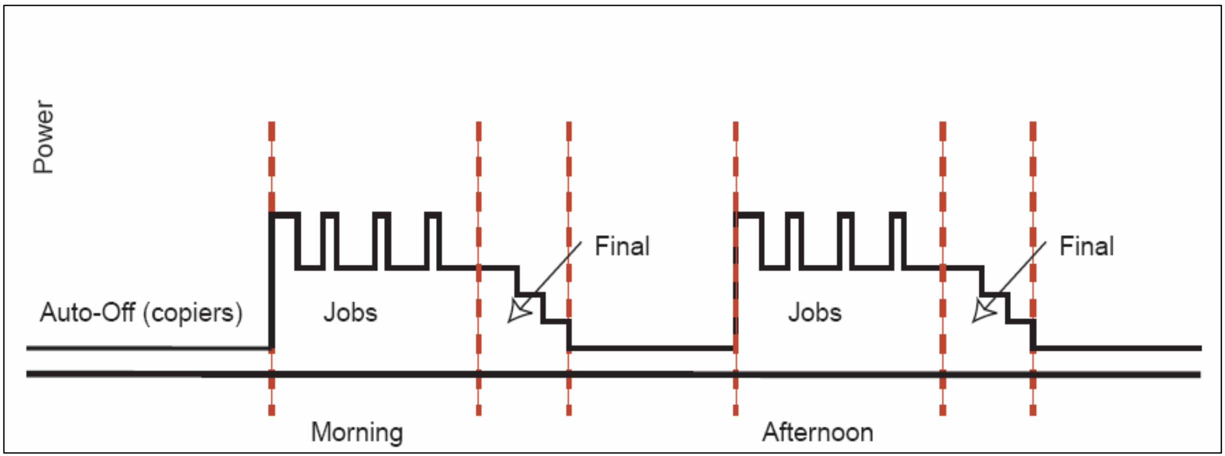

Figure 2: A Typical Day, per TEC Calculations

Figure 2 shows a schematic example of an eight-ipm copier that performs four jobs in morning, four jobs in afternoon, has two "final" periods and an Auto-off mode for the remainder of the workday and all of the weekend. The figure is not drawn to scale. Jobs are always 15 minutes apart and in two clusters. There are always two full “final” periods regardless of the length of these periods. Printers, digital duplicators and MFDs with print capability, and fax machines use Sleep rather than Auto-off as the base mode but are otherwise treated the same as copiers.

Establishing TEC Performance Criteria

Data Collection

Once the TEC test procedure was finalized, EPA asked industry to test products and submit the results for analysis. Stakeholders were given just under four months to complete testing, were encouraged to test their newest models, and were invited to submit data on products that both could and could not meet the current ENERGY STAR specifications. In advance, EPA created a data worksheet to ensure all important data were captured and reported in a consistent format for easy analysis. Stakeholder participation in testing and data reporting was a critical component to this effort, as this was a new test procedure and previous data were unavailable.

Initial Conclusions from Data Analysis

As of this paper’s preparation date, ICF and LBNL are in the process of assisting EPA with finalization of specification. Therefore, the following section on establishing criteria presents the best thinking to date, although some details of the final energy efficiency criteria may change.

The role of job energy in total TEC

As shown in Figure 3, job energy contributes significantly to the Total TEC. Specifically, job energy accounts for an increasing percent of total TEC as product speed increases; products with speeds above 25 ipm always attribute greater than 50 percent of the total TEC to job energy.

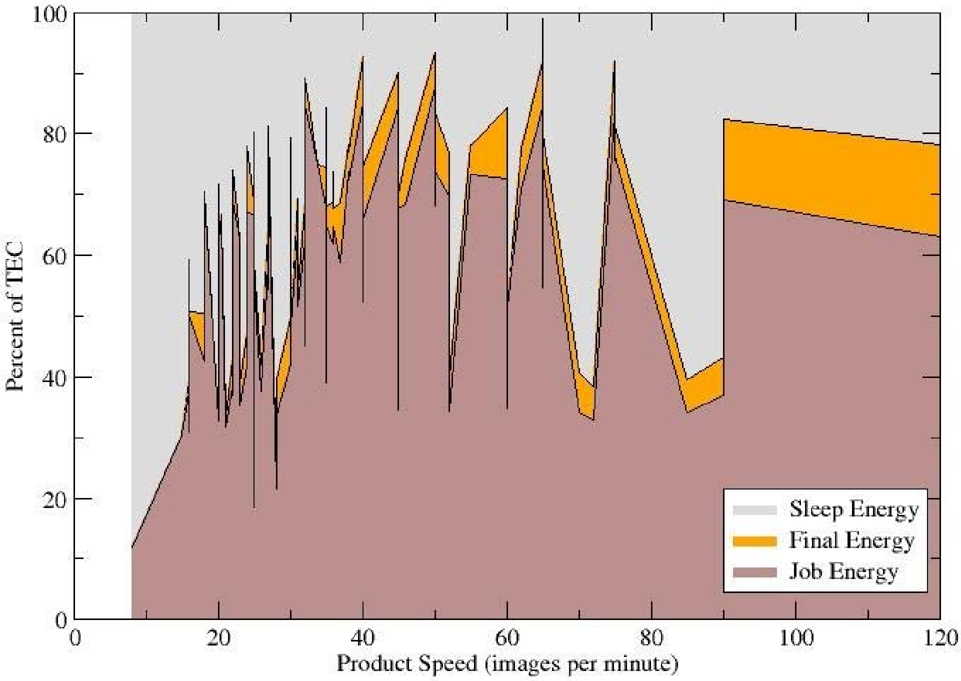

Figure 3: Share of TEC Energy Consumption among Key Modes

Use of efficiency formulas

Where possible, EPA attempted to use linear formulas when defining energy efficiency criteria that consider speed as the determining factor. Many stakeholders expressed a preference for this method, in particular, to avoid sharp jumps from small changes in product speed when bins of speed ranges are used. This suggestion is implemented in the Job Table as well as the proposed TEC specification. The simplest approach to setting a specification line is a linear formula based on product speed. This works well across large speed ranges, but the imaging equipment specification covers an order of magnitude in speed and such a large range necessitates more than one single line. At low speeds, TEC energy is dominated by Sleep/Off energy, which is well correlated with speed. At high speeds, however, Active energy dominated and is driven by the number of images per week, which varies with the square of speed. A pair of two linear segments generally seemed adequate for the job, and the TEC data suggested that their “elbow” should be close to 50 ipm.
Figure 4 shows the TEC data submitted to EPA for monochrome MFDs, contrasting the TEC metric with product speed in images per minute. As an interim measure, the ENERGY STAR specification includes an additional allowance for products between 20 and 70 ipm for MFDs. The line was drawn to ensure a sufficient number of models above and below the line at a variety of speed points, and to be consistent with the lines for other products (printers, copiers, and color versions of all).

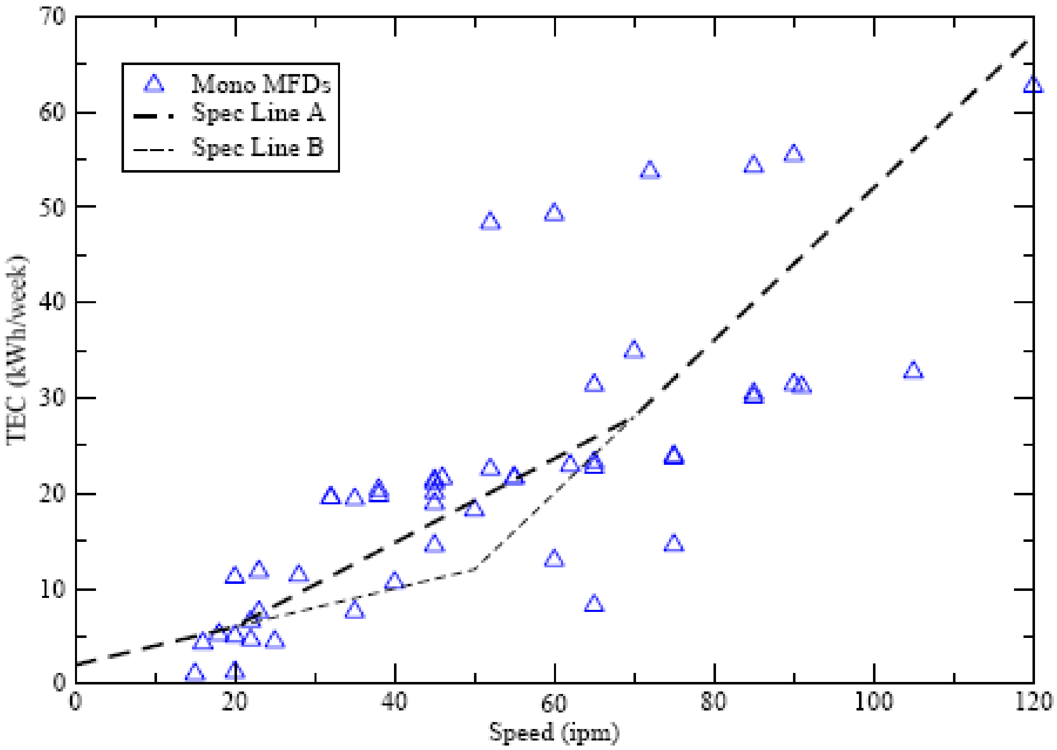

Figure 4: Specification Line: Standard-sized Monochrome MFDs

The effect of parallel requirements

To support other important energy efficiency initiatives, the criteria for ENERGY STAR qualified imaging equipment will include parallel requirements beyond a target TEC number. As examples, EPA plans to require standard and optional duplexing capability in various speed segments and will require that products with an external power supply use one that can meet ENERGY STAR requirements. As could be expected, these parallel requirements affect which models can meet ENERGY STAR and have an impact on EPA's goal to include approximately the top 25 percent of products on the market at the time the specification is set. To ensure parallel requirements do not reduce the number of qualified products below the intended level, EPA will consider the number of products that would fail the parallel requirements before creating formulas to set the TEC criteria.

Engaging Stakeholders

The open participation of industry and other energy-efficiency authorities is crucial to the success of ENERGY STAR specifications and is comprised of three main components: A) open communication that ensures everyone involved has equal access to information; B) ensuring that stakeholders' feedback is considered carefully and regarded in some manner in the specification; and C) providing sufficient lead time before a specification becomes effective to ensure the levels are attainable. Even the most refined process will fail if there is a general perception that stakeholder feedback is disregarded or that timeframes are unreasonable.

Communication

EPA began the imaging equipment specification revision process with an open letter to all interested parties to explain the upcoming effort and anticipated timeframes. EPA then began meeting with individual manufacturers to understand concerns about the current specifications and changes they would like implemented. A Directional Draft (February 10, 2004) preceded a more official first draft specification and identified objectives, summarized thinking to date, proposed a general specification framework, presented comments received and responses, shared a timeline, and invited further input. The Directional Draft contained many placeholders and was a unique opportunity for stakeholders to comment at the very early stages of the process. The Directional Draft also contained definitions and terminology. The definitions and terminology associated with TEC were circulated early and often for feedback to establish a common language stakeholders could use when sharing additional feedback.

Since the release of the Directional Draft, EPA has distributed for comment three drafts of the specification; six drafts of the TEC test procedure; summaries of and responses to all comments received; numerous interim updates, rationale, and discussion documents; and all data sets upon which conclusions have been drawn. To further ensure this process was transparent and collaborative, EPA has made all of the abovementioned documents available on the ENERGY STAR Product Development Web site at www.energystar.gov/productdevelopment, which is updated regularly.

EPA also gathered invaluable feedback from stakeholders during many meetings held in the US, Europe, and Asia. These meetings provided a unique opportunity to work through issues in an open forum, and for participants to hear the opinions of other stakeholders.

Incorporating feedback

EPA's goal for the TEC approach was to develop a test procedure that allowed for the relative energy efficiency of imaging equipment to be measured and compared in a precise, repeatable way, and to create a specification that recognized approximately the top 25 percent of the market while fairly accounting for the increased energy required of higher-functionality products. Industry representatives and international program implementers know their products and markets better than anyone else, and their comments throughout this process contributed to a quality result.

EPA attempted to accommodate all comments that would lead to the best possible specification. As an example, requests for small changes or additions that would not affect the outcome were not deliberated extensively in an effort for simplicity. However, other comments did not align with ENERGY STAR guiding principles and could not be accommodated. Perhaps the most difficult comments to resolve were those that conflicted with other feedback received, or those that presented plausible changes whose impact could not be understood immediately. In addressing these last two categories of comments, EPA attempted to obtain empirical data to support the final decision. This ensured that all feedback was investigated carefully, and that ultimate decisions were easily understood by all. The issue of monochrome versus color imaging presented earlier in this document is an example of where EPA consulted test data to inform a decision.

Sufficient Transition Time

As product specifications come up for revision, EPA is committed to accommodating production cycles via establishing reasonable effective dates for new requirements. EPA strives to allow a minimum of nine months transition time between the final specification's publication and the effective date.

Conclusions

In summary, the time was right for EPA to address Active mode consumption in imaging equipment and TEC provided a flexible framework in which EPA could consider Active while achieving other important goals. The process was methodical and done in collaboration with stakeholders, and should lead to significantly more energy efficient imaging equipment products. This paper has presented a number principles that were critical throughout the TEC development process. They include:

- Use of empirical data to drive key decisions;
- Embracing simplicity over strict "correctness" in many cases;
- The need for transparency, in process and result; and
- Cautions, deliberative decisions over time to produce a quality result.

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Set Top Boxes, Televisions and Consumer Electronics

The Digital TV Challenge, Sharing Knowledge Between China and the EU

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Abstract

Both China and the European Union face significant environmental and technological challenges from the growth of digital television but are at different stages of development - the EU has a mature yet growing market, whilst China has comparatively recently embarked on a programme of digital roll-out. There is potential for the EU to share its experience of building a digital television infrastructure and for China to play a leading role in developing products with improved environmental performance. As part of that process, the UK Government's Market Transformation Programme[1] (UK MTP) is supporting knowledge exchange activities, in the EU-China Energy Environment Programme[2] (EEP) aimed at developing a common approach to specifying products, which do less harm to the environment

In October 2005, a delegation from the principal Chinese standards and testing institutions, accompanied by some of the leading Chinese set-top box manufacturers, visited the UK under the auspices of the EEP to study the EU approach to the development of common test, performance, and interoperability standards for digital TV Set Top Boxes (STBs) and to share an insight into the Chinese adapter (basic STB) market. This paper will outline the background and objectives for that visit, and report on the progress that has been made since then in harmonising criteria for energy efficient STB development. The paper may also encourage similar activities in other product areas and therefore may be of interest to anyone seeking to explore collaborative activities with non-EU nations, especially those involved in the Marrakech Process[3].

Introduction

It is universally accepted that the introduction of digital TV reception platforms, particularly set-top boxes (STBs), has the potential to cause a step increase in the overall energy demand of domestic electronic products in Europe and in China.

European countries have varying schedules to stop analogue broadcasts completely over the next 10 years and China has ambitious plans for 130 million STBs to be in Chinese homes by the time of the 2008 Olympics. Evidence is already available, from products actually brought to the European horizontal and vertical markets, to show that the energy efficiency of these STBs could, today, be improved by 20% (on average) if best practice is applied, conversely the average energy consumption could increase to more than 50% above best practice if left to market forces.

Although China does have a programme for introducing appliance efficiency standards, digital TV STBs are not a priority and without external influence, it could take several years before the Chinese authorities address this issue. In the meantime, when the European Commission and European Member State governments discuss improved energy efficiency of products with major procurers, the typical response is that product efficiency is not in their hands but in the hands of the manufacturers who are predominantly Chinese. Neither side appears to be presenting proactive solutions to change the current position.

For this reason EEP intends to act as a catalyst that will bring together Chinese manufacturers with their European counterparts and with major European equipment purchasers with the common purpose of improving the efficiency of STBs and many other energy using products in volume production.

EEP organised the highly targeted study tour to the UK for representatives of China's STB manufacturing industry, the China Standard Certification Centre and two relevant research

[1] http://www.mtprog.com/
[2] http://www.eep.org.cn/
[3] http://www.un.org/esa/sustdev/sdissues/consumption/Marrakech/conprod10Yconcl.htm

institutions. The purpose of the visit was to engage Chinese stakeholders with their European counterparts and with large equipment buyers in Europe so that in the future the efficiency of the STB products imported to Europe would be optimised. This would improve the opportunities for export for the Chinese manufacturers and mitigate the projected increase in domestic energy demand in Europe and China that the wide-scale introduction of STBs is expected to promote.
During the Study Tour, the delegation visited several bodies influencing the STB product including manufacturers, test laboratories and major service providers. Experts from these organizations shared many valuable experiences on STB design, production, volume procurement, testing and deployment to a volume domestic market.

Objectives of Study Tour
A primary purpose of the Study Tour was to adequately prepare the Chinese manufactures and other stakeholders to contribute to the following meetings in Seoul Korea:

- International Harmonisation of Set Top Box Specifications, 31st October
- Special meeting of the European Code of Conduct for STBs working group, to engage International participants 31st October[4]
- IEA "Global cooperation on One Watt" (standby power) Conference, 2nd to 4th November[5]

The Seoul events intended to start a process for the STB product that would create a universal method of testing and would "put in one document" a harmonized set of energy efficiency performance requirements. This would build on discussions between California, Australia, the UK MTP the US EPA (Energy Star) and the EU Code of Conduct working group on STB. It would also address an imperative of the leading organizations involved in developing energy efficiency standards in Europe, notably European Commission DG JRC and the International Energy Agency underlining the importance of bringing Chinese Manufacturers to Europe and catalyzing their direct involvement in International standards harmonization work.

Outcome of Study Tour
The STB Study Tour to Europe provided significant help to Chinese STB manufacturers in identifying marketing opportunities in Europe in the context of the energy performance expectations for this globally traded product. These manufacturers recognized that the primary message on sustainable STB design obtained from the tour harmonized with the related requirements for the rest of the world.
With the preparation afforded by the Study Tour the Chinese delegation took an active part in the discussions at the Seoul event, understood what the International Community wanted to buy in terms of efficient products and obtained valuable guidelines to their manufacturing and testing.
Most importantly the study tour was the catalyst for the publication of a new set of energy efficiency criteria for basic digital TV STB cable platforms for the Chinese market that have been drafted in close cooperation between the CECP and the major Chinese manufacturers. (Appendix 1) The energy efficient design and manufacturing standards for these products will impact on all STB products sourced in China.

Overview of Study Tour Components

Advanced Silicon Manufacture.
The general purpose of this component of the tour was to review the very latest Silicon developments for Energy Efficient STB platforms for Terrestrial, Satellite, Cable and Internet TV services.

Outcome and observations: With the rapid development of Silicon technology, the STB can realize multiple functions in single device architecture. Each function can be software programmed to match the requirement of specifiers (for example the device could be updated by software to provide MPEG4 decoding and HD decoding standard from an original MPEG2 decoding and SD encoding specification without recourse to new Silicon design and fabrication). This allows the rapid development of new functions on existing silicon and allows remarkable levels of power management. Figure 1 provides a schematic overview of this Silicon architecture
The silicon functions are enhanced in speed, and energy efficiency by the progressive transition from 90nm to 32nm technology. Usually, continually evolving functionality, adversely affects the minimum

[4] http://www.energyrating.gov.au/pubs/2005-stb-program.pdf
[5] http://www.standbyforum.co.kr/and http://www.action1watt.com/

power requirement of STBs and the start up time from low (standby) power states. This new Silicon technology has readily programmed power management architecture. This can achieve very low minimum (standby) power levels and yet allow effective control of the transition between the low power standby state and the fully active on mode, for the whole system architecture, to guarantee full function within 2 or 3 seconds. The Integration of Silicon design group know-how ensures that lessons learned from mobile phone power management migrates to Silicon for STBs, and continuously improves the potential of this power management. The power requirement of this new silicon concept is further reduced by a dramatic improvement in DC to DC conversion efficiency for the supporting power supply source Silicon and power distribution regulators. Typical conversion efficiency of up to 95% is now commercially viable in the volume production of low cost products.

Major Digital Television Interactive Service System Provider

The purpose of this component of the study tour was to discuss the practical problems of broadcasting digital TV interactive services to a range of millions of set top boxes covering six years of technological change. Sky are noted for their long term support of the European Code of Conduct for STBs and discussions were also scheduled to cover the specification and procurement of energy efficient STBs to meet Code of Conduct criteria in the context of challenging commercial financial imperatives. Other topics for discussion were to include, the implications on energy requirement of the new generation of High Definition Television STBs and energy efficient solutions to multiple access Satellite TV (SMATV). The latter is a common solution to Satellite TV reception for Chinese homes.

Outcomes and Observations: The over–arching criterion for China or any emerging digital broadcasting market where there is no well structured dominant Service Provider must be that the policy makers who influence the major market (Government or Union of States / Authorities) must give firm leadership, to drive agreements on common standards for DTV Broadcasting and Networking and for the related reception platforms (STBs –IDTVs) This will catalyse the volume production of products that are interoperable and that meet good minimum standards of, technical performance, usability and energy efficiency.

STB power consumption targets must be realistic and technically possible in the time frame of a Service Providers commercial roadmap When planning such targets, policy makers, manufacturers, and TV service providers should be involved in cooperative discussion for an agreed set of criteria and an agreed implementation time frame. Common minimum standards that can be applied to large volume production runs of STBs will reduce costs and allow a higher investment in energy efficient design without compromising the commercial viability of the product in a competitive procurement market or in a retail market.

When specifying the functional and network requirements of an STB, the Service Provider must consider not only the cost, but also the ease of use and attraction of the features from the consumer viewpoint. This is particularly important in the pay to view market where there is often no competition in the type of STB available.

In BskyB's specification for the competitive procurement of STB's, each potential supplier is required to produce an STB that meets a common performance and physical specification and that must comply with the relevant energy efficiency criteria of the European Code of Conduct. The technical solution for this compliance is left to the design ingenuity of the manufacturer. This encourages innovation in technical solutions in a commercially viable cost framework.

The functions and ergonomic design of the remote control for an STB can influence the users ability to put the STB, the TV set and other connected devices into standby. In China consideration should be given to developing an industry standard for remote controls that combines good ergonomic design with the large energy saving cost benefit to the user and Government of ensuring that all peripheral products are not left on by mistake when the TV is switched off. A common Industry Standard for the remote control has the further benefit of significant reductions in volume production cost. All 10 million BskyB remote controls distributed since 1998 are to a common design philosophy and specification regardless of the suppliers of the STBs. Independent testing bodies regard the design as one of the most ergonomically successful (user friendly) ever produced and it should be studied as the template for Chinese volume production industry standards.

BskyB have experimented with some Subscription Service Integrated Digital TVs (IDTVs) for distribution through the retail market. In their opinion the IDTV is unlikely to ever be a suitable reception platform for subscription services because of the difficulty of protecting the encryption techniques of CA in a remote cam module. Even if this could be resolved, the manufacturing and subsequent retail cost of the IDTV is comparatively very high because software and middleware specification variations between Service Providers make large production runs of one IDTV chassis type impossible. The resultant impact on manufacturing cost makes the product uncompetitive in its class.

Without a step change in Silicon architecture, HDTV STBs will introduce much higher energy consumption. In current Silicon architecture (now up to 10 years old) particular problems exist with HD tuner power requirement and MPEG-4 processing. Some development time will be needed to improve the energy efficiency of HDTV STBs' and in discussion it was noted that the European Code of Conduct working group is regarding the impact of HDTV as a priority issue for International stakeholders.

There is a potential for significant power management advances in a new generation of HDTV STBs. The new HDMI interconnection standard for these platforms can recognize and control the required power state of peripheral devices connected directly or wirelessly. Sky recognizes that International standardization work is urgently required to agree common HDMI power management protocol applications and is steering a high-level working group on other HDMI connector issues to support this,

British Broadcasting Corporation and Digital Television Group (DTG) Testing Centre

The general objectives of this component of the study tour included, discussions of UK experiences in the development of free to view terrestrial digital television services and of maintaining the interoperability and usability of the set top boxes, low cost converters and IDTVs supplied through the horizontal market for the reception of those services. In the latter context demonstrations and discussions were scheduled in the DTG Testing Centre

Outcomes and observations: The STB products should conform to at least a minimum specification and applications delivered to that product in the broadcast data stream should be authored within strict specifications to ensure long-term interoperability of all installed STB platforms. Ideally published guidelines for broadcasters and domestic equipment manufacturers should be put in place by a commercially neutral organization (e.g. DTG, DVB etc,) or regulatory authority working with all stakeholders. The guidelines and related detailed specifications should be continuously reviewed in the light of technical and functional innovation.

A test suite and test programme development that can determine if a product conforms to the guidelines and specification should be implemented by a central body, which is supported by industry, standards organizations, broadcasters, and service providers. It was considered that the DTG Testing Centre was a good example of this. In this context it is considered essential that Chinese manufacturers have access to appropriate test suite equipment and test programmes to ensure that products meet the technical and interoperability standards of the targeted market. In China the CEPERI certification body should perhaps consider providing such facilities.

Specialist Consumer Electronic Product Testing Centre

In this component of the study tour discussions on the assessment of, STB ergonomics (usability) technical performance, operational (subjective) performance and energy efficiency, were planned around demonstrations of elements of complete test programmes.

Outcomes and Observations: When designing better products, user trials should be launched, and the ease of use of products should be assessed through an experienced panel of users under the guidance of a test programme devised and continuously reviewed by an ergonomic expert who is familiar with the product genre. The object is to ensure that the STB is easy to connect to the TV and other equipment and has good visual and aural interactivity to support a reliable tuning and installation routine. This is particularly important in simple low cost products that may be more commonly used by unskilled disabled and older consumers.

For energy efficiency STB products, both ergonomic testing and user trials should be implemented to assess the ease of operation of STBs featuring power management. These tests and trials should ensure that start up delays from standby are not excessive and that the control of the standby state of the STB, the connected TV and other peripherals is user friendly in achieving low power states.

Discussions led the tour group to related considerations for China. Once minimum energy efficiency, technical, operational and usability standards are established, the Government Standards bodies should arrange the continuous testing and approval of all STB products in the market place. Strict test programmes run by independent test houses should be used. Ideally conforming products should be given a publicized approval logo. For Government or provincial procurement, only the most energy efficient approved products should be short-listed for purchase.

Intertek bases its terrestrial digital TV STB tests on the detailed specifications in the "D-Book" published by the combined Industry and Broadcasting advisory body in the UK, the DTG. Testing of Satellite and cable equipment is based on guidelines agreed with equipment manufacturers and Service Providers.

For STB energy efficiency testing purposes, IEC62087 is the main reference standard and provides a good guide to general test conditions, simple operating mode definitions and test set up procedures for simple STBs,

However Many experts, including those at Intertek are warning that the advent of more complex platforms with multi media, and home networking capabilities will drive the need to urgently review this standard. In the opinion of Intertek experts, the revised standard should avoid the stricture of attempting to qualify performance criteria, functionality and usage patterns It was noted that International cooperation on issues associated with this standard was high on the agenda in the STB forum associated with the International Standby Power Conference in Korea November 2005. Chinese manufacturing and product testing experts should support this work.

Leading Manufacturer of Digital TV Reception Platforms

The purpose of this element of the tour included discussions on the key impediments to designing and manufacturing commercially viable energy efficient STBs in an intensively competitive world market, the potential impact on energy efficiency of the next generation of high functional specification multi media home platforms, energy efficiency testing methodologies and the implications for existing standards.

Outcomes and Observations: STBs are acquiring new advanced functions such as video-on-demand multi-room networking of separate entertainment streams, complex interactivity and universal broadcast data access, including the Internet. These developments are driven, mainly by subscription Service Providers to retain or attract end users. Because end users rarely make purchase decisions on energy efficiency considerations, these rarely feature in the current commercial development roadmap of most STBs unless the manufacturer drives that requirement.

Power management, automatically driving the lowest power level for a given functional requirement is the key to achieving energy savings or mitigating energy requirement increases in the next generation of high functional specification multi media home platforms. Mature evidence shows that most users cannot be educated to reliably perform manual power management functions. Surveys have shown that even in simple STBs, over 50% of users don't activate the standby mode if it requires a secondary remote control activity after the TV has been put into standby. So even in these basic products a simple form of power management such as an auto standby function is desirable.

Continuously revised and internationally agreed test specifications and methodologies are important for consistent testing results and criteria conformance testing. Pace bases its testing on nationally and internationally agreed standards and regulations for all types of digital broadcasting and platform technical criteria. It develops its own standards - compatible test material and very sophisticated broadcast data stream generating and analysis equipment.

Energy efficiency improvement requires the cooperation of all parties involved in the platform design, hardware designers, silicon vendors, service providers, software designers, external software suppliers, CA suppliers, LNB suppliers, the consumers, and government agencies. Pace put significant effort into communicating with these parties and contributing to many relevant International standards and national working groups such as the European Code of Conduct working group and the UK DTG.

Challenges to China Prompted by STB Tour Observations.

At present, there is no coordinated broadcasting and telecom service development plan, or even cooperation on the subject between the media regulator of China, SARFT, which also oversees cable television operators and MII, the telecom regulator of China. MII wants to promote an IP-based digital TV service that would be distributed though the telecommunications companies. This lack of high level coordinated policy for multi media communication contrasts badly with the European situation and inhibits long term investment in major Service Systems and related reception platform manufacturing.

This is compounded by delays in finalising the national DTV standards, STB related standards, and Card Separate-from TV Receiver standard. These uncertainties make the STB manufacturers reluctant to progress research and development of new products. With the exception of some large companies, most manufacturers prefer to wait-and-see. Besides these political issues there are many key factors to prevent STB production moving to the large-scale production that will allow China's Industry to drive forward to a new generation of high specification energy efficient yet commercially competitive world benchmark products. Observations on the Chinese situation prompted by this study tour highlight the following problems.

STBs are restricted in design and can't readily benefit from the economy of production volume. They are being tied to the limited cost driven requirements of technically uncoordinated and loosely regulated, cable companies. This situation is aggravated by the fact that the consumer can't obtain a better cable STB in the competitive free market and so drive up quality through competition.

Various cable companies monopolise very segmented markets and do not cooperate commercially or on technical standards. There are many differences on both interface software and Conditional Access systems. Manufacturing for such an uncoordinated set of market standards weakens the ability of the manufacturing Industry to excel in core technologies. (This contrasts very badly with the situation in Europe)

There is often no requirement to develop core technology in OEM procurement contracts from foreign companies, further weakening manufacturing expertise and innovation.

Lack of the essential foundation of independent working groups equally involving all stakeholders to drive common standards and testing / conformance regimes, will hold back the excellent potential of digital TV broadcasting and equipment manufacturing in China.

All these factors will bring uncertainty to STB industry development but may be mitigated by three factors. Firstly the last 5 years of industry awareness of the long term potential of these products has fostered an expansion of the expertise resource. Secondly, there will be a positive impact from the administration system reform that has allowed deepening and vigorous promotion of communication resources by local government. Thirdly the pull of high quality broadcasts from the 2008 Olympic Games, will be a good driver for digital TV start-up and will prompt great growth in a short period.

Conclusions and Actions

Under the challenging conditions outlined above it is simply not realistic to expect the Chinese Manufacturing industry to drive autonomously, excellence and energy efficiency in the STB product.

Many energy-saving opportunities in STBs will be missed if there is no coordination of the many different players in the technology, communications network, and broadcast industries. Energy efficiency improvement requires the cooperation of all parties involved, hardware designers, silicon vendors, service providers, software designers, external software suppliers, CA suppliers, LNB suppliers, the consumers, and Government agencies. With this cooperation there is the market potential to easily drive China to the forefront of benchmark STB production. The following actions will be a catalyst for this key objective.

- Energy efficiency agencies must provide proactive advice on Energy Efficient STB criteria to policymakers, like NDRC, MII, SARFT, and local government and support their coordinated involvement in energy efficient STB procurement or distribution.
- China must participate in the process of common international standard development and support those standards through internal market application. Relevant market transformation measures should be explored.
- Mechanisms must be established to cooperate with and advise service providers to coordinate design requirements and thus foster energy efficiency innovation in STBs through the R&D investment made possible by strong commercial road maps based on continuous volume production.
- Hardware and software designers must be given a market environment where they can achieve radical innovation in power management and cost-effective smart network interfaces. This innovation combined with international standards cooperation will ensure that

STBs from Chinese industry will achieve benchmark energy efficiency performance for any functional state.

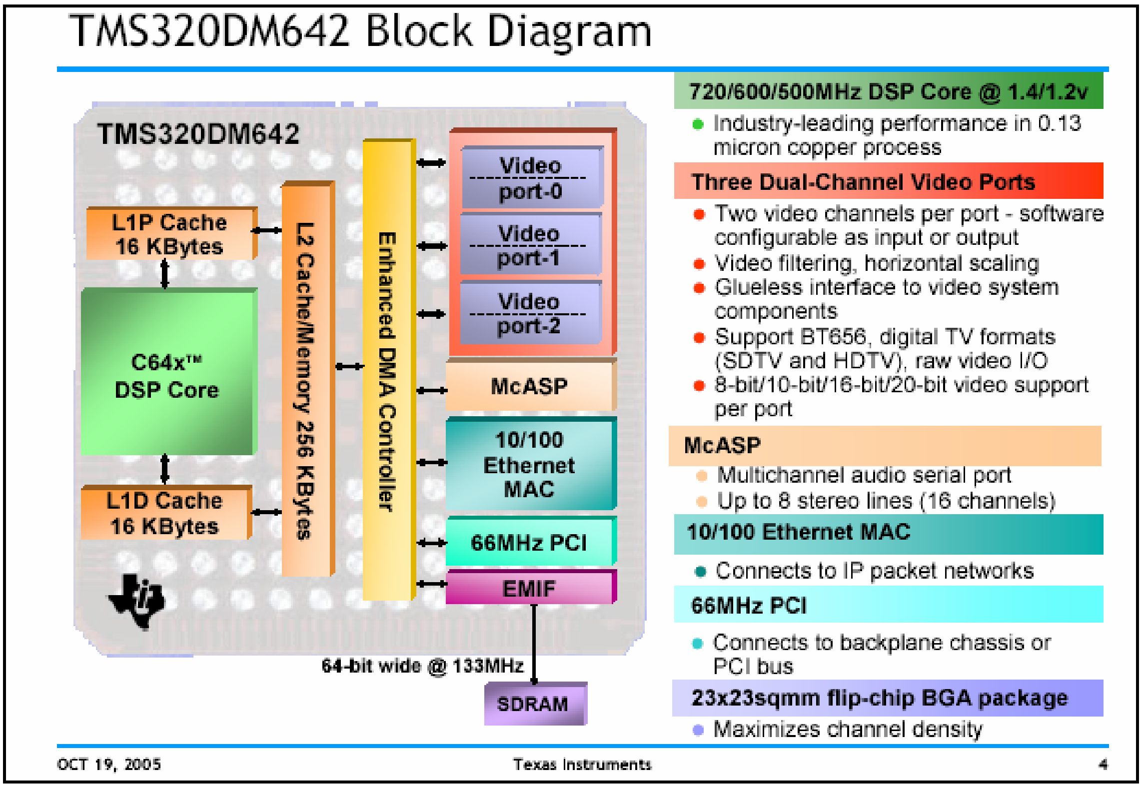

Figure 1: New Silicon Architecture allowing software programmable functionality of transport stream decode and output encode formats for fast to market Energy Efficient STB design.

Appendix 1.

CSC

Technical Specification for Energy Conservation Product Certification for Digital to Analog Set-top Boxes for General Digital Cable Transmissions

Preface

This Technical Specification is one of the series of the technical Specifications for Energy Conservation Products. It is especially established in order to, carry through and implement: the *Law of the People's Republic of China on Conserving Energy*, energy conserving product certification, protecting the environment, improving the energy efficiency of digital to analog set-top boxes for general digital cable transmissions, and driving the technical energy conversation advancement of Corporations.

This Technical Specification is formulated according to the current conditions of the manufacturing and use of digital to analog set-top boxes for general digital cable transmissions in China and by reference to similar foreign technical specifications.

This Technical Specification is proposed by and under the jurisdiction of China Standard Certification Center (CSC).

And in association with the main drafting units of the Standards: CSC, CNIS, China CEPREI Laboratory, National Computer Testing Center, Huawei Technology Co., Ltd, Skyworth Group Company Ltd, Shenzhen Tongzhou Electronic Co., Ltd

Main draftsmen of the Standards: Li Aizhen, Zhang Guoqin, Song Danmei, Zhou Xinghua, Qiao Mu, Xie Yongmin, Xu Bin.

Technical Specification for Energy Conservation Product Certification for Digital to Analog Set-top Boxes for General Digital Cable Transmissions

1. Scope

1.1 This specification defines the energy conservation evaluation and testing methods for digital to analogue set-top boxes for general digital cable transmissions (set-top boxes for short in the following text) which turn digital signals into analogue signals.

1.2 This specification is applicable only to the basic set-top boxes that turn digital signals of general cable transmissions into analogue signals.

1.3 This specification isn’t applicable to those set-top boxes that have additional functions such as interactive return path communication functions.

2. Standard documents quoted

The clauses in the following documents will, through quotation in this specification, become the clauses of the specification. For all the quoted dated documents any subsequent modification lists (including the content of erratum) or any modified version shall not be applicable to this specification. However, the parties that have reached agreements based on the specification are encouraged to investigate and determine whether later versions of those documents are applicable. For all the undated documents quoted, their latest versions are still applicable to the specification.

GB/T17975.1-2000

3, Definitions

For the purpose of this specification, the definitions listed below apply.

3.1 On mode

The state in which the set-top box is connected to the mains power source and is performing the main function.

3.2 Passive standby mode

The set-top box is connected to the mains power source and performing no function other than maintaining the functions required to switch to on mode from a remote control or local control signal.

3.3 Automatic switch time

The time that elapses before set-top boxes are automatically switched from on mode into passive standby mode..

3.4 Evaluating values of energy conservation

The technical target is for evaluating the energy conversation performance of set-top boxes. It includes the power consumption in the state of on mode, the power consumption in the state of passive standby mode, and the required automatic switch time.

4 Technical requirements
The set-top boxes shall meet the requirements of 4.1, 4.2 and 4.3 at the same time.
4.1 The power consumption in the state of on mode
The power consumption of the set-top boxes in the state of on mode shall not exceed 9 watts.
4.2 The power consumption in the state of passive standby mode
The power consumption in the state of passive standby mode shall not exceed 1 watt.
4.3 The automatic switch time
The time taken by the set-top box to switch automatically from the state of on mode into the state of passive standby mode, after the last user instruction has been received from remote or local controls, shall not exceed 4 hours.

(NOTE: If the set top box has received no remote or local control instructions for a period of time approaching four hours, indicating no user presence or a long programme it should provide a visual and aural warning that switch off is imminent. If the user does not respond to this message within two minutes, the device will switch automatically into passive standby mode. The auto switch off function should be capable of being disabled by the user for recording purposes but should automatically reset after the user designated recording period)

Test methods

5. Test conditions
5.1.1 Ambient conditions
Ambient temperature: (23± 5)º C
Relative humidity: 45%-75%
Atmospheric pressure: (86-106) kPa.
5.1.2 Power supply
Voltage: 220V(AC)
Frequency: 50Hz
The test sequences shall be carried out at the alternating current mains with steady voltage. The mains fluctuating of both voltage and frequency shall not exceed ±2%.
5.1.3 Equipment and requirement of the test
A wattmeter (or watt-hour meter) shall be used for all power requirement measurement. The testing accuracy of the wattmeter shall be more than or equal to 0.01W.
5.1.4 Input signals
5.1.4.1 MPEG-2 standard active image order transport steam shall be provided in accordance with with GB/T17975.1-2000. The images should be continuously looped without a stop and the basic cycle is 60s.
5.1.4.2 High / Standard definition testing signals
Color stripe signals

5.1.4.3 Format of image signals

Format of signals	lines ratio alternately	number of scanned lines	Line frequency (kHz)	Field frequency (Hz)	Amplitude ratio
720×576I	2 : 1	625	15.625	50	4 : 3

5.1.4.4 Audio testing signals
stereo 1kHz 0dBfs sine-wave signals

Testing methods

5.2.1 Standard testing signal parameters
Bit Rate 2Mbps-15Mbps
Symbol Rate 3.52-6.89MS/s 64QAM
database package size: 188/204byte
modulate mode 64QAM 256QAM
Reeling & Interweave Depth I=12
Rolling & Dropping coefficient a=0.15
Frequency 110-862MHz
Standard Input Voltage 60dBμV
Yawp Equivalent Bandwidth Signal Occupation Bandwidth/ 1+a
Audio output signals of the tested equipment at the maximum.
5.2.2 The power consumption in the state of on mode

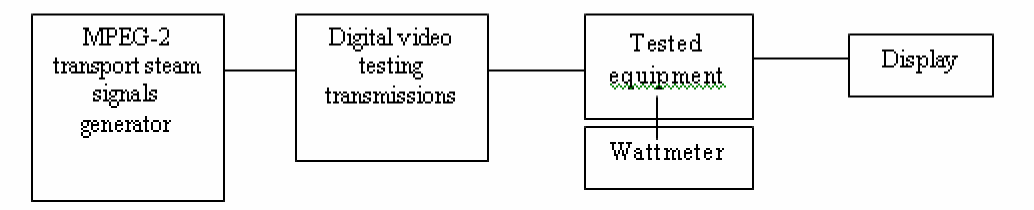

Figure 1: The schematic interconnection of test equipment and test sample

All the testing equipments and the tested samples shall be connected according to Fig. 1. The MPEG-2 transport steam signals generator produces standard active image order, and the whole testing system shall be set at the standard testing signal parameters, the tested equipments shall be adjusted to have a natural image in the display.
The test sample shall work continuously for 30 minutes before testing.
The period of measurement for the power consumption of the tested samples shall not be less than 10 minutes.
5.2.3 The automatic switch time
After the test according to 5.2.2, the sample shall be switched to standby and then to on mode No further operations of the remote controls or local controls should be performed. The time taken from the start of on mode (set top box producing images and sound) to the point of automatically switching to standby should be recorded. A note should be made of the time of appearance and the duration of the switch off visual warning.
5.2.4 The power consumption in the state of passive standby mode
According to 5.2.2, after the test sample switches into passive standby mode and achieves a steady state, the power requirement should be monitored over a period of not less than 10 minutes. The Final steady state reading should be recorded. If the power requirement fluctuates in the standby mode an integrating (watt- hour) meter must be used for a measurement period of 10 minutes from the onset of a regular fluctuation pattern.

Calculating method for stated power requirement when measuring with an integrating (watt – hour) power meter.
The power consumption per unit time =
The indicated power consumption (watt-hours) / The duration of the measurement period (hours)
The power consumption per unit time is expressed in Watts (W), to an accuracy of 0.1w.

Australian Mandatory Standards for Consumer Electronic Equipment

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Abstract

In late 2002 the Ministerial Council on Energy in Australia launched a 10-year strategy to deal with excessive standby. As part of this strategy Australia plans to regulate the maximum in-use and standby power consumption of digital Set Top Boxes (STB) from October, 2007. In Australia, it is planned to phase out analog TV from 2010 and an estimated 14 million TVs will require a STB. Projections of the energy use for these STBs show energy consumption could increase to over 2,000 GWh pa by 2012. Minimum Energy Performance Standards (MEPS) could reduce the business as usual energy consumption by STBs to as little as 300GWh pa.

STBs were initially identified for voluntary targets for standby power consumption, however industry groups requested the government consider mandatory requirements. Further, the regulation of in-use power consumption was identified as a priority due to the large number of STBs that will be potentially left in this mode.

Australia is also moving to regulate the standby power of a group of consumer electronic equipment covering the home entertainment products. The proposed regulation may provide potential energy savings of 1.7 GWh pa and greenhouse emission reductions of 1.7 Mt CO_2-e pa by 2020. Home theatre systems, DVD players/recorders, portable and integrated sound systems are some of the products included in the broad scope of the proposed requirements.

The paper explores the design of the MEPS, lessons learned from the Australian experience, energy impacts, test method issues and projected impacts of the proposed regulation

Introduction

In late 2002 the Ministerial Council on Energy in Australia launched a 10-year strategy to deal with excessive standby. Consumer Electronic equipment was initially identified with voluntary targets for standby power consumption. STBs used for the conversion of Digital TV broadcasts were identified as a priority product. Other Audio Video equipment was also identified as needing action on MEPS at the earliest time possible.

These targets were initially intended to be voluntary, however industry groups requested the government consider mandatory requirements. The reason for this will be discussed later. Further, the regulation of in-use power consumption was identified as a priority due to the large number of STBs that will be potentially left in this mode.

This paper will exam the factors surrounding the decisions associated with the development of these MEPS. STBs will be considered separately from the wider category of consumer AV equipment due to some unique circumstances surrounding their penetration into the market and the significant impact that this has on the energy consumption associated with these products. Australia's intention for MEPS on consumer equipment will then be discussed along with the potential impact that these products will have on energy consumption in Australia. Finally the paper will consider lessons learned from the development of these MEPS and how this knowledge may be used to assist the development of future MEPS under consideration.

The Development of Mandatory MEPS for Digital TV Set Top Boxes(STBs)

Background

On the 1st January 2001 free to air digital television broadcasts were started in order to replace analog broadcasts by 2008. This target has recently been under review and the likely start date for the initial turn off of analog broadcasts is now 2010. Under the Australian broadcasting regime broadcasters were required to simulcast the same material on the digital channels as they were broadcasting on the analog channels. In addition they were also required to broadcast by the end of 2003 no less than 20 hours per week of high definition programs.

The consequence of these new broadcasts was the introduction of STBs into the Australian consumer electronic market. There are 7.6 Million households in Australia(1) and the estimated the number of TVs per household is around 2 (2) with an expectation that this figure could rise to around 3 by 2012. If switch over to digital were to be achieved by 2012 this could mean, at worse case for energy consumption, that some 20 million STBs would be purchased.
Televisions with inbuilt digital tuners have now been introduced into the Australian market and over time most televisions in the Australian Market will have a digital tuner. In Australia it is estimated that around 80% of televisions sold annually are replacement televisions. For this reason not all televisions will need a STB to receive a digital signal. We are still left, however, with the potential for some 14 Million STBs being needed to fully convert all televisions in Australia to Digital.
In fact the take up of digital television has been less than impressive. To date estimated take up of DTV is about 17% of households or 1.3M STBs(6). Many models have been developed to forecast the take up. All have underlying assumptions Fig 1 shows one that was developed by one of the Authors of this paper which was presented at the 1 Watt conference in Seoul and subsequently supplied as evidence to an Australian Parliamentary committee review into the take up of DTV(3). This model forecasts the energy use of STBs under the proposed MEPS as approximately 1,000 GWh pa by 2012.

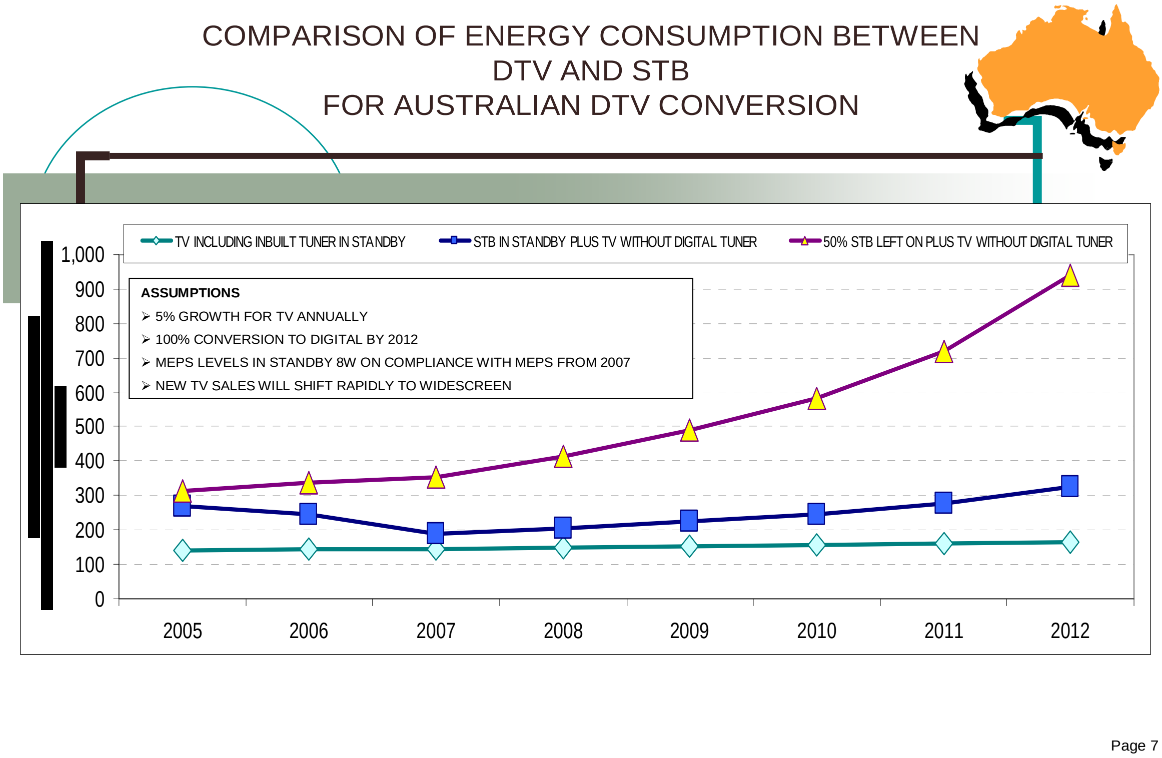

Figure 1: Energy Consumption Model for STB use due to DTV take up in Australia

An important development in the forecasting of DTV take up is the Parliamentary Committee review entitled “Digital Television: Who’s buying it” which conducted hearing late in 2005 to establish the cause of slow take up and to produce recommendations to improve the take up of DTV. This committee has released 11 recommendations that address the poor consumer proposition for DTV which in their view will allow a turn off of Analog signals by 2010. One of the recommendations is the adoption of MEPS for STBs which is a clear indication that in their view the energy consumption of STBs is an important consideration in the take up of DTV in Australia.

Set Top Box MEPS Voluntary of Mandatory

The proposed MEPS regime for STBs was to be a voluntary scheme. However, when industry was consulted there was concern raised that a voluntary scheme may not produce the outcomes that the scheme was designed for. Many suppliers reported that as a matter of cooperate policy they would comply with official standards whether it was voluntary or not. This had the potential to put them at a disadvantage compared to companies that did not have such policies. In general it was pointed out that the companies with such policies were the larger more established brand names such as Sony, Panasonic, LG and Samsung. In addition these suppliers pointed out that the structure of the market in Australia meant that there were a large number of suppliers in Australia with few having a large market share (See Fig 2).

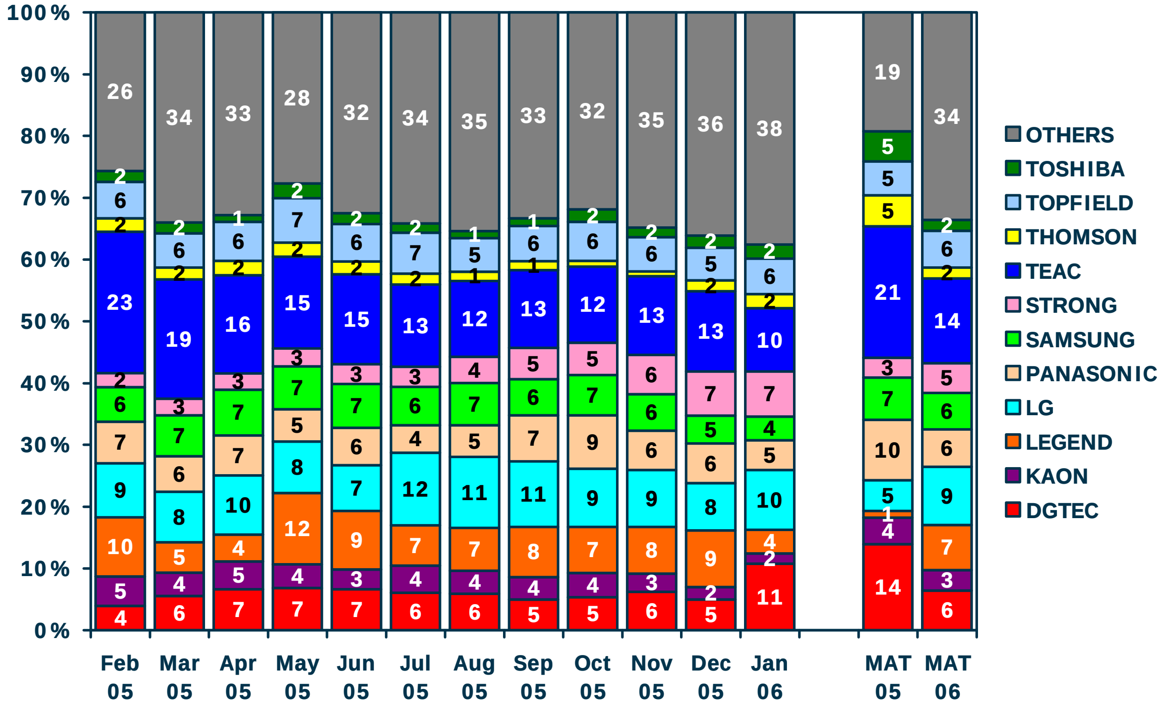

Figure 2: STB Brand shares in Australia (4)

From figure 2 it is evident that 66% of the market is supplied by 11 suppliers. The other 34% is actually supplied by at least 21 identifiable other suppliers. Many of these other suppliers, and indeed a number of the 11 larger suppliers, are in fact traders who source existing product from various OEM manufacturers. They have little input or influence into the design of the product and would have a strong propensity not to follow a policy of voluntary compliance with MEPS.
After much discussion the two main electronic industry associations (AEEMA and CESA) agreed to a mandatory regime for MEPS in order to maintain a level playing field and ensure that the desired outcomes of reducing STB energy consumption. This is not to say that industry would probably have preferred MEPS not be implemented at all. It was a position that if it were to be implemented then a fair system would have to be mandatory compliance. A similar position was also held for the yet to be developed MEPS for TV.

Set Top Box MEPS and Energy Saving

As has already been discussed a realistic figure for energy consumption for STBs even if MEPS is implemented could be as high as 1000GWh by 2012. If MEPS were not implemented, however, the situation would be considerably worse.
It is now commonly accepted that many STBs are never switched into passive standby mode. If we make the following assumptions:

- 50% of STBs are never turned off.
- 50% of STBs are used 4 hours per day
- On Power is an average of 23W (7)(Panasonic AVC Networks (Aust) 2005 Survey of STBs)
- Passive Standby is an average of 7W (Panasonic AVC Networks (Aust) 2005 Survey of STBs)
- 14 Million STBs sold to convert to Digital.

Then the annual energy consumption would be 2000GWh pa. If we introduce MEPS based around the specifications in tables 1 & 2. We can reduce this energy consumption by half (see Fig 1). If we add to the MEPS a High Energy Saving a mechanism to ensure the STBs are switched into standby when not in use the power consumption is reduced by another 70% to 300GWh pa.
It is crucial, therefore, that an effective MEPS regime is established for Australia.

Set Top Box MEPS the process for Implementation

Announcement and Consultation.
The intention to develop a MEPS regime for STBs was announced October 2004. This was followed by a period of consultation with all stakeholders.. There were several meetings held at which the scope of the STB MEPS was discussed and feedback was given by various stakeholders. When there was general agreement on the nature and scope of the STB MEPS it proceeded to the standards development phase.

Standards Development
The organization for Standards Development and Publishing in Australia is Standards Australia. Within standards Australia a Committee known as TE1 is responsible for following and where appropriate implementing the work of IEC committee TC108. Essentially TE1 is concerned with the safety of household appliances but its work has now been extended to include energy efficiency for products.
For the development of STB MEPS a working group was formed under TE1 and throughout 2005 met several times to develop and write the STB MEPS standard. This standard was then released in draft form for public comment. At the conclusion of the public comment phase a few minor editorial changes were recommended and the document was then processed for ballot.
It should be noted that some changes were made to the actual committee processes early in 2006. There was concern expressed by a number of members of TE1 that being safety regulators they may not have the appropriate expertise to examine and vote on the standard. To correct this, a constituted committee was formed under TE1 known as TE1-008. The work of the working group was transferred to this committee early in 2006. Being a constituted committee its members are able to vote on the document unlike the working group structure which relied on TE1 members for voting.

Regulatory Impact Statement (RIS)
Before any regulation can be applied to ensure the specification within the MEPS standard is met it is necessary to conduct a Regulatory Impact Study. The aim of this study is to determine the extent of the problem, what policy approaches were considered and the costs and benefits of the preferred option (typically Mandatory MEPS regulation). If the RIS is favorable then regulations will be enacted in each state of Australia to ensure product complies with the MEPS Standard.

The Technical Specification and Scope of the STB MEPS standard
The proposed regulation covers STBs suitable for free-to-air(FTA) broadcast TV and subscription (pay) TV (STV). Maximum power levels for MEPS are based on the existing requirements used by the voluntary agreement provided under the European Code of Conduct (CoC) and the mandatory requirements for digital television adapters in California. The Australian MEPS is tailored to mirror international requirements, while being moderated to address local industry technical issues. Detailed consultation was conducted with the local industry and specific requirements were developed to provide for Australian subscription TV services and high definition broadcasts.
The proposed MEPS includes requirements for passive standby, active standby and in-use modes, separate requirements for standard definition and high definition STBs as well as free-to-air and subscription TV services. The maximum power levels for MEPS are based on the power consumption of a basic platform configuration. The MEPS for a particular configuration of STB is made up of this maximum power level and an allowance for additional features. Finally, the total allowable power consumption for a STB is not to exceed a specified amount, regardless of the number and type of features that are included in the STB. The proposed regulation also includes recognition for those devices that automatically switch to passive standby after 4 hours of non-use and no user activity or that utilise a HDMI connection.

The basic requirement for energy consumption is shown in Table 1 and Table 2.

Table 1: Maximum Power Levels for Standard Definition STBs (From AC supply)

Product Type	Passive Standby – Max Power (W)	Active Standby – Max Power (W)	On mode – Max Power (W)
		MPA/MPL	MPL/MPL
Proposed Compliance Date	1 October 2007		
STB – FTA Either Option 1	1.0W	8W /15W	8W /15W
or Option 2	2.0W	7W /15W	7W /15W
STB – STV	Not applicable	9W /15W	Not applicable

Table 2: Maximum Power Levels for High Definition STBs (From AC supply)

Product Type	Passive Standby – Max Power (W)	Active Standby – Max Power (W)	On mode – Max Power (W)
		MPA/MPL	MPA/MPL
Proposed Compliance Date	1 October 2007		
STB – FTA Either Option 1	1.0W	12W /19W	15W /22W
or Option 2	2.0W	11W /19W	14W /22W
STB – STV	Not applicable	13W /19W	Not applicable

In addition to the basic allowance MPA the standard allows for additional power consumption depending on functionality. The extra allowance however must not exceed the Maximum Power Levels shown in Tables 1 & 2.
The Additional Power Allowances are shown in Table 3.

Table 3: Additional Power Consumption Allowance

Feature	Additional power consumption (Active Standby Mode)	Additional power consumption (On Mode: STB – FTA Only)
SCART Port	1.0W	1.0W
IEEE1394 interface	0.8W	0.8W
Ethernet interface 100 Mbit	0.4W	0.4W
Wireless interface	0.7W	0.7W
SPDIF port	0.1W	0.1W
Serial USB interface	0.3W	0.3W
Home automation interface	0.4W	0.4W
Broadband modem	2.0W	2.0W
Extra cable modem	0.7W	Not applicable
Extra LNB	Not applicable	Not applicable
Additional tuner	2.0W	2.0W
Powered remote IR receiver	0.25W	Not applicable

The development of Mandatory MEPS for Home Entertainment Equipment

Background

The government is considering a report that proposes a mandatory maximum standby power (5). The proposed regulation may provide potential energy savings of 1.7 GWh pa and greenhouse emission reductions of 1.7 Mt CO_2-e pa by 2020 in standby power alone. Over 4 million of these products are sold annually in Australia and the sales of home entertainment equipment are increasing rapidly. Home theatre systems, DVD players/recorders, portable and integrated sound systems are some of the products included in the broad scope of the proposed requirements. It is intended to develop a horizontal requirement for standby power that will apply to the entire group of products. In this way, emerging new product categories will be included in the coverage of the proposed regulation without the need to continually update the definitions.

Depending on the product group, maximum passive standby levels of between 4 and 6 watts are proposed by 2008 with 1 watt being required for all home entertainment products by 2012. These levels are based on international standby programs and aim eventually to meet the IEA long term target. In addition given that recording product such as DVD recorders and PDRs are emerging with Digital Tuners consideration is being given to treating these in the same way as STBs and Specifying "On Power" standards as well.

Australia's standby strategy is part of the IEA plan for standby, which encourages all member nations to address standby in a coordinated manner, and achieve a common long-term target for 2012 – "1 Watt" maximum for all low power modes. The IEA standby target however relies upon the user to switch the product off or into standby mode. Evidence from Australian surveys suggests that many products are not switched into this mode and remain in active standby for extended period of time. The proposal includes the requirement that the device automatically switches to passive standby after 30 minutes of non-use and no user activity.

Some products already include the auto power down feature as suppliers respond to the challenge set by various international and national standby programs. The impact of this requirement represents approximately 75% of the projected impacts and the benefit of auto power down will be more significant as the proliferation of such devices increases.

Why Develop Mandatory MEPS for Home Entertainment Equipment

Increasing Sales Volume

Home Theatre Equipment is a rapidly expanding product group. As the potential impact of a MEPS policy is highly dependent on the sales of the products, actual and forecast sales by product group were developed. Based on actual data from 2000 to 2004, projections were made for the various categories of equipment, as shown in Fig 3

The sales of home entertainment equipment are related, as some products replace or substitute the functions of other products, such as the decrease in VCRs which are being replaced by DVD&HD Recorders. Also, it is likely that sales of DVD Players will be plateau and decrease as both Home Theatre Systems and DVD&HD Recorders increase. In 2005, it is estimated that approximately 4 million home entertainment products will be sold in Australia.

The sales projection model does not yet consider the impact of product convergence, such as including DTV tuners in recording product. As more product emerges in this form, it is likely to impact on the sale of simple STBs. The inclusion of DTV tuners in these products will also further increase the sales of DVD recorders and Personal Video Recorders (PVR). The savings that have been predicted as a result of the STB MEPS could be diluted as more sales of STBs are substituted by PVR/DVD products were at present only standby power is considered. For this reason consideration is being given to treating recording product with a DTV tuner as a special class of product with the in-use power also subject to limits. In fact from an energy consumption view this class of product should be encouraged because it will reduce the actual number of pieces of equipment within the household that are consuming standby power.

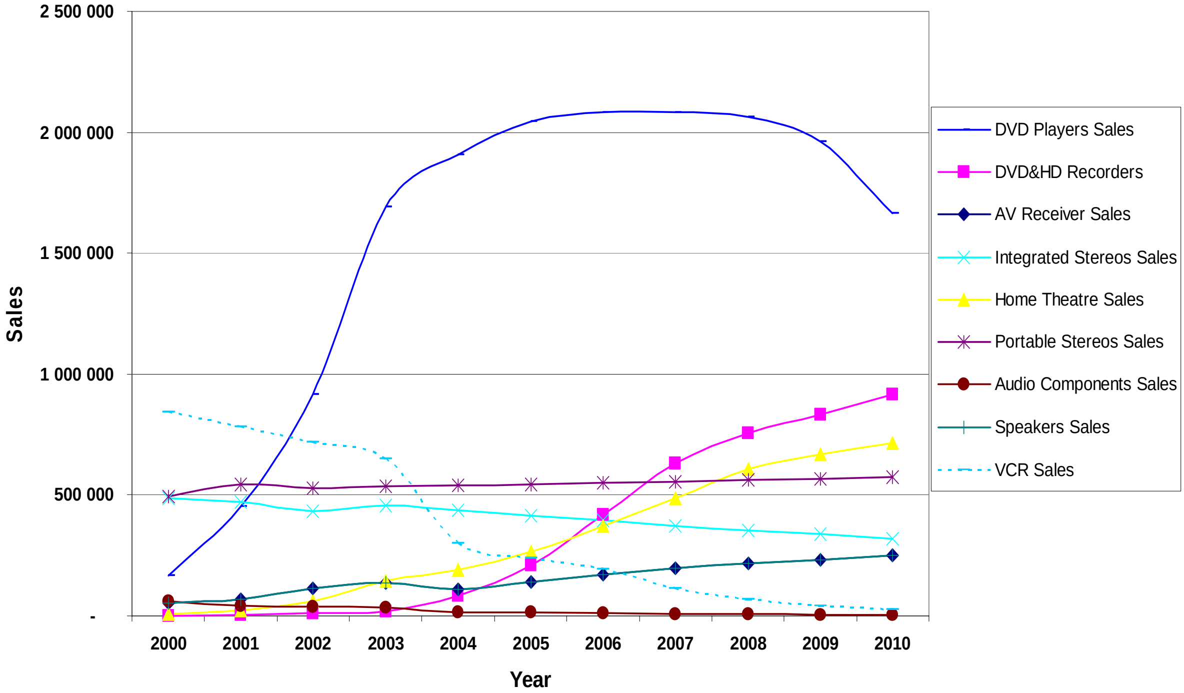

Figure 3: Annual Sales Forecast for Home Entertainment Equipment

Potential for Greenhouse Gas Reductions

By implementing MEPS on standby power for home entertainment products it has been estimated (Ref) that CO_2 emissions will be reduced by 970KT pa and 1,200 GWh of electricity will also be saved by 2020 See Fig 4 and 5. The greatest contribution to this saving is the saving associated with passive standby power. It is estimated that the contribution to the saving by standby power will be 800MWh pa by 2020.

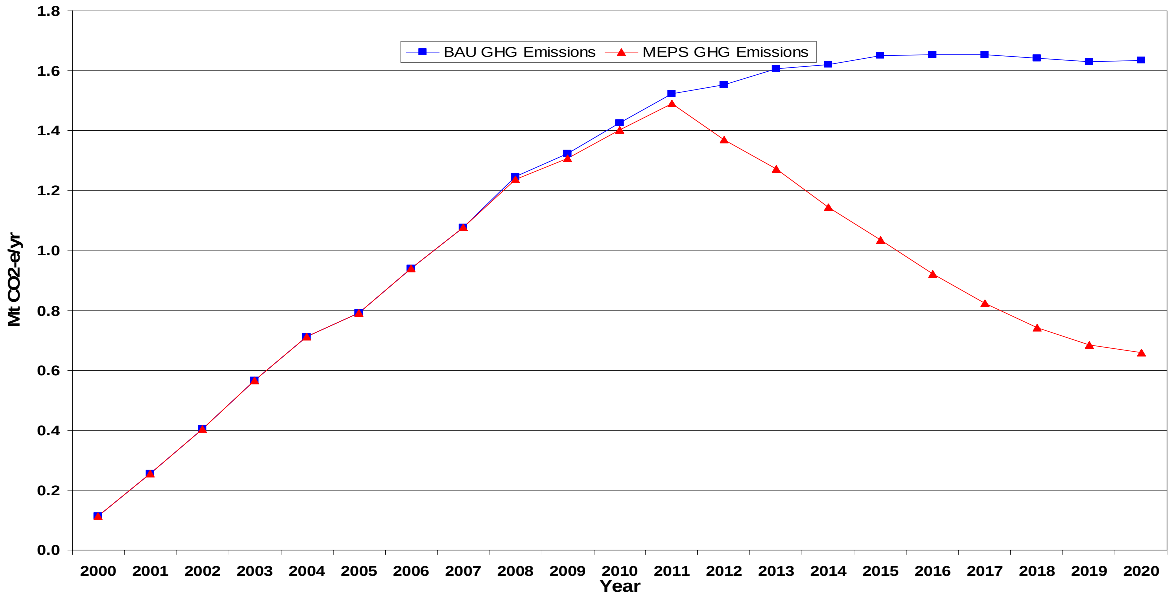

Figure 4: BAU vs. MEPS Policy – GHG Emissions for Home Entertainment Equipment

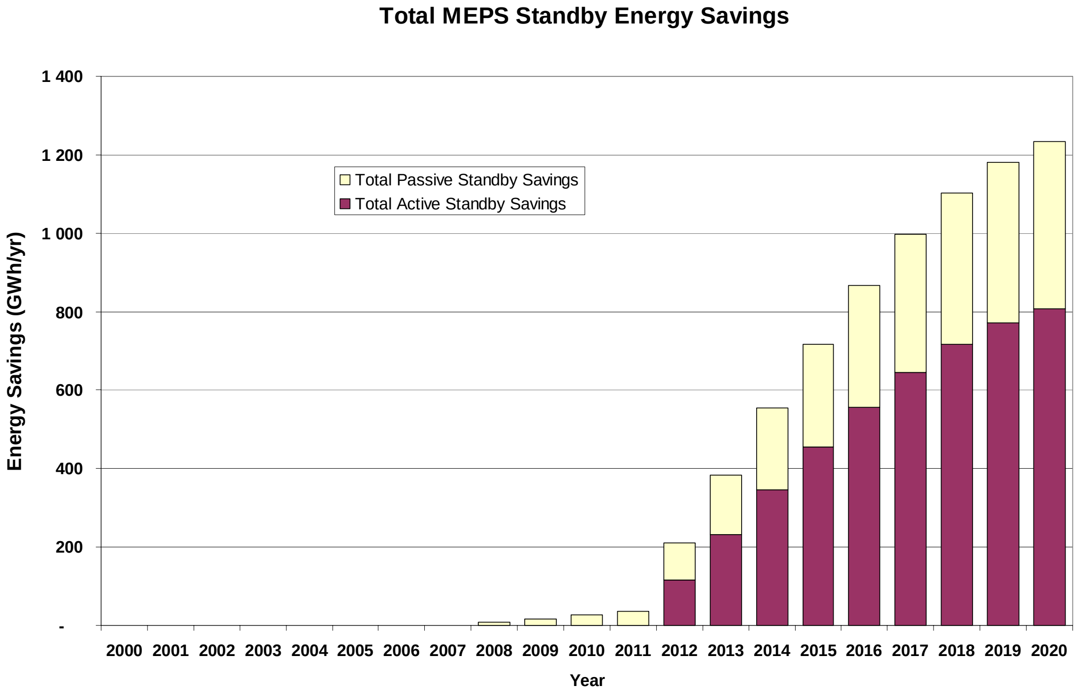

Figure 5: MEPS Potential Energy Savings by Standby Mode

The average standby power consumption by mode for these products is shown in Table 4, with significant power consumption in active standby mode.

Table 4: Summary of NAEEEC Store Survey Average Measurements 2004/05

Home Entertainment Product	*Mean Active Standby*	*Mean Passive Standby*	*Mean Off Mode*
AV Receivers	41.2	1.3	0.2
Home Theatre Systems	31.5	2.2	0.1
Integrated Stereos	18.0	4.6	2.4
Portable Stereos	6.7	2.1	1.9
Audio Components	9.0	3.0	0.0
Sub Woofers & Speakers	9.7	4.7	0.6
DVD Players	9.2	2.4	0.0
DVD Recorders	23.0	7.5	NA
Hard Disk Recorders	29.4	7.2	0.0
VCR's	7.7	2.9	NA
Total for all Hor Entertainment Products	**19.2**	**3.5**	**0.5**

Table 5: Summary of NAEEEC Store Survey Measurement Ranges 2004/05

Home Entertainment Product	*Active Standby*		*Passive Standby*		*Off Mode*	
	Max	*Min*	*Max*	*Min*	*Max*	*Min*
Av Receivers	112.3	11.1	6.4	0.2	0.7	0.0
Home Theatre Systems	55.7	12.1	18.1	0.2	0.9	0.0
Integrated Stereos	52.2	5.1	34.9	0.2	4.8	0.0
Portable Stereos	20.5	2.8	5.1	0.7	3.5	0.0
Audio Components	15.8	4.2	5.6	0.4	0.0	0.0
Sub Woofers & Speakers	20.4	0.5	17.8	0.1	10.2	0.0
DVD Players	21.5	4.4	9.8	0.1	0.0	0.0
DVD Recorders	36.5	15.9	24.4	2.8	NA	NA
Hard Disk Recorders	36.0	20.8	20.1	2.9	0.0	0.0
VCR's	11.3	6.1	6.3	1.2	NA	NA
Total for all Home Entertainment Products	***112.7***	***0.5***	***34.9***	***0.1***	***10.2***	***0.0***

These tables demonstrate a large variation in passive standby energy consumption across a range of products and within product categories. The largest differential was found to be AV receivers in active standby which varied by over 100W. When analyzed against price no relationship was found for price vs energy performance indicating that poor performers could be improved without a significant effect on cost.

It is clear from this discussion the proposed MEPS on standby power for home entertainment product is necessary given the clear proliferation of sales of these type of products. This category of product will significantly add to both the future energy requirements and Greenhouse Gas emissions.

It is also obvious from the field surveys that energy efficiency improvements can be made to product at little or no cost; and that much product already meets or exceeds the requirements imposed by the MEPS

Consistency with international trends

It is necessary when considering a MEPS regime for Australia that the requirements and levels are consistent with international thinking. It is clear that, although implementations of schemes may differ, many other countries have considered these products as having the potential to provide energy savings. The Australian MEPS regime is entirely consistent with other schemes, as shown in Table 6.

Table 6: Brief Overview of Energy Efficiency Programs

	Voluntary Programs							***Mandatory Programs***	
Program	***Energy Star***	***GEEA***	***EICTA***	***HomeSpeed***	***Nordic Swan***	***Energy Boy***	***IEA 1W***	***CEC***	***Top Runner***
Type	***Label***	***Label***	***Agreement***	***Database***	***Label***	***Label***	***Target***	***MEPS***	***Target***
AV Receivers	✓	✓	✓	✓		✓	✓		
Home Theatre Systems	✓					✓	✓		
Integrated Stereo	✓	✓	✓	✓	✓	✓	✓	✓	
Portable Stereo	✓	✓	✓	✓		✓	✓		
Stereo Components	✓	✓	✓	✓		✓	✓	✓	
Sub Woofers	✓						✓		
Speakers	✓						✓		
DVD Players	✓	✓	✓	✓	✓	✓	✓	✓	
DVD Recorders	✓	✓	✓	✓	✓		✓	✓	
Hard Disk Recorders			✓				✓	✓	
VCRs	✓	✓	✓	✓	✓	✓	✓		✓

These international programs establish a consistency in the approach Australia is taking and what other countries have done. This would indicate that the Australian requirements are achievable without any cost impact or limiting available product.

Proposed mandatory MEPS for Home Entertainment Equipment

A broad "horizontal" definition of products is proposed to be targeted by the MEPS and aim to simplify the issues associated with determining MEPS coverage. The definition proposed is based on the earlier definition, as follows:

> Commercial available consumer equipment that produces, records or assists in producing an audio or video signal/output.

Products that are specifically covered by other MEPS requirements (such as TVs and set top boxes and possibly video recording equipment with DTV tuners), would be excluded from this MEPS.

Stage 1 MEPS - 2008

The MEPS for implementation in 2008 is suggested at 4 watts for all home entertainment products without video recording capabilities and at 6 watts for those with video recording capabilities. Additionally all products with an off mode would be required to have consumption less than 0.3W.

Approximately 30% of all models surveyed in 2005 would not meet this MEPS level as demonstrated in Table 7.

Table 7: 2005 Home Entertainment Products excluded by proposed MEPS Stage 1

Product		***Passive Standby ≥4W***	***Passive Standby ≥6W***	***Off Mode ≥0.3W***
Av Receiver	No of Models	2	-	3
	% of Models	4%	-	6%
DVD Player	No of Models	18	-	0
	% of Models	27%	-	0%
Home Theatre System	No of Models	8	-	1
	% of Models	15%	-	2%
Stereo Component	No of Models	2	-	0
	% of Models	25%	-	0%
Integrated Stereo	No of Models	21	-	1
	% of Models	32%	-	1%
Portable Stereo	No of Models	2	-	6
	% of Models	10%	-	14%
Sub Woofer and Powered Speakers	No of Models	4	-	7
	% of Models	15%	-	13%
DVD Recorders	No of Models	-	17	Na1
	% of Models	-	40%	Na1
Hard Disk Recorders	No of Models	-	10	0
	% of Models	-	53%	0%
VCRs	No of Models	-	1	Na1
	% of Models	-	4%	Na1
Total of all Home Entertainment		**106**	**-**	**33**
Total % of all Home Entertainment		**29%**	**-**	**7%**

[1] No products were found with off mode

A MEPS level that removes the 30% of the least efficient models surveyed is consistent with the method used to determine the MEPS levels for other products, such as three-phase air conditioners and motors, while still somewhat consistent a significant trading partners

Stage 2 MEPS – 2012

It is anticipated that by 2012 the market would be ready to achieve a MEPS level of 1 watt or less in passive standby for home entertainment equipment. This would be consistent with the levels expected by international programs. To reduce the impact of active standby all home entertainment products would be required to power down to passive standby within 30 minutes of inactivity. Video recording equipment would be exempt from this due to the requirement for equipment to be preset for future recording. This level would currently exclude 70% of the market. However, given that the EU agreement requires manufactures to meet the 1 Watt level by 2007, it is not unrealistic to assume the Australian market will be able to adjust by 2012.

Conclusions

Australia after consultation with industry has adopted a mandatory approach to MEPS for Set Top Boxes and Home Entertainment Equipment. In the case of STBs the MEPS includes limits on both the standby and on mode operation. In the case of home entertainment the MEPS are based on standby power except for the consideration of a specification for on mode in the case of recording devices with DTV tuners.

The mandatory regime that will be imposed is with agreement with industry and will ensure a consistent and fair application of the specification.

The MEPS are considered necessary as they will result in significant reductions in CO_2 emissions any energy consumption associated with the use of this equipment.

Care has been taken to ensure that the proposed MEPS are achievable with current and emerging technology without dramatic cost or supply implications to suppliers. Indeed it has been found in the studies leading to these MEPS that equipment already exists that meets and even exceeds the limits specified.
The MEPS covers product categories that are consistent with international programs and the levels adopted are also consistent with international energy reduction programs.
The road ahead will require ongoing consultation with stakeholders to ensure these standards are implemented appropriately to provide the energy and greenhouse gas savings.

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The EU Codes of Conduct: What Have They Achieved and What are the Challenges?

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Abstract
There is no doubt that developments in digital TV and broadband communication will have a large impact on residential energy consumption if no adequate policy actions are implemented. The European Union has established a successful stakeholder forum through its Codes of Conduct for Energy Efficiency. This forum agrees on power levels for defined operating modes, and provides further guidelines, e.g. on power management, to achieve desirable efficiency levels.
Two Codes of Conduct are in operation: the Code of Conduct for Digital TV Service Systems (since 2001) and the Code of Conduct for External Power Supplies (since 2003). In 2005, the first draft of a Code of Conduct for Broadband Equipment was presented at the stakeholder forum. Together, it is projected that these Codes of Conduct will save 20 TWh per year from 2010.
This paper reports on the first results for the Codes of Conduct for Digital TV Service Systems and Power Supplies, based on data from participating manufacturers. Analysis of the data shows a considerable overall improvement in power consumption, not only in the standby modes but also in the on-mode. Furthermore, the paper shows how discussion with stakeholders based on a common road map provides guidelines for the continuous development of this innovative policy tool and leads to the efficient adoption of the new criteria required to mitigate the energy impact of the new features and functions in the product that are prompted by rapid technological development and market forces.

The Need for the Code of Conduct (CoC) Policy Tool

The market penetration and energy impact of domestic electronic products and appliances is often subject to step changes driven by new technology. Commercial secrecy about product development and marketing often makes the accurate prediction of these changes complicated, if not impossible without the direct engagement and support of the key stakeholders involved in production and marketing. This engagement is often resisted, or is subject to protracted negotiation, where mandatory policy tools such as energy labeling and minimum energy performance standards (MEPS) are introduced because perceived by manufacturers as imposed on them [2]. In addition, at least in the European context, the legislative process for MEPS and mandatory labels is rather slow, and once legislation is finally adopted it will take a while for changing it. This is why for fast changing technologies such as computers and digital set top boxes (STBs), there is a preference in Europe for voluntary approaches (Energy Star labeling for office equipment, and CoC for STB). As discussed later in the STB CoC the power level, definitions and allowances needs to be reviewed almost every year, and these specs can never be set established more than two years in advance (we do not know how technology, demand and services will evolve), and as well the specs can not last more than 2 years. This rules out the use of MEPS in the European context.
In 1997, a European Commission working group identified the digital service system STB as the domestic electronic device with the largest potential to increase the energy requirement of European households. To challenge and resolve this problem, the European Commission set up a working group of the key stakeholders in digital service system development – STB designers, STB manufacturers, component providers (e.g. Silicon[1], LNB, Tuners), service providers – and energy agency specialists. The continuous threat of introducing MEPS was a strong driver to bring key manufacturers to participate in the CoC development and in the end of sign it.

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[1] Throughout the text the authors use the term "Silicon" to describe the electronic components within the set-top box – components, since the principal functional blocks are embedded in LSI silicon chips.

Research into proposed development showed that by 2010, the STB could push domestic electronic energy consumption in the Europe Union (EU) above that of refrigerators and freezers [3]. With 150 million of these boxes across the EU - equivalent to one per household – the annual electricity requirement for digital service systems with full functionality and poor power management could be around 60 TWh (close to the total electricity consumption of Denmark for all sectors). The fast penetration will be driven by the announced phased put of the analogue signal in 2009. Generation of this electricity would also release 24 $MtCO_2$, which would have a significant impact on the EU's ability to meet its overall Kyoto CO_2 reduction target. This increased electricity consumption could be cost effectively be halved if polices and measures will be in place.
At the same time, in 1997, work also began on external power supplies, which at the time had high no load losses and very low on mode efficiency. External power supplies were predicted to penetrate the market due to many new uses (mobile computing, mobile telephones, consumer electronics, etc.). For this product, the fast technology change was not the main driver to introduce a Code of Conduct as for STBs. As with many other products in Europe there is a strong preference for voluntary and negotiated approaches to improve efficiency of end-use equipment [2]. For external power supplies the voluntary agreement approach was investigated; however, because too many different stakeholders were involved, included OEMs, it was decided to establish a Code of Conduct[2]. The savings potential for external power supplies was evaluated to be in the order of 10 TWh for the EU, to be achieved by 2010 if all external power supplies would meet the CoC.

The Basic Mechanism of the Code of Conduct Policy Tool

The new rationale of the CoC policy tool is to proactively engage stakeholders, at the earliest possible stage of a product's commercial roadmap, in a voluntary scheme, to mitigate the energy impact of the product, without stifling product development and commercial objectives. This activity has become an excellent example of a product policy initiative that has united stakeholders early enough to impact the design process *before* the product became ubiquitous.

The following stages can be identified, and they will be discussed in the next sections:

- Stage 1: Identify priority products and set up working groups
- Stage 2: Improved energy efficiency criteria and CoC roadmap
- Stage 3: Achieved outcome, agreed with stakeholders
- Stage 4: Continuous review to identify best practices

Stage 1: Identify Priority Products and Set Up Working Groups

In Stage 1 of the Code of Conduct mechanism, products with a potentially large market and high energy impact are identified by the European Commission through reports and papers prepared by expert consultants [4,2]. Products with the highest potential to impact on energy are prioritized, and approaches are made to key stakeholders to contribute, on a voluntary basis, in working group discussions on practicable options to mitigate predicted energy impacts. The membership of these working groups requires adroit planning and negotiation:

- The working group must involve the main manufacturers of a product genre. Manufacturers' representatives should be in a position to act as a conduit to senior levels of, product design and marketing.
- The interest and participation of major procurers, such as Service Providers, is essential, since their endorsement of CoC objectives has a significant influence on product manufacturers. For example, the early involvement of major procurers of external power supplies in the Power Supply and Charger CoC Working Group (mobile phone manufacturers) resulted in the fast uptake of relatively stringent criteria through the use of efficient switching power supplies.
- A balance of independent experts and industry experts (e.g. from the Silicon [3]Industry) is required to evaluate the factors qualifying product energy efficiency performance, identify best practice and define practicable criteria objectives to mitigate the energy impact of the product in the marketing roadmap. Ideally some of these experts should have involvement in related

[2] The difference between voluntary agreements, negotiated agreement and Code of Conducts in described in [2], and in a forth coming publication by the same author.
[3] Throughout the text the authors use the term "silicon" to describe the semiconductor industry components in the product – since the principal functional blocks are embedded in LSI silicon chips.

technical working groups of standards bodies and industry association, in order to ensure a common approach to product testing that supports the discussions in the CoC working group.
- Political representation is important, to ensure that both national and EU-wide energy-efficiency objectives are fully considered; to provide practical support with CoC working group research and testing commitments through national agencies; and to catalyze endorsement, procurement and fiscal support schemes for products that meet the CoC criteria.

Stage 2: Improved Energy -Efficiency Criteria and CoC Roadmap

The principal aim of a working group is to reduce the energy consumption of a product through the setting of agreed, practicable power requirement targets in a defined development timescale. To that end, a voluntary Code of Conduct is devised, and Europe's principal stakeholders in the product genre are encouraged to support the agreement.

The Signatories of the Code of Conduct[4] will make all reasonable efforts to:

- achieve the power consumption targets set for new products placed on the market after an agreed date, based on an agreed test method;
- support and contribute to the development and acceptance of new criteria based on the commercially practicable application of "best practice" technology;
- co-operate with the European Commission and Member State authorities in an annual review of the scope of the Code of Conduct and the power consumption targets for two years ahead;
- facilitate and encourage consumers to adopt energy-efficient practices in connection with the use of services involving the product;
- co-operate with the European Commission and Member States in monitoring the effectiveness of the Code of Conduct; and
- ensure that procurement specifications for related services, systems, equipment and components are compliant with the Code of Conduct.

Stage 3: Achieved Outcome, Agreed with Stakeholders

The achieved and committed objectives of the CoC in a product area are disseminated to a global audience to promote common international energy efficiency criteria for the product genre. It is important to notice that for the products covered by the two CoCs, there is a large degree of imports into the EU (almost 90% fro external power supplies), and also a large similarity with products commercialized in other economic regions. Therefore there is a strong interest to have similar energy efficiency polices and programmes in other region of the world, to assumer more compliance to the CoC levels. To this end Europe has been among the leaders in promoting STB and external power supplies polices since 1997, and to harmonization of test methods and specifications.

Stage 4. Identified Best Practice for CoC Reviews

This aspect of the CoC mechanism is of particular importance. Expert input to the CoC working group must continuously review the potential for innovation in the technology to mitigate the energy demands resulting from increased functionality in the product. On a regular basis, relevant industry and independent experts are asked to review power requirement criteria for the basic product and for the power demands of the increased functionality dictated by product marketing.

In this context, the CoC for Digital TV identified a key tool for the achievement of significant energy efficiency targets in digital service system platforms - the development of effective power management in the silicon for the principal functional blocks.

The CoC power management task force, originally formed and supported by the UK Market Transformation Programme, has created a dynamic Silicon development "roadmap" which helps to qualify future revisions of the power requirement targets in the Code of Conduct. A range of power requirements in the standby passive, standby active and on modes are assembled for each functional block or group of blocks for which power can be managed. These values, qualified by the likely uptake time of the new Silicon or hybrid component (e.g. tuner) are used to agree on the timing and value of criteria updates. The task force relies on the cooperation of platform designers and silicon suppliers in the construction and continuous updating of this roadmap of the functional blocks.

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[4] The list of the Signatories and the Codes of Conduct can be seen at the website of the EU Stand-by Initiative, the European Actions to Improve Energy Efficiency of Electrical Equipment while either Off or in Standby, at http://energyefficiency.jrc.cec.eu.int/html/standby_initiative.htm

A similar approach was also followed with manufacturers of external power supplies, where through discussions with all stakeholders the no load consumption has been dramatically reduced.

What Has Been Achieved by the Existing Codes of Conduct?

Conformance Results for the Code of Conduct for Digital TV Service Systems

The conformance of set top box products from signatories to the CoC for Digital TV service systems for the year ending December 2005 was presented to the March 2006 CoC working group. An overview of the results for 2005 shows declarations from four key signatory manufacturers. Also the data supplied by a major service provider was included. Conformance criteria for 57 products were returned. They comprised, 33 TVs with integrated receiver-decoder, 11 stand alone Satellite set top boxes, 7 stand alone Terrestrial set top boxes and 6 stand alone Cable set top boxes. 90% of these products complied with the CoC criteria. These products represent a major share of products for the vertical market (service providers specifying the box functionality to receive their services and in many cases providing the boxes to their clients), this because of the active engagement of the major service providers. In additional many other manufacturers and service providers in the EU market produce/specify products CoC compliant without having signed the CoC and/or reporting the consumption of their models.

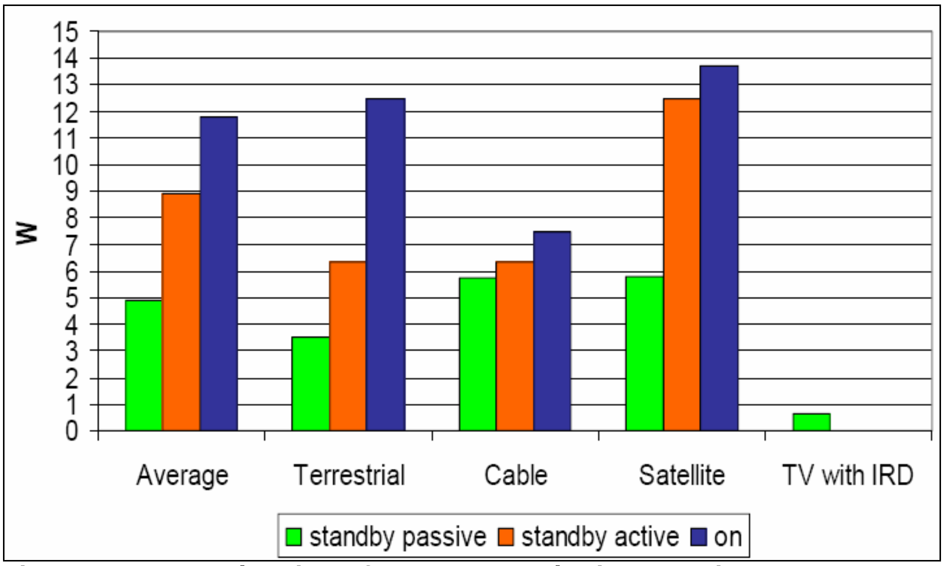

Figure 1: 2005 Declared Conformance Results (averages)

The average power requirements for the on mode and standby active mode for Terrestrial and Satellite STBs in Figure 1 show the impact of the trend toward Personal Video Recorder (PVR) functions in these products. Although the power requirement of the added functional characteristics in general meet the CoC's 15W criterion for maximum standby active power , the power management task force has prioritized actions to examine power management options for the hard disc, DVD R/W and additional tuner/decoder functions of these products to achieve a better energy efficiency in the standby active mode.

Figure 2 shows the impact of revised criteria on the energy efficiency of STBs in Europe and underlines the importance of the impact of power management in the context of a massive increase in platform functionality.

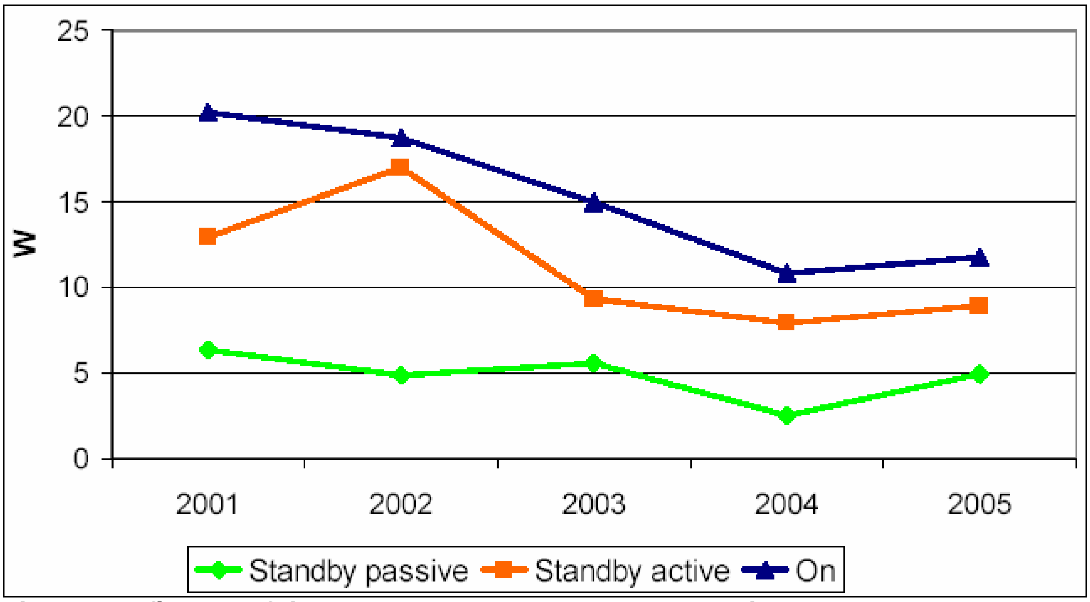

Figure 2: Influence of the CoC on Set-Top Box Power Requirement 2001-2005 (Average Power Requirement – All types STBs)

Conformance Results for the Code of Conduct for Energy Efficiency of External Power Supplies

The conformance of External Power Supplies from signatories of the CoC for the year ending December 2005 was presented to the March 2006 meeting of the working group. It should be noted that signatories to this CoC commit themselves to:

- Design power supplies or components so as to minimize energy consumption of external power supplies. Those companies who are not responsible for the production of power supplies shall include the concept of minimization of energy consumption in their purchasing procedures of power supplies.
- Achieve both the no-load power consumption and on-mode efficiency targets shown (see Tables 4 and 5) within the time schedule for at least 80% of products for Phase 1, and 90% of products for Phase 2, for the new models of external power supplies that are introduced on the market after the indicated date.

For these criteria, the on-mode efficiency is measured at 100% load (i.e. full rated output current) or declared as the simple arithmetic average of efficiency measurements made at 25%, 50%, 75% and 100% of full rated output current."

An overview of the declared results for the period ending December 31st 2005 showed that eight key signatory manufacturers reported on 130 power supply models. Of these models 92% conformed with the CoC criteria. Figures 3 and 4 below summarize the conformance details and show the number of products already meeting the next criteria phase. The coverage is very high in external power supplies for mobile telephones (the major mobile telephone manufacturers have signed the Code of Conduct and reported), and notebook computers (again major manufacturers have signed, together with major power supplies manufacturers). There are also other OEMs (mainly ITC equipment), and power supply manufacturers that participate in the stakeholder meeting, but have not signed the CoC. These manufacturers claim that they are meeting the CoC levels.

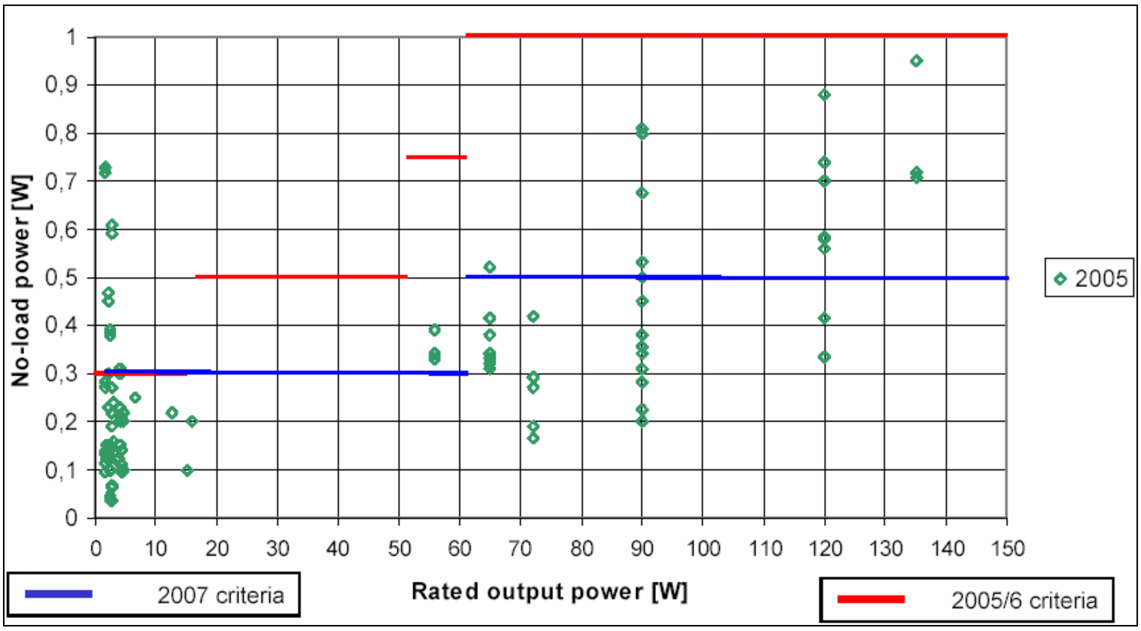

Figure 3: No Load Power Conformance

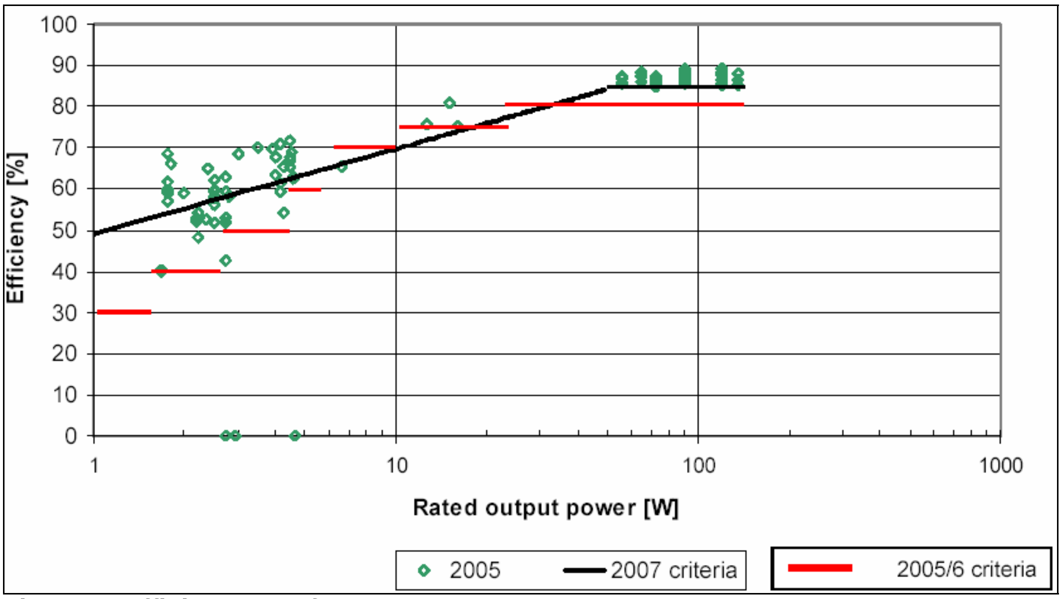

Figure 4: Efficiency Conformance

As indicated, the External Power Supplies CoC is rather successful in reducing energy consumption in mobile telephones (almost 90% of the market) and office equipment (more difficult to evaluate, estimated by the authors to be around 50%), however the CoC of conduct has been rather unsuccessful in other products categories, such as simple STB (DTAs), DECT telephones, small appliances and kitchen tools, consumer electronics.

What are the Challenges for the Existing Codes of Conduct?

The New Generation of Digital TV Reception Platforms.

New technologies are emerging for digital television in Europe particularly to service the fast developing market for high definition television (HDTV). This is likely to grow significantly in Europe from 2006 with a predicted five million homes using advanced (mainly Satellite) platforms for HDTV by 2008.
High definition requires higher data rates and new signal processing techniques. Advanced video Codecs (e.g. MPEG4) for this purpose require more power as do the tuner/demodulators for the DVB

– S2 standard for satellite HDTV signal delivery. This standard delivers a 30% increase in bit rate and has powerful error correction, but there is a power requirement penalty. This is compounded by the functional requirement of several tuner/ demodulators to allow local hard disc recording of multiple signals within the STB platform and decoding of multiple signals for distribution around the home.
The implications for power management are severe. There will be a higher overall power requirement generated by a large number of circuit blocks. The power management system will need to know the status of circuit blocks simultaneously supporting internal platform requirements and external network requirements. The management of network data streams will be complex, and remote command instructions from home network clients may mean that the box never has a standby active mode as the current CoC defines it. Intelligent "Auto-Standby functions may be needed. In satellite systems we will see multiple LNB combining units for single cable routing. These may well be separately powered and incorporate their own power management.
For the CoC, a task force has been mandated to address the issues raised by the new generation of platforms. This will not only have to address the implications on power requirement criteria limits of new functions and circuit blocks but will also have to review the relevance of the existing definitions of standby, standby active and on modes. Test set up and test methodology for these new platforms will require a radical review especially in the context of networked signals and single cable multiple LNB routing. This work will have to be completed in a relatively short time frame since one of Europe's leading Service providers, B-Sky-B has stated that 3 million UK subscribers will be using multi-room networking by 2010.

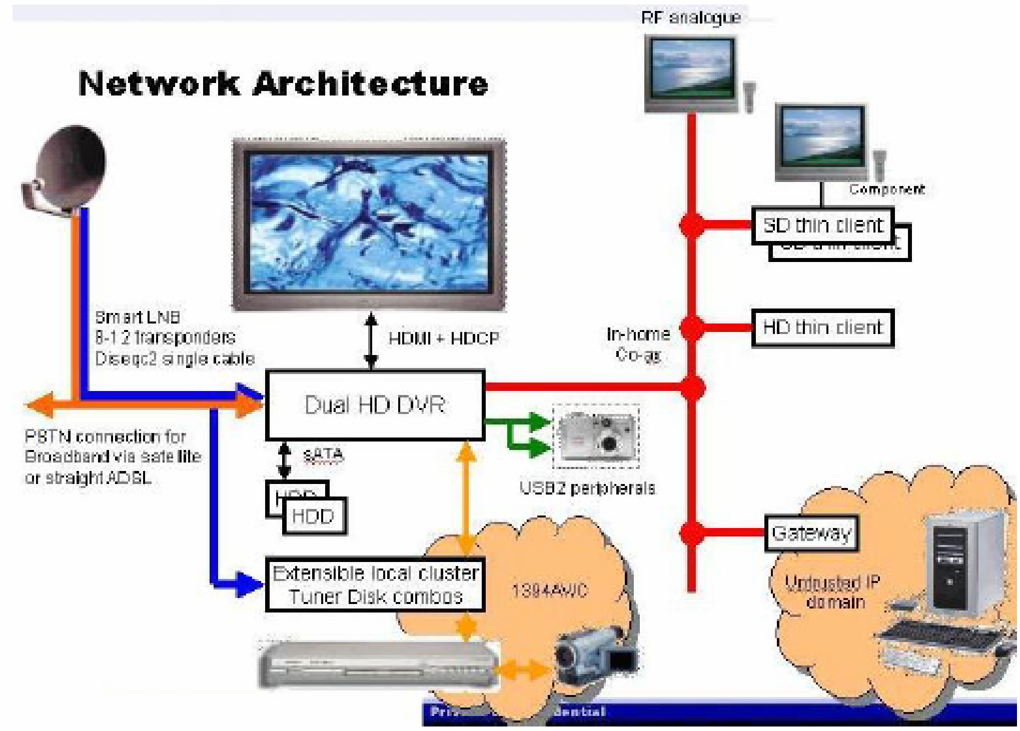

Figure 5: Network Architecture for the Next Generation of STBs *(Courtesy Pace Micro technology)*

The Challenge of Simple Digital TV Converter Boxes

It is likely that more than 200 million simple converters will be in operation in Europe, beyond 2015, to keep legacy analogue TVs and video recorders in operation in the transition to Digital TV broadcasting.
These converters will be, in the main, horizontal market products. The impact of cost competition on these products has already driven energy efficient design to an all-time low. Standby passive power requirement has moved from less than 1W in 2003 from two major manufacturers to a point where no manufacturer is currently meeting the CoC criterion of 2W. Conformance testing shows that there is a step increase in the average standby power of these products to an average level of over 6W. [5]

[5] Briefing note UK Market Tansformation Programme www.mtprog.com

Activity from CoC working group members to remedy this situation is concentrated on establishing a set of international criteria for simple converters, with the object of influencing OEM sources of the product to endorse good energy efficiency criteria. The large majority of simple converters are imported into the EU, and are manufactures by relatively known manufactures. There is in place a major efforts to try to make this manufacturers aware of the CoC specifications. Cooperation with China, the USA and Australia in this area, a very important initiative to further promote the CoC, is starting to influence production standards. But every effort must still be made by political representatives in the CoC working group to ensure that national product procurement schemes and product subsidy mechanisms endorse only the best energy efficiency standards.

Even if good standby passive performance is achieved for the majority of simple converter products in the market, the problem of mitigating their potentially massive energy impact is still not resolved. Unrelated surveys of user habits [6] show that around 60% of STBs are left on when the TV is put into standby, if another remote control or a secondary remote control operation is required. The CoC working group has discussed this problem over several meetings and has recently endorsed an elegant Auto-Standby solution proposed from the Pace Micro Technology[7]. Again every opportunity is being taken by working group members to drive this solution into an internationally accepted set of criteria for simple converters.

External Power Supplies - What are the Challenges?

Conformance testing for the CoC working group[8] has shown that the most popular external power supplies, those supplied for mobile phones, all comfortably meet CoC criteria. There are still major product groups where

Inefficient linear supplies are the norm such as DECT wireless PSTN phones, DAB Radios and of growing concern because of the spiraling volume of sales, Broadband, Modems, Switchers and Wireless routers. A priority for the political members of the working group is to convince major procurers of these products, such as supermarket chains, of the fact that CoC working group discussions show that the delivered cost at point of sale of a more efficient supply, meeting the CoC criteria, can be the same as or less than the inefficient linear alternative.[9]

A major step forward in further reducing external power supplies consumption will be the introduction of the Phase 2 levels on1.1.2007, when no lad consumption will be further reduced, and the load operation efficiency will be harmonized with the Energy Star current specifications.

In addition, both the Digital TV Service CoC and the Broadband CoC requires that products supplied with external power supplies, have models that are CoC compliant, this should further promote efficient power supplies. In additional the revised Energy Star specifications for office equipment will also require compliant external power supplies for the Energy Star labeled products.

Conclusions

The EU Codes of Conduct have served as an important platform for promoting energy efficiency in Europe. The Code of Conduct for Digital TV Service Systems has already reduced the energy consumption of STBs, even if these offer many more features and services. Now energy efficiency is among the design priorities of next-generation STBs and in the procurement specification of service providers. The full transition to digital TV and enhanced services such as HDTV and home networking will add further challenges for energy savings and climate change mitigation in the EU.

The revised Code of Conduct for Digital TV Service Systems also covers the 'simple' STBs used to convert free digital TV signals. It is hoped that the Code of Conduct will make an impact on the power demand of these devices before hundreds of millions of them are sold. Simple' STBs are now the principle target for the CoC, however if it proves too difficult to have them adequately covered by the CoC, MEPs should be introduced as soon as possible. The new European Directive on Eco Design (also known as EuP) offers an excellent platform for adopting effective MEPS. The only concerns is the

6 BSkyB 2003, UK Consumers' Association 2000

7 Presentation Ken Dale 30th Nov 2005 STB CoC meeting Draft Proposal for an Auto Standby Standard for STB http://energyefficiency.jrc.cec.eu.int/html/standby_initiative.htm

8 Presentation Bob Harrison 25th May 2005 Power Supply CoC meeting UK MTP Conformance testing overview. http://energyefficiency.jrc.cec.eu.int/html/standby_initiative.htm

9 Presentation Ben Sutherland Power Integrations at the CoC Power supply meeting: http://energyefficiency.jrc.cec.eu.int/html/standby_initiative.htm

time requested to arrive to have MEPS in force, and the ambitiousness of the MEPS levels. For more traditional and technological stable products, imported in large quantities such as external power supplies and simple STBs, in the authors' view MEPS will be a more appropriate policy tool for achieving savings. In any case, the experience made so far with the external power supplies CoC has been useful to show that efficient power supplies could be used also with mass market end-use products (e.g. mobile telephone), and that cost-effective technologies exist to meet challenging efficiency requirements (even with linear technologies).
Last but not least, given the success of the Codes of Conduct in creating a useful stakeholder forum and in achieving concrete results in a very dynamic technological sector, the European Commission and national experts have prepared a new Code of Conduct to reduce energy demand in broadband equipment for the residential sector. This activity has raised an interesting expansion of the CoC to influence energy-efficiency standards in the Broadband Service Provider network exchanges and road boxes, where savings in power at the subscriber interface will drive large savings in cooling power.

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The Need for a New Television Power Measurement Standard Based on Average Picture Levels (Apls) due to the Emergence of New Technologies Including LCD and Plasma

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Abstract

Television technology has changed over the last few years with the introduction of new technologies such as Plasma and LCD technologies. In addition, particularly in developed nations, there has been a strong shift in the screen sizes of televisions purchased toward larger screens.

This paper reviews this trend and the applicability of a number of standards that have been developed to measure the power of televisions. A new approach to the measurement of television power is discussed using the notion of Average Picture Level (APL) as an important component of the test signal applied to televisions in order to better simulate the signals that are actually applied to televisions and the resulting video that is displayed.

It is hoped that this contribution will lead to a new standard that is applicable to all television technologies and reflects a fair and real life use and resulting energy consumption of television.

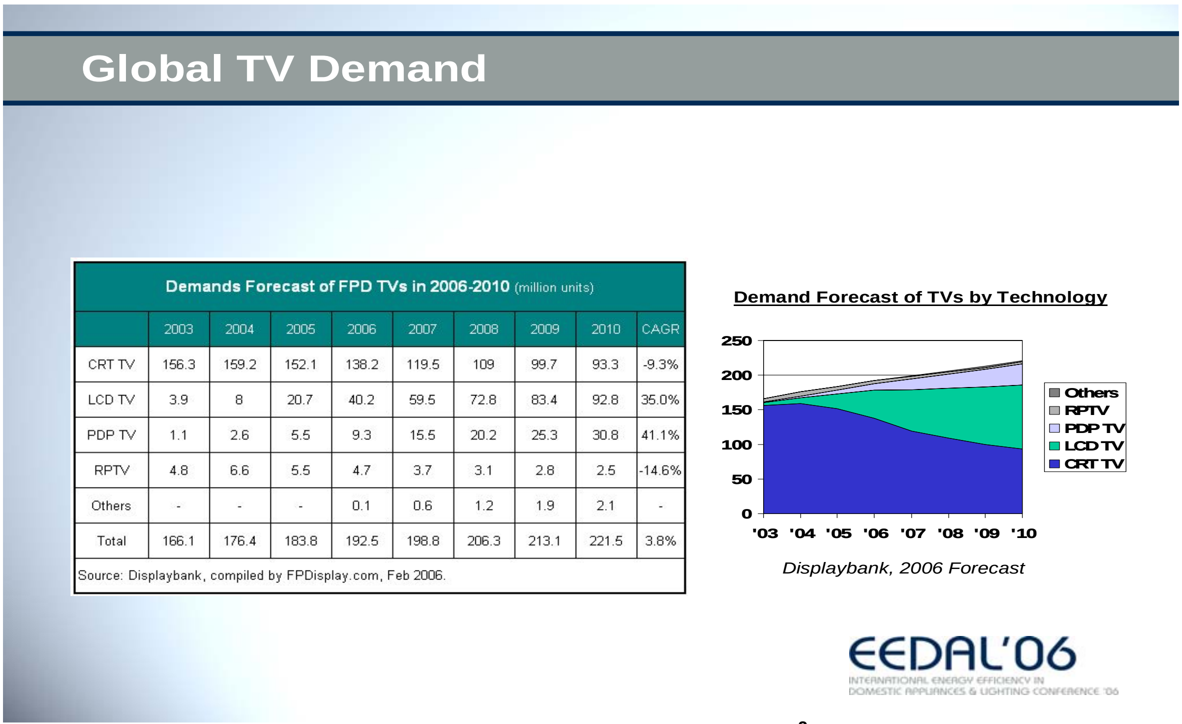
Background

Over the last several years there has been much discussion at many forums as to the inadequacy of current test methods for the power consumption of Televisions. In 2005 Dr Larry Weber delivered a paper[1] in San Francisco that highlighted the inadequacy of current test patterns to correctly simulate the Average Picture Levels (APLs) that are inherent in the video signals being displayed on TV display devices.

Recently the work on characterizing APLs and the power consumption characteristics that differing display type exhibit as a result of APL level has been continued in Australia, UK and the USA. This paper presents the result of this effort and proposes a way forward. Also included in this report is a comparison of the APL method as opposed to the JEITA method.

The need for a new method

Over the last several years television technology has seen the emergence of Plasma and LCD technologies which are rapidly replacing CRT technologies in developed countries and will become the dominant technologies over the coming years (Fig1 and 2). As these technologies are suited to larger screen sizes and as the market particularly in developed countries moves toward larger screen sizes there will be a resultant increase in energy consumption. To asses the impact of this power consumption and to establish programs to ensure efficient use of these products an accurate real life use measurement of power consumption will be required.

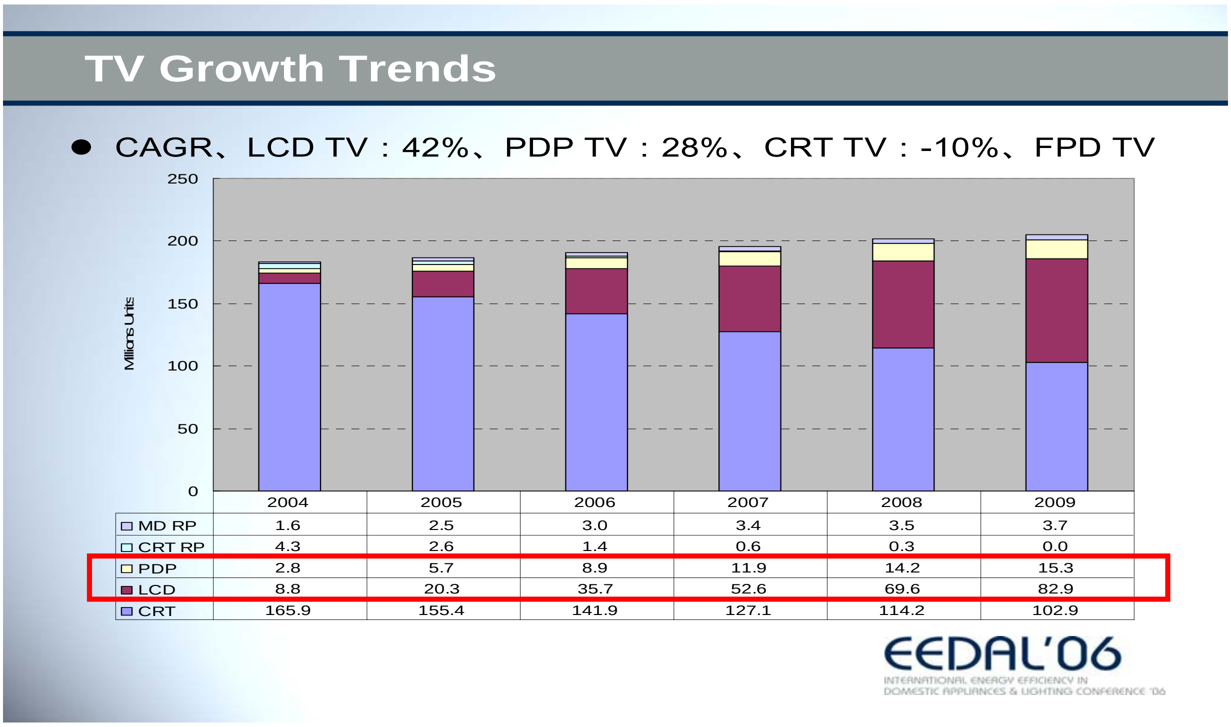


Demands Forecast of FPD TVs in 2006-2010 (million units)

	2003	2004	2005	2006	2007	2008	2009	2010	CAGR
CRT TV	156.3	159.2	152.1	138.2	119.5	109	99.7	93.3	-9.3%
LCD TV	3.9	8	20.7	40.2	59.5	72.8	83.4	92.8	35.0%
PDP TV	1.1	2.6	5.5	9.3	15.5	20.2	25.3	30.8	41.1%
RPTV	4.8	6.6	5.5	4.7	3.7	3.1	2.8	2.5	-14.6%
Others	-	-	-	0.1	0.6	1.2	1.9	2.1	-
Total	166.1	176.4	183.8	192.5	198.8	206.3	213.1	221.5	3.8%

Source: Displaybank, compiled by FPDisplay.com, Feb 2006.

Figure 1: Global TV demand and migration to LCD and Plasma [2]



	2004	2005	2006	2007	2008	2009
MD RP	1.6	2.5	3.0	3.4	3.5	3.7
CRT RP	4.3	2.6	1.4	0.6	0.3	0.0
PDP	2.8	5.7	8.9	11.9	14.2	15.3
LCD	8.8	20.3	35.7	52.6	69.6	82.9
CRT	165.9	155.4	141.9	127.1	114.2	102.9

Figure 2: Growth of Plasma and LCD Technologies [3]

Figure 3 shows the estimated global power consumption for 2005 and the contributions made from each technology type.

Estimated Global Power Consumption 2005

	Sales 2005	Screen Size	Power Rating	Annual GWh
CRT	155400000	51	70	22546.60
LCD	20300000	66	130	5168.13
PDP	5700000	106	300	3219.57
Rear Pro	5200000	120	180	1798.36
Total	186600000			32732.65

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Figure 3: Estimated Global Power Consumption 2005 [3]

Objectives of a New Test Method

Given the proliferation of display technologies, and the differing nature of their power consumption characteristics, the primary objective of any new test method must be to develop a test methodology that provides realistic power consumption measurements for all display types under real world use conditions. The test method should be a simple as possible to administer.
In addition to the power consumption associated with the pictures being displayed the test method must also consider the contribution to power consumption of the following factors:

- Audio
- Digital Tuners
- Standby Power
- Energy Saving Features and Settings

Lastly, the new test method must have some way to handle TVs with other devices built in such as DVD recorders etc.
This report demonstrates that a method that meets the above requirement is indeed possible and could be developed relatively quickly.

Results of the APL sampling survey from Australia, USA and the UK

APLs have been collected from a variety of sources over the last several months. The objective of the survey was to gain a better understanding of the nature of the APLs inherent in the video that is then displayed on a display device. To ensure that representative APLs were being sampled it was proposed to ensure that a wide variety of program material was sampled over the main platforms of Terrestrial, Satellite and Cable.
Three aggregated sample sets are shown in Figure 4. They represent 80 samples from NSW in Australia being a mix of Digital Terrestrial and Satellite. There were 27 samples from Victoria in Australia being a mix of Analog and Digital Terrestrial and DVD. There are 8 samples from the USA being a mix of Cable, Satellite and DVD.

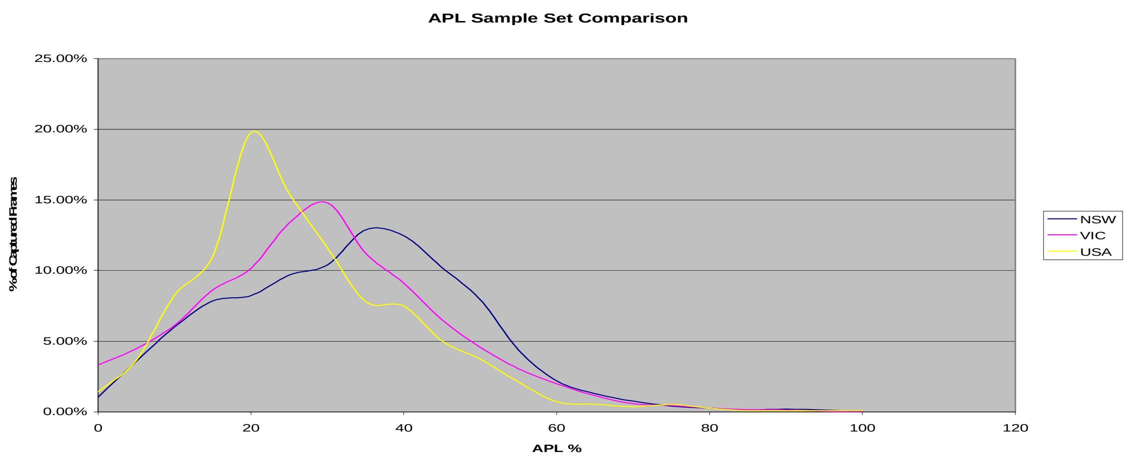


Figure 4: APLs sampled from Australia and USA [4]

From a TV power consumption point of view the most important trend that is evident is that only 10% of APLs exist above a level of 55% brightness. The three curves do vary a little. Analysis shows that the NSW samples had a larger number of sporting content than the other two samples and this content was captured in either bright conditions or under lights. The APL distributions (See Appendix 1) demonstrate a higher average for these types of content. This has the tendency to pull the average of the aggregate higher. In addition the other two samples had more Movie APLs captured. The profile of the Movie APLs is darker than many of the other APLs (See Appendix 1) captured and would have pulled down the Aggregate average of those samples. This is also evident from the percentage of APLs below 15% brightness. For the NSW sample this was 10% for the Victorian and USA samples it was 22.5% and 24.3% respectively.
The NSW sample has been analysed for this trend and is shown in Figure 5. The other samples are very similar.
Independent of the category the important point still remains that few APLs exist above 55% brightness and the effect of category is merely the shifting of the APL distribution higher or lower in the bottom half of the capture range.
On last comment on the APLs captured. The APLs are shown as non Gamma corrected. CRT TVs will Gamma correct due to the characteristic of the picture tube. As has been discussed previously this is indeed where the Gamma factor came from as it was decided at the onset of TV broadcasting that it was easier to compensate for the response of the CRT display in the camera rather than every television. A question needs to be asked as to whether Gamma in its own right plays any part in the power consumption of the differing display technologies. This paper contends that any TV or display device will exhibit a power consumption dependent upon an input signal level. What any particular TV does to that signal to account for display characteristics does not change the eventual power consumption outcome and therefore does not need to be considered.

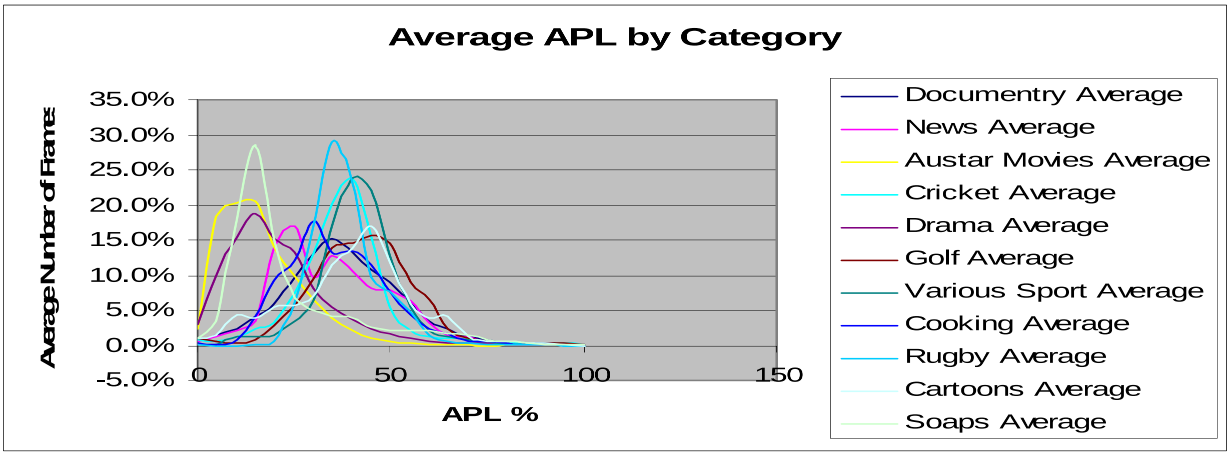


Figure 5: NSW Australia average APL by category [4]

In fact, as will be shown when the power consumption characteristics of differing display types is reviewed, there is evidence of quite complicated processing of the video signal to enhance the picture quality which are not consistent with pure Gamma correction.

Power Consumption Characteristics of Display Technologies

Along with understanding the nature of APLs to understand the power consumption of TVs it is necessary to analyse how the TV consume power. In order to do this a test sequence of 20 APL levels in 5% increments from 0% - 100% was developed. This test sequence of patterns was then applied to a variety of TV display types and for each type a number of samples were measured. For the purposes of this study the actual models and brands will not be named.
The TV types measured were Plasma, CRT and LCD. The results are shown in Figures 6,7, and 8.

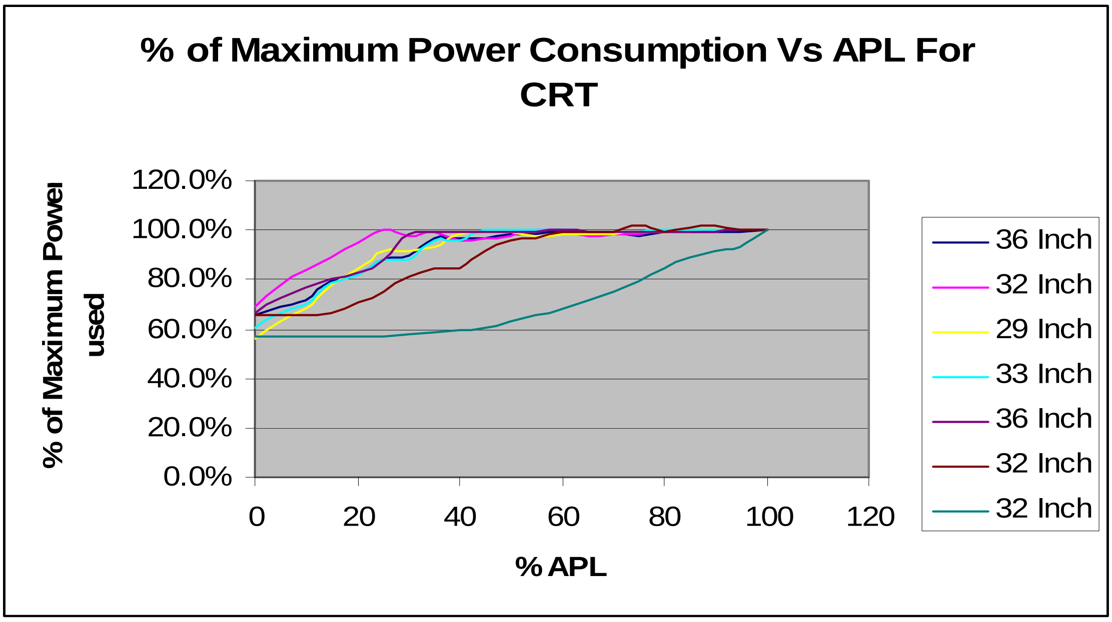


Figure 6: [4] Per Cent of Maximum Power Consumption vs APL for CRT

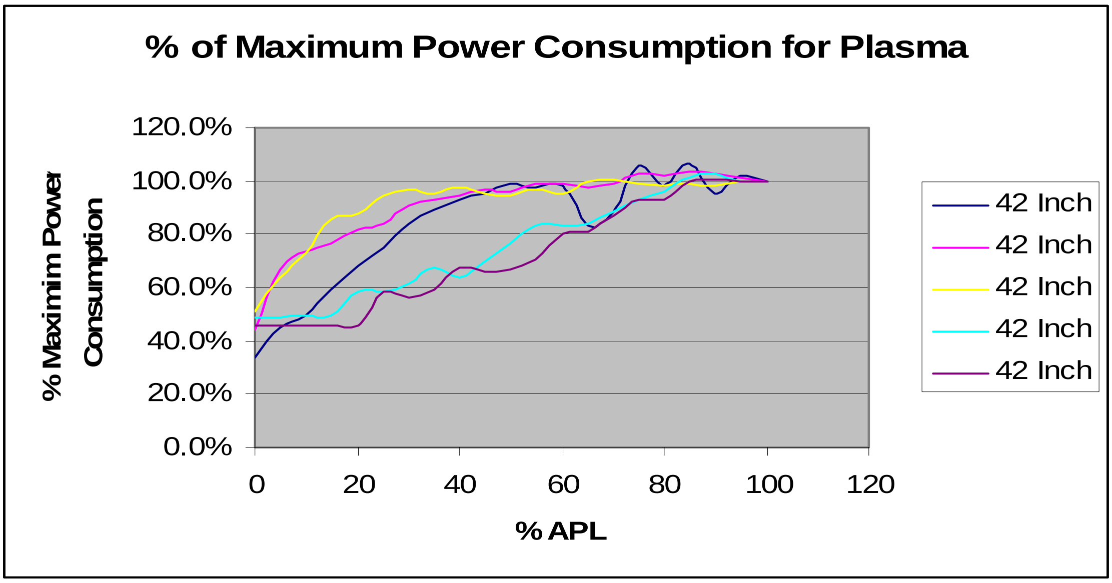


Figure 7: [4] Per Cent of Maximum Power Consumption vs APL for Plasma

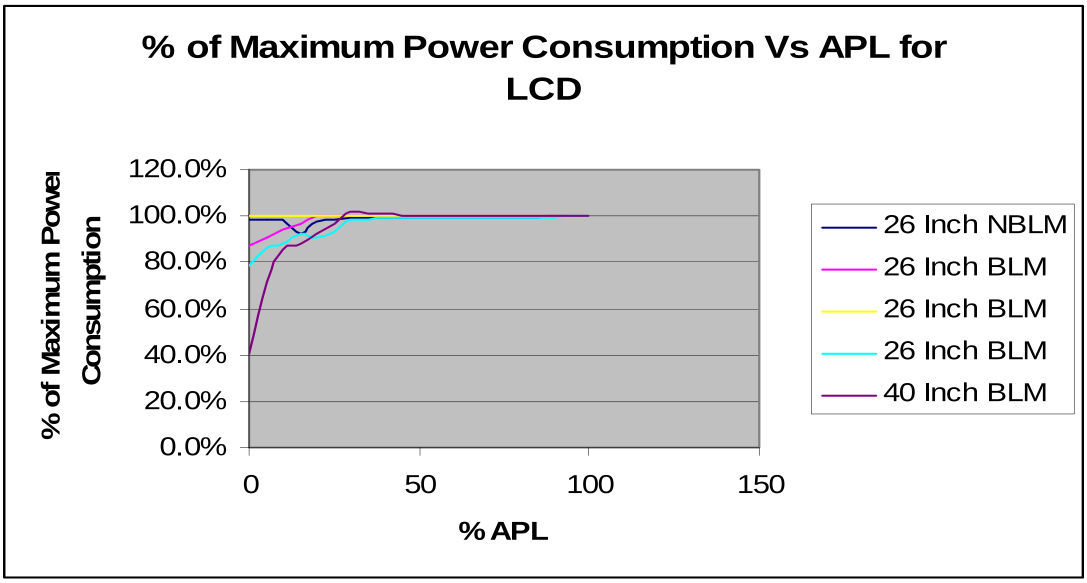


Figure 8: [4] Per Cent of Maximum Power Consumption vs APL for LCD

What is evident from these results is that with the exception of a few TVs the tendency is for maximum power consumption to be achieved before 50% APL levels. The exceptions also exhibit high power consumption (Between 60% and 80%). The reason for this is associated with the operation of what is known as Automatic Brightness Limiting (ABL) in CRT and Plasma technology and Back Light Modulation (BLM) in LCD technology.

ABL is applied so as to ensure that CRTs and Plasma panels are not overdriven thus causing the potential for damage and/or reducing the potential life of the product. It acts to limit the brightness of the display and thus caps the power consumed.

BLM is almost the reverse. LCDs suffer from relatively low contrast ratios. This is caused by black level bleed where the crystals cannot shut out all the light at low black levels so for these levels of black they appear grey. To over come this problem, designs have been introduced recently where the APL is continually monitored and when conditions are right and the picture is darker the backlight is reduced to give an apparent improvement in black level. This has the effect of reducing power for those levels of black. The effect of this is seen in Figure 8. Not all LCDs displays have this feature and for those that don't, because the backlight is no all the time, there is no variation in power consumption against APL level.

Review Of JEITA and IEC 62087

For the purposes of this paper only the On Mode power measurement method of the JEITA and IEC 62087 will be considered. In doing this it is not implied that other aspects of the power consumption for TVs are not important. However, by limiting the discussion at this point only to the On Mode it will be easier to assess the effect each method has on the final measurement.

IEC 62087

IEC 62087[5] uses a three bar black and white pattern for the measurement of ON Mode Power. This pattern has an APL of 50%. As has already been discussed, from the power consumption characteristics of most display types, TVs at this APL level will show a power consumption of 100% of maximum. This pattern therefore, in effect, will give the same power measurement as a 100% APL white raster in most cases. Given that the TVs are actually showing pictures with APLs below 50% ninety percent of the time the suitability of this test pattern must be questioned. This is reflected with the IEC currently in the process of forming a working group to look at this issue.

JEITA

The other standard of interest is the JEITA[6] standard. This uses four patterns. 0% Black, 100% White Raster, three bar Black and White and Colour bars both with an APL level of 50%. The results of these measurements are then averaged according to the formula:

$$((Pw+Pb)/2 + Pc + Pt)/3$$

Where:

Pw is Power Measured with 100% white
Pb is Power Measured with 0% Black
Pc is Power Measured with Colour Bars
Pt is Power Measured with Three Bars

This method would be more accurate because it is at least considering power consumption at black level which would effectively reduce the measured power. However, across all our APL samples the highest 0% APL frame count was 3.3%. The other two being 1.0% and 1.4%. In light of this the validity of using a 0% pattern and giving it an effective weighting of 16.75% in the calculation would have to be challenged.
The same could be argued for the 100% white raster although given the figure that 10% of APLs are greater than 55% and that almost all the TVs sampled did consume 100% of their maximum at that level it is indeed a closer representative figure.
The method becomes more distorted when we consider the Colour Bars and the Three Bars. These have an APL of 50% which means most TVs are at or close to full power and their weighting is 66.6% of the calculation. When in fact at best case less than 20% APLs from our sample reach this level.
In summary then the JEITA method gives effectively a weighting of 83.25% to 100% power consumption when in fact less than 20% of pictures reach this level and 16.75% weighting to the power consumed at 0% APL when from our analysis less than 3% of pictures are at this level.

Conclusion
The conclusion is that due to the nature of TV video signals and their APLs and the power consumption characteristics that neither the existing IEC62087 or the JEITA adequately measure TV power consumption in a way that reflects real word use. To be relevant the new test method must take into account the real world APLs. Power consumption of most TVs varies over a similar range of APLs that actually make up the pictures displayed so to measure power realistically the video used for the measurement must also have APLs that exist in the 0%-50% region.

A proposed Test Methodology

This proposal is not to be taken as anything more than a discussion point. It has some validity, but, suffers from a relatively isolated development by a small group of individuals. Test methods need to be flushed out properly with all stakeholders and in the appropriate forums. It is offered, however, as an example to establish that a test method based on APL measurements can be developed and can potentially produce better results than the existing methods.
It also needs to be noted that the results of this work are simulated and not actual measurements. The simulation is achieved by using the Power Consumption Characteristic curves from the TVs sampled. As these curves were produced by actual measurements against the APLs it would be expected that actual measurements would confirm the results. This must be done as further work.
The two biggest challenges in developing a test method based on APLs are:

- Establish an appropriate profile for the representative viewed APLs or a good estimate
- Establish the actual video signal that represents that APL profile. It is possible to use normal moving pictures that have been selected to replicate the APL profile. It is also possible to produce a series of test patterns with fixed and moving segments that can also replicate the APL profile.

APL Profiles

To create an appropriate APL profile the first step is to understand the differing distributions that different content produces (see Figure 5). Simply aggregating these APLs with equal weighting for each content type is not going to guarantee the average viewer profile. This will certainly be subject to more research.
For the purposes of this report the author profiled his own weekly watching habits which provided the following breakdown. This is not implying a typical viewer but is intended a starting point to develop the test method.

Table 1: Author's TV viewing for an average week

Content	Weekly Hrs	%
Sport	10	23%
Movies	4	9%
News	12	27%
Drama	12	27%
Documentary	6	14%
Total	44	100%

By applying this weighting to the collected APLs the following profile was generated (Figure 9).

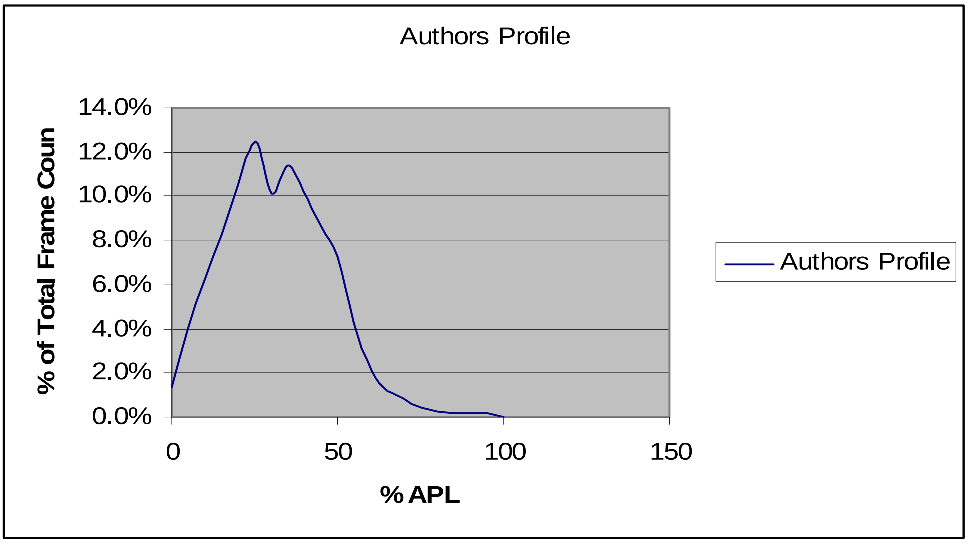


Figure 9: Author's APL viewing profile

This was then used as the basis to model the power consumption of the various TVs that had been measured for the Power vs APL response.

Estimated APL profile Approach

By considering the nature of the distribution of the APL, only 10% of APLs are more than 55% brightness. We also know that of the remaining APLs, very few occur below 15% and the majority fall between 15% and 55%. From this a simple profile has been developed that distributes the APLs as follows:

Table 2: Estimated simple APL approach

APL Level	Weighting
5%	10%
15%	10%
20%	10%
25%	10%
30%	10%
35%	10%
40%	10%
45%	10%
50%	10%
100%	10%

The idea behind this approach is to see if a simpler method may suffice rather than trying to resolve the more complex issues of what is actually watched.

Test Simulation
Using the two APL profiles outlined above and the representative APLs for both the JEITA and IEC62087 test patterns, the power consumption for ON Mode has been simulated and the results are shown in Table 3.

Table 3: Simulated Power consumption – Comparison of methods

Model	Authors Profile	Simple APL	% Variation	JEITA	% Variation	IEC62087	% Variation
Plasma 42 Inch	184	192	104.4%	217	117.5%	210	114.0%
Plasma 42 Inch	209	216	103.3%	250	119.6%	250	119.7%
Plasma 42 Inch	270	274	101.7%	300	111.0%	336	124.5%
Plasma 42 Inch	317	318	100.3%	307	97.1%	330	104.2%
Plasma 42 Inch	300	302	100.6%	303	100.8%	330	109.9%
LCD 40 Inch	182	181	99.9%	172	94.5%	191	105.2%
LCD 26 Inch	117	117	99.9%	116	99.1%	118	101.2%
LCD 26 Inch	105	106	100.4%	106	100.6%	110	104.6%
CRT 32 Inch	109	110	101.1%	123	113.3%	129	118.7%
CRT 29 Inch	107	108	100.6%	111	103.4%	119	111.1%
CRT 33 Inch	150	151	100.6%	157	105.0%	169	112.7%
CRT 32 Inch	68	72	105.4%	78	114.5%	72	105.9%
CRT 32 Inch	129	128	99.9%	126	97.9%	132	102.7%
CRT 36 Inch	165	166	100.6%	173	104.5%	182	110.1%
CRT 36 Inch	252	253	100.4%	259	102.7%	274	108.7%

The Power figures are in watts. The % variation is against the Authors Profile. We find that the correlation between the Authors profile and the Simple APL is very close with no more than a 4.4% variation and 9 of the TVs within 1%.
The JEITA method as expected does not give such a good result with a maximum deviation of 19.6% and only 2 TVs within 1%.
The current IEC62087 is the worse with a maximum deviation of 24.5% and no TVs within 1%.

Simple Profile and Test Video

If it can be shown that the simple profile is sufficiently representative of normal viewing profiles using such criteria as the variation in measurement and it greatly simplifies the creation of a test signal. The APL levels are not hard to replicate and the actual test patterns can contain moving objects that better simulate a moving picture. Also the technique is really an extension of existing methods with the additional patterns within the APL ranges that the sampling has shown video signals to contain. This does offer a potentially easier route to adoption.

Validation of Results and Further Work

The simulated results will need to be validated with actual power measurements. In addition a wider range of TVs should be sampled to confirm the existing pool of data on the power consumption characteristics.
At the beginning of the paper other factors of power consumption within TVs will need to be considered. Some methodology for this exists within the existing standards and may well be suitable for use. Others will have to be developed such as how energy saving modes are considered. An important aspect of this is careful consideration of the differing modes of operation between Off Mode, Passive Standby through to On Mode. The impact of Audio should also be considered although recent work[8] may suggest that the impact of this on overall power consumption is minimal.
Much work still needs to be done both on validating this work and consideration of other aspects of TV power consumption. It is hoped however that this work can form the basis for a wider discussion process with all stakeholder and at the appropriate forums.

References

[1] L. Weber. *Challenge of Measuring Annual Energy Consumption of TV Sets*. New Paltze New York.

[2] Jon Fairhurst. Sharp Cooperation USA 2006

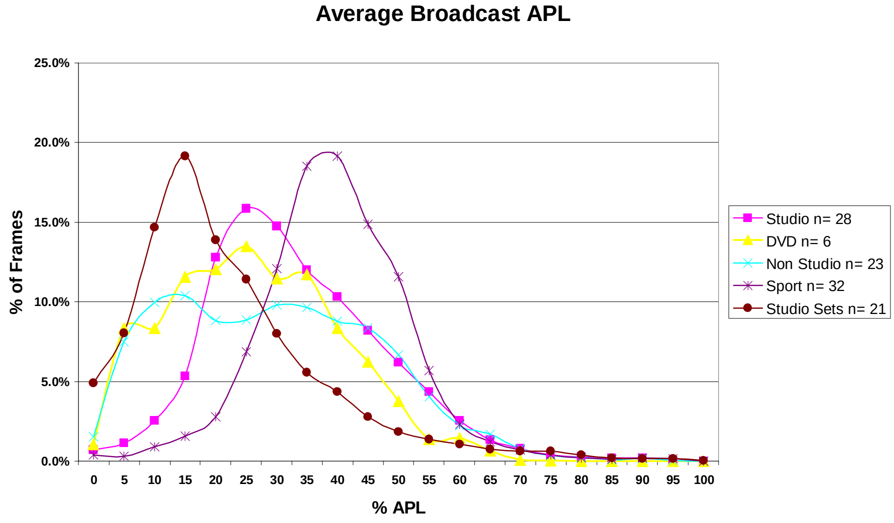
[3] K. Jones. Digital CEnergy Australia 2006

[4] K. Jones. Digital CEnergy Australia 2006, Study on the nature of APLs and TV power consumption Characteristics.

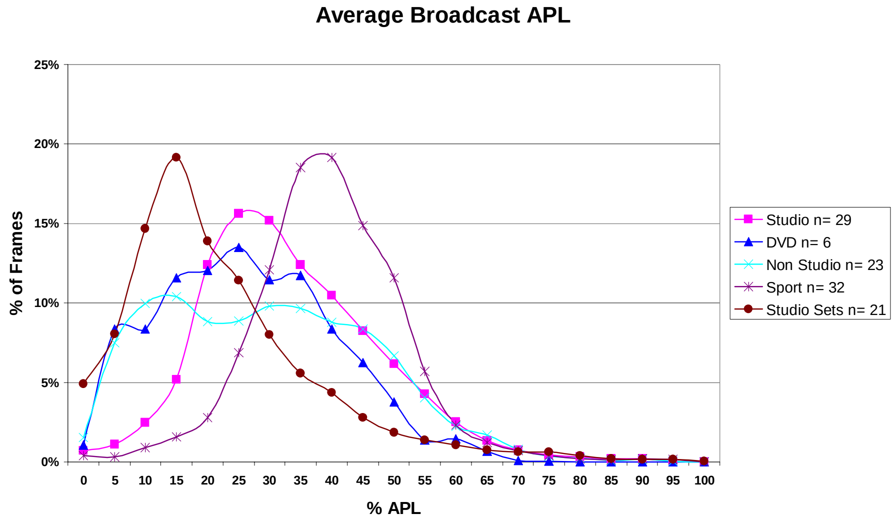
[5] IEC 62087 2002

[6] JEITA PDP05-B05-16

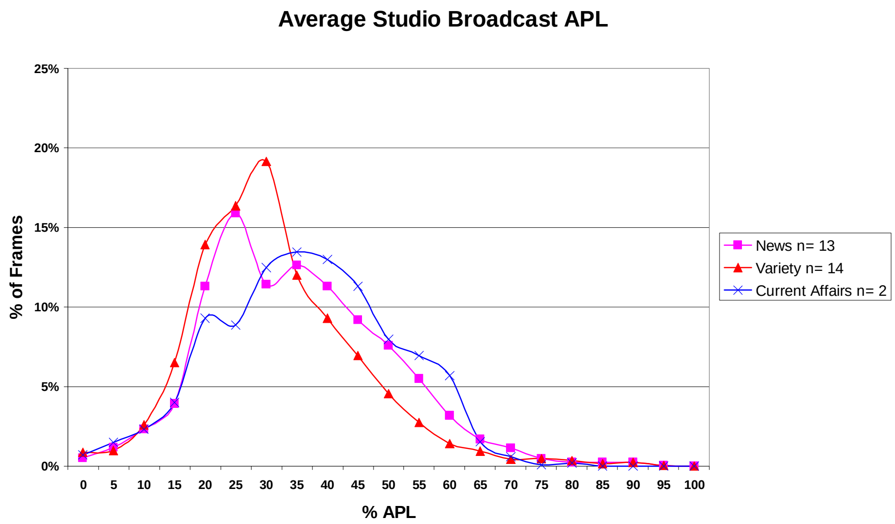
Appendix 1
APL by differing Sampled Categories and Conditions



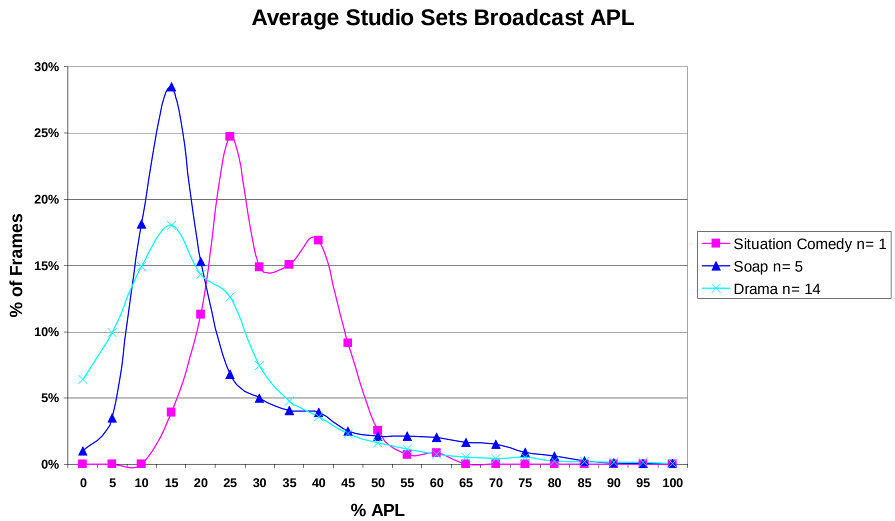
Category	*Sample*	*<20%*	*20 to 50%*	*>50%*
Studio	28	9.7%	73.9%	16.3%
DVD	6	29.3%	63.3%	7.4%
Non Studio	23	29.4%	54.3%	16.3%
Sport	32	3.2%	74.3%	22.5%
Studio Sets	21	46.8%	46.0%	7.2%



Category	*Sample*	*<20%*	*20 to 50%*	*>50%*
Studio	29	9.4%	74.4%	16.2%
DVD	6	29.3%	63.3%	7.4%
Non Studio	23	29.4%	54.3%	16.3%
Sport	32	3.2%	74.3%	22.5%
Studio Sets	21	46.8%	46.0%	7.2%

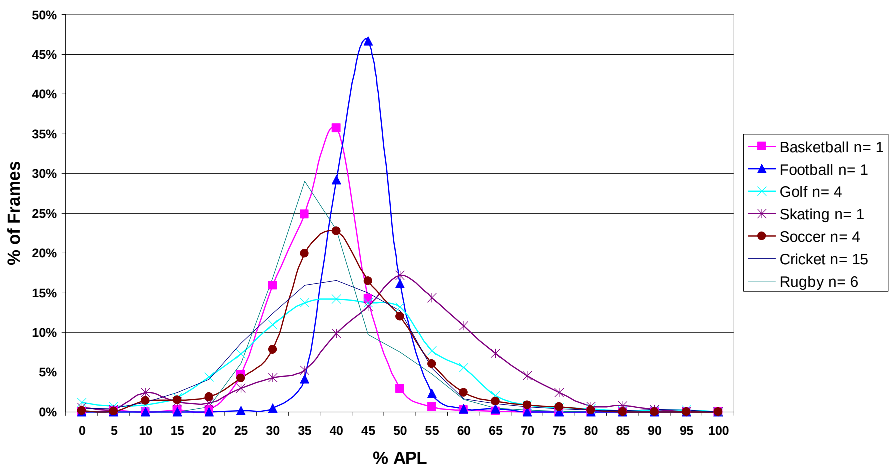


Category	Sample	<20%	20 to 50%	>50%
News	13	8.0%	71.7%	20.3%
Variety	14	10.9%	77.7%	11.4%
Current Affairs	2	8.5%	68.4%	23.0%



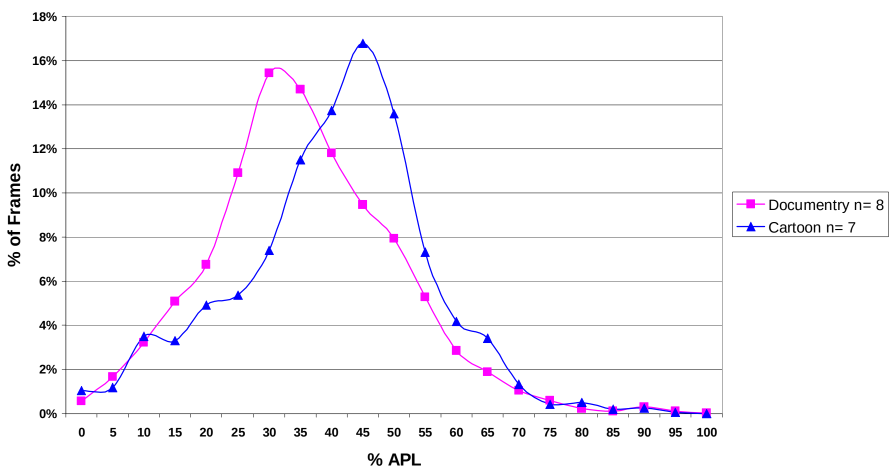
Category	Sample	<20%	20 to 50%	>50%
Situation Comedy	1	3.9%	92.0%	4.1%
Soap	5	51.1%	37.6%	11.3%
Drama	14	49.3%	45.0%	5.7%

Average Sport Broadcast APL



Category	*Sample*	*<20%*	*20 to 50%*	*>50%*
Basketball	1	0.4%	95.8%	3.8%
Football	1	0.0%	80.7%	19.3%
Golf	4	4.6%	64.4%	31.0%
Skating	1	4.6%	36.8%	58.6%
Soccer	4	3.2%	73.2%	23.6%
Cricket	15	4.5%	72.6%	22.9%
Rugby	6	0.0%	85.3%	14.6%

Average Non-Studio Broadcast APL



Category	*Sample*	*<20%*	*20 to 50%*	*>50%*
Documentary	8	10.6%	69.0%	20.4%
Cartoon	7	9.0%	59.7%	31.3%

An Approach to the Environmental Analysis of the Eco-design of Television Devices

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Abstract
In 2004/05 AEA Technology plc conducted a project for the EC Joint Research Centre's Institute for Prospective and Technological Studies which aimed to provide a reference for the potential application of eco-design in the consumer electronics sector through a case study dedicated to television devices, taking into consideration both current and future designs. The definition of television devices for the project covered current and future screen designs, and considered the trends towards deconstruction and convergence.
The study assessed environmental impacts by TV screen design technology, both current and future. It identified:

- The main environmental impacts of televisions
- Performance indicators selected to enable their application to other consumer electronic products, and indeed other electrical appliances in a generic way.
- How these performance indicators are influenced by TV design.
- Market sales distribution trends and performance indicator variations by TV design
- Alternatives for benchmarking.
- Priorities for eco-design options, and policy options to achieve these improvements.

The project examined the environmental impacts throughout the lifecycle of televisions, including energy, material resources and hazardous content.
It developed a set of micro and macro performance indicators for greenhouse gas and resource impacts, and used these to evaluate performance of a variety of screen designs including CRT, plasma, LCD, OLED and Field Emissive Display types.
Using market data and assumptions about future trends in the EU market, the study quantified the impacts for alternative technologies and eco-design potential over a period to 2020.

Evaluating the Environmental Impacts

The project assessed the environmental impacts, aspects and product characteristics which are applicable to existing TV designs using cathode ray tube (CRT), liquid crystal display (LCD) and plasma display (PDP) technologies from 29 sources of analysis including LCA, eco-label and environmental related studies available in the public domain, and concluded that life-cycle impacts are dominated by energy in the in-use phase (in-use accounts for 80% of energy consumption according to Reference no. 1, Bang & Olufssen). TVs share this characteristic with other products that are long-lived, frequently used and consume electricity in operation. Depending on a TV's use pattern, operation accounts for the major share of the energy consumed in-use (as opposed to stand-by consumption).
However, in the search for indicators which allow description of the relevant product characteristics and environmental aspects in a measurable and comparable way, it was the aim to define indicators which have a broad application to other consumer electronic products.
Although energy consumed in the use-phase of a TV is generally considered to have by far the largest environmental impact with the current dominant TV technology (CRT display TV), there is a danger in isolating this impact and, furthermore, there is an obvious difficulty in comparing different kinds of environmental impacts. Lifecycle energy (i.e. that associated with production, use and recycling) but also virgin resource depletion and the use of hazardous substances have to be taken into account and included if these indicators are to influence and meaningfully compare the eco-design of developing and new TV display technologies. Likewise, a system of indicators for the TVs as well as for other consumer electronic products must consider or reflect a product's entire life cycle.

A list of indicators which were been considered for consumer electronics products is shown below, thus including three groups, energy, resources and hazardous substances. These indicators were at a later stage filtered to highlight the most important ones for television design.

Energy Indicators

- Material production (kg CO_2 per product)
- Electronic part production (kg CO_2 per product)
- Display device material production (kg CO_2 per product)
- Production – finished product (kg CO_2 per product)
- In-use power consumption – function of standby power + on-mode power + duty cycle (kg CO_2 per product)
- Product transportation (kg CO_2 per product)
- Consumable materials (kg CO_2 used in the manufacture rationalised to single product)
- End of life products transportation (kg CO_2 per product)
- Recycle / disposal operations (kg CO_2 per product)

The unit "kg CO_2 per product" was later replaced by maybe the more straightforward "energy consumption in kWh".

Resource Indicators

- Recovered resources (by content weight in kg), meaning reused components and re-cycled materials which are obtained from re-processed components and materials used at least once.
- Recoverable resources (by content weight in kg), implying resources which has been used at least once in the TV-product and can be used in other products/processes.
- Disposed resources (by content weight in kg).
- Newly supplied resources (by content weight in kg).

For each of these categories, the materials of which they are composed will also be indicators, e.g. glass, copper, flame-retarded plastics, silicon etc.

Hazardous Substances Indicators

- Phosphors
- Lead in solder
- Lead
- Mercury
- Flame retardant Tetra-bromo-bis-phenyl A (TBBPA)
- Flame-retardant Poly-brominated diphenyl ethers (PBDE)
- Flame-retardant Poly-brominated biphenyls (PBB)
- Hexa-valent chromium
- Cadmium
- Poly-vinyl chloride
- Bismuth

It was important that the suggested indicators were robust enough to be used for other domestic electronics products (used peripherally with the TV) as well. The tables below show how the suggested indicators for energy and resources are relevant for other products. Similarly, all but mercury and phosphors in the list for hazardous substances will apply to the indicated products.

Indicator	Product			
	Surround Sound System	**DVD & Hard Disc (Player/Recorder)**	**Games Machine**	**Set Top Box**
Material production	✓	✓ **Includes DVD medium**	✓ **Includes DVD or Silicon software medium**	✓
Electronic part production	✓	✓	✓	✓
Production of finished product	✓	✓	✓	✓
In-Use power consumption	✓	✓	✓	✓
Consumable materials production	✓	✓	✓	✓
Product transportation	✓	✓	✓	✓
End-of-life Product transportation	✓	✓	✓	✓
Recycling and Disposal operations	✓	✓	✓	✓
Others not related to TV product	**None**	**none**	**none**	**none**
Display Device component production and assembly	**n/a**	**n/a**	**n/a**	**n/a**

Micro Indicators for Resource Factor

Indicator	Product			
	Surround sound System	**DVD & Hard Disc (Player/Recorder)**	**Games Machine**	**Set Top Box**
Recovered Resources	✓	✓	✓	✓
Recoverable Resources	✓	✓	✓	✓
Disposed of Resources	✓	✓	✓	✓
Newly Supplied Resources	✓	✓	✓	✓
Others not related to TV product	**none**	**none**	**none**	**none**

Benchmarking the Product

The study detailed the different methodologies for comparing the impact of technology improvements, and finally opted for a factor system approach. This system has been adopted by many major global industries in recent years as an effective Eco indicator tool that incorporates not only environmental aspects but also attempts to add the products value to the community in terms of its lifetime and functions. The factor system was developed by considering three issues separately: prevention of global warming, effective utilization of resources and use of non-toxic materials. Factors are calculated for each of the three areas and, thus, a transparent system is created where different impacts and causes for impacts are kept separated. As shown below, an environmental factor is calculated by comparing the product being evaluated with a reference product. The environmental factor is not a composite index including the impact of all the three areas mentioned above. Instead, three different environmental factors are proposed, each of them covering one of the three areas but including the environmental impact over the whole lifecycle. In that sense, the environmental factor is a compound value.

Environmental Factor	=	Eco-Efficiency of the (new) Evaluated Product
		Eco-efficiency of the Base (reference) Product

Thus, the comparison is being made through eco-efficiencies, which are individual for the three separate areas i.e. energy used, resource efficiency and use of hazardous substances. The eco-efficiencies combine the product's value to the community in terms of lifetime and functions (i.e. it is taken into account if the product functions only as a TV or also as a PC, a DVD etc.) with its environmental impact (by summing up the indicators presented previously) in each area. The approach does not place any value of the use of the devices, it merely incorporates possible multiple functions of a product, so that e.g. a device with multiple functions but with higher energy use than a device with only one function is not treated unfairly in the comparison of products. The general formula is shown below and the environmental impact (as well as the unit used) would change depending on if the eco-efficiency is calculated for energy use, resource efficiency or the use of hazardous substances.

Eco - Efficiency	=	Product life x Number of product functions
		Environmental Impact

Or

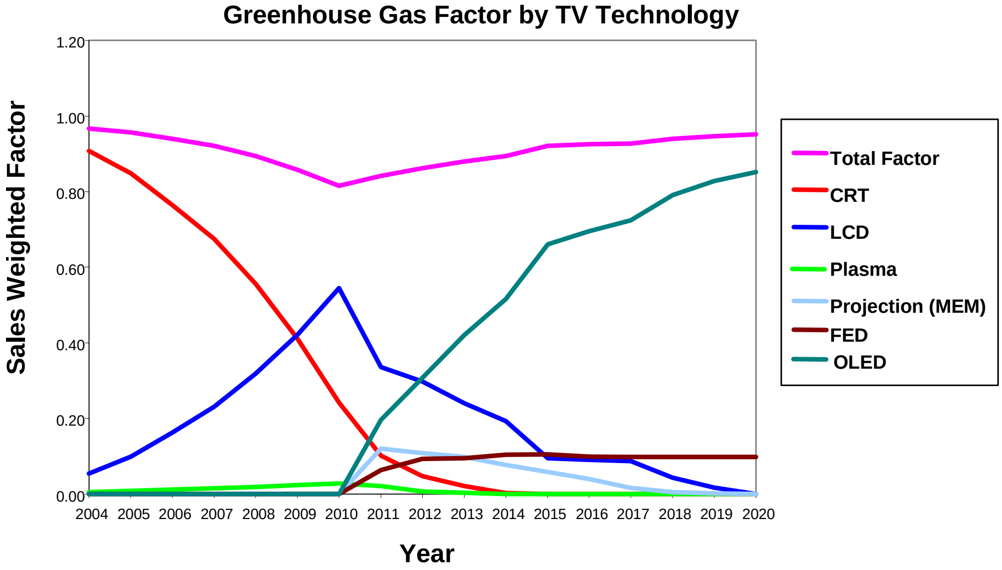
GHG efficiency	=	Product life x Number of product functions
		Lifecycle GHG emission

Resource efficiency	=	Product life x Number of product functions	=
		[Newly supplied resources + Resources disposed of]	
		(i.e. resources that do not re-circulate into the product over its entire lifecycle)	

=	Product life x Number of product functions
	(Used resources – Recovered resources) + (Used resources – Recoverable resources)

Forecasted Environmental Performance

The factor system can furthermore be used to illustrate forecasted environmental performance. As it is considered important that such illustration is adequate for benchmarking as well as for the prioritisation of environmental indicators for those products that will have the greatest overall environmental impact, the study has opted to include a sales weighting element. In this approach, individual technology trends are multiplied with each technology's proportion of the (sales) market at a given point in time and, thus, the method shows the contribution of each technology to the overall performance of the sector. This allows the technologies that will have the greatest current and future impact to be identified and priorities set accordingly. As an example, the figure below shows the sales weighted trend of the greenhouse gas factor (GHG) for each technology as well as a trend for the "total" factor. The trends are derived by multiplying the calculated GHG factor for each screen technology with forecasted sales.



Sales weighted trend of the greenhouse gas factor per screen technology

Establishing The Base Case

Through close co-operation with EICTA, the European trade association for consumer electronics appliance manufacturers, the project was able to obtain environmental data from a variety of sources such as manufacturers stated in-use energy consumption, partial bills-of-material, and partial Life Cycle Analysis (LCA) results. However, very few complete LCAs are available in the public domain and it was necessary to expand the review to capture computer monitor LCAs (there being little difference between screen technologies for TVs and computers) as well as eco-labels.

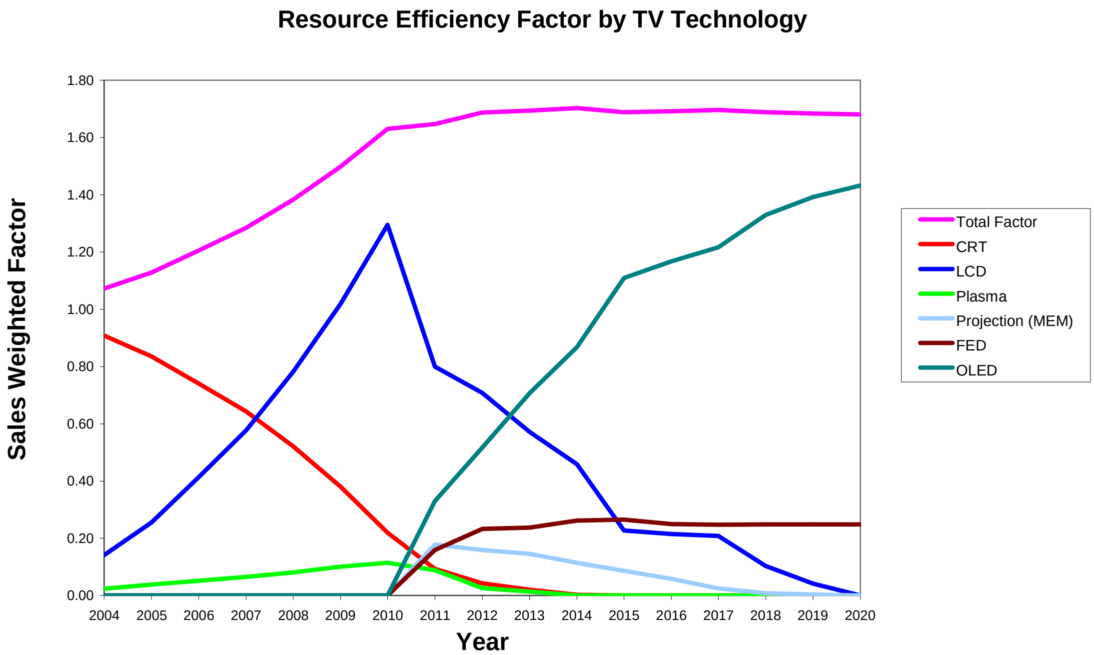
Moreover, any available information covers mostly the CRT technology and throughout the project it was necessary to resolve partial data sets together in order to derive a composite representative of non-CRT technologies. For the yet to emerge OLED and FED screens, the project used anecdotal evidence, industry evidence, and media reported claims of energy and resource usage to estimate their eventual impact.

Once materials and energy data had been obtained, the factor system allowed the comparison of different technologies against an established benchmark:

GHG factor (energy factor)	=	GHG efficiency of the evaluated TV
		GHG efficiency of a base (reference) TV

Resource factor	=	Resource efficiency of the evaluated TV
		Resource efficiency of a base (reference) TV

As the dominant technology is CRT it was chosen as the reference TV and allowed the relative impacts of the emerging technologies to be assessed. The following graph shows the projection obtained for resource efficiency.



Assessing Design Improvements

From discussions with manufacturers as well as using market intelligence, a number of potential improvements to the design of televisions which could result in a reduced environmental impact were identified. The table below shows a small selection of the 16 improvements which were identified:

	Screen Technology	Primary 'Area of Effect' (GHG/RE/HSF)	Innovation		Earliest Introduction	Date Effective (100% of sales)	Quantified Saving/ Improvement
1	LCD	GHG	CFL/Discharge Backlighting Replaced by 'super-bright' LEDs	Primary Secondary	2006	2010	380W to 250W (On) 70W to 47W (On)
	LCD	HSF		Primary Secondary	2006	2010	45 mg Mercury 23 mg Mercury
	MEM	GHG		Primary	2006	2010	195W to 125W
2	Plasma	GHG	Energy Recovery Circuitry Incorporated Plus Additional Effect of LSI		Current	2008	410W to 310W (On) 410W to 260W (On)
3	All	RE	Magnesium Alloy Casings (fewer barriers to recycling)	Primary	2006	2008	10kg material can be recycled that currently is not
4	All	RE	Metal Sintered Plastics in Casings	Primary	?	?	10kg material can be recycled that currently is not

For the above design measures for which an impact can be quantified, it is possible to calculate new values for GHG and resource efficiencies and, consequently, their respective factors. When sales weighting is applied, the resultant impact of each potential improvement on the EU fleet can be derived. In this way, the design improvements which have the most significant impact at a market level can be assessed and prioritised. For example, the following table illustrates that although the incorporation of energy recovery circuitry in plasma screens (example 5) produces a significant GHG efficiency improvement in that product, this improvement is minimal at the EU level in the long term due to the relatively low penetration of plasma technology into the EU market. Whereas innovation policy might have centred on such measures in the past, this system of assessment allows policy makers to focus on those measures which will achieve the best overall impact.

		Efficiency Improve-ment	Factor Improve-ment	2010 Improve-ment in 'Fleet Factor'	2015 Improve-ment in 'Fleet Factor'
	GHG Measures				
1	Current Laptop Technology (buck regulator) Designed into PSU in OLED	0.4443	0.0100	0.0000	0.2345
2	CFL/Discharge Backlighting Replaced by 'Super-bright' LEDs in MEMs	0.3403	0.0076	0.0000	0.0151
3	Development of Improved OLED Screens	0.1707	0.0038	0.0000	0.0532
4	CFL/Discharge Backlighting Replaced by 'super-bright' LEDs in LCDs	0.4321	0.0022	0.3130	0.0551
5	Energy Recovery Circuitry Incorporated into Plasma (Pus LSI)	0.0841	0.0019	0.0042	0.0000
6	Rectangular Deflexion Coils in CRTs	0.0009	0.0009	0.00	0.00
	Resource Efficiency Measures				
7	Metal Sintered Plastics/Magnesium Alloy Casings	0.0320	0.0036	0.0297	0.0382
8	Rectangular Deflexion Coils in CRTs	-0.0172	-0.0012	-0.0037	0.0000
9	Reduced CRT Glass Envelope Profile	0.0729	0.0050	0.0160	0.0000

Using performance factors to set overall fleet-based benchmarks

If the factors for each model is multiplied with its share of sales or forecasted share of sales, one gets a good view of where the most important environmental impacts are and where they will be. Sales could be the entire TV product output of all manufacturers – the EU ‘fleet’ - and would cover the blend of different technologies, or could be applied to the sales of a particular manufacturer, group of manufacturers or design technology. In this way, benchmarks can be established for the whole EU fleet or for certain manufacturers or products. This allows the consideration and negotiation of benchmarks, agreements and policy with both individual manufacturers or as a collective through a representative body. Establishing an EU fleet benchmark for the “average TV”, gives manufacturers the flexibility to allocate varying benchmarks among themselves, which would not hamper innovation.

This approach has the flexibility to accommodate new technologies entering the market. As long as the overall benchmarks are not exceeded, manufacturers are free to bring new products onto the market. However, projecting a benchmark for future years presents a rolling target for manufacturers that ensures that the market constantly moves forward.

Although the fleet factor method offers significant advantages over alternatives such as simple minimum environmental performance standards, there are complexities involved in its introduction. For example, the adoption of a common LCA tool must be resolved with manufacturers.

Compatibility with other EuP Methodologies

The flexibility of the fleet factor method means that it could readily support, or be supported by, the methodology and tool developed by VHK as part of a separate EuP Pre-preparatory study. In fact, these seemingly different approaches might compliment each other very well, with the 'factor' approach being used to set overall policy and the VHK tool helping to calculate product factors based on manufacturers inputted data. An 'interfacing' tool could easily be created which could allow manufacturers to securely input their product bills of materials and sales figures, and the software could then automatically calculate their fleet factor, set future benchmarks, and provide instant impact data to policy makers.

Conclusion

The methodology of a sales-weighted fleet factor allows manufacturers flexibility across their range of TV products/technologies - and as such is positive for innovation – whilst allowing environmental improvements to be assessed at a "macro" level. This allows policy makers to set meaningful targets for improvements and to monitor them. It takes into account functionality of product can accommodate new technologies. However, the concept is radical and it may take time for manufacturers and policy makers to assimilate. It also involves a higher degree of maintenance and would require manufacturers to collate and submit comprehensive product and fleet data (assurance needed about confidentiality). It would also require a comprehensive auditing and policing process to verify manufacturers' data.

Perhaps, the main advantage of adopting this type of system over straightforward minimum standards is that it can be applied as a preventative measure rather than a reactive one. This is particularly beneficial in the consumer electronics market where the rapid process of technology turnover will increasingly mean that minimum standards, which are difficult to set in advance of a technology's growth, are developed too late to have meaningful impact on the environmental impact of a product.

Table of References Consulted in the Project

Ref #	Title	Material production	Manu-facture	In-use	Disposal
1	LCA of a Cathode Ray Tube Television (B&O)	✓	✓	✓	✓
2	LCA of a Cathode Ray Tube Monitor	✓	✓	✓	✓
3	Nordic Swan Ecolabel (Audio-Visual Equipment)	×	✓	✓	✓
4	Blue Angel Ecolabel (Monitors)	×	✓	✓	✓
5	Canadian Environmental Choice	×	×	×	×
6	US Green Seal Program	×	×	×	×
7	Australian Good Environmental Choice Programme	✓	✓	✓	✓
8	Korean Environmental Labelling Association	?	?	?	?
9	Taiwan Greenmark	×	✓	✓	✓
10	Environmental Choice New Zealand	×	✓	✓	✓
11	LCA of CRT and LCD Monitors	✓	✓	✓	✓
12	EU Ecolabel – Feasibility Study for Portable Computers	×	✓	✓	✓
13	EU Ecolabel for Personal Computers	✓	✓	✓	✓
14	EU Ecolabel for Portable Computers	✓	✓	✓	✓
15	EU Ecolabel – Feasibility Study for TVs	×	✓	✓	✓
16	EU Ecolabel for TVs	×	✓	✓	✓
17	UK Market Transformation Programme TV Innovation study	×	×	✓	✓
18	Design for Environment Guide	×	✓	✓	✓
19	Case Study for Calculation of Factor X (eco-efficiency) – Comparing CRT, PDP and LCD TVs	✓	✓	✓	✓
20	European Energy-Based Legislation - EuP	×	×	✓	×
21	European Energy-Base d Legislation – the EU Ecolabel	✓	✓	✓	✓
22	European Energy-Base d Legislation – Industry self commitment	×	×	✓	×
23	European Energy-Base d Legislation – Code of conduct for DSS	×	×	✓	×
24	International Energy Based Legislation – US EPA	×	×	✓	×
25	International Energy Based Legislation – Japanese Top Runner	×	×	✓	×
26	International Energy Based Legislation – - GEEA	×	×	✓	×
27	Life Cycle Assessment of a Colour TV – Samsung Electronics Co, 1997	✓	✓	✓	✓
28	PRe Life Cycle Tool	✓	✓	✓	✓
29	Product Design Tool	✓	✓	✓	✓

CE and IT - Market Continuously Driven by New Technologies and by the Development of Changing Consumer Approach

Jürgen Boyny

GfK Marketing Services Europe

Consumer Electronic Market today is not anymore only watching TV or listening music.

Approximately 50 years ago, when consumer started to watch TV or to listen to music, recorded on vinyl the use of consumer electronic products have been very easy, very concentrated on specific times and the number of devices, which have been in use have been very limited. Beginning of this century, 50 years later, the usage of consumer electronics is much more different. Not judging the quality of content here, the use of consumer electronics has changed into different directions: more frequent use, at home and mobile outside, more media as for example internet, more content as e.g. TV programs now are running 24 hours a day. But the most significant change is, that content became digital.

What is Consumer Electronics in private households?

Basically Consumer Electronics can be differentiated by to different experiences:

- viewing pictures
- listening music

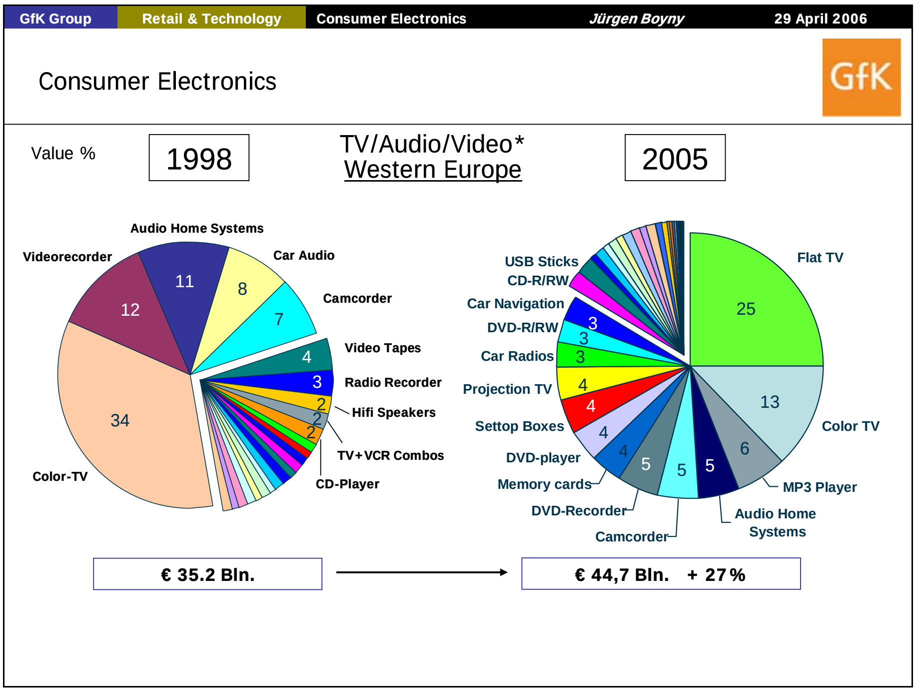
Pictures can be moving pictures as for example TV programs or still pictures, taken by a camera. Nowadays Digital Still Camera is absolutely accepted as a part of Consumer Electronics. But we can differentiate also by another criteria: consumer electronics can be passive or active.
In the beginning, all have been passive only. People sat down in front of the TV or in front of a radio or record player. During the seventies however, Consumer Electronics became active, which means consumer had the possibility, not only to playback, but to record first of all music with a Cassette Deck. During the 80ies they new technologies have been developed. Video Tape Recorder came up and a view years later also Videocameras or Camcorder.
But we have to be aware, basically even today Consumer Electronics is nothing more than viewing pictures or listening music.

Innovation steps became faster and faster

Even Consumer Electronics can be focused on viewing pictures and listening music, the whole branch is at least developing only via innovative products. Let's take a view examples to demonstrate the innovations of that branch and even the acceleration of the innovations

- In the 50ies TV started with black and white programs
- 17 years later 1967 the programs changed to color
- 1983 Video Tape Recorders, even with different systems have been developed
- 1886 – 3 years later - Camcorder have been introduced in the market
- parallel at that time CD-Player came up – the first step into digitalization
- in the 80ies the products became tiny and portable – Walkman have been introduced
- then in the 90ies a longer time with a brake of new products
- and then – even it seems as in a hurry – beginning and of the 90ies: DVD – Flat-TV – DVD-Recorder – MP3-Player – Car Navigation

The basket of a retailer, dealing today with consumer electronic products is complete different to the basket 7 years ago:



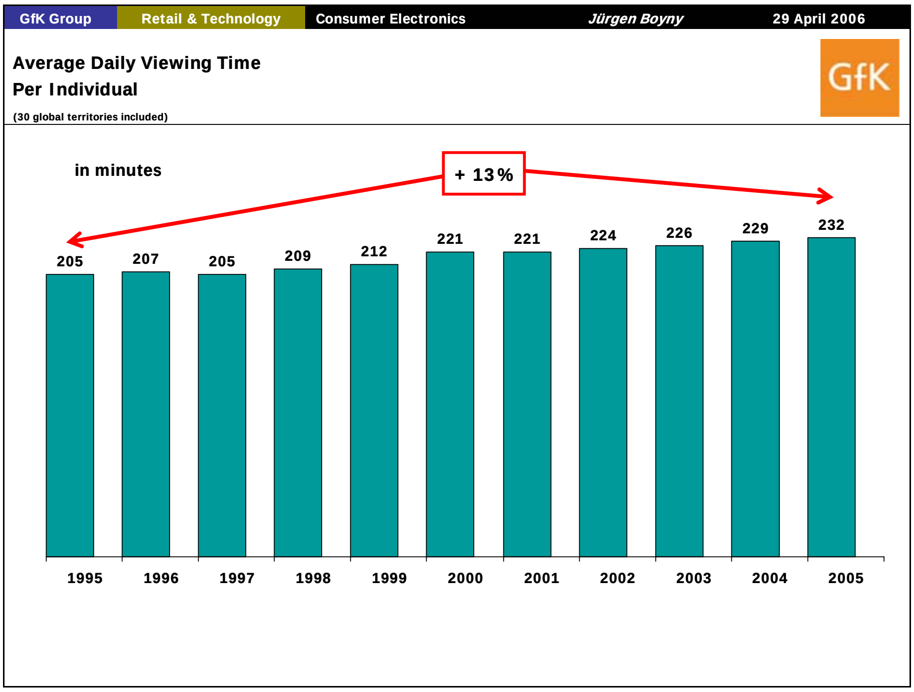
Consumer Electronic assortment changing from 1998 to 2005

Also usage of Consumer Electronics has changed

Watching TV today might even be basically the same as 50 years ago, beside the fact, that it is colored instead of black and white, however, it is more often.

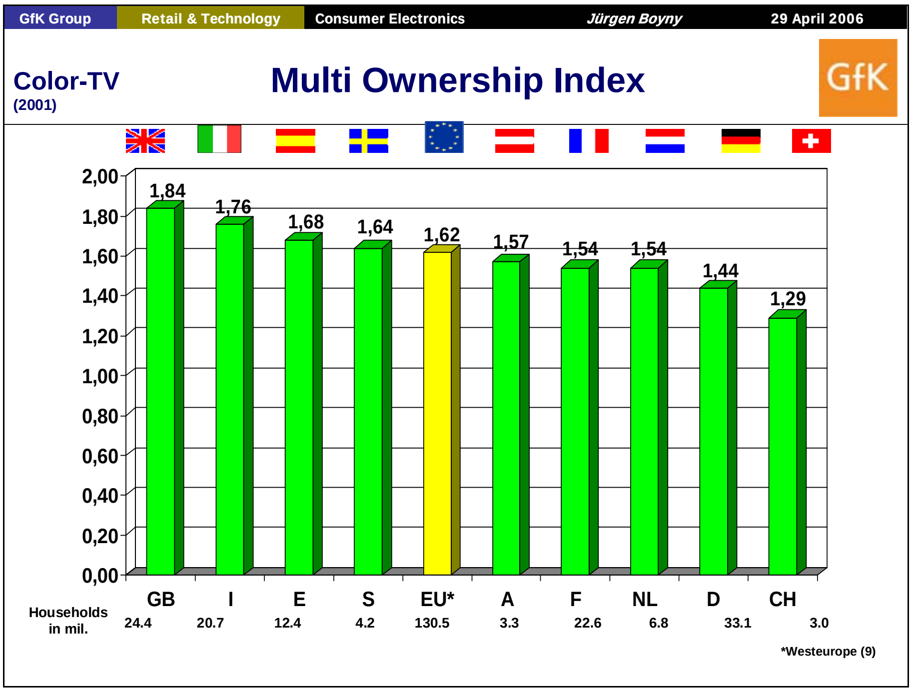
Worldwide personal time of viewing TV programs is more than three and a half hour. More the 230 minutes a day one single person switches on the TV-set. The reason for that is easy to understand. Beside the fact, that more programs are available (in Germany today app. 50 programs are available free of charge, 30 years ago there have been only 3 available), content can be received 24 hours a day.

But also social situation is changing. Number of elder households is increasing, number of households with unemployed people is in creasing, number of single person households is also increasing. And all these different points bring person to a situation to watch more TV:



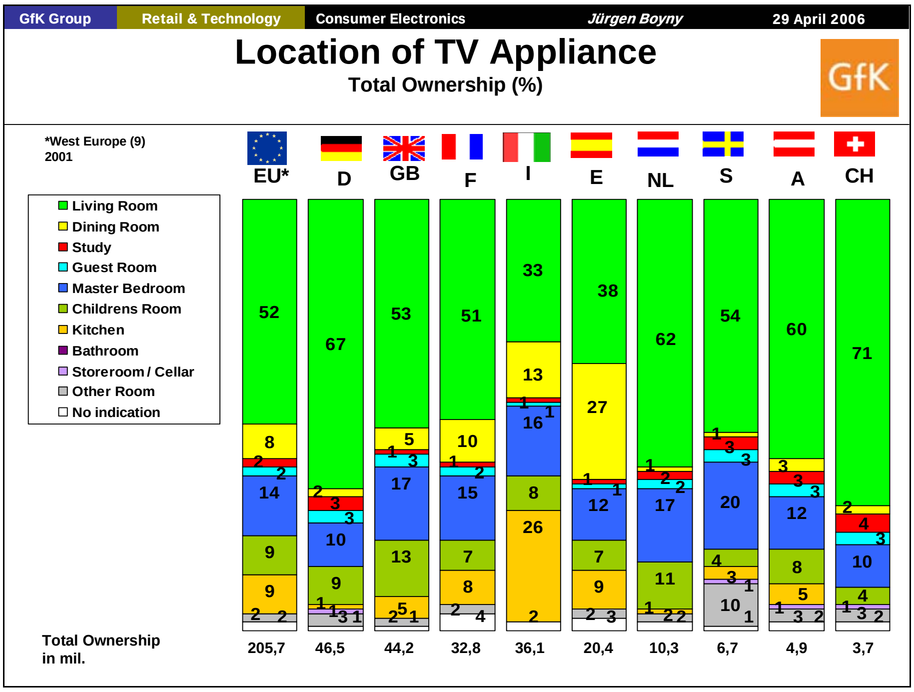
Average Viewing Time per Individual 1985 – 2005

But in total usage of TV has been changed. If we remember back, in former times family and maybe friends came together in the evening to watch TV, Sitting down in the living room, maybe at 8 p.m., having some kind of social family event in front of the TV. Today, maybe a single person is coming home in the evening after work, no direct contact person is available for conversation. Quite often automatically the TV-set is switched on. Even that person is doing something complete different, maybe having a meal in the kitchen, maybe even starting PC to check the emails, which came in. The TV is mostly running all the time.



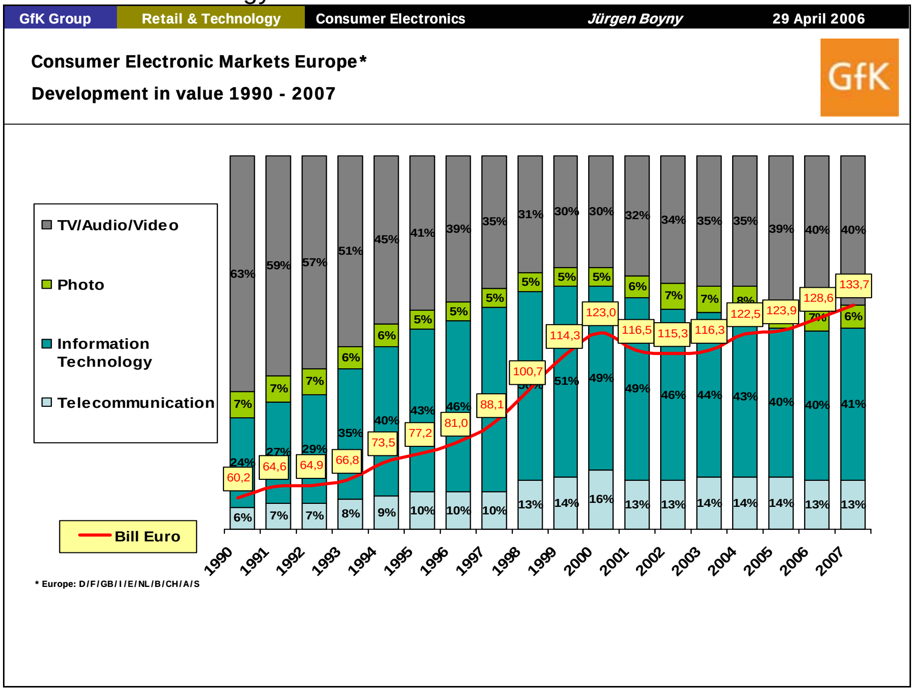
TV Multi Ownership 2001

And also number of TV-sets in a household has been increased over the years. In Western Europe we have had in 2001 a household penetration of TV-sets of 162%, which means app. 55% of the household own more than one TV-set. This second TV-set might be located in the kitchen, in the bedroom, in the children room or anywhere else.



Location of TV Appliance

And we have to be aware, the more often usage of TV is only one part of increase use of Consumer Electronics. Videorecorder came up, DVD-Player and Recorder came up, CD-Playe or Digital Dolby Audio Receiver and at least the household penetration of PC at home.
Meanwhile we have in Europe 65% of the household, who own a PC. And also additional PC environment have been added: a printer, a scanner, a digital camera – household penetration meanwhile 55% - a webcam or a MP3-Player.
Even at the time it seems, that we have a re-launch of traditional consumer electronics, driven by Flat-TV, DVD and MP3, during the 90ies the market have been grown enormous by the growth of the information technology:



Enlarged market of Consumer Electronics to IT, Telco and Photo

With all these development we learn at least: as far as innovative products, totally new for the consumers are offered, the consumer will try to catch this train as soon as possible. The consumer seems at least to be fascinated by the technology, only by the technology, probably not by the content.

Heating and Water Heating

Tomorrow's' Heating Technology in the Light of Eco-Design and Labelling

Thomas Behringer

Chairman Technical Commission EHI, association of the European Heating Industry

Abstract

Heating appliances have an important environmental impact mainly due to their energy consumption. In Europe the variety in households, building types and climate conditions requires specific responses. State of the art and future heating technologies can provide solutions to these challenges.
Several European directives and a multitude of standards define the legislative framework. The saving potential of boilers and water heaters is discussed by policy makers, alongside relevant trends in building insulation levels, fuel switching, integration of renewable energy sources leading to new and improved technologies, etc.
Yet, the visibility of the product group is low and product life is long, often leading to a lack of awareness on the potential energy saving. Obviously the economics of Least Life Cycle Costs –the payback a higher purchase price against lower running costs does not automatically lead to market transformation. Both conventional and innovative technologies offer advantages to achieve better efficiencies. Member states have developed policy instruments and the relevance of these will be discussed in terms of their results. Using the example of a base case representing a typical household in Europe financial investment, operational costs and energy savings are validated.
Lessons learned from these evaluations may provide for the development or re-evaluation of policy scenarios.

Who are we?

Founded in 2002, the Association of the European Heating Industry (EHI) represents and promotes the common interests of 18 market leaders producing heating systems, burners and boilers, and 13 national industrial associations from the EU Member States, Liechtenstein and Switzerland. In Europe, the heating industry directly employs approx. 120,000 people. Besides big players such as BALTUR, BAXI, BBT, CARADON IDEAL, DE DIETRICH, ENERTECH, GIANNONI, HONEYWELL, HOVAL, IMMERGAS, MERLONI TERMO SANITARI, RIELLO, SIEMENS, SIT, VAILLANT, VIESSMANN, WEISHAUPT and WOLF most companies are small and medium sized enterprises. Heating industry contributes € 20 billion to the European Union's GDP.
Approximately one third of energy consumed in the EU is used to heat buildings. As a result, the heating industry has a key role to play in helping to protect the environment and in developing energy efficient instruments. Maximising the potential for saving energy and reducing CO_2 emissions is considered a top priority for EHI members. The industry has therefore invested massively in research and development, to create technically advanced, energy efficient heating systems.

Status quo – Role of heating and hot water production

As mentioned before, roughly one third of energy consumed in the EU is used to heat buildings including hot water production (in the following text hot water production is generally included in the term 'heating' if not indicated otherwise). Despite the fact that its importance is understood by European Commission and specialists in some national administration bodies, others often lack expertise or are simply not interested. The visibility of the boiler may play an important role, as they are often found in basements and therefore the boiler is 'forgotten'. Another 'psychological' reasons may be the long and quiet running times - over decades - of those heat generators. The fact that very few people are confronted with the appliance in day-to-day life makes them not very 'thrilling' and less exciting than e.g. cars.
However, at least once a year private house owners have to pay the heating bill and this may be cause for some excitement, at least from the financial point of view. As an example in one middle Europe country, the total expenditure for space and water heating was over € 34 billion (€ 34.239 million) Euro in 2005. This is almost 50% more than 10 years ago. Overall, these households spends

around € 2.300 annually in energy costs with heating and the car each are 40% of that sum. In a larger single family home of e.g. 150 m² with –as isoften the case in the building stock— sub-optimal insulation, the heating costs alone can amount to sums of over € 2000,- (e.g. 40 000 kWh) per year, based on May 2006 energy prices. It is often forgotten that this substantial amount of money has to be paid just to keep the indoor temperature of a building at a certain level in the cold periods of a year. And it is too easy just to blame the boiler, but is the total package of building insulation, consumer behaviour and heating installation that determines the bill. And at current trends of ever increasing energy prices this bill is very likely to increase in the near future. It s not difficult to imagine that most households would then run into serious financial trouble…
But it is not only from the financial and thereby social policy point of view that boilers and water heaters are exciting. It is no secret that there are enormous potentials to save both fuel and CO_2 in the domestic sector across Europe. CO_2 emissions are proportional to energy consumption, that is 0,27. kg/kWh for oil and for gas 0,194. kg/kWh. Ways to achieve this in a relative short period of time and without reducing comfort – which is a precondition here – will be discussed below.

What the customer, legislation and politics wants

There are a large number of requirements and wishes from the different stakeholders affecting the heating industry and its products. A selection of those requirements, mainly related to legislation, is listed in the following table.

Parameter	**Require-ment**	**EC legislation**
Efficiency	High	• *92/42 Boiler Efficiency Directive (BED)* • *93/76 Limiting of CO2 emissions (SAVE)* • *2002/91 Energy Performance of Buildings Directive (EPBD)*
Emissions (NO_x, CO, …)	Low	• some member states (national) legislation
Lifetime	High	• *2005/32 Eco-design of energy using products (EUP)* – lifetime is discussed in this context as well as most other parameters in this table
Include renewable energies	High	• *2002/91 Energy Performance of Buildings Directive (EPBD)* • *??? RES-H*
Recycling	High	• *2002/96 Waste of Electric and Electronic Equipment Directive (WEEE)*
Eco-friendly materials	High	• *2002/95 Restriction of Hazardous Substances Directive (RoHS)*
Noise	Low	• some member states (national) legislation
Hygiene, Health	High	• *98/83 Drinking Water Directive (DWD)*
Transparency of efficiency	High	• *92/75 Energy Consumption Labelling Directive (ECLD)*
Price for product	Low	-
Safe operation	High	• *89/336 Electromagnetic Compatibility (EMCD)* • *89/392 Machinery Directive (now 98/37)* • *90/396 Gas Appliances Directive (GAD)* • *97/23 Pressure Equipment Directive (PED)* • *89/106 Construction Products Directive (CPD)* • *2001/95 General Product Safety Directive (GPSD)*
Compactness	High	-

It is clear from the table that the number of regulations for heating products is relatively high and that for many parameters there is a strong correlation between the product price and the technical requirements. To complete the picture, the additional requirements that may arise from the 2005/32/EC directive on *Eco-design of energy using products (EUP)* should be mentioned.
This framework directive will possibly have the biggest influence in the near future, and not just on heating products. Main drivers for the EUP directive are the Kyoto protocol and European Climate

Change Programme (ECCP), but also several other EU environmental objectives and of course the objective of a single EU market (Art. 95).
As a first reaction after publication of the draft EUP directive the heating industry argued that such a directive would just increase the level of regulation. Taking into account that some of the above listed EC directives such as the BED and ECLD did not yet overcome some of their inherent weaknesses it was criticized that just a another new directive would be squeezed into the hierarchy of legislation. But after an intense dialog with the European Commission also chances emerged. If the implementing measures under the EUP directive could clarify and improve existing directives under one ‘umbrella’, industry and ultimately the consumer could gain considerably. The single EU market would certainly be strengthened if

- Gaps of existing legislation would be closed
- Overlapping of existing legislation would be avoided in the future (CPD, GAD, EPBD, BED, ECLD)
- National relics such as German Ü-marks and Belgian HR+ label would disappear
- Double and multiple efforts such as UK SEDBUK database would be unified / standardized

One could argue that almost every other sector of industry should be affected and has to do his ‘homework’. In that context also the automotive industry with their pretty low ‘well-to-wheel’ efficiency should be considered. Consider power generation technology with a high potential to improve on today’s relatively low efficiency. And the energetic improvement of the building stock, not just the heating installation, should fit that picture. Technically speaking, in the field of heating technology considerable progress has already been made and quite often physical limits have been achieved. This will be shown in the next paragraph.

Status quo of technology – what has been already achieved?

Parameter	**State of the art**	**Remarks**
Efficiency	Nearly 100% (condensing)	The longer the operation times the shorter the payback time, i.e. some countries with long heating periods use more and more condensing technology, for others in southern areas the situation may be different
Emissions (NO_x, CO, etc)	Down to some 10 ppm (best practice)	Low level if compared to automotive and industry sector
Lifetime	15-25 years	Corresponds to lifetime in industrial plants
Include renewable energies	Standard	Most modern heat generators can be combined with solar hot water collectors
Recycling	Quote of recycling is high	Since lot of valuable materials are used such as brass and copper almost all materials will be reused (recycling)
Eco-friendly materials	High	See above
Noise	Low	Products are often installed near living rooms therefore low noise level is a design criterion
Hygiene, Health	High	In most countries boilers heat up drinking water
Transparency of efficiency	Good	Today most professional product documents (data sheets) already contain efficiency information
Price for product	Low	Full range from “low budget to premium products”, on average low, very strong competition
Safe operation	High	Safe operation is priority # 1 design parameter (product liability)
Compactness	High (if wanted by customers)	wall hung boilers

The table shows the already high level of technology achieved by modern heating technology. Modern designs, materials and sophisticated controls ensure a reliable, low emission and highly efficient operation of heating generators.
In other words, the heating industry doesn't see the technology as a problem in meeting the highest environmental standards. However, there are several barriers of another nature that may stand in the way. For instance:

1. The heating market is to a large extend –typically over 70-80%-- a replacement market. And most customers are just looking for that: A simple 1:1 replacement of the old equipment for the new equipment. In that context, already the replacement of e.g. a standard boiler by a condensing boiler is considered a huge step, despite the fact an individual customer could stand to gain over 30% of energy saving and the economics are obvious.
2. For some legislators –however—this is not deemed enough. It is often felt that also existing houses should be equipped with the best front-runner technology, imposing the customers by law to a completely new concept of how they should heat their house or produce their hot water. This could cause substantial friction in the existing housing market
3. This friction is aggravated by methodological problems with the legal instruments being developed. For instance, the mandatory energy labelling of water heaters is on the political agenda since 1992, but has suffered a series of setbacks due to methodology. The evaluation of tapping patterns, in- and outlet temperatures, etc. across Europe is not a self-evident issue that has required considerable effort not only by the European Commission but certainly also by the industry. Another example is posed by combi-boilers and especially indirect cylinders, where the difficulty lies in having to evaluate a part of an installation, rather than the whole system. The assessment of auxiliary energy or the problem of tolerances within the narrow A-G bandwidth are other problems that need to be tackled.
4. Against that background, the latest ideas on labelling of hot water appliances –enlarging the scope to include also solar water heaters—are surprising and will introduce new problems to be solved, relating to the different climate zones in the EU and the wide variety of possible combinations with conventional technology.

The future – what can still be done

Let us now briefly state principal ways to achieve energy and CO_2 savings - without reducing comfort:

1. Increase building insulation and make buildings more airtight
2. Adjust all existing heating equipment properly, especially controls
3. Use combined heat and power (CHP) technology to heat the building
4. Replace old and inadequate boilers
5. Use renewable energies for heating

While measure # 1 is outside the scope of this paper, it certainly makes sense to take a holistic approach and combine building insulation with the other measures listed. Energy savings from insulation of an existing building can lead to energy savings of 50% or more. However, in most cases the payback time is longer than what can be achieved with improvement of the heating installation. Just to provide an order of magnitude: A complete insulation (walls, roof, floor, glazing) of the 150 m² single-family house described earlier would cost more than 30.000 Euro in middle Europe for technical reasons the insulation thickness is limited to 10-15 cm for existing buildings. At 50% energy saving, the simple payback period (SPP, i.e. without taking into account interest) would be as high as 30 years.
Concerning measure # 2, studies have revealed that typically up to 10% energy saving in a single installation can be achieved by simply adjusting all the heating equipment properly – especially the controls of a boiler. To realize this, the heating industry is permanently training installers and is improving the technology. Examples are better control designs such as self-adjusting electronics, new sensors to automatically check combustion, Internet remote control of complete boiler operation, sophisticated measuring devices such as energy efficiency monitoring systems. But in the end, responsibility is more on installers than on industry. Therefore official support of authorities to better train installers and increase awareness of both installers and end customers on that topic would be welcomed.
Regarding measure # 3 one can state that most of (big) companies already offer CHP products. Today's most reliable technology is the conventional internal combustion engine that is combined with an electricity generator. Both engine and generator are (heating) water cooled, encapsulated together and designed to run up to 40.000 hours without replacing the engine. Electrical power output is down

to 1-2 kW for single houses, total system efficiency up to nearly 90%. Bigger units can be used in multi family houses. Depending on what is taken as a reference situation and in ideal operating conditions, energy savings can be up to 25% and 30% in CO_2 reduction. Unfortunately, this technology is not yet widespread because of certain installation requirements and relatively high investment costs. To reach the aforementioned saving potential, the installations need steady electricity demand and simultaneous heat demand. Not every installation can provide this. Alternative CHP technologies are Stirling driven generators and fuel cells as most promising future devices. However, it will take at least another 5 years to make a final statement on the competitiveness of fuel cells.

Replacement of old boilers (measure # 4) is the fœus of today's heating industry. Since in many northern European countries the number of new buildings per year will decrease, the replacement market –which is already by far the largest segment—will become even more important. Internal studies of EHI on Eco-design of conventional boilers were conducted largely using the methodology developed for the Eco-design of EuP directive studies. These studies on the life cycle of the product confirmed the dominance of the use phase in terms of environmental impact, i.e. energy needed for production of boilers is small compared to energy consumed by the boiler over its lifetime. As a consequence, better efficiency of new boilers is essential. Based on actual replacement figures in the various member states it was shown that for EU-15 countries1,5% of total heating energy per year can be saved. Over a 10-year period this amounts to as much as 15% saving. Since these numbers are based on actual sales figures and realistic customer behaviour it is strongly recommended to policy makers to support measures in the field of appropriate boiler-replacement.

Regarding the use of renewable energy sources for heating purposes--measure # 5-- it is essential that policy makers combine ambition with a realistic view. It is often said that renewable energy sources alone will solve all energy problems. And in the wake of such a statement, conventional boiler technology is immediately dismissed as 'yesterday's technology'. Probably these indiscriminate statements make 'good politics', but it would be nice for both the voters and the environment if they had a basis in reality. It is true that solar thermal collectors can provide users with a fairly good amount of energy saving for hot water production. A solar thermal collector area of typically 5-10 m^2 can cover 50-60% of total hot water production of a household in Central Europe (depending on collector technology and quality used). In new buildings and in Southern Europe, where hot water production may constitute up to 40% of the total heating energy, this is a significant amount. However, in the existing buildings, constituting the vast majority of the heating market, with their significantly lower level of insulation, the hot water production constitutes only 10-20% of the total and the use of solar energy would result only in savings of 5 to 10% of that. This effect is not to be ignored, but it won't solve all energy problems. If the user wishes to use active solar systems to assist his space heating things become even more difficult, especially in existing buildings. To realize e.g. 10% coverage from a solar system for space heating not only a larger collector surface is needed, but also one or more really big (and costly) heating water storage cylinders are required. As long as no long term and high energy density system to store heat is available, most people would need considerable subsidies to install such systems.

Another technology to be mentioned here only briefly is heat pumps that are normally driven by electric motors. Environmental heat is used in a thermodynamic cycle to achieve total efficiencies up to 130%. Heat pumps need an environmental heat source such as earth heat collectors, ground water, geothermal heat sources or simply the outside air. They are normally restricted to modern or new (insulated) buildings with relatively low heat demand and low heating system temperatures.

The next promising technology also discussed here only briefly is using wood as a fuel. Most sophisticated technology is the "pellet" oven, using very small pieces of before processed wood. Generally, wood fired boilers or ovens can substitute fossil fuels. Yet, there are several issues to be solved: The large-scale supply of biomass is one issue, the long-term behaviour of the appliances is another. Furthermore, although the technology is beneficial to the CO2 –balance, the emission of other pollutants (e.g. particulate matter) especially in urban areas is still an issue to be carefully considered.

All in all, of the measures mentioned above, conventional boiler technology, i.e. high efficiency heat generators such as modern low temperature or condensing boilers are the most effective solution in big replacement markets. With respect of measures such as building insulation it is well established that for the existing building stock the payback time for improving the heating system is much better than that of insulating the building shell. With respect of the development of renewable energy sources, the heating industry is fully committed. Therefore if possible, the new boiler should be combined with solar hot water production since this technology is already mass produced The routes of heat pumps and CHP will continue to be explored and applied whenever appropriate. But it must be recognized that not every installation can be easily and immediately adapted to the very latest technology and that in some cases this technology that looks good on paper still is not fully mature.

Conclusions

The European heating industry is fully committed to building a sustainable and energy-efficient future. Having said that, the industry would like to urge policy makers to develop a balanced package of measures to achieve environmental objectives, reflecting the reality sketched in this paper. And this balance would have to be found in more than one way:
Policy makers should not just focus on restrictive legislative measures, but also develop indispensable lateral measures regarding

- Installer training, raising the standard of expertise in the field of energy –efficient installations and controls
- Subsidies and direct rebates to allow the low-income groups to benefit from the energy saving measures in a responsible way,
- Financial incentives and tax rebates to support house owners facing extra investments to make their building and installation suitable for the new technologies,
- Appropriate information campaigns to the end users,
- In as much as labelling is used it should be fair and transparent,
- In as much as legal measures are deemed necessary they should be aimed at simplifying the current and future body of national and EU legislation rather than rendering it more complicated, and in that context the measures should be directed to truly developing the single EU-market.

Policy makers should also not just focus on the more spectacular 'green' heating alternatives, but should direct their measures and budgets in function of effectiveness of the technologies for the society as a whole. And their commitment to these objectives and measures should not be ad-hoc and short-term, but structural and long-term. This would allow the industry and all other actors –not in the least the installers—to build an economically and ecologically sustainable strategy for the future.

High Efficiency Circulators for Domestic Central Heating Systems

Niels Bidstrup[1], David Seymour[2]

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[2]Grundfos Pump, UK

Abstract

High efficiency circulators for commercial buildings have been on the market since 2001. Now high efficiency circulators are also available for domestic central heating systems. These circulators can save up to 80% electrical energy compared to conventional circulators installed today. This is achieved by using high efficiency permanent magnet motors and speed control. To increase market share of circulators with higher efficiency, a labeling scheme has been introduced. Circulators are now labeled with A-G energy label - well known from white goods and household lamps market. The labeling scheme came in force in March 2005 and is controlled by a voluntary industry commitment agreement which is managed by Europump It is estimated that 120 million domestic circulators are installed in EU25 today. These circulators are responsible for up to 15% of the electricity consumption for some European households. The average energy efficiency of installed circulators today corresponds to label “D” or “E”. If those circulators were changed to “A” labeled high efficiency circulators the electrical energy saving potential in EU25 could be 44 TWh per year, with a reduction of 17,6 million tonnes CO_2 per year. This paper describes how energy labeling in combination with national schemes can increase the market share of high efficiency circulators for domestic central heating systems.

1. Background

Energy consumption of circulators has been high on the agenda for the last 10-15 years. The reason for this is the huge energy saving potential, which could have a significant influence on CO_2 emissions. Circulators consume a lot of energy due to the high running hours in some countries and the very large installed numbers. In SAVE II [1], the installed base in EU15, was estimated at 87 million units. Based on this figure the pump industry estimate the current installed base in EU25 is 120 million. The estimated energy consumption of those circulators is 57 TWh per year, assuming a heating season of 285 days.

The typical lifetime of a circulator is 10-15 years, but circulators, which are 15-20 years old, are also operating today. These old circulators are less efficient and are responsible for up to 15% of the electricity consumption of some European households. By replacing the old circulator it is possible to save up to 10% of the electricity consumption for these households.

2. High efficiency domestic circulator

High efficiency circulators for commercial buildings have been on the market since 2001 [2]. Since 2005 high efficiency circulators are also available for domestic central heating systems. Figure 1 shows a high efficiency and a standard domestic circulator. A high efficiency domestic circulator looks similar to a standard domestic circulator from outside and is interchangeable with these. Internally the induction motor is replaced by a permanent magnet motor and the terminal box contains a full three phase frequency converter with motor control, system control and intelligent adaptive functions.

Figure 1 High efficiency and standard domestic circulator

A high efficiency circulator uses considerably less energy per year than a standard circulator. This is not only achieved by higher efficiency in the component i.e. pump and motor, but also due to speed control. Speed control enables the circulator to adapt to the changing demands in the heating systems, which would otherwise result in hydraulic loss in control actuators i.e. thermostatic radiator valves etc.
Speed controlled circulators for domestic heating systems have shown savings up to 50% compared to a standard circulator. A high efficiency circulator combines speed control with a permanent magnet motor, which has higher efficiency especially at part load. This results in energy savings up to 80% compared to the circulators installed today.

3. A-G energy labeling of circulators

Speed controlled circulators have been on the market for approximately 15 years. Despite short pay back time for the end user (typically 2-3 years in replacement situations) less than 20% of circulators sold today are speed-controlled. To increase market share of circulators with higher efficiency a labeling scheme has been introduced. Circulators are now labeled with A-G energy label well known from white goods and household lamps market. The labeling scheme came in force in March 2005 and is controlled by a voluntary industry commitment agreement [3], which is managed by Europump. Seven companies with a total market share of more than 80% have signed up to this commitment agreement so far.

3.1 Classification scheme

A-G Energy labelling of circulators is based on a classification scheme developed by Europump. The classification scheme is summarized below. A detailed description of the theory behind it is given in [4] and [5]. The A-G labeling comprises all circulators for heating systems, which fulfill all conditions below

- Stand alone (not an integral part of a boiler)
- Pump and motor integrated
- Wet runner (glandless)
- Centrifugal pumping
- $P1 < 2500\,W$

Stand alone circulators with pump and motor integrated are circulators which are sold as a separate products and not as an integral part of, for example, a boiler. Wet runner means that the rotor is running in the pumped fluid. Only circulators with a power input $P1 < 2500$ [W] (for every head on double pumps) and based on centrifugal pumping principle are comprised.
Circulators are labeled based on an Energy Efficiency Index (EEI). the EEI is calculated as

$$EEI = \frac{P_{L,avg}}{P_{ref}} \quad [-]$$

,where

$P_{L,avg}$: is the average compensated power input

P_{ref}: Reference power input

$P_{L,avg}$ is a weighted averaged power input based on a yearly load profile and compensated for control error. Pref is the reference power input for a standard circulator at a specific size. By dividing these two figures the EEI expresses how efficient a specific circulator is compared to the circulators on the market in 2002. The system is calibrated as shown in table 1

Table 1 Calibration of EEI to A-G energy label

Class	Energy Efficiency Index (EEI)
A	$EEI < 0.40$
B	$0.40 \leq EEI < 0.60$
C	$0.60 \leq EEI < 0.80$
D	$0.80 \leq EEI < 1.00$
E	$1.00 \leq EEI < 1.20$
F	$1.20 \leq EEI < 1.40$
G	$1.40 \leq EEI$

This calibration implies that circulators on the market in 2002 will get a "D" or "E" label (EEI=1.00). To get an "A" label the average power input must be reduced by at least 60% compared to that.
The label is shown in figure 2.

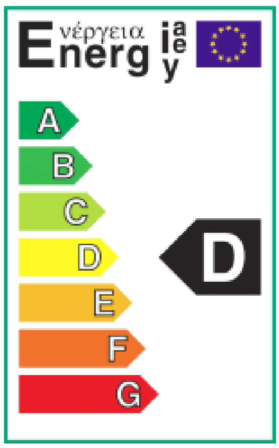

Figure 2 EU A-G energy label for circulators

Only information about average power consumption is on the proposed label, which is indicated by the letters and arrows on the label. The yearly energy consumption depends on running hours of the circulator, which depend on the heating system.
The average energy efficiency of installed circulators today corresponds to label "D" or "E". If those circulators were changed to "A" labeled high efficiency circulators the electrical energy saving potential in EU25 could be 44 TWh per year, a reduction of 17,6 million tonnes CO_2 per year.

4. Energy consumptions and savings – an example

Energy consumption and savings vary a lot between installations and depends on circulator age, dimensioning, setting and running hours. In the following example a comparison between different circulator options in a specific heating system is made. The idea with this comparison is to show the energy consumption and savings in an ideal case where pumps are dimensioned and set correctly. Actual consumption and saving would be higher in most systems, where the pump very often is too big and/or the setting is too high.
The heating system for this example is defined as

- Dimensioned heat load: 15 kW

- Dimensioned flow temperature: 75 °C
- Dimensioned return temperature: 60 °C
- Dimensioned pump flow: 860 l/h
- Dimensioned pump head: 2 m

Calculations are based on a heating season of 285 days, which is a typical heating season in mid EU25.
Four different circulator options are chosen. A “C” labeled fixed speed circulator set on speed 2 (mid setting), which is 1-10 years old. A new “B” labeled fixed speed circulator set on speed 2 (mid setting). A high efficiency “A” rated circulator operated as fixed speed circulator in speed 2 (mid setting). This is an option if uncertainty about boiler minimum flow rate exists in relation with variable speed mode. The last option is an “A” rated high efficiency circulator operated as variable speed.
In table 2 the annual energy consumptions of the different circulator options are calculated. The load profile is the same used for EEI calculation. Notice that circulators only operate at 100 % flow 6 % of the time and are below 50 % for nearly 80 % of the time. This is due to the distribution of outdoor temperature and the nonlinear characteristics of the heating system.

Table 2 Yearly energy consumption of different circulator options in a specific system

		Fixed speed circulator <2005 **UPS 25-40 Labelled: “C”**		**New Fixed speed circulator >2005** **UPS 25-40 Labelled: “B”**		**High efficiency circulator (fixed speed)** **Alpha Pro 25-40 Labelled: “A”**		**High efficiency circulator (variable speed)** **Alpha Pro 25-40 Labelled: “A”**	
Load Profile									
Flow [%]	Time [%]	P1 [W]	E [kWh]	P1 [W]	E [kWh]	P1 [W]	E [kWh]	P1 [W]	E [kWh]
100	6	44	18	34	14	25	10	19	8
75	15	44	45	33	34	25	26	15	15
50	35	42	101	32	76	25	60	11	26
25	44	41	123	31	93	25	76	9	27
		∑E	**287**	∑E	**217**	∑E	**171**	∑E	**76**

The power input shows that a high efficiency circulator only draws 9W at 25% load, where the corresponding fixed speed circulator draws 41 [W]. Most circulators installed today draw between 60 – 100 W at 25 % load.
The bottom line of the table shows the yearly energy consumption in bold letters. A high efficiency circulator in variable speed mode consumes only 76 kWh per year instead of 287 kWh per year, which is a saving of 73 %.
These results are also shown in the figure 3 below, where consumptions in percentages are also depicted.

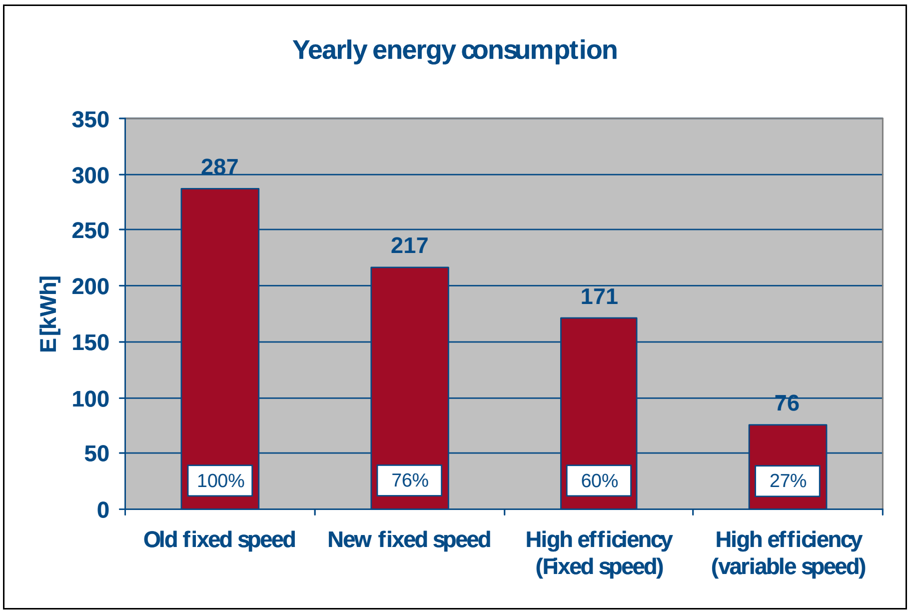

Figure 3 Comparison between different circulator options in a specific system

4. Promotion of high efficiency domestic circulators

A-G labeling is first of all a marketing tool directed towards end-users, but labeling can also be used to set minimum standards and targets, which is easier to monitor and evaluate. From that point of view labeling is a useful tool for promotional campaigns on national and EU level to accelerate market transformation towards circulators with higher efficiency. Different national schemes are already using these possibilities.

4.1 Denmark

Danish ELFOR is running a campaign to change all pumps towards better efficiency. A key element in this campaign is the “List of Energy Efficient Pumps” [6], which is a website that enables installers and consultant engineers to identify and select the right energy saving pump for a specific installation. Only circulators with rating “A”, “B” and “C” are on the energy saving pump list, which means that labeling is used to set minimum standards. Furthermore the actual labels for the different circulators are also displayed, which make it easier to select the most efficient circulators for a specific job.
Another campaign is carried out by the Energy Saving Trust in Denmark. This campaign is focused on domestic circulators and directed towards the end-user. TV commercials and website [7] are used to increase awareness of old energy wasting domestic circulators and how to select an energy efficient circulator by using the A-G energy labeling.
It is difficult to measure the impact of different campaigns separately, but today 50 % of domestic circulators sold are energy saving circulators with the majority belonging to class “A” or “B” and a few in class “C”. Before A-G labeling and these campaigns only 20% of the circulators was energy savings circulators belonging to class “B” and “C”.

4.2 UK

In January 2006 the Energy Saving Trust approved the Grundfos “A” and “B” rated circulator as Energy Saving measures. The labeling scheme and EEI were used to classify the measures and using the UK SAP assumption of 2000 running hours, the savings were sanctioned as 78 and 52 kWh respectively. This enabled Grundfos to approach the UK Energy suppliers to secure promotional funding from the Energy Efficiency Commitment scheme operating in the period 2005 to 2008. These new measures were particularly attractive as the savings are attributed to electricity not gas and oil. Grundfos will work with Energy Suppliers to create market transformation in the new and replacement circulator market.

5. Conclusions

High efficiency "A" labeled circulators are now available for domestic central heating systems. These circulators can save up to 80% electrical energy compared to conventional circulators installed today. An example calculation showed that even in an idealized case, where standard circulators were dimensioned and set correctly, savings of 73% were achieved by using a high efficiency circulator in a certain situation

The A-G labeling scheme of circulators came in force in March 2005. The labeling is controlled by a voluntary industry commitment agreement and is managed by Europump. Seven companies with a total market share of more than 80% have signed up to this commitment agreement today

It is expected that the A-G energy labeling will have a great impact on the circulator market in EU25 in the coming year, especially if combined with other market transformation programs. In Denmark A-G labeling is combined with two different promotional programs and the sale of energy efficient circulators have increased from 20% to 50%.

The average energy efficiency of installed circulators today corresponds to label "D" or "E". If those circulators were changed to "A" labeled high efficiency circulators the electrical energy saving potential in EU25 could be 44 TWh per year, with a reduction of 17,6 million tons CO_2 per year.

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[1] Bidstrup, N., van Elburg, M. and Lane, K., *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems*, Study under SAVE II program, June 2001.

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Electricity in Non-electric Central Heating Systems

Nick Davies

UK Market Transformation Programme

Abstract

In a house heated by a gas or oil boiler, about 8% of the annual electricity consumption of the household is required to operate the heating system. This is about the same level of electricity consumption as the Consumer Electronics Sector (9 TWh/yr in UK). Yet the electrical components of typical heating systems (fans, pumps, motorised valves, boiler electronics, controls) have received scant attention in terms of power demand and power economy. Installer choices based on price, ease of fitting and familiarity also impact on the electricity consumption, but there is little information available for the consumer to make informed choices. Until recently there was no comprehensive model, measurement method nor analysis of the prospects for improvement.

This policy gap has been recognised in the European SAVELEC project (completed in June 2005), and the findings from the project show that worthwhile savings are possible, and could be achieved by an agreement to cover measurement, labelling, provision of information and a commitment to improve design. The paper will explore these and other opportunities, particularly with reference to the UK market (1.5M domestic boiler sales per year).

This paper will summarise the findings of the SAVELEC project, outline the common system components, the scope for energy improvement and discuss options for the way ahead.

Common heating system electrical components

The common electrical components were identified along with their typical instantaneous power consumption and estimates of market levels, where available. BRE contacted several UK boiler and system component manufacturers and reviewed industry datasheets. The other project partners within this task; GdF, DTI, VTT and OWI presented information from their respective EC countries using a similar method. Table 1 presents the most common system components for gas and oil fired systems.

Table 1: common system components and power ratings

Component	Typical instantaneous power - Watts BRE (UK)	Typical instantaneous power - Watts Other partners	Consumes if system off?	Consumes if system on boiler not firing?	Consumes if system on and boiler firing?
Pumps	65	GdF 55, SAVE[*] 70	N	Y	Y
Boiler fans	50	30	N	N	Y
Zone valves - 2 port, 3 port	5	6W during state change	3 port 5W, 2 port 0W	Y	Y
Programmers	2	0.4W; 2 – 6VA	Y	Y	Y
Thermostat(s)	Note1				
Gas valves	~ 7	~ 7	N	N	Y
Keep hot heaters	15 – 30	25	Y	N	N
Boiler standby power	8	< 15 'Blue angel'	Y	Y	Y
Igniters	Note 2	2	N	N	Y for 10 s typically
Oil preheat	Note 3	40- 150	N	N	Y for 50 s on cold start
Oil – pressure type		90 - 200	N	N	Y
Oil - atomisation type		75	N	N	Y
Oil igniter	Note 2	60	N	N	Y for ~ 35 seconds

[*] SAVE is the earlier EU SAVE II Project on the Promotion of Energy Efficiency in Circulation Pumps, especially in Domestic Heating Systems (Contract No 4.1031/-Z/99-256)

Note 1: bimetallic strip types have a small 'shunt accelerator heater' – generally a ¼ watt resistor ~ 250kΩ resistance to reduce hysteresis. Power dissipation at 230 volts is around 0.2 W so is assumed negligible.

Note 2: Consumption is assumed negligible - gas boilers the duration is 5-10 s, for oil upto 35 s.

Note 3: Light fuel oil is typically preheated to 70°C. Power required varies with the oil flow rate. VTT found the range to be 54W – 305W for boiler powers 17.8kW-101kW with underground oil tanks. The operating time with cold start is around 50 seconds. Warm starts do not need preheating. Therefore consumption is assumed negligible.

There is wide variation in instantaneous power consumption in some instances. Worthy of note is the large variation of oil fired boiler components with thermal power rating and the consumption of some components when the system is off.

Estimated system annual electricity consumption

Many of the components have a wide range of instantaneous power ratings. To put this into context the operating hours need to be considered and this depends on many factors, including system type, plant size ratio (boiler output/heat load), local climate and length of heating season. Fig.1 shows the spread of expected annual consumption for six common UK gas systems with the same heating season of 250 days. The heating and hot water programmes are the same in all cases (CH + DHW 10 hrs for 250 days, DHW 2 hours for 165 days).

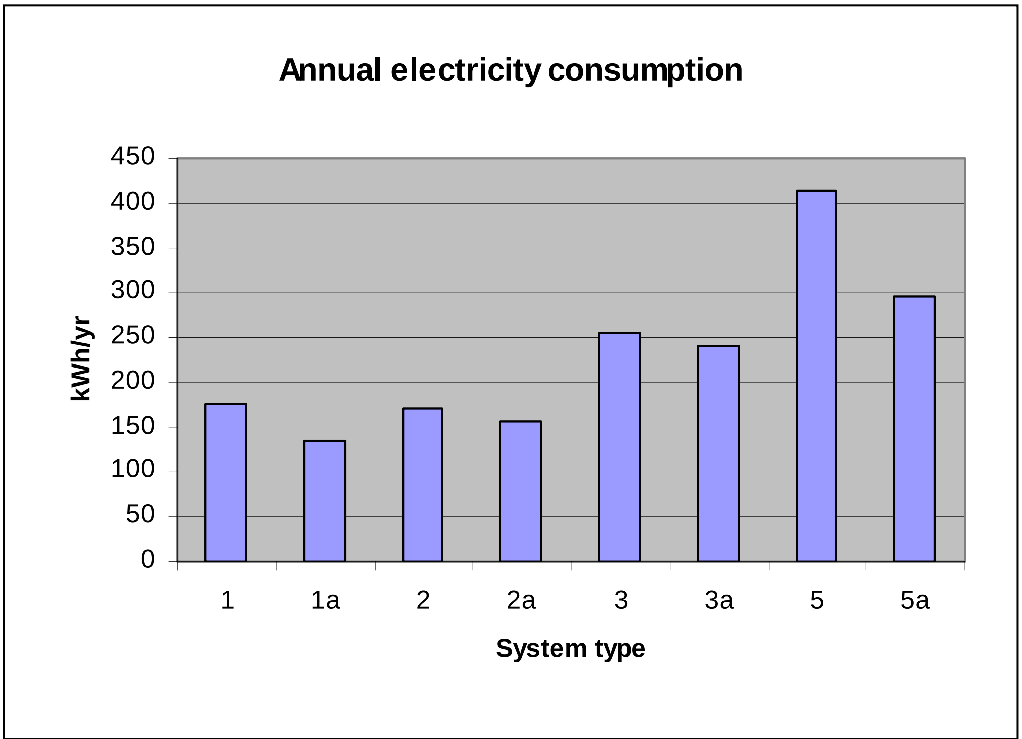

Fig.1 Electricity consumption / system type for 6 UK gas systems.

- Type 1 shows a typical cast iron boiler with gravity hot water and poor controls, 1a the effect of a room thermostat controlling the pump.
- Type 2 shows a natural draught boiler with a fully pumped system and 3 port mid position valve, type 2a is the same system with two 2 port spring return zone valves.
- Type 3 is the same system as type 2, but with a fan-flue fixed output boiler.
- Type 5 is an instantaneous combination boiler without, and 5a with, room thermostat.

Fig.1 clearly shows the effect of system type on the annual electricity consumption. This typically varies from 135 kWh for a semi-gravity system through to around 415 kWh for a combination boiler system with temperature control by TRVs and bypass. Although this shows the simplest systems with poor controls have the lowest electricity consumption, the thermal efficiency of systems with better controls is higher.

Annual consumption by system components

In order to prioritise the saving potential, the proportion used by each component becomes important. Taking system 3a in Fig.1, which uses 241kWh per year, the consumption proportion is shown in Fig.3. This is indicative of many systems designed to current good practice using widely available components. The system comprises a regular boiler with fixed speed fan flue, no standby power, fixed output burner and separate pump and programmer. The heating system is fully pumped with interlock by room and cylinder thermostats controlling 2 no. 2 port motorised spring return valves. An example schematic for such a system is shown in Fig.2.

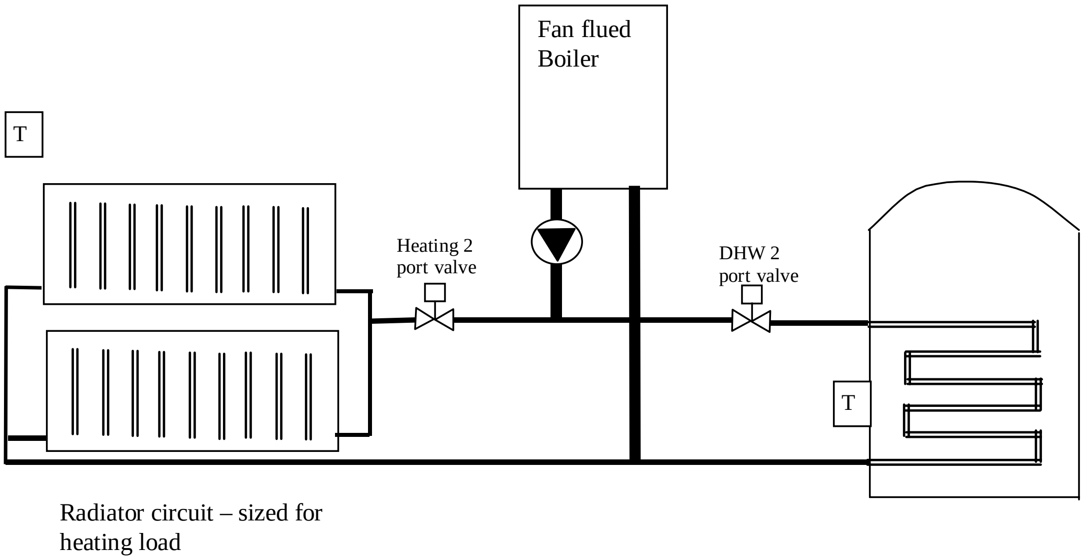

Fig.2 Simplified UK system 2a with fully pumped circulation and two 2-port motorised valves

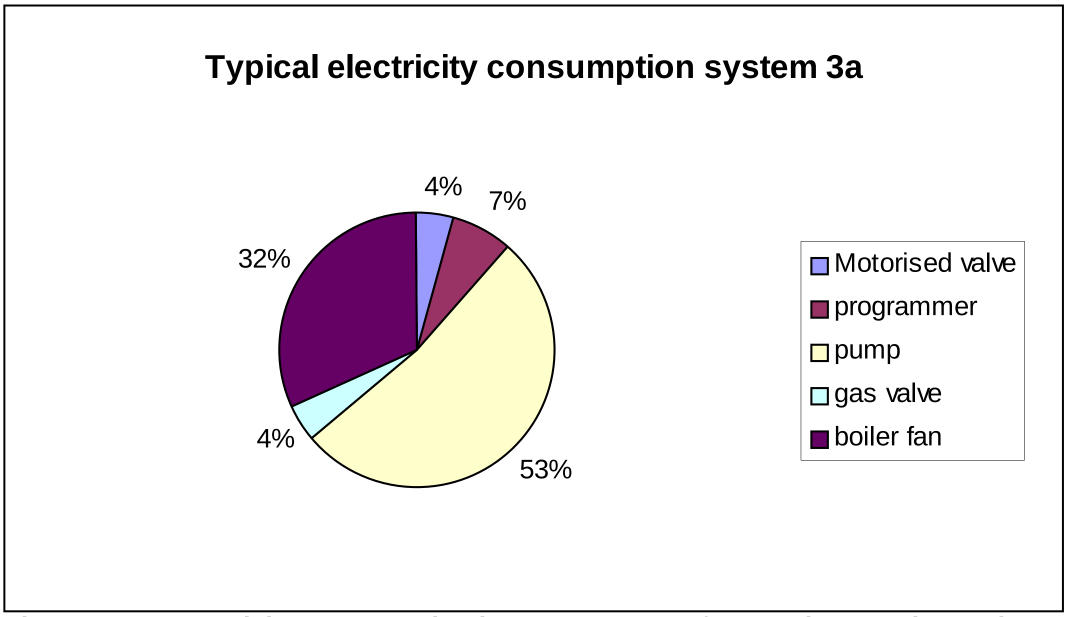

Fig.3 Annual electricity consumption by component % for a typical UK domestic system

Fig.3 shows the pump represents 53% of the electricity consumption (124 kWh/a), the boiler fan 32% (77kWh/a), programmer 7% (18kWh/a), motorised valves 4% (11kWh/a) and gas valve 4% (11kWh/a). The following section considers scope for improvement prioritised in order of power consumption.

Scope for component energy improvement

Pumps
Fig.3 shows the pump typically uses 53% of the system electricity or 124 kWh annually. The earlier EU SAVE project (see table 1) identified savings via improved efficiency and better control. The report also suggested conventional pump efficiency was around 18% and that this could be improved with design changes, in particular the use of permanent magnet motors. Some of these design changes are now commercialised, and permanent magnet (PM) pumps became available on the market in late summer 2005. PM pumps offer similar head and flow rate performance but potentially using only 30% of the electricity of the conventional type.
The PM pump requires power-switching electronics to control the stator field so it is easier to add speed control based on system pressure and this is included on some designs. Replacing a conventional 65W pump with a PM pump would use around 25W for similar performance. If this replaced the UK pump in Figure 2, the energy used would be 48 kWh/a, a 61% saving on the 124 kWh/a used by a conventional pump.

Boiler Fans
Fig.3 shows the boiler fan typically uses 32% of the system electricity or 77 kWh annually. Boiler fans are typically the radial blower type, driven by a shaded pole motor which are cheap, well proven and widely available but have poor efficiency and limited speed control. Modulating burners usually have continuously variable fan speed and hence the ac shaded pole motor becomes less attractive in this application.
DC motor speed can be varied by efficient power electronics giving better opportunity for reduced electricity consumption, with brushless motors becoming common. The motor is smaller and inertias are kept low since permanent magnets are used in the rotor. Less heat is generated in the rotor since there is no current flow, and any heat that is created is dissipated to the surroundings more quickly than a brush dc motor as the stator winding is on the outside, often fastened to the casing. Typical efficiencies are approximately 90 - 95%, and generally efficiencies are 5 -10% higher than for a typical ac induction motor.
Many fan manufacturers are now offering brushless DC motor fans with on board speed control and these are being fitted to some boilers. The electricity saving potential is assumed to be in the region of 10 – 20%.

Programmers
Fig.3 shows the programmer typically uses 7% of the system electricity or 18kWh annually. Despite having small instantaneous power consumption of around 2W, the running hours are continuous. All controls manufacturers visited make both electromechanical and electronic programmers and the true power consumption (in Watts) is similar for both for all brands. Although electronic programmers are often cheaper to produce, the market for electromechanical devices is still significant, particularly for users with special needs.
Few manufacturers indicated significant energy improvements were imminent or that they were possible with existing designs. The call for permanently illuminated displays from some user groups was seen to be an energy retrograde step by the manufacturers, although all agreed if it meant the controls were better used there would be an overall energy saving because of fuel saved.

Boiler standby power
The boiler modeled in system 3a in Fig.3 has a simple bourdon gauge type thermostat and consumes no power when heat is not required. Increasingly, many boilers use an electronic control card that provides the thermostat function along with flame detection, ignition phasing and so forth. These typically have power supply capability to drive dc fans and therefore have a fairly large power supply even though the full capability is seldom used. GdF identified the typical standby consumption of such cards using mains frequency transformers to be 8W.
New generation cards have switched mode power supplies and standby consumption is thought to be in the region of 1W, in line with other standby power initiatives. It should be noted most of these cards have capability for advanced thermal control such as weather compensation and separate set points for heating and domestic hot water. However, manufacturers indicated these functions were rarely enabled as installers were often unfamiliar with the benefits of such advanced controls. If they were, it is thought the fuel savings would easily outweigh the electricity penalty.

Motorised valves
There are two common types in service, 2 port and 3 port, usually based on spring return operation in the UK. The zone thermostat (cylinder or space) energises the valve motor to open the valve that is held open against spring force. A shaft mounted microswitch switches on the boiler and pump once the valve is open and the spring shuts the valve once the supply to the motor is removed. Consumption is a continuous 5 watts when the zone is calling for heat – there is no standby or holding current when there is no call for heat.
The conventional 3 port valve is particularly wasteful and often consumes power in a holding state when the heating system is off such as overnight. This energy burden can amount to around 18kWh pa if a 3 port valve is used in a heating system similar to that of Fig.2. and manufacturers estimate between 7 – 10 million such three port valves are in service in the UK. The reason for the holding consumption occurring relates to the construction of the valve and the way it is integrated into the controls system, detailed in the SAVELEC report.
One strategy for improving the energy efficiency of zone valves would be to avoid spring return and use motor on, motor off therefore consuming power only during state change. One manufacturer quotes a 30% electricity saving using this type.

Conclusions

The annual electricity consumption of non-electric heating systems varies considerably according to component choice and system type and is a significant proportion of domestic electricity consumption. Within the SAVELEC project the annual electricity consumption of typical UK central heating systems was simulated and found to vary from 131 kWh/a for a semi-gravity system through to 415 kWh/a for a combi boiler system, placing it in a similar context to some A rated cold appliances. With system 3a, which uses 241 kWh/a, the pump represents 53% of the electricity consumption (124 kWh), the boiler fan 32% (77kWh), programmer 7% (18kWh), motorised valves 4% (11kWh) and gas valve 4% (11kWh).
Using recent technical developments, this consumption could be reduced to 139 kWh per annum, a 42% saving. The largest saving is attributable to replacing the pump with a PM type. However, there is currently little available consumer information to enable them to assess how much their system uses or to make an informed component choice.
One way forward would be to develop a voluntary agreement that manufacturers could participate in and this has achieved success in standby power in other industries, notably television. Combined with component, or preferably system, energy consumption measurement and labelling consumers could then make informed choices. For the scheme to be successful, the industry partners would need to establish a commitment to improve and set an achievable target.
The agreement would need to develop an agreed measurement procedure and method for converting instantaneous power into annual consumption. Within SAVELEC, considerable differences occurred in annual energy consumption between the partner countries due to different climate, heating running hours and installer preference. One solution to these difficulties is to focus on the biggest consuming components and treat them in isolation – for example set a maximum standby power for boilers and programmers, or a specific energy consumption (e.g. watts per litre at fixed head) for pumps.

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European Initiatives on Labelling of Central Heating Gas Boilers

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Abstract

Society is moving towards more information to the consumer. The labelling of white goods has been a success and shown that the market can change toward the most efficient products.
However boiler are so called "installed products" witch performances are depending on the installation conditions therefore the labelling of such appliances shall be carefully designed and information systems shall accompany labels.
The present paper illustrates by examples in the UK, Spain and Denmark how such schemes have been designed and implemented. The paper also concludes (in the light of the experience gathered) on the way to design and implement a European scheme.

1. Introduction

CH boilers are a huge market in the EU (5 to 6 million appliances sold every year) and heating represents more than 20 % of the whole energy consumption in the EU. As a result the impact of CH boilers on the whole energy consumption and saving is very important for the individual consumer, but for the whole society as well.
In most countries the final user shows a lack of interest in the choice of a new boiler and the decision is left to the installer. As a result the boiler chosen is not always selected with due consideration to energy savings. Despite initiatives from the Commission to regulate the market toward high efficiency boilers (dir. 92/42) the system proposed (minimum efficiency + star rating = labelling) has not had the impact expected.
The new ECO design directive provides the opportunity for new measures like labelling and information systems on boilers. Such initiatives have already been launched in the UK and in Denmark.
In the UK, the SEDBUK method consists of an Information System and a Database aimed at informing the end user in a simple way through the Internet, giving consumers, installers and designers an accurate tool to compare different boilers. At the same time, the application of a label on the same basis makes it possible to obtain simplified information using the now well-accepted A to G system of the labelling directive 92/75. This has encouraged all manufacturers to provide the highest rated energy efficient boilers and the success of this initiative is such that the latest UK Building Regulations generally only allow for A or B rated boiler types to be installed.
In Denmark, such a label was also introduced and similarly an information system is made available on the Internet. The difference is that in Denmark the system is interactive and can take into account the specificity of the installation.
These cases complement each other in the two systems and tools used. The label gives a first indication to the end user (and a message that "boilers on the market are different!"). Next, the information system may enable the end user to have a more informed discussion with installers and to fine-tune the choice of the boiler. The label is clearly targeting the end user, where the information system has a wider target group (end user + installer + energy adviser + architects etc.).
The impact of such systems has dramatically changed the market mechanism in the two countries, and the end users become increasingly involved directly or indirectly in the choice of their heating appliances. Labels have become strong marketing tools in both countries and as a result, manufacturers have withdrawn some appliances, where the level of efficiency was not attractive enough for the market.
At the same time, the DGTREN has become more and more interested in introducing such a system at the European level. The industry has been reflecting on how this could be done and Marcogaz has

issued a paper that gives some indications of what could be the main features of such a system. In order to go ahead with the implementation of the measures described in the ECO design directive, DGTREN has recently launched two tenders (on BED and ECO design directive) that should help clarify the situation.
In the meantime, more countries tired of waiting for a European label have decided to launch a label of their own, as in Denmark or the UK. At the present time, such a system is also being developed in Spain. Thanks to the effort of Marcogaz and gas utilities, at present a lot of efforts are being put into harmonising such individual initiatives.
This paper will give some details on the labelling and information systems that have been developed and will discuss their impact on the market. The paper will further develop on the industry's point of view of how to design such systems at EU level in order to fulfil the requirements of the ECO design directive and its implementation measures. Among other issues the paper will discuss the relevance of an EU appliance database, with the design of a European label and information system.

2. Heating with CH boilers; short explanation of the technique

The heating system and its parts (source: www.boilerinfo.org [1])

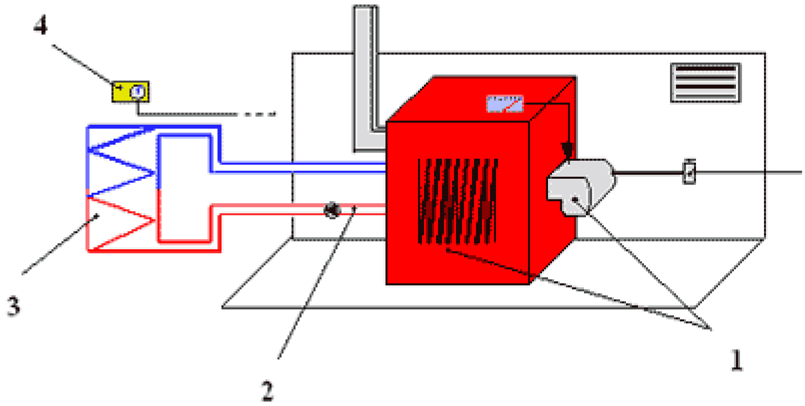

Figure 1: The main parts of the heating installation

The main parts of a heating installation
1. Boiler/burner combination: the part producing the heat
2. Piping with pumps and valves: the part distributing the heat
3. Radiators, convectors,…: the part emitting the heat to the room
4. Control equipment as room thermostat, outside temperature control: the part controlling room and water temperature

The central heating system provides heat to all rooms of the dwelling. In the EU this is mostly done via water (or in a more limited number of cases via heated air). To produce the heat and deliver it correctly to all rooms the heating system consists of 4 main parts.

Production system
The production system is the part of the installation that produces the heat. In the case of a central heating system, this is the boiler/burner combination.

Distribution system
The distribution system transfers the heat to the radiators or convectors. It consists of piping with pumps and valves.

Emission system
The emission of the heat in the room is achieved by radiators, convectors or floor heating.

Control system
The control system is the part of the installation that manages and controls the boiler. There are two main ways to operate the control: either on indoor temperature or on outdoor temperature. It generally consists of a thermostat, the radiator valves etc.

The different parts of the heating system interact
Convector, radiator or floor heating requires different water temperatures for their optimal use. Different water temperatures will be obtained by using different types of control systems and different emission system sizing. These differences in water temperature will, of course, lead to differences in boiler efficiency and in distribution losses.

The heating system interacts with the building
The main function of the heating system is to compensate for the heat losses of the building. When the heat losses of the building decrease, the requirements for the heating system change at the same time. This has practical consequences on the boiler efficiency as well.

Annual efficiency
Each boiler is characterised by a **nominal efficiency**, which is measured in the laboratory. As explained above, once installed, the efficiency of the boiler could depend on many parameters, such as:

- type of boiler
- design of the water circuit distribution and emitters
- heat demand
- etc.

So in real life the annual efficiency of the same boiler may differ considerably from one installation to another.
This is the reason why the annual efficiency shall be preferred to the nominal efficiency when choosing a boiler for a given installation.

BOILSIM
BOILSIM is a sophisticated boiler model that works with simple parameters measured by the application of boiler standards. It was developed over several years and validated over more than 80 boilers. Today it is used for the basis of labelling (in Denmark) and information systems (Denmark, Spain).

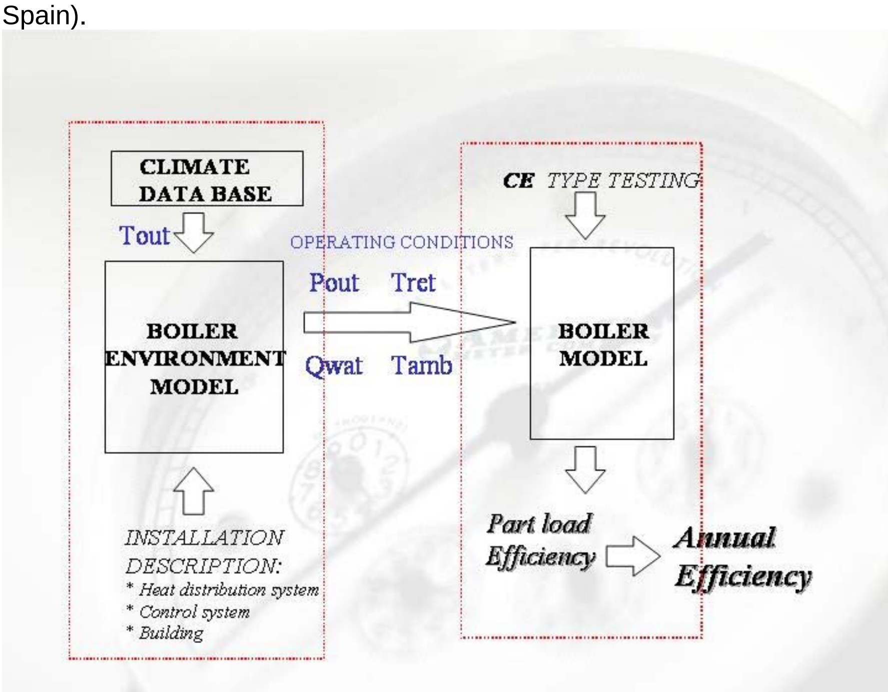

Figure 2: The principle of the BOILSIM method

3. Overview of the EU boiler market

The size of the EU market is probably about 6 million units a year. The existing boiler population is some 60 to 80 million. Knowing that the average energy consumption is probably somewhere between 15.000 and 25.000 kWh a year the heating with boiler represents a considerable amount of the total energy consumption in the EU. Therefore, the impact of policies on the market could be quite considerable.

Most of the new boilers sold today are traditional, but there is a clear trend in favour of the condensing technology. In countries like Denmark or the Netherlands condensing boilers are today the most sold type of boiler (see below).
The efficiency of most existing boilers older than e.g. 15 years is probably 10 to 15 % lower than the new condensing boilers available. Therefore, there is a considerable potential of energy saving.
More details on the market data will be available at the end of 2006 as the Commission has ordered a study that should clarify a number of points, including the market.

4. EU regulations, boiler directive, EPB directive and standards. Impact on the market

In order to generally improve energy efficiency in Europe, the Commission has recently issued different instruments like the Directive 2002/91/EC on the Energy Performance of buildings or the proposed Directive on Eco-design requirements for energy Using Products which will amend the Directive 92/42/EEC on energy efficiency requirements for new hot water central heating gas boilers. Furthermore a new Directive on Energy Services is also discussed.
Directive 92/42/EEC provides a star rating system intended to ascertain the energy performance of boilers. This star rating system has proved not to deliver the expected results and Directive 92/42/EEC will be revised.
There are mainly 4 framework directives that are relevant to boilers:

1. Boiler Directive 92/42 (Council Directive 92/42/EEC of 21 May 1992) on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels.
2. Labelling Directive 92/75 (Directive 92/75/EEC Council Directive 92/75/EEC of 22 September 1992) on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances.
3. EPB Directive 2002/91/EC of the European Parliament and Council, on the energy performance of buildings.
4. Directive 2005/32/EC on the eco-design of Energy-using Products (EuP).

The boiler directive (1) effect was to remove from the market the boilers with very poor efficiency. The labelling system (star rating) that was included has never been successful; one reason being that the system was not adapted to the interlaboratory reproducibility of efficiency measurement. Since then, there has been a stronger focus on measurement aspects, and laboratories grouped in a network, LABNET, have been working for the improvement of the situation.
The labelling directive (2) does not apply directly to boilers, but as the eco-design directive (4) makes the labelling system mandatory, the directive becomes highly relevant.
The EPB directive (3) implementation (in the national building codes) did in many countries result in direct or indirect new minimum requirements on boiler efficiency. As a result, the condensing technology appears to be the only choice possible in many countries.
According the present version of the Eco-design Directive (4), central heating boilers shall be subject to labelling and the Commission has also confirmed that Directive 92/75/EEC on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances will apply to central heating boilers. This directive will also apply to domestic hot water production.

5. The labelling directive. Marcogaz point of view for its application to boilers

Background
In many countries there has been a long tradition of informing the final users and installers about the real performance of central heating gas boilers and this was done in the past mainly by gas utilities. For most gas consumers the image "gas" is given through the gas appliance installed. A “bad” appliance will therefore lead to a poor image of the energy “gas". Therefore, it was and still is important that the gas utilities are present in this discussion.
Boiler performance is not only dependent upon nominal efficiency but also on the conditions of installation. Therefore in order to achieve the targeted savings a broad collaboration and action are needed. Labelling, education and training, inspection, consultation and information should be organised in collaboration with the Authorities, Energy utilities, manufacturers, designers and installers.

How to achieve energy savings for central heating gas boilers? Overall organisation

As already mentioned, central heating gas boiler efficiency depends both on the boiler itself and on the system as well as the users habits. Therefore an action on the boiler is useful but will not necessarily lead to a significant improvement without consideration being given to the whole of the central heating installation. So the emphasis should be put on the right choice of the boiler at the installation design phase.

It should be noted here that gas boilers are commonly sold by installers. The existence and quality of the information given to the gas appliance installers is therefore a key issue.

Labelling

The labelling of boilers is a first action that aims at informing the public widely about the fact that the boilers have different efficiencies and that different technologies exist. This label needs to be based on simple assumptions and be valid for an average installation.

The parameters used for the calculation of the label should be the same: EU CE type testing. The label shall include information on the boiler efficiency, heat output and electric consumption.

As the label is a simplified information, the choice of the efficiency to be used as basis for the label is not a determining discussion for MARCOGAZ: it can be part load efficiency or annual efficiency, it could also be the efficiency for a given load determined with models such as BOILSIM that has proven to be more accurate than measurements at low load, it can also be the SEDBUK efficiency: 50% of full load + 50% of part load (which halves the uncertainty of the part load efficiency tests).

The label is aiming at fair consumer information and this aspect shall be reflected in the design of the system (e.g. the same basis shall apply for fuel oil and gas). MARCOGAZ is flexible as to the exact content of the label as long as there is an agreement on having an information system launched together with the label. One role of this information system would be to correct from the inaccuracies of the labelling system that would always be too simple to take into account the particularities of a given installation.

Whilst the label is primarily for new boilers on the market, it should also be used in a simplified way for existing boilers. Obsolete boilers can be rated and included on a database which will then allow a comparison between the existing boiler and a new 'A' rated boiler showing the running costs savings achievable. This has been implemented in the UK with SEDBUK (www.sedbuk.com) and has lead to increase in the boiler exchange market (currently 800,000 plus per year).

Information system

Besides the labelling there is a strong need of an information campaign aimed at the installers and possibly the interested end users. This system aims at bringing some additional information and will take into account the influence of the design, installation, controls, commissioning and operation of the central heating system. Information relative to energy consumption and performance, corresponding to annual consumption and covered by standardised test method, should not be mixed up with comfort criteria such as waiting time or temperature fluctuation at constant water flow. This system should help the installers to find the best adapted boiler for a given installation. We believe this system should be implemented on the Web for easy access.

The information system will deal with energy saving, but also with cost. It is important to give to the user of the system, elements helping to calculate e.g. payback time of a new boiler.

Replacement of old boilers shall be done in consideration to energy and cost savings for the consumers. The Directive 2002/91/EC related to Energy Performance of Buildings offers a platform which can be used. The opportunity should be taken to choose an appropriate replacement boiler and consider central heating system improvements to optimise potential energy savings benefits.

Connection between the different tools needed

In order not to create confusion or contradiction in the data given by a label or by any information system, basically the same data and same models (if such are to be used – some validated models exist e.g. for the annual efficiency) shall be used for the label and information system.

In practice, there is a need for a centralised boiler database that would list the boilers tested and data needed for the labelling and information system. Such a databases already exists as (www.boilerinfo.org, SEDBUK www.sedbuk.com) , and a similar system shall be further developed at EU level under the control of Organisations such as the Notified Bodies in order to guarantee the validity of the data used (see further in section 5).

Need for harmonised testing and measurement (art 7.1 of dir 92/42)

The quality of the data to be used in the information system and especially the measurement accuracy of laboratories and inter-laboratory reproducibility are key issues for the successful application of the label and information system.

The various Round Robin Tests (inter-comparison tests) organised between EU accredited laboratories have all demonstrated that the inter-laboratory reproducibility of test results for the measurement of efficiency is giving problems. Especially part load (30%) efficiency is a problem and it is necessary to consider this very seriously when designing both the labelling system and the information system.

It would be the responsibility of an organisation such as BEDAC to set up the criteria for the acceptance of the data to be used for the labelling and used in the data base. It is known that a number of measurement problems can affect the result in such a way that the labelling or information system cannot be used in practice.

Therefore, specific attention shall be given to this point and it is advised to involve LABNET (network of laboratories) in the discussion about the criteria for test result acceptance.

The efforts to improve the measurement accuracy and consistency between laboratories should be continued, and especially in the phase of enlargement of the EU. Already much progress has been achieved in LABNET. It could be suggested that the laboratories which are providing test data for the database should work together with the Notified Bodies for the definition of the measurement requirements and perhaps with Round Robin Tests (inter-comparison) every two years or so.

6. National initiatives for labelling and information. Short description and impact

The UK

First issued in 1999, the SEDBUK (Seasonal Efficiency of Domestic Boilers in the UK) method estimates seasonal efficiency as a percentage figure. SEDBUK results are used to rank boilers and give an accurate comparison of their energy efficiency. SEDBUK is a fuel efficiency value (maximum 100%, using gross calorific values), averaged over one year, for boilers installed in a typical UK house. It has helped transform the UK market for domestic gas and oil-fired boilers in recent years.

The UK government introduced SEDBUK after a comprehensive 3-year test programme during which laboratory tests were carried out on 20 different boiler models and these were combined with field trials of boilers in some 100 premises.

The SEDBUK numbers are listed as percentages that indicate how much of the heat obtained from burning fuel (gas or oil) is transferred into the heating and hot water system. The figures have been calculated by combining a series of factors which affect boiler performance once it is installed. This includes the boiler type, fuel type, the ignition arrangement, any internal water storage, patterns of usage, and the control system, as well as the results from standard laboratory performance tests.

This laboratory performance data is obtained as part of the manufacturers' compliance with the European Boiler Efficiency Directive (BED), to which all boilers are tested at their approvals stage. Full and part load (30 %) performance tests are carried out to meet the requirements of the directive and these are fed into the SEDBUK calculations.

A joint industry programme, funded by the UK government and managed by BRE, provided cooperation between appliance manufacturers, trade associations and the test houses, and this led to the development of a set of ten equations. The type of boiler, control system, water storage etc. dictates which equation is relevant to a boiler model. Seven equations are used for natural gas and LPG boilers with the remaining three equations being used for oil-fired boilers.

Boiler manufacturers submit their efficiency test results, with independent certification, to the manager of the UK's Boiler Efficiency Database, who verifies the figures and calculates SEDBUK from them. The results are entered in the database, where they are used to calculate and certify the energy performance of dwellings and to show compliance with Building Regulations. They are also published on the internet for all consumers to access and make decisions on their appropriate choice of appliance (www.boilers.org.uk).

Boilers are graded into efficiency bands from A to G with A being 90 % or above and G being below 70 %. The database gives brief details of each boiler model with its A-G efficiency band and an annual running cost indicator. Gas boilers with a SEDBUK efficiency of 90% or more (band A), and oil boilers with 86% or more (bands A & B), qualify for endorsement and can display an "Energy Saving Recommended" logo as part of an energy efficiency product promotion scheme. All these activities are helping to increase public awareness of energy savings benefits.

Further to this, there have been changes made to the UK Building Regulations (part L) in April 2005 such that installers must now only install high-efficiency condensing boilers with SEDBUK rating band of A or B, unless there are exceptional circumstances that make this impractical or too costly. It is thought that these exceptions will apply to some 5 % of new boiler installations.

Denmark

An energy labelling scheme for electrical appliances has been used for the consumer imformation for more than 10 years. The Danish gas companies and Danish Gas Technology Centre decided to use this well-know design as the basis for development and implementation of a voluntary labelling scheme for small domestic gas boilers.

The aim of this initiative was to give the user an easy-to-use and fair tool for choosing a new domestic gas boiler and thus to promote the use of high-efficient boilers.

The labelling scheme was established with the support from the entire gas industry in Denmark; this was essential since the extended use of the label to a very large extent depends on the broad support of all parties concerned.

The annual efficiency method and the calculation program BOILSIM have formed the measurement and calculation basis for the boiler labelling scheme. The advantage of choosing this basis is that these tools were developed under the collaboration of a wide range of European partners including manufacturers. Therefore, the method is considered as the standard for determination of boiler annual efficiency by a large number of EU test laboratories.

The “arrow label” for electrical appliances is already well established among consumers as a tool for choosing the most energy efficient electrical appliance. This is the reason for choosing the same design as basis for the design of the layout of the boiler label.

The support of the Danish gas industry has been ensured by involving all parties in the development and implementation work of the boiler labelling scheme.

Labelling of gas boilers

The arrow label graduated from A-G and with key figures with comparable information on energy utilization and environmental load of the individual boilers is meant as a decision tool for the consumer. To further assist the consumer in achieving a high sanitary hot water comfort and energy optimized operation of the heating system guidelines for choosing the best boiler/hot water tank combination were developed. Storage technology is the main market for sanitary hot water production. Figure 3 shows the template of the design of the label.

A detailed description of the calculation method for the energy label is found in the document “Description of the calculation method for the Danish labelling of gas fired boilers” that can be downloaded from www.dgc.dk.

Apart from the label, other tools were developed that explain the contents of the label and facilitate comparison of alternative boilers. Different tools were developed for the consumer and the installer, respectively. Boiler manufacturers are yet another target group. Apart from the advising tools the manufacturers need to know what they are required to do in order to have their new boilers included in the labelling system.

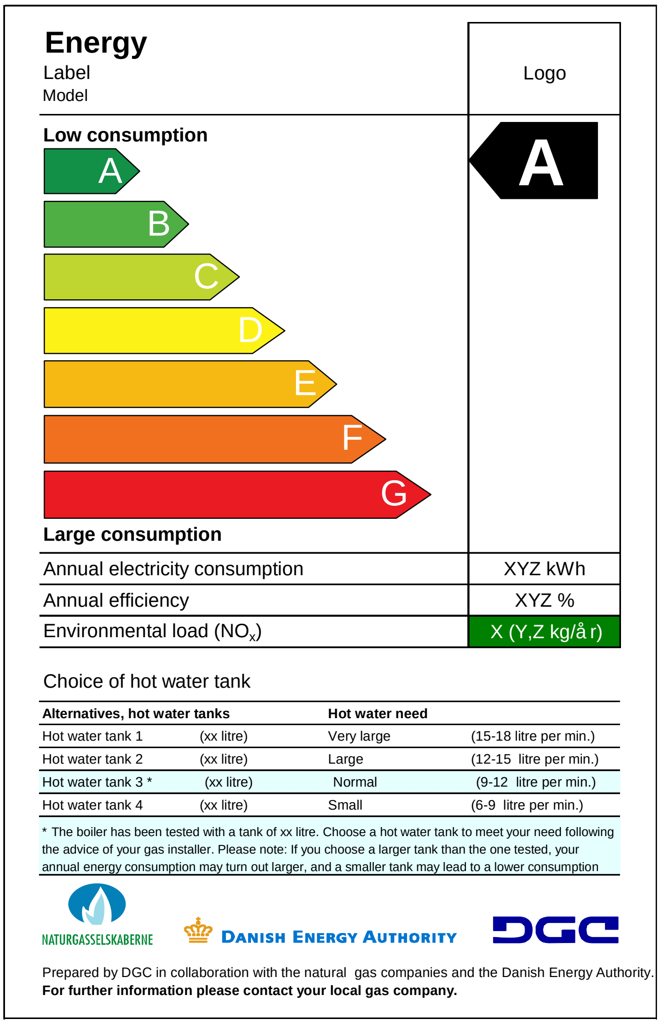

Figure 3: The template of the design of the label

Report on the situation after a one-year pilot period
The implementation of the labelling scheme in the market was based on a close cooperation between DGC and the gas companies, boiler industry, Danish Electricity Saving Trust, National Consumer Agency and Danish Energy Authority.
After the pilot period it appears that the energy labelling scheme has indeed influenced the boiler market:

- During this one-year period, the boiler manufacturers have adapted their boilers regarding the electrical components. Boilers that originally were sold with three-stage pumps have been modified to be sold with modulating pumps.
- The supply of the best A labelled boilers is increasing at the expense of B-G labelled boilers.
- The gas company show rooms only show A labelled boilers today.
- As the labelling system is a voluntary system, some boilers are still not labelled.

The Danish gas industry has fully supported the labelling system. The boiler manufacturers' commitment is mainly due to the fact that the labelling system has been prepared for EU standardisation. Such standardisation may in the long run result in a reduction of the number of boiler tests in the individual countries.

Spain
The aim of the Spanish administration is to develop a boiler database in order to promote the use of the most efficient boilers in new installations, normally combi-boilers without storage system or, as much, a micro-storage (4 litres) device. It is noticeable that, in the case of Spain, the installation of solar panels for producing hot sanitary water (60 % of annual coverage) will be compulsory from 2006.

The heating requirements in Spain (and other countries such as Portugal) are a bit different compared with other countries in Europe.
In the first place, the heating requirements are much lower because of the climate, this means that in most parts of the countries the boilers are working only 4-5 hours/days as an average, but very dependant of the climate and the type of installation. Therefore, the use of simple methods for estimating annual efficiency is difficult, because boilers are working most of the time at a high load but for short periods. This is the reason why condensing boilers, which are common in other countries nowadays, are not so efficient (they are used in non-condensing way) when used in Spain.
These difficulties have given a strong impulse to the use of more sophisticated tools, such as Boilsim. Currently there is a common project between the Spanish Administration, gas companies and the Spanish Boiler Manufacturer Association for developing a new tool that will be partially based on Boilsim and will allow installers or customers to choose the best boilers. The tool also will take into account climate and building, not only nominal efficiencies. The new tool is planned to be available on a public web, and maintained by the Spanish Administration. Because the system is Boilsim-based, the database will admit data obtained by a certified laboratory of Europe, and for this reason technical aspects such as repeatability, reproducibility, and intercomparisons between labs are very important.

7. Conclusion

Society is moving towards more information to the consumer and implementation of a single labelling system is a positive initiative. Information sent out and labels used should be simple, easy to understand, and should permit the comparison between different energies only if information are established on the same basis.
Such a system, however, can only be considered together with an information system able to complete the general information given by discriminative and efficient label. Boiler performances as other “installed products” depend greatly on the system (installation) and the users’ habits, therefore, such an information system is needed. The Directive on Energy Performance of Buildings is also bringing up the discussion of the evaluation of existing installations. It is important to ensure that a consistent approach can be used which includes new installation of full central heating systems, existing system improvements, and boiler replacement (including appropriate system improvements) in order to realise energy saving potential.
The huge boiler population and market leads to the conclusion that only few % change on boiler efficiency will result in considerable amounts of energy. Therefore, there is a strong focus on boilers in the EU, but as things are moving slowly, national initiatives have been undertaken as there is a real need for labelling and information systems.
The national systems implemented show that the labelling systems are moving the markets. In Denmark the market has moved almost exclusively to “A” boilers.
Experience with the UK labelling system SEDBUK since 2000 has shown that the greatest success has been the comparison between existing boilers and new ‘A’ rated boilers. By showing the rating of the old boiler (usually F or G rated) and the running savings possible, customers are exchanging their old broken down boilers rather than repairing.
It would certainly be useful to extend those initiatives to all countries, but it is urgent to work on the future EU label as the multiplication of national labels would create an unacceptable difficulty for the open market of boilers.
Beside the label it would also be useful to have a European information system able to take care of the individual situation and bring a more accurate figure of energy consumption in the choice phase of a new boiler.
Finally, the efforts done for the improvement of the interlaboratory reproducibility should be continued in order not to create doubts on the validity of the future labels and information systems.

References

[1] www.boilerinfo.org - an informative website on Domestic Central Heating Boilers
[2] SEDBUK www.sedbuk.com
[3] LABNET http://labnet.dgc.dk/

Glossary and definitions

BEDAC
Boiler Efficiency Directive Advisory Committee

CEN
The European standardisation organisation

CH
Central heating. A central heating installation consists in a heat generator and a heat distribution system. It is typically a boiler connected to radiators.

FL
Full load. (see also PL = part load)

GLP
Good Laboratory Practice. The document developed by LABNET is describing in detail the procedures for testing and measuring efficiency. It is a complementary document to the procedures described in CEN standards

LABNET
Network of laboratories testing boilers - has about 25 members (http://labnet.dgc.dk/default.htm)

PL
Part load (see also FL = full load).

RRT
Round Robin Test: This is also called Inter-comparison test and it consists in sending the same reference material (boiler) to different laboratories.

SEDBUK
Seasonal Efficiency of Domestic Boilers in the UK (http://www.sedbuk.com/)

The Emerging European Water Heating Labelling Directives

Bruce Young

UK Market Transformation Programme

Abstract

The Energy Labelling Committee of the European Commission has turned its attention to domestic water heaters, and development of three directives to deal with them is now in progress. The directives define 19 product categories, embracing a wide variety of appliances, systems, and fuels. But, unlike products covered by earlier labelling Directives, the categories behave in very dissimilar ways, they are manufactured and installed by several separate industries in competition with one another, and there are competing fuel interests too.

The aim of the new Directives is to supply consumers with information across the whole range of choices, helping them to understand the different product and system types, as well as differentiating products of the same type. Comparable measurement of the annual average energy performance of so many categories presents a formidable technical challenge, and the mandate to create a set of harmonised standards recognised that by emphasising "*... the need to avoid distortion or bias which would unfairly favour one type of product or industry relative to another*". As an important first step, the mandate has provided some firm foundations by defining three principal patterns of daily hot water demand to be used as common loading conditions.

Water heaters also use a variety of fuels, including electricity, gas, oil, and renewable energy sources. That forces consideration, for the first time, of how fuels should be treated under a single labelling scheme to indicate not just cost but wider environmental impact.

The paper summarises developments so far, explores some of the complex issues raised, and discusses options for the way ahead.

Introduction

Hot water service is either the largest or second largest requirement for energy in housing in most countries of Europe. In the UK it accounts for about 23% of the energy consumed by the housing stock, and in newly built houses (which have a far lower demand for space heating) it is likely to be nearly 40%. In both cases it exceeds, by a substantial margin, the energy demand for lighting and appliances. It might therefore be expected that hot water in dwellings is a prime target for attention in the energy efficiency policy arena.

Yet there has been little policy intervention at European level so far, and it has been left to national building codes to impose minimum performance standards. Slow progress may reflect the complexity of the subject, which arises from:

- the many types of product and system on offer
- the variety of configurations
- integration with space heating systems
- the interaction of separately purchased components
- the selection of fuels, including renewable energy sources
- the different (and competing) industry interests.

Early activities of the European Energy Labelling Regulatory Committee concerning water heaters go back to 1994, though after September 2000 were concentrated on electric storage water heating only. A comprehensive history is set out in [11]. More recently the Committee decided, in February 2002, that energy labels should be introduced for nearly all types of water heaters installed in single family homes. Later in 2002 the Committee issued a mandate [12] to CEN and CENELEC to develop test standards, with the provision that they should produce comparable results, should be fair, and should all use the same daily load patterns. In October 2004 the Committee then issued for discussion the first drafts of the new Water Heater Energy Labelling Directives.

Scope of the Directives

At the time of writing (February 2006) there are three draft directives for water heaters under development by the Energy Labelling Regulatory Committee. There is one for electric water heaters [5], one for gas and oil water heaters and water storage devices [6], and one for solar water heaters and water storage devices [7]. They cover 4, 9, and 6 product categories respectively, as shown in Table 1.

Table 1 : Categories of water heater in the Directives

Directive & category	Category description	Partial diagram (see Appendix B)
Electric – 1	Electric Storage water Heater	A
Electric – 2	Electric Night Storage water heater	A
Electric – 3	Electric instantaneous water heater	-
Electric – 6	Electric Storage water Heater (with heat pump) i) air, ii) ground	C
Gas/oil – 1	Gas Storage water Heater	B
Gas/oil – 2	Gas instantaneous water heater	E
Gas/oil – 5	Gas fired heat pump water Heater	D
Gas/oil – 6	Gas combi boiler	E,F,G
Gas/oil – 7	Oil Storage water Heater	B
Gas/oil – 8	Oil instantaneous water heater	E
Gas/oil – 11	Oil fired heat pump water Heater	D
Gas/oil – 12	Oil combi boiler	F,G
Gas/oil – 13	Hot water storage tanks (with heat exchanger)	B,C,D
Solar – A	Solar water heaters with no auxiliary heat source	B
Solar – B	Solar water heaters with auxiliary heating by gas or oil (including combi appliances also designed to provide heating)	B with E
Solar – C	Solar water heaters with auxiliary heating by electricity	C
Solar – D	Solar water heaters with auxiliary heating by means of a heat exchanger driven by a gas or oil central heating boiler, even if they can also be heated by an electrical resistance (immersion heater)	D
Solar – E	Solar hot water tanks	D
Solar – F	Solar Collectors (suitable for use in water heating systems), sold separately	-

The intention of the Directives is to measure the energy performance of nearly all water heating products and systems designed for a single family home, and label them on a comparable basis. There are exceptions for systems that are very small, very large, very powerful, or that provide for a single outlet only. A few uncommon product categories and combinations have been omitted (eg, water source heat pumps, thermal stores, micro-cogen), but the range is otherwise comprehensive and a laudable attempt to embrace the very wide selection available to purchasers.

Requirement for comparable performance measures

It is the requirement for comparability across this wide range of products and systems that presents the greatest challenge. Performance is to be measured by harmonised test standards, where possible. Mindful of the different fuel and industry interests, the mandate [12] declared in resounding words that harmonised standards "*... need to avoid distortion or bias which would unfairly favour one type of product or industry relative to another*".

But this important aim will not be easy to achieve. Performance evaluation methods are required that, in the context of energy labelling, are straightforward to apply, without undue expense, across the whole range of products and systems on sale. Their purpose is to produce data for an energy label to inform the purchasing decisions of consumers. If the methods are too difficult they will take a long time to develop and agree; if too simple, they will be unable to discriminate fairly between similar products. Performance of domestic water heating systems generally was discussed at EEDAL 2003

[13], and since then the draft water heater directives have been issued with energy classification scales. The relevant factors affecting the development process are discussed below.

Common load patterns

A restricted working group was convened in 2001 to determine a small number of standard daily hot water demand patterns ("tapping patterns") against which all products and systems could be tested. Tapping patterns strongly influence test results, so there is good reason to impose uniformity rather than permit different patterns for different products. For example, it might be alleged that certain patterns favour, say, electric storage water heaters (good for rapid delivery; slow to recover) over instantaneous water heating by combi boilers (significant start and stop losses; no recovery time).
The restricted working group was informed by recent SAVE projects ([8], [9]), which indicated average hot water consumption of 36 litres per person per day and 100 litres per household per day in the 142 million homes of the EU. These figures became the basis for two of the tapping patterns defined by the group, and were later copied into the mandate and draft Directives. It is important to remain aware that, while reasonably consistent across the different countries, the consumption figures are averages of very wide individual variations. Also, the energy demand for any given volume of hot water varies significantly with climate.

Functional and operational characteristics

The product categories covered by the Directives (see Table 1) are not functionally equivalent; for example, some are relatively simple components (eg, Gas/oil – 13) while others are complex systems (eg, Solar – D). Operationally they differ too, as they range from "instantaneous" (meaning hot water production on demand) to storage systems in which heat generation is decoupled from draw-off, with hybrid options sharing some characteristics of both.
Systems may be constructed in a variety of configurations, and it is impractical to anticipate and analyse them all for the purpose of energy labelling. Probably the most important distinction is between those that contain a heat generator and those that don't.

Range of measured performance

The many product categories and disparate behaviour will lead to a wide range of assessed energy performance. If the results for all product categories are placed on a single energy classification scale, comparison between types will be clear, but steps on the scale (bands) may prove to be too coarse to discriminate between products of the same type. One way to overcome that would be sub-division of the bands; eg, A1, A2, A3 to discriminate between products of the same type with similar performance.

Fuel variety

The variety of fuels, including renewable energy sources, introduces a difficulty that did not arise in earlier labelling directives, as the products were all electric. For water heating, it is very likely that combinations of two or three fuels will be used in the same system (eg; solar, gas, electricity), and reliable methods are needed to assess their quantities and relative contribution to an overall energy rating.
The different fuels have greatly different environmental impact, and the Energy Labelling Regulatory Committee has not announced its policy on how fuel types affect the measures of performance required for energy labelling, where the types must be combined and placed on a single energy classification scale. The treatment of different fuels in the draft Directives has been examined from the perspective of delivered energy, primary energy, CO_2 emissions, and annual fuel costs (using UK figures), and results are shown in Appendix A. It can be seen that the classification scale chosen for the Directives is closest to primary energy.

Test standards

The plethora of standards for different hot water products was one of the reasons that impelled the Regulatory Committee to issue a mandate calling for testing under common conditions. To describe hot water products, the mandate refers to 14 existing standards. Not all of them include energy performance measurement requirements, and, where they do, that may not have been their primary purpose and they may not have set minimum levels. Historically, the standards have been seen as independent, with no requirement for co-ordination during development.

The mandate now requires CEN and CENELEC to develop test measurement standards for water heaters with a common loading pattern. This calls for adaptation, or re-writing, of existing standards, and possibly new ones. They will still be developed by different committees, and effective co-ordination is necessary if comparable results are to be assured.
Furthermore, the scope of the relevant standards for water heaters has previously been limited to individual products rather than complete systems in which such products are installed. For an assessment of the energy performance of complete hot water systems, a rather different approach is required, more like that adopted for the standards being written for the Energy Performance of Buildings Directive ([14], [15], [16], [17]).

Industry structure
Water heaters comprise diverse technologies and fuels, and separate industries are responsible for their design and manufacture – often as part of a range of other products of similar type and construction unrelated to water heaters. As noted already, standards development is the responsibility of several unco-ordinated CEN and CENELEC committees, and such committees are dominated by experts from the particular industries involved. Against this background, the requirement to deliver comparable performance measurement standards for the full range of products and systems, on parallel development tracks, will need careful independent monitoring.

Methods of performance evaluation

Although harmonised performance test standards are seen as the preferred option, it is recognised that they will not always be feasible or even practical. It is relatively easy to design a performance test standard for a self-contained product such as a hot water tank with an electric heater element, or an instantaneous gas water heater. The results from such tests can be used to predict annual energy demand with reasonable confidence. But testing of products that do not include the heat generator, and are merely component parts of a larger system, is another matter.
Three approaches to performance evaluation are possible, as discussed below.

Laboratory tests
Laboratory tests can be carried out under carefully controlled conditions, to defined levels of accuracy specified in EN standards, and, if properly designed, should at least provide a fair comparison between products of the same type. The scope and complexity of tests may vary widely, and it is helpful to distinguish them on that basis.

(i) Testing of a self-contained product, operating as a water heater
Provided the product under test includes the heat generator and represents behaviour of the whole water heating system, the performance results can be combined into an average daily or annual energy figure to be shown on the energy label. If the product does not include the heat generator, of if there is a second heat generator (eg; a solar collector), then test results of the product alone are inadequate as a guide to overall system performance.

(ii) Testing of products that are components of larger systems
If the aim is to measure a product intended to be installed as part of a larger system and give it an energy label of its own, it must be installed in a reference system where the qualities of the other components have been rigorously defined. There might be a number of possible system configurations in practice, but only one reference system configuration can be allowed if results are to be comparable.
For example, a product in category “Gas/oil – 13” (a hot water tank) could be installed and tested in a system with a boiler of defined efficiency operating under a defined control regime. The weakness of this approach is that boiler efficiency and behaviour may well be the dominant characteristic from the point of view of overall energy performance, and the tank would affect the outcome only to a modest extent. If that were so, the accuracy and repeatability of tests could not be expected to be very high, and the results may not discriminate between tanks under test with sufficient resolution. A more serious objection is that the results are irrelevant when the tank is to be installed in a system with a boiler of entirely different characteristics, and potential customers would then be gravely misled by the energy label.

(iii) Testing of complete water heating systems

Testing becomes far more complex if it extends to a complete water heating system that is an assemblage of different components, separately specified and purchased. For example, in product category "Solar – D" (a water heating system containing a solar collector, boiler, and tank with two heat exchangers), the interactions between components affect overall performance. Relative sizes and other characteristics influence the annual energy consumption, and the outcome of the test would depend on all of:

- size of solar collector
- efficiency of boiler
- volume of solar zone in tank
- total volume of tank
- insulation of tank
- performance of solar heat exchanger within tank
- performance of boiler heat exchanger within tank.

It is difficult to see how testing of a complete system such as "Solar – D" can be specified accurately and carried out economically for the purpose of energy labelling, and it seems likely that alternative methods will be adopted.

(iv) Testing of secondary characteristics

Secondary characteristics are properties of the product that affect its energy performance but do not give enough information, on their own, to say what the energy consumption will be when the product is installed and used. In the case of hot water tanks, the relevant characteristics would be insulation and heat exchanger performance, both quoted in their normal units of measurement (not energy). For products in category "Solar – F" (a solar collector), it would be temperature rise under specified conditions of solar radiance, inlet water temperature, and flow rate. It is not possible to equate the measured values to energy consumption directly, but that can be done indirectly by using them in calculations based on an analytical model.

Testing for secondary characteristics is far cheaper and simpler than testing of complete systems, and harmonised standards are relatively easy to produce.

System models

An alternative to laboratory tests of whole systems is to develop an analytical system model, in which system and boiler behaviour is simulated mathematically and measurable characteristics of the product to be labelled are entered as parameters to the calculation. Such models need not be very complicated, but even if they are the final application of them may be reduced to a straightforward procedure or set of equations. The paradigm is SEDBUK ("Seasonal Efficiency of Domestic Boilers in the UK"), in which EN standard test results for boiler efficiency are converted to an annual average installed efficiency, making reasonable assumptions about controls, occupancy patterns, climate, etc.

If analytical modelling is adopted as a solution to labelling some water heater product categories, it is essential to ensure that underlying assumptions are realistic and representative of the typical systems in which they are likely to be fitted. Identification of typical central heating systems, some integrated with water heating, has already been carried out for the SAVELEC project [10].

Modelling assumptions must always be clearly stated, and may be subject to challenge and dispute. For those reasons, development of acceptable models for the more complicated water heater product categories will probably be a slow process.

Secondary characteristics

Measurement of secondary characteristics, as described under *Laboratory tests (iv)* above, is a less ambitious alternative to a full analysis of systems, and can be achieved in a shorter timescale. An energy label can be based on secondary characteristics alone, though if it is also to show average energy consumption to assist consumers (rather than designers or installers) further calculations and a system model are required.

Other relevant Directives

The Boiler Efficiency Directive

The Boiler Efficiency Directive [1] is severely out of date and sets a very low minimum standard that does not take account of major improvements in boiler design over the last 15 years. Its relevance to water heating is marginal, as it does not extend to hot water tanks connected to a boiler, nor does it require measurement of the performance of combination boilers while they are producing instantaneous domestic hot water. Nevertheless the efficiency test standards used to demonstrate compliance with the Directive remain relevant for water heating systems with certain boiler types (regular boilers, but not combination boilers).

The Energy Performance of Buildings Directive (EPBD)

The Directive [3] demands a methodological approach to the design and analysis of new and existing buildings, with a certification scheme to declare their energy performance. Installed plant, such as water heaters, is an important contributor to overall building performance and is included in the methods of analysis now being developed. There are four standards for hot water systems in buildings – see [14], [15], [16], and [17]. However, their scope is not the same as that for the labelling directives, and the initial drafts could not be adapted for labelling purposes without substantial further work.

For the purpose of analysing and certifying buildings, clear identification of the water heating system and its energy performance would be a great benefit to building assessors. An energy label, including relevant technical data, would be able to provide that. However, the label would have to be permanent and visible, which is not among the provisions of the current energy labelling framework Directive [2].

The Energy Using Products Directive (EUP)

The Directive [4] proposes whole life cycle costing as the principal method of analysis. Unlike other energy using products, it is probable that energy consumption over product lifetime will be the dominant factor for boilers and water heaters, with embodied energy and disposal costs exerting only a minor influence on the results.

A study of 14 products to be covered by the Directive has commenced, including boilers and water heaters, and will take 18 months to complete. It is too early to say how the performance measures for water heaters under the EUP will correspond with those for the water heater energy labelling directives.

Conclusions

A large number of product categories have been defined in the draft Water Heater Directives, and differences between them are so great that separate treatment is needed in almost every case. Measurement standards for some categories are well advanced and can be introduced in the near future; others are less advanced but straightforward to complete, while a third group presents considerable difficulties that have not yet been pursued in sufficient detail.

If the Directives are to be finalised within the near future (a period of two years was forecast by the Regulatory Committee at its meeting in November 2004), then some means of expediting progress must be found. Some expedient options worthy of consideration are:

- continue with harmonised performance measurement test standards for the product categories that are straightforward to measure and label as self-contained water heaters. These include categories Electric 1 to 3 and Gas/oil 1, 2 and 6, for which the test standards are nearly ready.
- simplify the requirements for product categories that are components of larger systems by adopting an interim labelling scheme based on secondary characteristics, instead of overall system performance. These include Gas/oil 13 and Solar E and F. Modelling of overall performance of typical systems in which they are installed should be pursued, but is unlikely to be completed in a short period.
- abandon or postpone whole system labelling for product categories such as Electric 6 and Solar B, D, on the grounds that test methods or system models are extremely complex and will take a long time to develop and agree.

Other points worthy of further investigation include:

- comparability of performance test standards on separate development paths will be difficult to assure unless positive action is taken to co-ordinate the work of different standards committees and critically examine their output.
- placing all product categories on a single energy classification scale makes clear the comparison between types, but may prove to be too coarse to discriminate between products of the same type. One way to overcome that would be sub-division of the bands; eg, A1, A2, A3 to discriminate between products of the same type with similar performance.

- standards already under development for the EPBD contain analytical methods that could be adapted and used for system models for labelling, if that is to be the chosen method of evaluation of some product categories.
- energy labelling of water heaters would assist building assessors responsible for certifying buildings under the EPBD, provided the labelling scheme can be extended to require labels to be permanent and visible.

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[3]European Council: Council Directive 2002/91/EC of 16 December 2002 on the energy performance of buildings

[4]European Council: Council Directive 2005/32/EC of 6 July 2005 establishing a framework for the setting of ecodesign requirements for Energy-Using Products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council

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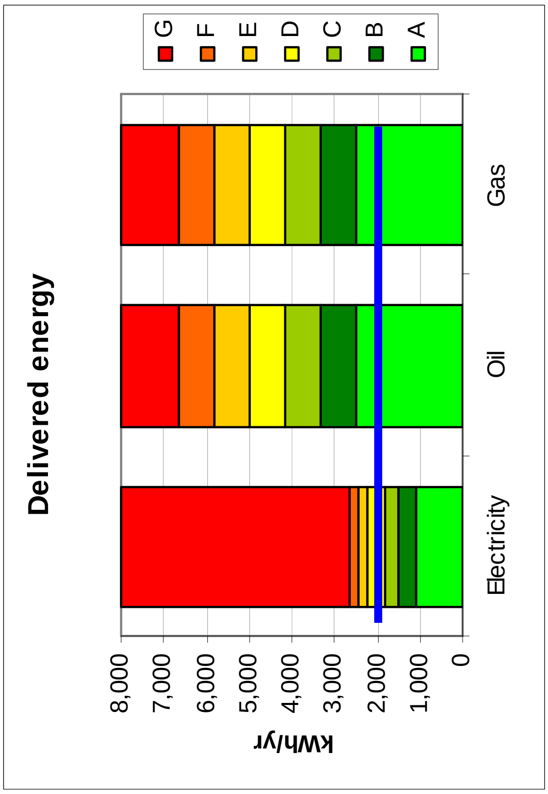
[15]prEN 15316-3-2 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-2: Domestic hot water systems, distribution

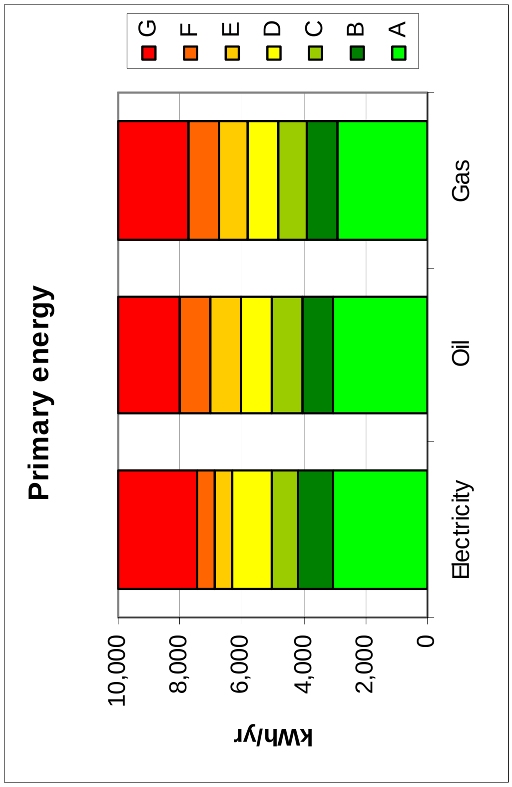
[16]prEN 15316-3-3 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-3: Domestic hot water systems, generation

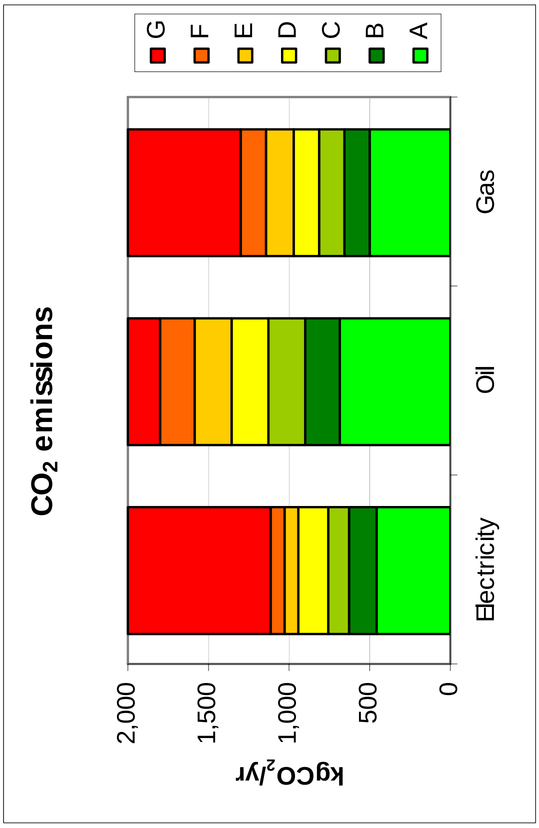
[17]prEN 15316-4-3 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-3: Space heating generation systems, thermal solar systems

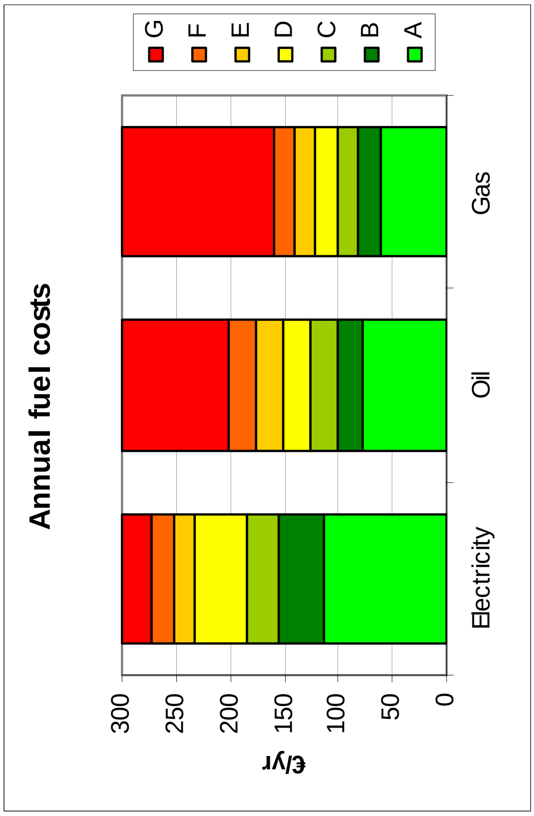
Appendix A : Energy Classification Scales

derived from Annex 2 of the May 2005 draft Electric Water Heater Directive and Gas and Oil Water Heater Directive



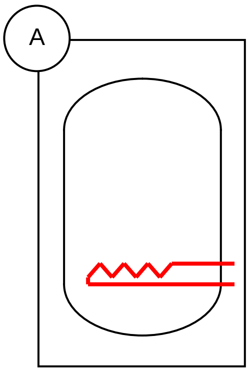






Appendix B : Types of Water Heater

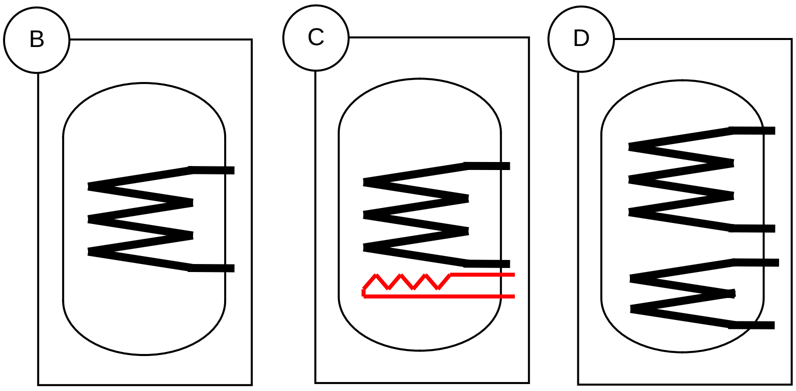
(A) Electric storage water heater



Standing loss label will give good indicator of relative appliance efficiency. It will not indicate performance relative to other types.

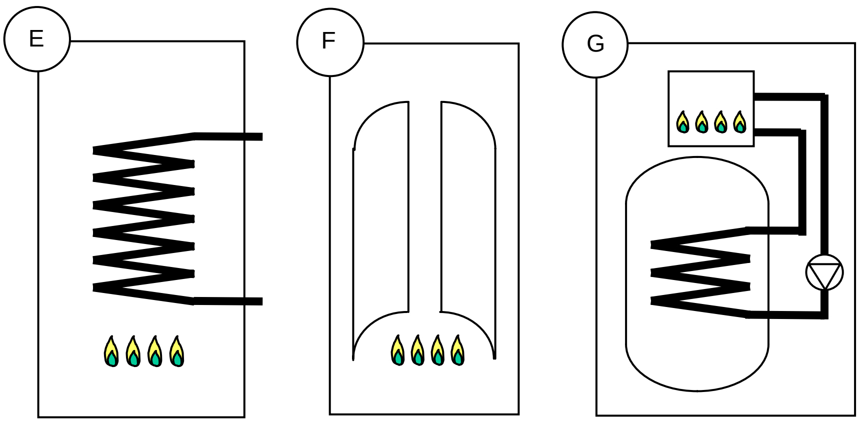
A label based on standing losses should not claim to represent "energy efficiency".

(B) Indirect **(C) "Mixed"** **(D) Twin coil (for solar, etc)**



Coupled to separate heat generator(s) (eg, boiler, solar collector). Both standing loss *and* heat exchanger information are needed. Overall efficiency depends largely on the heat generator(s) and controls.

(E), (F), (G) Combustion appliances, with or without internal store



No store

With store

With store

The principal energy performance indicator is the fuel efficiency.

A standing loss label is less relevant, though increases in importance with larger stores.

Electricity and Natural Gas Efficiency Improvements for Residential Gas Furnaces in the U.S.

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Abstract

This paper presents analysis of the life-cycle costs for individual households and the aggregate energy and economic impacts from potential energy efficiency improvements in U.S. residential furnaces. Most homes in the US are heated by a central furnace attached to ducts for distributing heated air and fueled by natural gas. Electricity consumption by a furnace blower is significant, comparable to the annual electricity consumption of a major appliance. Since the same blower unit is also used during the summer to circulate cooled air in centrally air conditioned homes, electricity savings occur year round. Estimates are provided of the potential electricity savings from more efficient fans and motors.

Current regulations require new residential gas-fired furnaces (not including mobile home furnaces) to meet or exceed 78% annual fuel utilization efficiency (AFUE), but in fact nearly all furnaces sold are at 80% AFUE or higher. The possibilities for higher fuel efficiency fall into two groups: more efficient non-condensing furnaces (81% AFUE) and condensing furnaces (90-96% AFUE). There are also options to increase the efficiency of the furnace blower. This paper reports the projected national energy and economic impacts of requiring higher efficiency furnaces in the future. Energy savings vary with climate, with the result that condensing furnaces offer larger energy savings in colder climates. The range of impacts for a statistical sample of households and the percent of households with net savings in life cycle cost are shown.

Background

The residential furnace is an appliance that provides heated air through ductwork to the space being heated. It is equipped with a blower to circulate air through the duct distribution system. In North America, most houses are heated by forced air systems. Residential furnaces, for statutory purposes, are defined as furnaces having a heat input rate of less than 225,000 Btus per hour (66,000 watts). In the United States, 70% of households have furnaces of this type.

The National Appliance Energy Conservation Act (NAECA) legislation of 1987 established the initial minimum standards for furnaces and boilers, effective in 1992. Current regulations require new residential gas-fired furnaces (not including mobile home furnaces) to meet or exceed 78% annual fuel utilization efficiency (AFUE), and in fact nearly all furnaces sold are at 80% AFUE or higher. In 2000, the U.S. Department of Energy (DOE) identified residential furnaces and boilers as priority products for an updated standards rulemaking. The analytical approach and results reported here are part of DOE's rulemaking process for the Advance Notice of Proposed Rulemaking (ANOPR), which was issued on July 29, 2004. [1]

Furnaces use electricity in addition to fossil fuel energy for combustion. Most of the electricity is used by the circulating air blower. The furnace uses electricity for other purposes as well. The combustion air is pulled through the furnace by a draft inducer fan, and a furnace also has various controls and an electronic ignitor to assure proper ignition of the fuel.

The circulating air blower of the furnace pushes cool air returning from the inhabited space of the house past the outside of the heat exchangers and supplies heated air to the house through a system of ducts. Heat is provided by burning gas and moving combustion products through the inside of the heat exchangers. The products of combustion are exhausted to the atmosphere through a flue passage connected to the heat exchangers. The amount of air the blower can force through the house's ducts depends on the pressure and flow relations of both the house and the furnace. If the house has an air-conditioner, as over three-quarters of houses with furnaces in the U.S. do, the furnace blower and the same ducts will be used to circulate cooled air. To operate properly, air-conditioners need more airflow than furnaces, so the blower motor is run at a higher speed during air-conditioning operation.

Residential furnaces are rated with annual fuel utilization efficiency (AFUE) as an efficiency descriptor. AFUE represents the equipment's performance over an entire year's heating season. It is intended to represent the effective annual operating efficiency of a furnace under dynamic conditions. It includes performance during start-up, steady-state, and cool-down operations. The AFUE is calculated from performance parameters that are measured under laboratory conditions using the DOE test procedure. [2] These include a set of temperatures, fuel consumption, and a few other performance parameters. AFUE does not account for the electricity consumption of the appliance and, therefore does not include the circulating air and combustion fan power consumption, except to account for the amount of waste heat produced by these fans.

There are two main types of residential furnaces: weatherized and non-weatherized furnaces. Weatherized furnaces are generally installed outdoors (often on rooftops), and non-weatherized furnaces are installed indoors. Manufacturers test non-weatherized furnaces as an isolated combustion system (ICS), which means it is isolated from the conditioned space where it is located and the furnace draws combustion and dilution air from the outdoors. Manufacturers test weatherized furnaces under outdoor conditions. The main difference between a weatherized furnace and a non-weatherized furnace is that the weatherized furnace is well insulated and has a weather-resistant external case. The heat loss through the jacket in a weatherized furnace is totally dissipated outside, resulting in a lower efficiency compared to an equivalent non-weatherized furnace installed indoors.

Non-weatherized gas furnaces can be either non-condensing or condensing. When the flue temperature is substantially higher than the dew point of the combustion products, the latent heat (the heat from condensation of water vapor in the combustion products) is lost in the flue. In this case, the furnace is classified as non-condensing. The AFUE of such furnaces is generally below 83 percent AFUE. Condensing gas furnaces recover more heat from the combustion products by condensing the water vapor and can reach efficiencies as high as 96% AFUE.

Mobile home furnaces are a separate class of furnaces, due to three differences. They employ sealed combustion, pre-heat the combustion air, and have very tight space constraints. Mobile home furnaces have historically had a lower efficiency standard and were considered as a separate product in rulemakings in the early 1990s.

Approximately, 2.7 million units of non-weatherized gas furnaces were shipped in the U.S. in 2003, compared to 0.4 million units of weatherized gas furnaces and 0.14 million units of mobile home gas furnaces. Thus, we devoted most attention to non-weatherized gas furnaces.

LCC Analysis

Life-cycle costing is a standard engineering economic approach for choosing between alternative products or designs that provide equal service to the user. It allows for a comparison between products having different initial and long-term operating costs. The goal of this LCC analysis was to calculate the LCC for alternative equipment designs in houses that are representative of those in which new furnaces will be installed. The life-cycle cost consists of two main components: (1) the cost of buying and installing a furnace, and (2) the operating costs summed over the lifetime of the equipment, discounted to the present.

To account for the uncertainty and variability in the inputs to the LCC calculation for a given household and between different households, we used a Monte Carlo simulation. A Monte Carlo simulation uses a distribution of values to allow for variability and/or uncertainty on inputs for complex calculations. For each input, there is a distribution of values, with probabilities (weighting) attached to each value. The simulations sample input values randomly from the probability distributions. For some variables, such as energy price and climate, the calculations used the values associated with each sampled household. We used Microsoft Excel spreadsheets with Crystal Ball, an add-on software, to perform the Monte Carlo analysis.

The LCC analysis estimated furnace energy consumption under field conditions for a sample of houses that is representative of U.S. homes. These conditions include outdoor climate during the heating and cooling season which influence the operating hours of the equipment.

We calculated the LCC for a representative sample of houses, one house at a time, using appropriate values for the inputs each time. We selected a sample of households from the 1997 Residential Energy Consumption Survey (RECS97). [3] For each sampled household, we estimated the energy consumption of the furnace, incorporating: (1) baseline design characteristics, and (2) design options that yield higher efficiencies.

We treated a furnace in a new home differently from one purchased as replacement equipment for three reasons. First, heating equipment prices are different for new construction and retrofit applications. Equipment cost for new construction includes a builder markup and does not include

sales tax. Equipment cost for replacement installations includes sales tax and does not include a builder markup. Second, the financing method (and therefore the discount rate in the LCC calculation) for new construction is usually a mortgage loan. Financing methods for replacement installations can take a variety of forms that have different interest rates. Third, new construction tends to be built with more insulation and more energy-efficient products, compared to houses that receive replacement installations, and is also concentrated in certain parts of the country. We estimated that 26% of annual shipments of non-weatherized gas furnaces are installed in new construction.
The change in LCC resulting from a change to higher-efficiency equipment is calculated relative to the equipment a house would have in the absence of any change in standards (the base case). We used the distribution of efficiencies in shipments in the year 2000 as the base case. Thus, some houses in the base case are assumed to purchase higher-efficiency furnaces.

Design Options
We calculated the impacts for furnaces incorporating a variety of design options that increase fuel and electricity use efficiency. The design options shown in Table 1 were those that met the screening criteria used in this study.

Table 1: Design Options Considered for Non-Weatherized Gas Furnaces

Design Option	Fuel-saving	Electricity-saving
Improved Heat Exchanger Effectiveness	X	
Condensing Secondary Heat Exchanger	X	
Modulating Operation	X	X
Increased Motor Efficiency		X
Increased Blower Impeller Efficiency		X

Heat exchanger effectiveness can be improved in many ways. Furnace manufacturers optimize the heat exchanger size and geometry, gas input rate, combustion air delivery system, heat transfer coefficient and heat exchanger mass, and may apply other enhancements to provide the greatest comfort, reliability, and safety.
A condensing furnace requires some extra equipment, such as an additional stainless steel heat exchanger and a condensate drain device. Condensing furnaces also require a different venting system, since the buoyancy of the flue gases is not sufficient to draw the gases up a regular chimney. Plastic through-the-wall venting systems are typically used in conjunction with condensing furnaces. Condensing furnaces present a higher initial cost, but provide significant energy-efficiency gains.
A modulating control is any control that uses either gradual or step-wise adjustment of the furnace input rate in response to changes in the heating load. Two different types of modulating controls can be applied to furnaces, two-stage and step control, to decrease fuel and electricity use. Both two-stage and step modulating gas furnaces are currently available on the market.
Two-stage control refers to a modulating control that cycles a burner between reduced heat input rate and off or between the maximum heat input rate and off. Two-stage controls are limited to these two operations. Step modulation can operate at a large number of heat input rate.
Furnaces that operate at substantially reduced output over longer periods of time can provide more uniform space temperatures, quieter operation, greater efficiency, and reduced emissions. Achieving these objectives requires that the combustion stoichiometry (the proper fuel/air mixture to assure clean combustion) be carefully controlled at all firing rates to assure safe operation and minimum emissions.
Most furnaces sold in the U.S. use forward-curved impellers directly driven by a permanent split capacitor (PSC) motor. Two design options to improve blower efficiency were considered: 1) an electronically commutated motor (ECM); and 2) a backward-curved blower with a modified ECM motor (BC/ECM+). ECM motors have permanent magnets on the rotor. By changing the frequency and voltage across the stator coils, the speed and torque of the motor can be adjusted. The BC/ECM+ motor operates at a higher speed, has a smaller diameter, and has improved magnets and electronics. Furnaces with ECM and BC/ECM+ blower motors take advantage of the adjustable speed and torque of ECM motors to provide constant airflow, regardless of the static pressure. Backward-curved blowers have different aerodynamic characteristics than forward-curved blowers. For each of the above designs, the burner operating hours are different, since the furnace efficiency, overall air moving efficiency, and blower motor electricity consumption are different. Therefore each design requires a different operating time to provide the same amount of heat to the same house.

Equipment and Installation Costs

The cost of buying and installing a furnace consists of three main elements: the manufacturing cost, markups in the distribution chain, and the installation cost.

In order to compare the total additional consumer cost of improved equipment efficiency, a baseline design was defined for each product class. The baseline model establishes the starting point for analyzing technologies that provide energy-efficiency improvement. Based on the market assessment and input provided by manufacturers for this study, a baseline model was defined as an appliance with an efficiency at the minimum level prescribed by EPCA (78 percent AFUE for non-weatherized gas furnaces), and having commonly available features and technologies.

To estimate the manufacturing cost of alternative furnace designs for this study, several design options were evaluated that could meet each considered efficiency level. It then selected the design option(s) it believed manufacturers would most likely implement to achieve a given considered energy efficiency level. To estimate the manufacturing costs of these design options, this study relied primarily on a reverse-engineering approach.

Using the manufacturing cost as a base, we applied markups for manufacturers, wholesalers, contractors, and builders, as well as sales tax. The markups and sales tax was applied depending on the type of installation (i.e., in new construction or replacement).

The LCC analysis used manufacturing costs from the reverse-engineered cost of the baseline size furnace. To derive the manufacturing costs for the other sizes, we scaled the reverse-engineered model costs. To represent the majority of combinations of input capacity and nominal maximum airflow, we developed generic “virtual” models to represent 25 different combinations of those two variables. (We refer to these as virtual models because they are not real models on the market.) Each virtual model had its own cost and energy characteristics. The virtual models include models with the most commonly-occurring input capacities, with corresponding nominal maximum airflow rates at static pressure of 124.5 Pa [0.5 inches water gauge].

The installation cost is the cost to the consumer of installing a furnace; it covers all labor associated with the installation of a new unit or the replacement of an existing one. This includes costs of changes to the house, such as venting modifications that would be required for the installation. The estimates of installation costs vary by efficiency level. Installation of 81% AFUE equipment may require use of more expensive venting systems to prevent problems from condensation. At this efficiency level, this study estimated that 8% of installations that would require such a venting system.

The size of the equipment, the type of installation, and the installation costs depend on the households for which the equipment is bought. Characteristics listed in the RECS data set enabled us to make reasonable assumptions about these factors for each household in the analysis.

Calculating Furnace Energy Use

Estimating the energy consumption of alternative furnaces in the sample houses requires estimating the heating and cooling loads of each particular house. The loads represent the amount of heating and cooling required by a house to keep it comfortable for an entire year. The annual house heating load is the total amount of heat output from the furnace that the house needs for an entire year. This includes the heat from the burner and the heat generated by the inefficiencies of the blower and the blower motor. The house heating load was determined for each sampled household from the annual space heating energy consumption reported in RECS97 and the assumed characteristics of the existing furnace. The annual house cooling load is the total amount of cooling provided to the house for the entire cooling season. It includes the cooling provided by the existing air conditioner, and accounts for the waste heat from the inefficiencies of the blower and blower motor. The house cooling load was calculated from the cooling energy consumption reported in RECS97 and the assigned efficiency of the existing air conditioner.

To estimate the energy consumption of furnaces if they used alternate designs rather than the existing equipment, the LCC analysis used representative virtual model furnaces. These virtual models incorporate typical features of currently marketed furnaces. One virtual model was created for each of 25 combinations of maximum airflow and input capacity to represent the available range of actual models. Specifications from actual models were used to determine the specifications for the corresponding virtual models. The specifications include blower size, motor size, supply air outlet area, power consumption of the draft inducer and the igniter, and several delay times.

The estimation of heating and cooling loads requires calculation of the electricity consumption of the furnace blower, since waste heat from the blower and blower motor heats the house. The amount of waste heat produced depends on the overall efficiency of the blower and blower motor and the amount of electricity the blower motor consumes. The electricity consumption of a blower motor depends on the type of motor, the speed at which the motor operates, the external static pressure difference across the blower, and the airflow through the blower. To calculate blower motor electricity consumption, the operating conditions (the pressure and air flow) at which a particular furnace in a particular house will operate were determined. Circulating air blower motor electricity consumption at full-load steady-state is a function of airflow, external static pressure, and the overall air-moving efficiency of the furnace.

The blower moves heated air through the house whenever the furnace is on. It also operates in the cooling season (summer) if the house is air-conditioned. Since the efficiency of the blower will have different impacts on the overall energy consumption in different seasons, the electricity use calculation was carried out separately for winter and summer.

Table 2 presents the average energy calculation results from the LCC analysis. These results show 2-stage modulation reducing gas use but slightly increasing winter electricity use. (In practice, though, the reduction in gas use may not actually occur, as discussed in the Selected Issues section.) The reason for the electricity use outcome is that when the blower operates at lower speed, the blower runs for a longer period.

The 90% condensing furnaces lowers gas use by 11% relative to the 80% AFUE furnace. Note that these results do not reflect furnace performance of the various design options as it would be under identical conditions. Rather, the results are influenced by the assignment of equipment to the sample houses. The ECM option reduces total electricity use by one-third for the 80% AFUE furnace, while the backward-curved blower with a different ECM motor reduces it by 50%. Note that improving the efficiency of the blower in a gas furnace reduces electricity consumption, but slightly increases gas consumption (due to the need to make up for the reduction in heat given off by a more efficient motor).

Table 2: Average Energy Use for Non-Weatherized Gas Furnaces in the LCC Analysis

Design Options			**Annual Gas Use**	**Winter Electricity Use**	**Summer Electricity Use**
AFUE	**Controls**	**Blower Motor Type**	GJ [MMBtu]	kWh	kWh
80%	single-stage	PSC	68.4 [64.9]	475.5	153.9
80%	single-stage	ECM	69.2 [65.6]	300.2	115.2
80%	single-stage	BC/ECM+	69.5 [65.9]	239.3	76.2
80%	two-stage	PSC	67.0 [63.5]	492.3	153.9
80%	two-stage	ECM	68.5 [64.9]	247.5	115.2
80%	two-stage	BC/ECM+	69.0 [65.4]	201.9	76.2
81%	single-stage	PSC	67.6 [64.1]	469.8	153.9
90%	single-stage	PSC	61.1 [57.9]	421.0	153.9
90%	single-stage	ECM	61.6 [58.4]	277.8	115.2
90%	single-stage	BC/ECM+	61.8 [58.6]	223.6	76.2
91%	two-stage	ECM	60.4 [57.2]	240.0	115.2
91%	two-stage	BC/ECM+	60.8 [57.6]	198.6	76.2
92%	single-stage	PSC	59.8 [56.6]	412.0	153.9
96%	step modulation	ECM	56.9 [54.0]	226.3	76.2

PSC = permanent split capacitor
ECM = electronically-commutated motor
BC/ECM+ = backward-curved impeller and improved ECM

Other Operating Cost Inputs

In addition to annual energy consumption, calculation of operating costs requires data on the future prices of natural gas and electricity. We used marginal energy prices to calculate the cost of saved energy associated with higher-efficiency equipment. Marginal energy prices are the prices consumers pay for the last unit of energy used. We calculated average and marginal energy prices for each sample house in 1997 using RECS data. We estimated marginal energy prices from the RECS monthly billing data by a linear regression of monthly customer bills to monthly customer energy consumption for each household for which billing data were available. We divided the natural gas billing data into two seasons: winter and the rest of the year. We estimated the marginal electricity price for those two seasons as well.

We used the average and marginal prices for 1997 of each sampled house combined with the forecast annual price changes in EIA's Annual Energy Outlook 2003 (AEO2003) [4] to arrive at prices in 2012 and beyond. The projected average residential natural gas price is in the $7.81-7.91/GJ

[$7.40-7.50/MMBtu] range between 2012 and 2019, but then begins to increase at a strong rate, reaching $8.44/GJ [$8.00/MMBtu] in 2025.

The maintenance cost is the annual cost of maintaining a furnace in working condition. Several groups of maintenance costs were developed. For the LCC analysis, we assumed a triangular distribution for maintenance costs to capture the variability of these costs. We assumed a minimum and maximum of 15% around the average.

The lifetime is the age at which furnaces are retired from service. For non-weatherized gas furnaces, we used an average lifetime of 20 years, with a range of 10 to 30 years.

We derived the discount rates for the LCC analysis from estimates of the finance cost to purchase furnaces. Following financial theory, the finance cost of raising funds to purchase furnaces can be interpreted as: (1) the financial cost of any debt incurred to purchase equipment, principally interest charges on debt, or (2) the opportunity cost of any equity used to purchase equipment, principally interest earnings on household equity. Consumers use different methods to purchase equipment for new and existing homes. Furnaces purchased for new homes are financed with home mortgages. Furnaces for existing homes (replacement equipment) are purchased using a variety of household debt and equity sources. We used different discount rates corresponding to the finance cost of new construction and replacement installations.

We estimated the discount rate for equipment in new housing based on mortgage interest rate data provided in the Federal Reserve Boards' Survey of Consumer Finances (SCF). [5] This survey indicates that mortgage rates carried by homeowners in 1998 averaged 7.9%. After adjusting for inflation and interest tax deduction, real after-tax interest rates on mortgages averaged 4.2%.

In the residential sector, replacement equipment is usually purchased using cash or some form of credit. One approach for deriving an average discount rate is to identify the types of credit used to purchase a given type of equipment (e.g., dealer installment loan, credit card), the associated interest rates, and the shares of each credit type in total replacement purchases. Such information is difficult to come by, however, and there are reasons to favor an alternative approach. When a household makes a major appliance purchase, the short-term effect may be an increase in debt if the purchase is financed with a dealer loan or credit card, or a decrease in cash if the product is purchased with cash. However, financial theory suggests that in the medium-term, households should tend to rebalance their overall equity/debt portfolio to maintain approximately the same relative shares of different equity/debt classes. According to this line of reasoning, the appropriate opportunity cost (or discount rate) for purchase of major appliances should reflect a household's overall equity/debt portfolio, and not simply the financial or opportunity cost of the debt or equity used to purchase the equipment.

The types of equity and debt likely to be affected by appliance purchases include second mortgages, credit cards, transaction accounts, certificates of deposit (CDs), U.S. savings bonds, stocks, and mutual funds. We estimated the shares of each type in the total household equity and debt portfolio from SCF data and estimated interest or return rates associated with these equity and debt classes from a variety of sources. The weighted-average real interest rate across all types of household debt and equity used to purchase replacement furnaces is 6.7%.

Payback Period Inputs

Numerically, the simple payback period (PBP) is the ratio of the increase in purchase (and installation) price to the decrease in annual operating expenditures (including maintenance). We made the comparisons based on replacing the base case furnace with a furnace incorporating another design option. Payback periods are expressed in years. A payback period of three years means that the increased purchase price for the energy-efficient furnace is equal to three times the value of reduced operating expenses in the year of purchase; in other words, the increased purchase price is recovered in three years because of lower operating expenses.

The data inputs to the PBP calculation are the cost of the equipment to the customer and the annual (first-year) operating expenditures. The PBP calculation uses the same inputs as the LCC analysis, except that energy price trends and discount rates are not required. Since the PBP is a "simple" payback, the required energy prices are only for the year in which a new standard is to take effect—in this case the year 2012.

LCC and PBP Results

For each of the design options, we calculated LCC savings and payback period relative to the base case equipment assigned to each house, and then averaged the LCC savings and payback period. The base case assumes, in the absence of new standards, purchase of equipment that best represents equipment that is sold today. We sampled the AFUE of the base case furnace assigned to each house from a distribution of AFUEs that is representative of shipments for the year 2000, and is correlated with climate. Therefore, the base case equipment is not limited to only baseline model equipment. To some houses, we assigned furnaces that are more efficient than some of the design options. We considered these as “no impact” cases, since they would not be affected by new standards.

Table 3 shows LCC and payback results for non-weatherized gas furnaces. Going to 2-stage modulation results in positive average LCC savings, but, in practice, the reduction in gas use may not occur, as discussed in the Selected Issues section. The 81% AFUE level shows basically no change in average LCC. The 90% AFUE condensing furnace has a negative average LCC impact, but it does have a benefit for houses in colder climates.

Table 3: LCC and PBP Results for Non-Weatherized Gas Furnaces; Fuel Consumption Design Options

Design Option (AFUE and technology description)*	LCC					Payback	
	Average	Average Savings	Net Cost	No Impact	Net Benefit	Median	Average
	$	$	% of houses	% of houses	% of houses	years	years
80%	$9,795	$0	0%	99%	1%	2.1	37.8
80% 2-stage	$9,718	$41	33%	27%	40%	8.6	13.5
81%	$9,789	-$3	32%	27%	41%	8.8	27.8
90% Condensing	$9,917	-$154	56%	26%	18%	17.9	42.5
92% Condensing	$9,924	-$166	60%	15%	25%	16.1	41.7
96% Condensing	$10,724	-$954	89%	2%	9%	32.3	88.9

Note: Due to the form of the payback calculation, a very small change in operating cost can result in extremely large paybacks. These extremely large paybacks will skew the average payback. In these cases, median payback is probably a better indicator.
* All design options include a PSC blower motor, except for 96% AFUE, which includes step modulation and ECM motor.

Table 4 shows results for the electricity design options. The electronically-commutated motor (ECM) and BC/ECM+ options have a negative effect on the average LCC. Yet, when these options are used with two-stage modulation the LCC results are not as negative and in the case of the 80% AFUE 2-stage modulation with BC/ECM+, the average LCC savings is slightly positive. Therefore, the current extra cost of these technologies more than offsets the sizable electricity savings.

Table 4: LCC and PBP Results for Non-Weatherized Gas Furnaces; Electricity Consumption Design Options

Design Option (AFUE and technology description)	LCC					Payback	
	Average	Average Savings	Net Cost	No Impact	Net Benefit	Median	Average
	$	$	% of houses	% of houses	% of houses	years	years
80% PSC	$9,795	$0	0%	99%	1%	2.1	37.8
80% ECM	$9,873	-$59	60%	27%	14%	23.0	33.7
80% BC/ECM+	$9,822	-$21	51%	27%	23%	17.2	26.3
80% 2-stage, ECM	$9,795	-$13	48%	27%	26%	15.4	21.1
80% 2-stage, BC/ECM+	$9,782	$1	45%	27%	28%	14.3	20.9
90% PSC	$9,917	-$154	56%	26%	18%	17.9	42.5
90% ECM	$10,007	-$226	66%	15%	19%	21.5	47.0
90% BC/ECM+	$9,957	-$180	63%	15%	22%	19.1	42.0
91% 2-stage, ECM	$9,898	-$141	58%	15%	26%	16.5	40.6
91% 2-stage, BC/ECM+	$9,878	-$118	58%	15%	27%	16.2	37.8

Note: Due to the form of the payback calculation, a very small change in operating cost can result in extremely large paybacks. These extremely large paybacks will skew the average payback. In these cases, median payback is probably a better indicator.

Analysis of National Impacts

This section describes the estimation of national energy savings (NES) and the net value to consumers from new furnace efficiency standards. For specific efficiency levels, it describes: 1) cumulative NES in the considered period (2012–2035), and 2) the net present value (NPV) of efficiency standards for consumers, accounting for products installed in the period considered. The NPV represents the difference between the present value of operating cost savings and increased installed costs.

National Energy Savings

We calculated annual NES as the difference between: annual energy consumption (AEC) in the base case forecast (without new standards), and AEC in a case with new standards. Cumulative energy savings are the sum over 2012 to 2035 of the annual national energy savings. We calculated the national annual energy consumption by multiplying the number of existing furnaces (by vintage) by the unit energy consumption (UEC) (also by vintage).

The UEC is the site energy (natural gas and electricity) consumed by a furnace per year. The annual gas consumption is directly related to the efficiency AFUE of the unit. Using the energy consumption calculations described in the LCC section, we determined the national average annual natural gas consumption that corresponds to each AFUE level. The UES used in the NES model is the average value from the energy consumption calculations that correspond to each AFUE level.

The NES model considers non-condensing and condensing gas furnaces market segments separately. The average current AFUE (based on data from the Gas Appliance Manufacturers Association) is approximately 80 percent for non-condensing furnaces and 93 percent for condensing types. [6] Most non-condensing furnaces operate at 80 percent AFUE and most condensing furnaces operate at either 90 or 92 percent AFUE, with just a few percent of market share at other values. There is a limited amount of historical efficiency data available for furnaces, but the evidence suggests that there has been little change since the early 1990s within non-condensing and condensing market segments. Therefore, the base case forecast assumes that current efficiencies remain constant.

We forecasted the share of condensing furnaces in the base case using the average growth rate in 1991–2000. The share grows from 23% in 2000 to 27.4% in 2012 and 30.4% in 2020.

For non-weatherized gas furnaces, we forecasted shipments as a function of new construction and expected replacements. In the standards case, the shipments model takes into account that, increased installed cost of more-efficient gas-fired equipment will cause some customers to purchase electric rather than gas equipment. Therefore, projected shipments of gas equipment are lower in the higher-efficiency cases, and there is a corresponding increase in electric heating equipment shipments.

The stock in a given year is the number of units shipped from earlier years that survive (remain in use) in the given year. The NES model keeps track of the number of units shipped each year, and the average UEC of each cohort. The effect of standards is to raise the minimum efficiency to the target level. The fraction of the market already at or above the standard level is not affected by the standards. We assumed that the units have an increasing probability of retiring as they age. The survival function is the probability of survival as a function of years-since-purchase.

In determining national annual energy consumption, we initially calculated the annual energy consumption at the site. We then calculated primary (source) energy consumption from site energy consumption by applying a conversion factor to account for losses associated with the generation, transmission, and distribution of electricity and gas. We used annual site-to-source conversion factors based on the Lawrence Berkeley National Laboratory (LBNL) version of the National Energy Modeling System (NEMS), which corresponds to DOE's Energy Information Administration (EIA's) Annual Energy Outlook 2002 (AEO2002). [7] The factors used are marginal values, which represent the response of the system to an incremental decrease in consumption. Primary energy for electricity generation is about three times site energy. Natural gas losses include pipeline leakage, pumping energy, and transportation fuel. Primary energy for natural gas is about 90% of site energy.

Consumer Impacts: Net Present Value

The NPV is the difference between the present value of operating cost savings (PVS), which includes energy and maintenance costs, and the present value of increased installed costs (PVC), which includes equipment and installation. We determined PVC for each year from the effective date of the standard to 2035 and calculated PVS for each year from the effective date of the standard to the last year when units purchased in 2035 are retired. The NPV of the standards is the sum over all years of the difference between PVS and PVC.

The average installed cost for the base case forecast and each efficiency level in 2012 comes from the LCC analysis. Because of the uncertainty concerning future trends in furnace manufacturing, we assumed no change in average real equipment costs at each efficiency level after 2012.

The total incremental cost of equipment between a standards case forecast and the base case forecast depends on the average incremental cost of each unit, and on any changes in shipments. In addition, for the portion of the market expected to switch to electric equipment in the standards case, we accounted for the cost differential of electric equipment versus a gas furnace and air conditioner combination.

The annual operating cost savings to consumers are equal to the difference between site annual gas and electricity consumption in the base case forecast and a standards case forecast, multiplied by the respective marginal energy price. We accounted for the operating cost of additional electric heating equipment purchased instead of gas-fired equipment in standards cases.

The savings calculation uses the marginal price for gas and electricity. For the years after 2025, we applied the average annual growth rate in 2010–2025 for gas and heating oil prices and the average annual growth rate in 2015–2025 for electricity prices.

The discount factor is the factor by which monetary values in one year are multiplied in order to determine the present value. We used both a 3 percent and a 7 percent real discount rate in accordance with the Office of Management and Budget's (OMB) guidelines. [8] We defined the present year to be 2001, for consistency with the year in which the manufacturer cost data were collected.

To illustrate the basic inputs to the NPV calculations, Figure 1 presents the non-discounted annual installed cost increases and annual operating cost savings at the national level for the 81 percent AFUE non-weatherized gas furnace (single-stage). The figure also shows the net savings, which is the difference between the savings and costs for each year. The annual equipment cost is the increase in equipment price for products purchased each year over the period 2012–2035. The annual operating cost savings is the savings in operating costs for products operating in each year. The NPV is the difference between the cumulative annual discounted savings and the cumulative annual discounted costs.

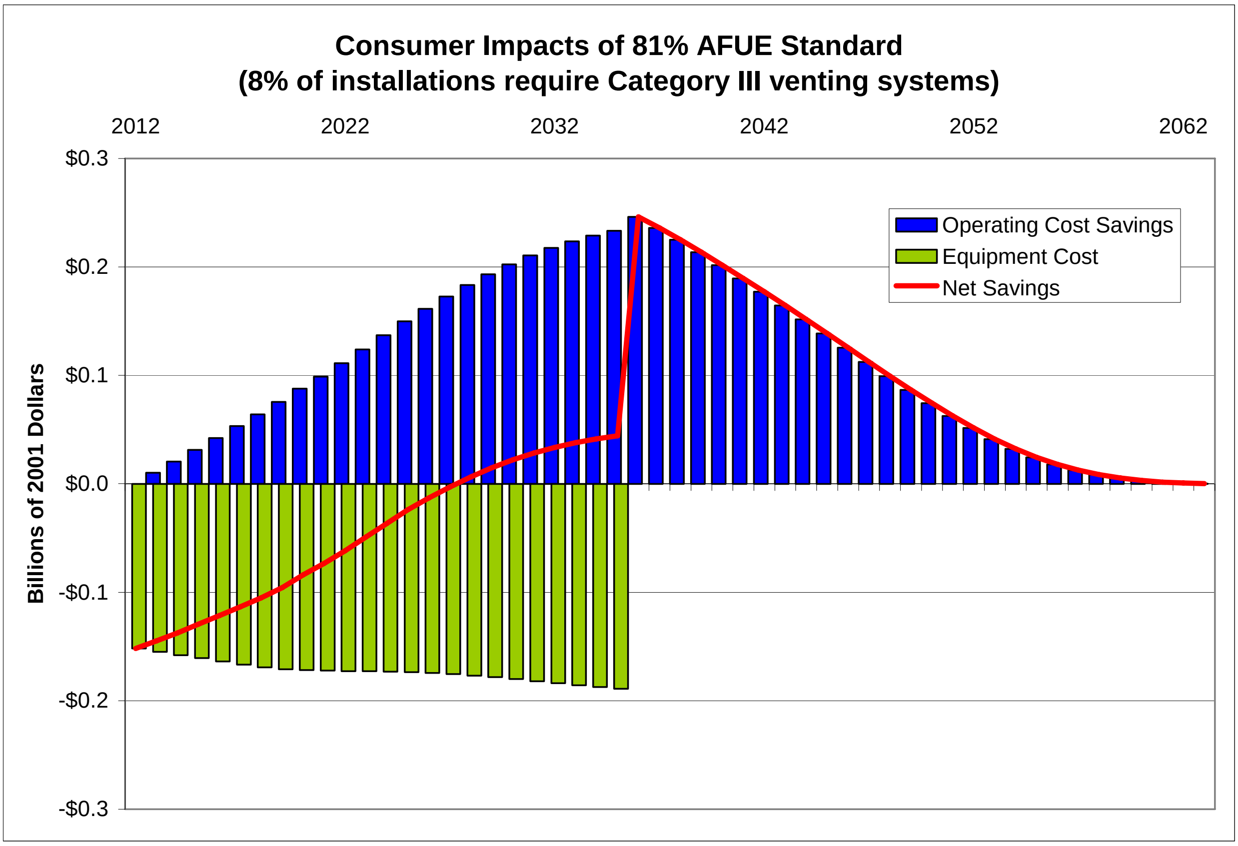

Figure 1: Non-discounted Annual Installed Cost Increases and Annual Operating Cost Savings at the National Level for the 81 percent AFUE Non-Weatherized Gas Furnace

NES and NPV Results

The NES model offers a range of possible outputs all of which depend on the inputs used on deriving the results. Table 5 shows the NES and NPV results for non-weatherized gas furnaces for various design options. Since few furnaces sold are less than 80% AFUE, there is little to be gained by a standard at this level. The 81 percent AFUE level has positive energy savings, but the NPV is negative at 7% discount rate and barely positive at 3%. The 90 percent AFUE level has substantial energy savings. It has a negative NPV at 7% discount rate, but a large positive NPV at 3%. At the 80% AFUE level, the ECM option has small energy savings, but either slightly negative or positive NPV.

Table 5: Cumulative National Energy Savings and Consumer Net Present Value for Non-Weatherized Gas Furnaces

Design Options			**NES (EJ [Quads])**	**NPV (billion 2001 $)**	
AFUE	**Controls**	**Motor Type**		**3% Discount Rate**	**7% Discount Rate**
80%	single-stage	PSC	0.03 [0.03]	0.15	0.05
80%	two-stage	ECM	0.07 [0.06]	0.09	-0.02
81%	single-stage	PSC	0.46 [0.44]	0.04	-0.29
90%	single-stage	PSC	4.33 [4.10]	5.11	-0.56
91%	two-stage	ECM	5.78 [5.48]	3.96	-2.20
96%	step modulation	ECM	7.54 [7.15]	-14.53	-11.61

Selected Issues

Two important issues that arose in the analysis are (1) the limits to improving the efficiency of non-condensing gas furnaces due to the costs of providing appropriate venting to avoid condensation problems; and (2) the energy impacts of modulating operation.

As mentioned earlier, installation of 81% AFUE equipment may require use of stainless-steel material venting systems to prevent problems from condensation. The conditions which determine the type of venting system are defined based on the operating pressure and temperature in the vent. An 81% AFUE efficiency level is close to the limit (for non-condensing furnaces) at which the temperature of the flue gases is sufficiently low to cause condensation in the vent system. U.S. National Fuel Gas Code (NFGC) [9] venting tables describe the configuration of these systems in terms of length and diameter of the vents. In the analysis reported here, to insure safe operation, we estimated 8% of installations of 81% AFUE equipment would require stainless-steel venting system. For this fraction of the installations, the analysis assigned the appropriate cost.

In the case of modulating furnaces, the DOE test procedure calculates the fuel energy consumption at maximum input capacity mode, while during the actual operation the modulating furnaces operate largely in reduced input capacity mode (about 90%-100% of the time). This test procedure assumption causes overestimation of the calculated fuel energy savings. Therefore, the gas use for modulating furnaces in actual usage may not decline as shown in Table 2. Note that a currently proposed update of the ASHRAE test procedure corrects this problem. [10]

Conclusion

Gas furnaces are somewhat unusual in that the technology does not easily permit incremental change to the AFUE above 80%. The results indicate that for non-weatherized gas furnaces, the 81 percent AFUE level has positive energy savings, but the NPV is negative at 7% discount rate and barely positive at 3%. This level shows basically no change (-0.03%) in average LCC.

Achieving significant energy savings requires use of condensing technology, which yields a large efficiency gain (to 90% or higher AFUE), but has a higher cost. The 90 percent AFUE level has substantial national energy savings. It has a negative NPV at 7% discount rate, but a large positive NPV at 3%. The condensing furnace has a negative impact on average LCC, but has a positive LCC impact for some households (mainly those in colder climates). This result suggests that some States in cold climates may benefit from establishing a furnace efficiency standard at 90% AFUE.

With respect to electricity efficiency design options, the ECM has a negative effect on the average LCC. The current extra cost of this technology more than offsets the sizable electricity savings.

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Optimizing Heating Energy in the Domestic Sector

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Abstract

This paper focuses on reducing primary energy use in the domestic sector by changing from conventional to renewable resources. Starting from an analysis of present available energy consumption data in the EU-25, the area for higher energy efficiency is identified on hot water consumption. Introduction of renewable energy technologies in the built environment gives opportunities to improve the overall energy performance of buildings. In particular the application of solar energy technology offers a variety of possibilities. The Renewable Electricity Sources Directive [1] and the Energy Performance of Buildings Directive [2] require all Member States to implement national regulations within the near future. Other European Directives are under preparation to stimulate further improvements in energy performance and energy efficiency in the building sector. Integration of renewable energy sources for heating and electricity in the built environment is also stimulated through national regulations in a few Member States.

Introduction

The philosophy underlying this study starts from the integral energy performance concept for a building. All options for energy demand and supply must be considered together if society is to attain significant levels of energy efficiency and renewable energy deployment. The building sector that consumes about 40% of the total energy consumption in Europe offers several possibilities to contribute to achieve higher energy efficiency by introducing distributed renewable energy resources.

The traditional conversion chain from fossil fuel to end-use electricity is composed of a thermal to electricity step at the power plant. Distribution losses have to be considered also before final electricity is delivered to the user.

In general, in the household sector an important part of the supplied electricity is used to heat water for domestic appliances such as hot tap water, washing machines and dishwashers. Integrating solar energy technology in the built environment will improve overall efficiency and reduce primary energy since distribution losses do not count for. Moreover solar thermal energy will reduce electricity demand for water heating and lower the cost for domestic energy use, while at the same time it contributes to lower greenhouse emissions, supporting the Kyoto protocol. For several Member States this paper discusses energy and cost analysis based on climate data and electricity prices.

Remarkable is the fact that the present market penetration of solar collectors in Cyprus, Greece, Austria and Germany do not appear from the economic analysis as the most advantageous countries for private investment. Electricity prices have not been for private persons the driving force to purchase a solar collector system. In figure 1 one can find the solar thermal capacity per capita and the market share in EU-25 countries in 2004. Germany takes almost half of the solar thermal market.

Spanish recent implementation [3] of the EC Directive on the Energy Performance of Buildings includes an obligation to cover 30-70% of the Domestic Hot Water (DHW) demand with solar thermal energy. It is expected that this will support the boom in the solar collector market in Europe. In addition the European certification scheme, the Solar Keymark [4] for solar thermal collectors (EN 12975) and factory made systems (EN 12976) is more and more accepted, both by the industry and by public authorities.

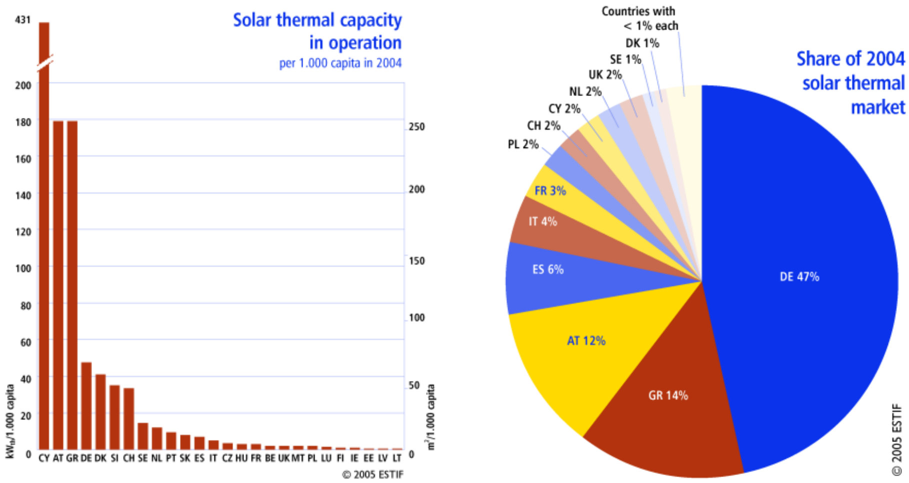

Figure 1: Source: European Solar Thermal Industry Federation; ESTIF

An important part of electricity consumption in the residential sector is used for heat, being hot water demand. One of the major problems for statistics is that measured data on heat in the building sector is hardly available, in comparison to electricity. Most of the information about domestic thermal energy is derived from empirical methods. Because of this lack of data renewable heating energy knows several barriers to overcome. Two running EC projects, K4RES-H and THERRA [respectively 5 and 6] are trying to assess more up-to-date information on renewable energies heat production and consumption.
First of all it should become visible in statistical data as provided at national level and at European level by Eurostat. Clear definitions have to be made for thermal energy production and consumption. Secondly it should become an energy consumption figure and not an energy-saving mean for other energy resources. In principle one could measure thermal energy as easy as electricity consumption or telephone usage. In the tertiary building sector it is quit common to express energy consumption in kWh/m^2/year for space heating and light. A similar approach could be developed for the domestic sector for different building types and occupancy. Once such an approach has been defined, an integral energy performance can give clear insight in the different energy flows, energy savings and use of energy resources.

This paper studies the contribution of households to reduce CO_2 emissions and energy consumption by changing energy resources for electric domestic water heating, moving from conventional to renewable energy use.

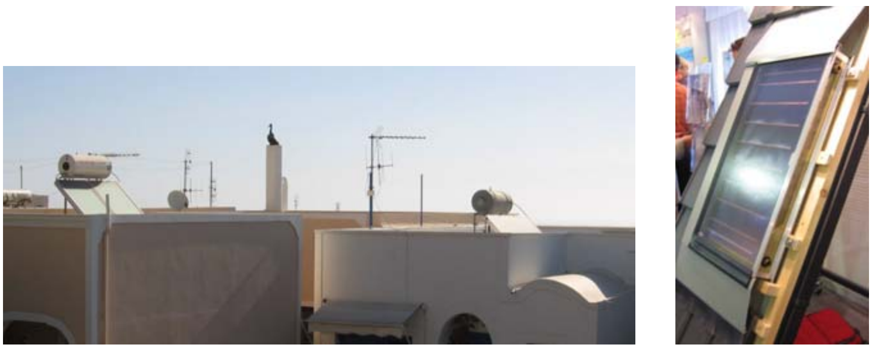

Figure 2: Photo of solar thermal system, rooftop and integrated systems

Energy Consumption in the Residential Sector

To maintain a desired level of comfort people have energy resources and modern technology available. In Europe about 60% of the energy is used for space heating, 20% for water heating, about 13% for lighting and cooling appliances and another 7% for others things like cooking. Energy resources are usually electricity, gas, in some countries an important part is coal or oil. In all 25+ European countries on average the electricity consumption in households is around 27% and if the tertiary building sector is included, 52% [data sources: references 7 and 8].

Taking into account that about 27% of the produced electricity in Europe is consumed in the domestic sector it offers possibilities for distributed energy resources such as solar energy, to contribute to the reduction of primary energy sources demand. Solar energy produces electricity and heat close to where it is consumed. In residential buildings solar thermal technology can be applied very effective in cases where water is heated only by conventional produced electricity. In a recent study the solar energies technologies are recognised as the most clean energies [9].

Several reports are available on the subject of domestic hot water energy consumption. A good report is the analysis of energy efficiency of DESWH, a SAVE report from March 199 [10]. A second report on EURECO [11] , also a SAVE project on end-use metering in the residential sector, has been used for this paper also, giving detailed data for electricity consumption. The EURECO report concludes with potential savings/household by changing appliances that are more efficient in terms of energy consumption. Potential savings are reported from 20 to 37% for the investigated countries. The Ecodesign studies [12] by VHK and the market study by BRG Consult in the context of the Boiler directive revision is expected to supply more quantitative data on the thermal energy use in Europe.

Photo credit: Ken Butti and John Perlin, *Coevolution Quarterly*, Fall 1977

The application of solar thermal technology is not new. This picture from 1911, shows a solar water heater installed on the front roof of a house in Pomona Valley, California, (the panels are circled above the four windows). Source Energyquest, California.

Energy Conversion

The conventional conversion from primary energy resource (coal, oil, gas, biomass) to electricity is a thermo-mechanical process with an efficiency depending on the process. On average the conversion efficiency is about 47%, see for example UK energy flows in2004 [13] or the the figures for the Dutch renewable energy monitoring protocol [14]. Taking into account as well the distribution losses of electricity supply to the consumer for EU-25 which is according to Eurostat around 15% [7], the electricity consumption efficiency will be around 40% from primary energy supply. This means that for every *toe*-equivalent electricity quantity that is consumed in the domestic sector, an equivalent of 2.5 *toe* primary energy is required .

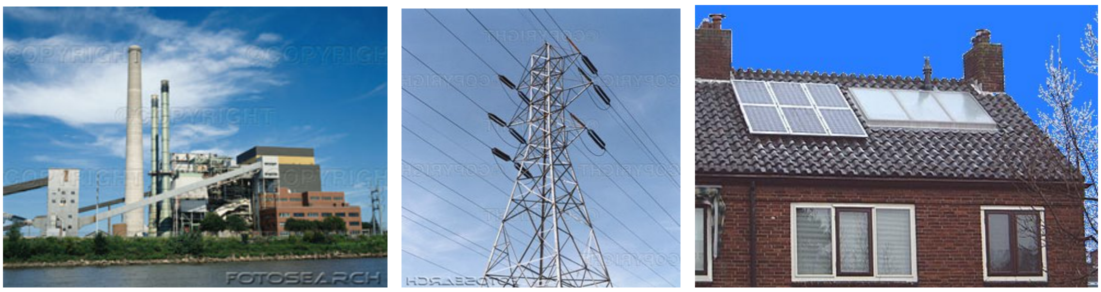

Figure 3: Electricity production – distribution – end-use

As a distributed renewable energy source, solar energy would contribute strongly to reduce primary energy consumption and emissions.

Calculation

This study focuses on the domestic use of hot water by appliances and direct use. In general energy is required to heat the supplied water from 5 – 10 ° C up to a desired level of 60° C. The temperature difference is proportional to the energy consumption. A decrease of conventional energy consumption

can be established by reducing the temperature difference using renewable energy sources. Data from Eurostat about the number of persons per household reveals 2.5 for EU-15 and about 3.0 for EU-10. Calculating with an average use of 80 liters of hot water per day per household, an estimate of electricity consumption per year can be made.
The calculation in this paper assumes a very conservative use of electricity for water heating of 1.5 MWh,th /yr, partly to show results for an average electricity consumption per household and partly to demonstrate to house-owners the possible results for their specific situation, which can be based on gas heated combi-boilers. The new Spanish technical building regulation [3] distinguishes for the minimum solar contribution between electricity and other sources for hot water, depending on five different climate zones. This figure ranges from 50 to 70% for the building in which electricity being the energetic source and from 30 to 70% for the other (gas, oil) energetic source.
The problem with Eurostat data is that no solar radiation data is used or available. Concerning solar electricity from photovoltaic plants the produced MWh are reported by the national offices. Solar electricity has become very popular in Germany by means of an attractive feed-in tariff, whereas solar thermal is quite common in Germany, Austria and Greece and is about to boom in Spain. It is common that solar thermal statistics usually show the solar thermal collector area in square meters. This has frequently prevented solar thermal from showing up in (renewable) energy statistics, which are typically given in MW or MWpeak.
Solar thermal data are available from the European industry federation (4) and are expressed in m^2 sold or installed. The International Energy Agency's Solar Heating & Cooling Programme, together with ESTIF and other major solar thermal trade associations have decided to publish future statistics in MWth (Megawatt thermal) and have agreed to use a factor of 0.7 $kWth/m^2$ to convert square meters of collector area into MWth.
Although only the Dutch have supported a non-metering PV subsidy programme in the past, based on average daily consumption, the feed-in tariff incentive schemes, based an annual production, look to be the future for solar electricity [3 and 4]. Solar thermal energy production is rarely measured and is in most countries supported by means of capital incentive schemes.
The intention of this paper is to give an idea of the potential of applying solar thermal energy in the domestic sector for the situation that electricity is used for producing hot water. Electricity for water heating is common in all households when considering clothes washing, dish-washers ans sanitary use. A washing machine and dish-washer consume each, on average 250 kWh/yr per household. In case of electric hot water production solely by electricity, a household is estimated to consume around 1 to 1.5 MWh/yr [11 and 15] depending on fully use of electricity or electricity assisted hot water production.

Results

Calculations have been carried out using solar radiation data from the GIS based solar radiation database [16]. In addition an average household is supposed to be composed of 2.5 persons [7] consuming 70 liters of hot water / day, for sanitairy use, clothes and dish washers.

2.4. Solar irradiation
Monthly and yearly (figure 4, Table 1) values of solar global irradiance for an optimal inclined surface facing south [8] have been applied in the calculation for all cases.

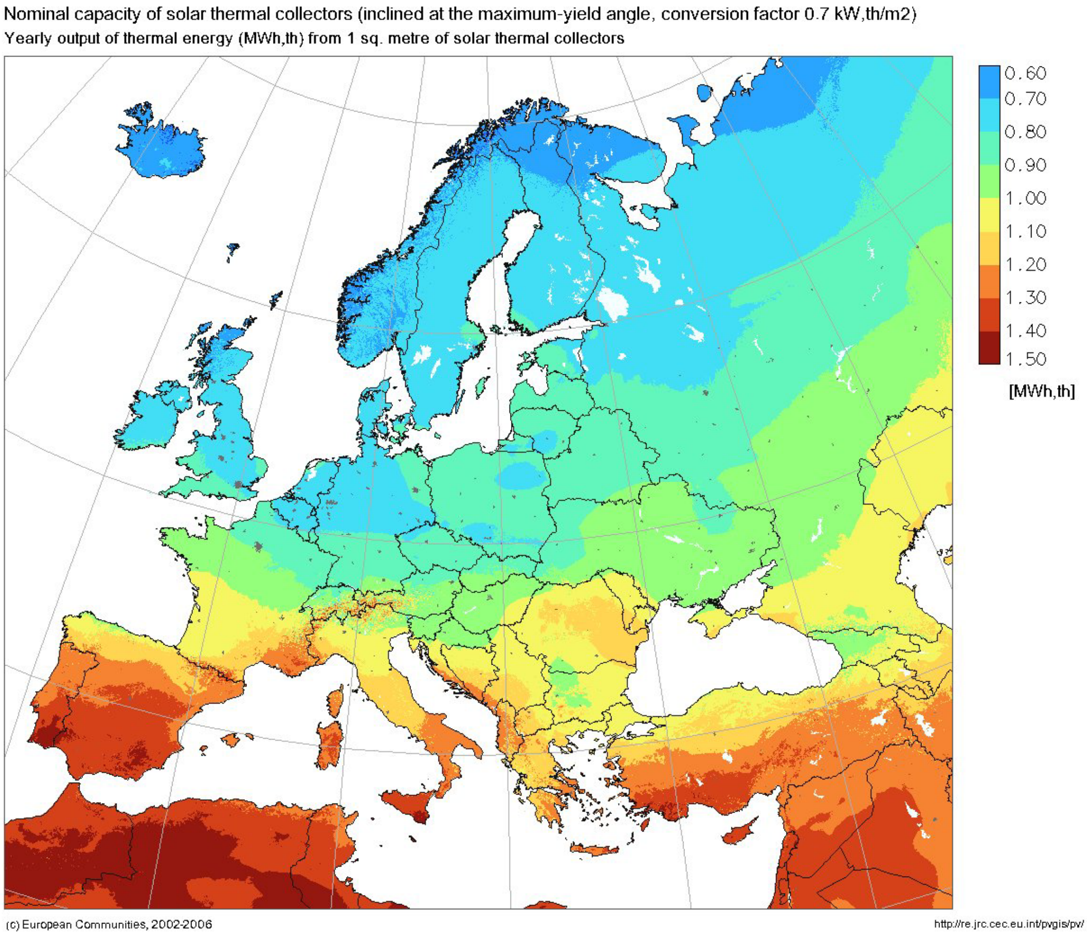

Figure 4: Yearly global irradiation at optimal inclination for solar energy applications. See also http://re.jrc.cec.eu.int/pvgis/pv/

Note that roughly a factor 2 can be applied when Northern Europe is compared with the Mediterranean area. In practise this means that a house-owner in Scandinavia will need twice more m^2 of solar collectors than in Southern Europe to achieve the same capacity. A further remark has to be made concerning the optimal inclination because of its definition as the angle the produces the most energy over the whole year. However during the winter months the low level of solar radiation at this inclination is not sufficient to fulfil the request for hot water, and therefore the angle of the solar collectors might be more inclined for more efficiency in the winter than in the summer months.

Table 1: Global irradiance at fixed optimal angle for the following locations:

Location	January [Wh/m^2/day]	July [Wh/m^2/day]	irradiance [Wh/m^2/day]	Year [kWh/m^2/year]
Germany (Munich)	1601	5212	3477	1269
Graz (Austria)	2061	4977	3595	1312
Greece (Athens)	3099	6611	4890	1785
Italy (Milan)	2500	5976	4155	1517
Italy (Calabria)	3277	6877	5211	1902
Spain (Barcelona)	3481	6312	4945	1805
Spain (Malaga)	4157	6831	5460	1993
Sweden	646	5363	3118	1138
Denmark	887	5133	3074	1122
Belgium	957	4845	2980	1088

In principle the optimal inclination should be derived from hot water demand during the winter month and requires therefore a calculation based on monthly data input. Detailled calculations for a given load and system dimension can be made for every site in Europe.

Taking into account a utilisation factor of 0.7 for the consumption of hot water produced by solar collectors, one arrives at the annual need of 1.5 MWh,th based on a conservative use per household of 70 liters per day for sanitary use, washing machines and dish-washers. Calculations for different hot water consumption have been carried out as well but the 70 liter figure gives the most informative information at European scale.

The same amount of hot water produced by electricity would cost the house owner a total for the year 2005 as indicated in table 2. In the calculation for savings on electricity after 10 years is taken into account a 30% of use of electricity supported hot water heating.

Table 2: Economical analysis

Location	electricty price 2005[1] [€/kWh]	Costs for 1.5MWh[2] [€/year]	excluding 30% by electricity[3] [€/year]	Savings[4] after 10 year [€]
Germany (Munich)	17.85	264.52	185.16	2050
Graz (Austria)	14.13	209.39	146.57	1623
Greece (Athens)	6.88	101.95	71.37	790
Italy (Milan)	19.70	291.93	204.35	2262
Italy (Calabria)	19.70	291.93	204.35	2262
Spain (Barcelona)	10.97	162.56	113.79	1260
Spain (Malaga)	10.97	162.56	113.79	1260
Sweden	13.97	207.02	144.91	1604
Denmark	22.78	337.58	236.31	2616
Belgium	14.81	219.47	153.63	1701

[1] Calculations are based on electricity prices including taxes, for each Member State.
[2] When electricity is used for heating water, the costs for an average household is given here
[3] In particular for the Winter period, other resource have to be utilised for heating water.
[4] An increase of 2.5% / year is assumed when calculating the 10 year period of savings on the electricity bill.

Based on these calculations a house-owner may decide to invest in a solar collector installation, with or without considering financial support by national or regional incentives. Taking into account an installed system price of 800 - 1000 € / m^2 and the size of collectors needed for the local climate, one may find the following results, Table 3.

Table 3: Payback time

Location	Required collector area[1] [m^2]	Installation costs[2] [€]	Payback time[3] without incentive [yr]	Payback time[4] with incentive [yr]
Germany (Munich)	2.4	2400	12	9
Graz (Austria)	2.3	2400	15	12
Greece (Athens)	1.7	2000	25	20
Italy (Milan)	2.0	2000	9	7
Italy (Calabria)	1.6	1600	7	5
Spain (Barcelona)	1.7	2000	16	12
Spain (Malaga)	1.5	1600	13	11
Sweden	2.7	2800	17	14
Denmark	2.7	2800	11	9
Belgium	2.8	3000	18	15

[1] Calculations are based on the requirement of 1.5 MWh,th/yr.
[2] for an average cost of 800 – 1000 € / m^2 (note that collector area has been unified at 0.4 m^2.)
[3] No governmental financial support is considered.
[4] A capital incentive of 250 € / m^2 is taken into account

The conclusion that can be made from the above calculation is that an Italian houseowner should be quite interested to invest in a solar collector installation for hot water supply. Even without any financial support the payback time would be within the warranty and lifetime expectation of the installation. Note that the calculations are based on conservative figures for utilisation and installation costs.

The government could put in place incentive schemes based on electricity tax reduction for those house-owners that substitute electric hot water systems by solar collectors. The reduction could be based on a proportional part of the tax and the collector area that is installed or on the savings on electricity consumption (for example up to 1 MWh,th).

Conclusions

Conclusions can be made from three points of view: energetical, economical and political. The house-owner is most interested in paying less for his energy bill and therefore will be interested in consuming less energy [17]. He might therefore be looking into options to use energy in a more efficient way of which changing fuel type is a relative cheap solution. The calculations in this paper have been based on electricity prices provided from the Eurostat database. The economics might differ for day/night tariff and regions that have different tax systems. Energy required to heat up water is energetical seen, more efficient when gas is used. The best would be to apply solar collectors to support a gas combi system. From political point of view, solar energy in the building sector as a distributed energy source would be a resource that contributes a lot on reducing emissions and energy losses from conversion at the powerplants and distribution of electricity. Opportunities will become available to governments to support industry in developing innovative building components that integrate these technologies and support investment of house-owners. The conclusion of the paper is that highest priority therefore should be given to integrate thermal solar energy systems in the built environment.

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Micro CHP

Micro-CHP to Increase Energy Efficiency: Emerging Technologies, Products and Markets

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Abstract

Micro-CHP has the potential to be a disruptive heating technology that decreases carbon dioxide emissions through increased energy efficiency in households and small businesses. A handful of products are already being manufactured and offered on a commercial basis, with a raft of product developers racing to join them. Markets are emerging in Japan, parts of Europe and the U.S.

In 2005, some five manufacturers were selling micro-CHP product (defined as generating 5-kW electrical and below) on a commercial basis. Around 16,000 units were sold in 2005, representing 31-MW of generating capacity with a value of approximately €135 million. The DACHS unit – manufactured by German-based SenerTec, and the ECOWILL unit – developed by Honda, Osaka Gas, Toho Gas and others – together accounted for over 90 percent of this market in terms of unit sales.

Although only five companies offer product to customers on what can be termed a commercial basis, several others express confidence in having products ready for market by 2007 or 2008. Micro-CHP markets may see exponential growth over the next three to five years. As each micro-CHP installation is expected to yield between about 0.2 and 0.5 t/CO_2/kWe per year, such growth could bring substantial reductions in CO_2 emissions.

Micro-CHP Markets at the Beginning of 2006

Delta estimates that some 16,000 micro-CHP units were sold in 2005, representing some 31-MW of generating capacity. In this paper, micro-CHP is defined as generating 5-kW or below as broadly this represents units suitable for mass markets – single family (and small multi-family) homes. This is in contrast to the less than 50-kW definition under the EC Cogeneration Directive. Japan accounts for over 75% of these sales through the ECOWILL unit and Yanmar's Genelight unit. The German market contributes nearly one fifth of these sales, through the SenerTec DACHS unit and Power Plus Technolgies' Ecopower unit. The ECOWILL and SenerTec DACHS unit together account for over 90% of all units sold.

The value of these markets is estimated by Delta to be €135,000,000, up about 20% on the previous year. Companies with product available for sale and delivery in 2005 are shown in Table 1 below.

Table 1: Global Micro-CHP Product for Sales in 2005

Manufacturer	**Product**	**Electrical output (kW)**
SenerTec (owned by Baxi)	DACHS	5.5
PowerPlus Technology (owned by Vaillant)	Ecopower	4.7
Honda and partners	ECOWILL	1.0
Whisper Tech	WhisperGen	1.2
Yanmar	Genelight	5.0

Source: Delta Energy & Environment

Japanese Markets

In Japan the ECOWILL product continued to sell well, with most major gas companies offering the product to housing developers and homeowners, with the notable exception of Tokyo Gas. Annual sales for financial year 2005-6 amounted to over 10,000 units. Yanmar made steady progress with it's Genelight product, with sales of a few hundred units. This product is typically sold to small businesses such as restaurants. Other CHP products in the 6-kWe to 10-kWe range sold in Japan include those from Aisin Seiki and Sanyo.

All of these products currently sold in the Japanese market are based on internal combustion engines. Japanese manufacturers have successfully controlled noise and emissions to acceptable levels, and have extended servicing requirements to long intervals.

European Markets

In Germany SenerTec continues to successfully sell it's DACHS micro-CHP product, with much of the sales growth in 2005 coming from the single-family and two-family home market. Annual sales were more than 2,500 units, with the German market accounting for the vast majority of these sales. Vaillant, also one of Europe's top five boiler manufacturers, owns Power Plus Technologies, which offers the Ecopower micro-CHP product.

The DACHS and Ecopower units are also both built around internal combustion engines. Noise and emissions, as with the Japanese engines, are controlled down to acceptable levels.

Elsewhere in Europe most other micro-CHP activity focussed on the UK, where electric and gas retailer E.ON-UK offered Whisper Tech's WhisperGen micro-CHP unit to households and housing developers. Current activity is more akin to a market trial rather than a commercial launch. E.ON-UK's current objectives appear to be to build a solid base for a mass launch of their system through establishing an installation and servicing network, and learning about installation, sales and marketing issues. Actual installations – in the region of hundreds - lagged sales in 2005.

Two new micro-CHP manufacturers – both based in Germany - started taking orders for micro-CHP products in 2005, although none of these were available for installation until 2006. Otag took orders for it's 3-kWe steam-driven LION micro-CHP product, which is designed for single family homes. Sunmachine sold distribution licenses for it's 3-kW biomass fuelled Stirling engine in 2005, with units available for sales in 2006.

North American Markets

In North America activity was more muted in 2005. Vector Cogen, who had brought a 5-kWe micro-CHP product (built around a Kawasaki internal combustion engine) to market in 2004, closed their doors to business. Marathon Engine systems continued to plan to bring the Ecopower product to the U.S, and Climate Energy unveiled a micro-CHP prototype based on Honda's internal combustion engine, to be launched in 2006.

Market Prospects for Micro-CHP

Micro-CHP markets promise to take off, possibly with exponential growth in the next four years. The exact timing that this may happen is not clear, partly due to the uncertainty about product developers plans to commercialise their micro-CHP products. In this section we analyse the commercial prospects for micro-CHP in the U.S, Europe and Japan.

Commercial Prospects in Japan

Japanese micro-CHP markets are likely to continue to develop on two fronts. On one hand the market for the ECOWILL product is expected to continue to grow strongly, particular with Tokyo Gas starting to sell the unit from the beginning of 2006. We expect to see gas utilities continuing to aggressively market this product, with this activity partly driven by the threat from electric utilities in marketing all electric homes.

On the other front, fuel cell systems are currently the focus on intensive research, development and field testing in Japan. In 2005 Tokyo Gas and others started offering fuel cell micro-CHP systems to homes through leasing packages. This is not termed as commercial sales, as the activity is more similar to a large scale field trial rather than the widespread launch number of product for purchase by customers. By the end of 2005 Tokyo Gas had installed 100 fuel cell micro-CHP systems, and had the target of reaching 200 installations by the end of March 2006. In total the Government expects 400 such systems to be installed by March 2006.

Tokyo Gas and others are targeting a mass-launch of fuel cell micro-CHP systems in 2008, aiming to sell thousands of units a year. However further progress is necessary to reduce costs and improve lifetime in order for these targets to be met. It remains to be seen whether the necessary progress will in fact be made.

The overall market environment in Japan for micro-CHP is very favourable. Government support, together with gas utility action and investment, is leading to strong micro-CHP growth and development of new products – both PEM and solid oxide fuel cells. Japan is likely to continue to be the leading micro-CHP market in the world for the next few years.

Commercial Prospects in Europe

Micro-CHP markets in Europe currently are dominated by 5-kWe products sold into the German market. Whilst these markets are showing steady growth, it is unlikely that sales will rise much above 5,000 to 10,000 units a year for these products by 2010.

Perhaps of greater interest is the emerging market for 1-kWe to 3-kWe sized products, designed for single-family homes. The initial markets for these products are likely to be the UK, Netherlands and Germany. This market is currently constrained by three issues:

- Product availability
- Engagement by utilities and boiler manufacturer
- Regulatory barriers and issues

A large number of companies are developing micro-CHP product for the European market, with several of these hoping to commercialise product in 2007 or 2008. Selected developers include Microgen Energy Ltd, ENATEC, Stirling Systems Ltd, Baxi Group, and Honda (looking to commercialise their 1-kW engine with a European partner.

Utilities interest in micro-CHP in Europe is still patchy. In the UK E.ON-UK are leading the market by offering the WhisperGen unit to households. Of the other six major utilities involved in electricity and gas retail, Centrica have a heads of terms agreement with Microgen, and an agreement with Ceres Power. There are signs that some of the other four utilities may follow these two utilities in offering micro-CHP products to customers. But they face significant challenges in developing a brand in the heating business and building up a installation and servicing infrastructure.

In the Netherlands gas wholesale company Gasunie Trade and Supply is encouraging the development of the Dutch micro-CHP market. They have sponsored a field trial of WhisperGen units, involving most Dutch electricity and gas retail companies. They are also working with Microgen to develop a combi-version of their micro-CHP product. Although the Dutch electricity and gas retailers are currently very focussed on the opening of electricity and gas residential markets, there are signs that at least one, and possibly more, are keen to offer micro-CHP products to their customers in the near future.

The situation amongst German utilities is harder to read. Several have been involved in, and a number continue to be involved in, fuel cell micro-CHP field trials. However only a few are also testing other micro-CHP technologies that are arguably nearer to market than fuel cells. With fuel cell micro-CHP products unlikely to be commercially available much before 2010 (if at all), it will be interesting to see the degree to which German utilities engage with other forms of micro-CHP.

The engagement of European boiler manufacturers is important as:

- A number of boiler manufacturers are developing their own micro-CHP products, or are working with technology developers to develop a micro-CHP product.
- Independent micro-CHP product developers (such as Whisper Tech) are likely to need the manufacturing capability of boiler manufacturers to help them commercialise their micro-CHP products.
- Some micro-CHP technology developers such as ENATEC have a business model to license their technology to boiler manufacturers, so they need to see interest from boiler manufacturers in order for their technology to reach the marketplace.

The degree to which European boiler manufacturers *further* engage in micro-CHP is not yet clear (all have at least some micro-CHP activity at present), and this area should be closely watched.

Finally in Europe, regulatory issues need to be resolved in order for micro-CHP market to develop. There are no major issues, but minor issues are capable of acting as significant barriers to the development of micro-CHP markets. Activity is already underway in the UK, Netherlands and Germany to resolve these issues, and it is likely just a matter of time before they are resolved.

Commercial Prospects in North America

The North American market is, generally, a more challenging market for micro-CHP. This is due to low electricity prices in much of North America, resistance (for example in the form of interconnection arrangements and tariffs) from electric utility companies, the penetration of low cost warm air furnaces rather than the boilers found in Europe and Japan, and a greater focus on local air pollutants rather than greenhouse gas emissions.

However modest micro-CHP activity is likely in the next few years in North America. Climate Energy is field testing their Honda engine-driven micro-CHP product in winter 2005-6, with a target of launching commercial sales later in 2006. Marathon Engine Systems, manufacturers of the engine at the heart of the Ecopower micro-CHP system sold in Europe, are also expected to launch their product in 2006 or 2007. But both of these products are likely to play initially in niche markets, at least for the first few years of availability.

Carbon Dioxide Savings From Micro-CHP

The CO_2 savings that micro-CHP brings are dependent upon a range of assumptions that include:

- Micro-CHP average electricity and thermal efficiencies
- Running hours of the micro-CHP unit
- Average efficiency of the boiler that micro-CHP displaces
- Assumptions about the source of electricity that micro-CHP displaces, the efficiency of the power station and associated grid loses

Using a proprietary model together with boiler, power plant and grid loses values (using draft reference values from the implementation of the EU Cogen Directive), and manufacturers and product developers data (planned and expected), Delta calculates carbon dioxide savings as shown in Figure 1.

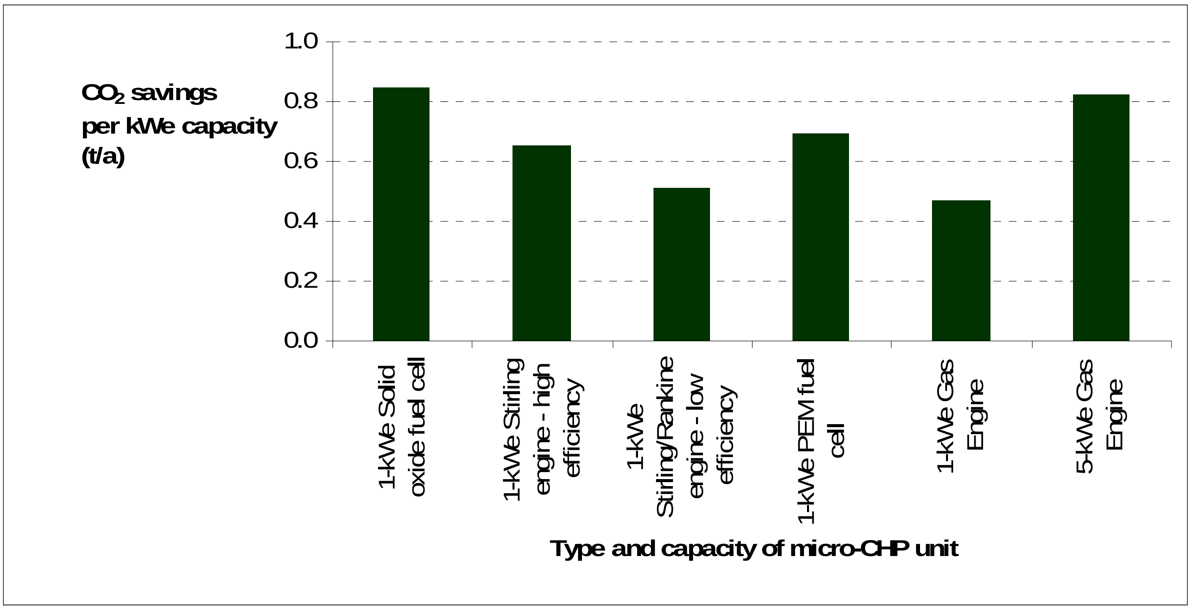

Figure 1: Annual Micro-CHP Carbon Dioxide Savings Compared to Grid Electricity and Boiler Alternatives. Source: Delta Energy & Environment

Note that the 1-kW units are assumed to be installed in a single family house with the 5-kW gas engine installed in a multi-family house. Efficiencies (all figures quoted are higher heating values) range from 9% electrical and 74% thermal, to 36% electrical and 38% thermal. The reference values assumed for separate electricity and heat production are 52.5% efficiency for a new CCGT power plant (assumed for an average ambient temperature of 15^{o}C) and 82% for a gas boiler. Grid loses are 14% for grid-supplied electricity, and 7.5% for electricity exported back to the grid.

Conclusion

Micro-CHP sales are likely to continue growing strongly over the rest of the decade. From 2008 there is the chance that an inflexion point may occur in market growth, leading to very rapid growth as new products suitable for mass-markets become available. This growth may bring substantial reductions in carbon dioxide emissions.

Japan is likely to continue to be the world's leading micro-CHP market. The major point to watch here is whether fuel cells have been sufficiently developed to be widely commercialised in 2008.

In Europe there is more uncertainty. Niche micro-CHP markets are currently showing steady growth, but there is the potential for explosive growth if new micro-CHP products suitable for single family homes are brought to market and utilities and boiler manufacturers aggressively push micro-CHP to customers.

North America has lagged these other two markets, and is expected to continue doing so. Micro-CHP is expected to establish itself in niche markets over the next few years. More aggressive growth is possible towards the end of the decade if HVAC manufacturers engage more firmly with micro-CHP, and other barriers are removed.

Scenarios for Carbon Abatement in Dwellings by Implementation of Stirling Engine Micro-CHP Systems

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Abstract
The Building Integrated Micro-Generation Model, a transient thermal and electrical demand estimation tool, has been developed to predict the performance of four micro-generation systems within a dwelling of specified construction during four simulation days corresponding to different climatic conditions. The thermal and electrical demands were estimated for a specified pattern of occupancy, appliance and domestic hot water usage relating to one of the domestic building variants from the Carbon Vision Buildings TARBASE programme. Consideration was given to a base case condensing boiler and three micro-CHP systems of varying electrical capacities (i.e. 0.5kWe, 1.1kWe and 1.8kWe) and electrical efficiencies (i.e. 18%, 28% and 38% respectively). The results of these simulation scenarios were quantified. For example, on the overcast winter day, the relative carbon saving (versus the base case) of each of the respective micro-CHP implementations was 6.4%, 11.7% and 17.7%. The primary aim of this research is to investigate the factors that affect the simulated and actual performance of micro-CHP systems in terms of carbon emissions. The main factors identified were transient thermal and electrical demand, micro-CHP system efficiencies and capacities, thermal and electrical storage capabilities and system control regime. The importance of carbon credit for the export of electrical output to the national grid to the carbon saving figures was highlighted, as was the major contribution to carbon saving from electrical import avoidance.

Introduction

In the UK, the domestic sector accounts for 30% of total energy demand, with an average 83% of this demand for the provision of space heating and domestic hot water, and the remainder for electrical lights and appliances [1]. Of the approximate 25 million dwellings in the UK, around 17 million are fitted with domestic gas central-heating (DCH) boilers [2]. The maturity of gas DCH boiler technology has resulted in efficiencies of up to 93% for gas condensing DCH boilers, leaving minimal possible carbon savings through further improvements of DCH technology. Therefore, research into carbon abatement has pursued other avenues, one of which is co-generation of heat and electricity, using a micro-CHP system. This generates electricity whilst recovering the majority of otherwise wasted heat, and can reach overall efficiencies in excess of 90% [3]. The carbon saving is primarily attributable to the reduction in use of centrally-generated network electricity, which has a carbon intensity ($kgCO_2$/kWh) that is more than twice that of natural gas.

Several candidate technologies for micro-CHP are under development and the ultimate market potential for countries with extensive natural gas networks is large. One recent study [4] estimated that the UK market potential for micro-CHP systems based on Stirling Engine prime-mover technology was 13.5 million units, or around 40% of the housing stock. Hence it is prudent to investigate and identify the factors affecting the carbon savings achieved by dwelling-integrated micro-CHP systems. This work has ramifications for the estimation of possible carbon abatement, and the specification of future micro-CHP systems, as it seeks to illustrate the variation in carbon savings between micro-CHP system specifications, and target dwelling construction and occupancy.

In this paper, the major factors which influence the effectiveness of the micro-CHP approach are highlighted. Using the specifically designed, in-development Building Integrated Micro-Generation (BIM-G) Model, the predicted performance of three generic micro-CHP systems within a specified dwelling is analysed. The temporal variation of the electrical and thermal demand profiles generated for the dwelling corresponds to a specified construction, occupancy pattern and appliance utilization schedule. By evaluation of “real-time” thermal and electrical demand and transient generation response, on a 5 second basis, dwelling carbon emissions can be calculated with more accuracy, a hypothesis supported by a recent paper [5].

BIM-G Model Overview

The BIM-G Model is under development as a research tool to produce synthetic thermal and electrical demand profiles for domestic buildings, at high temporal precision, in order to permit the investigation of detailed changes in end use and micro-CHP system design. The BIM-G model can be used to quantify the performance of the system using pre-defined performance metrics. The model utilizes a bottom-up approach to domestic energy modelling through the use of scripts which specify the nature and timing of appliance, lighting and DHW usage, dwelling occupancy and thermal comfort requirements. The model accounts for the transient nature of thermal energy demand in the building by considering the effects of thermal mass in both the building fabric and space heating distribution system.

The model itself simplifies the geometry of the dwelling into two 1-dimensional boundaries (separating the total volume of internal air from the external environment) representing the wall and roof; and a 1-dimensional boundary separating the internal air from the ground. Heat is exchanged between the external surface of each element and the environment through convective and radiative processes. Heat exchange between the internal surface of each element and the internal air is via conductive and estimated radiative processes. Energy is conducted between surfaces of each element, which acts as a thermal storage mechanism, governed by the specific heat and volume of each element.

Simulation Scenario Definition

The initial step in this research was to define a set of scenarios, in terms of BIM-G input scripts and physical dwelling characteristics. The work utilises the domestic variant definitions emerging from the Carbon Vision TARBASE programme [6], which aims to deliver technological interventions to appliances, building fabric and energy generation to reduce the carbon footprint of existing buildings by 50% within a 2030 timeframe.

Physical Dwelling Characteristics

The selected building variant is a detached dwelling, of 180m^2 floor area, constructed between 1988 and 1994, conforming to the building regulations of that time. The dwelling is of timber frame construction, with a 25% glazing/gross external wall ratio and a total ventilation rate (comprising infiltration and manual ventilation) of 0.76 air changes per hour. The dwelling is assumed to reside in the area of Oban, on the west coast of Scotland, and all thermal calculations are performed using corresponding climate data (i.e. external air temperature, and diffuse and direct solar irradiation measurements).

Household Characteristics and Occupancy Pattern

The household selected to reside in the dwelling is relatively financially prosperous (the relevance of which is discussed later), and comprises two working parents, one working offspring and a school-attending child. The scenario defined for this round of simulations represents a typical working day, characterised by “active occupancy” (i.e. household occupied and occupiers arisen from sleep) for several hours in the morning, followed by a long period of vacancy, and finally a long period of “active occupancy” starting from late afternoon, stretching until all occupants retire to bed. Such an occupancy pattern is utilised by a popular daily steady-state domestic energy estimation model developed by the Building Research Establishment [7].

The timing of appliance, DHW and manual ventilation events correspond to times of household occupancy, as do the corresponding metabolic and appliance casual thermal gains.

Appliance Ownership

A range of possibilities exists with respect to the number, variety and age of appliances fitted in a home. Load signatures vary with appliance type and in some cases depend on age and usage technique. The aggregate electrical load profile is determined by the transient nature of appliance (including illumination) usage. For this initial analysis, the dwelling was assigned a set of appliances, both electrical and DHW related, from which the appliance and DHW usage scripts were composed. The selection of appliance set was made using ownership data referenced by the assumed socio-economic status of the household.

The appliance set for this scenario includes an electric oven, gas hob and DHW mixer shower. In comparison to other possible scenarios, the electrical appliance usage on the simulation day can be assumed to be low, in comparison to other possible simulation scenarios, as supported by data from a previous TARBASE study [6].

Climate Data
The climatic data set used with the BIM-G Model was converted from International Weather for Energy Calculations measurements for Oban, Scotland [8]. For the purposes of this scenario, four climate day varieties were specified; extreme summer day, extreme winter day with clear skies, extreme overcast winter day and shoulder day. The spread of climate days allow the micro-CHP systems to be analysed over a range of space heating requirements, due to variations in external air temperature, incident solar radiation and thermal energy stored in the building fabric.

Space Heating & DHW Distribution System
As discussed previously, a 1-dimensional space heating distribution system was specified for the dwelling, in order to estimate the transient nature of thermal supply and demand. This distribution system entails a heat emitter and pipework, each with a surface area equal to that estimated using an industry design guide [9] and the Energy Saving Trust's "Whole House Boiler Sizing Method" [10]. The volume of space heating water, also estimated by the same method, is heated by the heat-generating device, i.e. DCH boiler or micro-CHP system. The transient temperature profile of this space heating water dictates the required heat generator output and space heating input to the dwelling from the radiator and exposed pipework.
The DHW system comprises a 180-litre DHW tank, insulated appropriately to achieve an average heat loss of 76 Watts. In specification of the DHW usage profiles for the mixer showers, it is assumed that the DHW undergoes a 10 degrees Celsius drop between tank and shower water mixer, which requires a higher draw-off rate than a zero heat loss assumption. For all DHW events, a dead-leg period of 30 seconds is assumed, to account for sub-requirement temperature water in the DHW piping which is discarded.
All micro-generation systems defined in this scenario utilise the existing distribution systems and DHW storage tank.

Micro-Generation System Specifications

Base Case – 20kW Condensing Boiler
In order to quantify carbon emission reduction due to the implementation of micro-CHP to the dwelling, a reference case must be considered, representative of the dwelling before intervention. In this case, a standard DCH condensing boiler was specified, with a constant generation efficiency of 88.0%. The maximum thermal output of the boiler is 20kW, and the minimum operating output is 4kW.

Stirling Engine Micro-CHP Systems
The prime mover incorporated in each of the generic micro-CHP systems is a Stirling external combustion engine, with varying electrical and thermal capacities as detailed in Table 1. As the heat recovery efficiency remains constant across each system, both the electrical and overall efficiencies vary, as detailed in Table 1. An auxiliary burner can supply a maximum and minimum of 15kW and 3kW respectively, at a constant generation efficiency of 88.0%. The prime mover is controlled in a manner where it operates only at full load, i.e. no part load operation, whereas the auxiliary burner, if called upon, can freely modulate between minimum and full load operation.

Table 1: Electrical and Thermal Capacities and Efficiencies of Generic Micro-CHP Systems

Generation System	Electrical Capacity (kW)	Thermal Capacity (kW)	Electrical Efficiency (%)	Electrical Efficiency (%)
0.5kWe Micro-CHP	0.5	1.97	18.0	88.7
1.1kWe Micro-CHP	1.1	2.44	28.0	90.1
1.8kWe Micro-CHP	1.8	2.53	38..0	91.5

Results & Discussion

Reference Case
The following section displays and discusses the results for the base case scenario, where thermal energy is supplied from the condensing boiler, and electrical demand solely from the national electrical grid.
In Table 2, details of the estimated energy demand of the dwelling for each climate day are given, where the appliance usage and occupancy patterns remain unchanged. Variations in DHW demand between days are attributable to the proportional assignment of boiler thermal output between space heating and DHW circuits. As space heating demand, and hence boiler output, increases, small

amounts of thermal surplus (i.e. when demand is below minimum boiler operating output) may be transferred to the DHW circuit, overshooting the DHW storage tank temperature by an allowable margin. The increases in electrical demand with total thermal demand are due to increased boiler firing and circulation pump usage.

Table 2: Estimated Energy Demand of each Climate Day disaggregated by Type

Climate Day	Space Heating Demand (kWh)	DHW Demand (kWh)	Total Thermal Demand (kWh)	Electrical Demand (kWh)
Overcast Winter Day	72.1	15.1	87.2	14.0
Clear Winter Day	62.6	13.9	76.5	13.9
Shoulder Day	37.7	14.0	51.6	13.8
Summer Day	0	14.0	14.0	13.7

NB: Energy Demand estimated as the energy delivered to Space Heating and DHW heat exchangers

The graphs below (Figures 1 and 2) illustrate the transient space heating, DHW and electrical demand, resultant internal air temperature and external air temperature on the overcast winter day and shoulder day respectively.

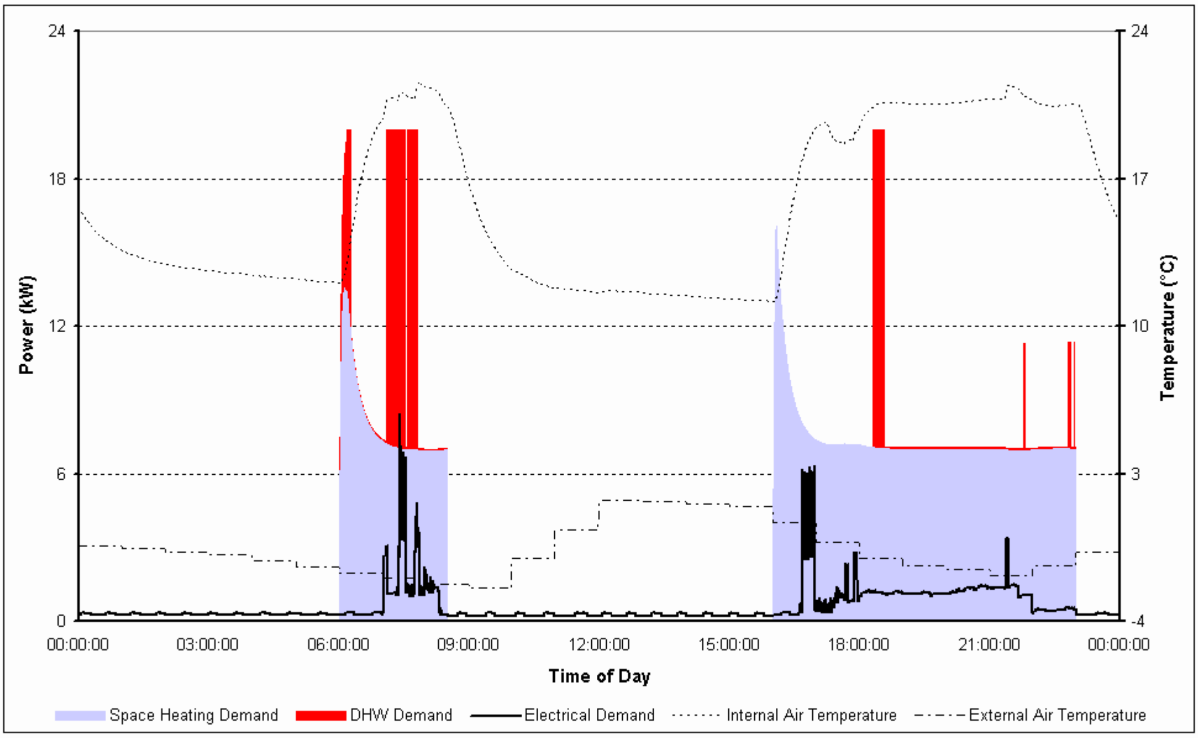

Figure 1: Transient Demand and Internal & External Air Temperatures for Overcast Winter Day

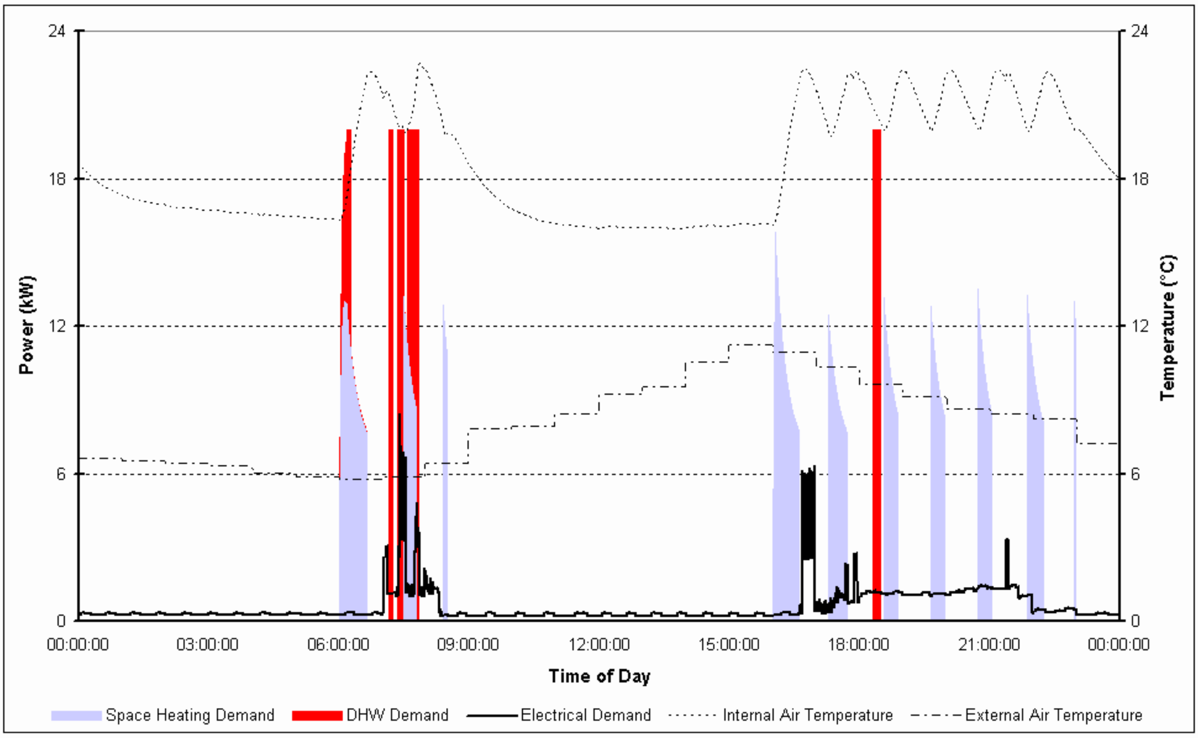

Figure 2: Transient Demand and Internal & External Air Temperatures for Shoulder Day

The primary performance metric of any thermal generation device supplying a space heating system is the internal air temperature during thermal comfort demand periods, and the difference from thermal comfort target temperature. The thermal comfort target temperature used during these simulations is 21° C, where occupants regard any temperature within a +/- 1.5° C band of this temperature to be acceptable. Therefore, any internal air temperature between 19.5° C and 22.5° C would fulfil thermal comfort requirements. Furthermore, previous research [11] has identified a band of temperatures outside this range (16-23° C during winter, 18-25° C during shoulder months) where the internal air temperature is acceptable to 80% of possible occupants. The thermal comfort demand periods during this simulation are between 07:00 and 08:30, and 16:30 and 23:00.

Micro-CHP Implementation Cases

The BIM-G Model was used to estimate the transient performance of three micro-CHP systems, with a spread of electrical output and efficiencies. The system specifications of these units where chosen for several reasons. The system with 0.5kWe output was chosen to represent a unit with output less than the average electrical demand (approximately 580 Watts, as calculated on a daily basis). A 1.1kWe unit was designed to match performance information found on a micro-CHP system in current development; and the 1.8kWe unit was selected to investigate the effects of larger electrical output systems.

The tables below (Tables 3 – 6) depict the thermal and electrical output of each micro-CHP system on each climate day type. Additionally, the electrical import and export to the grid is quantified.

Table 3: Estimated System Generation Levels – Shoulder Day

Generation System	SE Thermal Generation (kWh)	Aux Burner Thermal Generation (kWh)	SE Electrical Generation (kWh)	Electrical Import (kWh)	Electrical Export (kWh)
Condensing Boiler	0	51.6	0	13.8	0
0.5kWe SE CHP	7.4	44.0	2.1	12.0	0.3
1.1kWe SE CHP	10.4	41.0	4.6	10.6	1.4
1.8kWe SE CHP	12.6	38.9	7.6	10.2	4.0

Table 4: Estimated System Generation Levels – Summer Day

Generation System	SE Thermal Generation (kWh)	Aux Burner Thermal Generation (kWh)	SE Electrical Generation (kWh)	Electrical Import (kWh)	Electrical Export (kWh)
Condensing Boiler	0	14.0	0	13.7	0
0.5kWe SE CHP	1.8	12.2	0.6	13.3	0.0
1.1kWe SE CHP	2.5	11.5	1.0	12.9	0.2
1.8kWe SE CHP	2.9	11.1	1.7	12.7	0.7

Table 5: Estimated System Generation Levels – Overcast Winter Day

Generation System	SE Thermal Generation (kWh)	Aux Burner Thermal Generation (kWh)	SE Electrical Generation (kWh)	Electrical Import (kWh)	Electrical Export (kWh)
Condensing Boiler	0	87.2	0	14.0	0
0.5kWe SE CHP	16.4	68.9	4.7	9.7	0.4
1.1kWe SE CHP	23.2	62.3	8.9	6.1	2.5
1.8kWe SE CHP	27.9	57.5	17.0	4.9	7.9

Table 6: Estimated System Generation Levels – Clear Winter Day

Generation System	SE Thermal Generation (kWh)	Aux Burner Thermal Generation (kWh)	SE Electrical Generation (kWh)	Electrical Import (kWh)	Electrical Export (kWh)
Condensing Boiler	0	76.5	0	13.8	0
0.5kWe SE CHP	14.1	62.1	2.1	12.0	0.3
1.1kWe SE CHP	19.9	56.4	4.6	10.6	1.4
1.8kWe SE CHP	24.0	52.3	14.6	6.4	7.0

As expected, Stirling Engine thermal and electrical output increases with Stirling Engine electrical capacity, as does electrical export, whilst electrical import and auxiliary burner thermal output decreases. The variation in total thermal output is attributable to the maximum and minimum operating thermal output of each system, and the resulting effects on transient generation.

In the graph below (Figure 3), the carbon emissions from each generation system, on each climate day, are districtised by source, i.e. total system gas consumption (at an intensity of 0.19kgCO_2/kWh) and electrical import and electrical export (at an intensity of 0.43kgCO_2/kWh). In this research, it has been assumed that full “carbon credit” is given to exported electricity, as it is assumed that it displaces electrical generation required for other users, at full grid electrical intensity of 0.43kgCO_2/kWh.

In Figure 4, there are several trends apparent in the carbon saving results, if the summer climate day results are discarded. The summer results, in percentage carbon saving terms, appear disproportionally high in relation to the remaining climate days. This is a consequence of fuel wastage experience during the boiler “cold start” periods, which is not as apparent during other days with much higher thermal demand. Ongoing development of the BIM-G model will clarify this effect and it’s applicability to real-life situations. The carbon saving for any climate day increases with electrical output of the Stirling Engine, within the size range investigated in this research. This appears to be a consequence of avoided electrical imports and credited electrical exports, both of which have a carbon intensity around 2.3 that of the natural gas consumed by the generation systems. The carbon saving for any generation system increases with the daily thermal demand of the simulation day, a consequence of longer total prime mover operation time, which in turn increases avoided electrical imports and credited electrical exports.

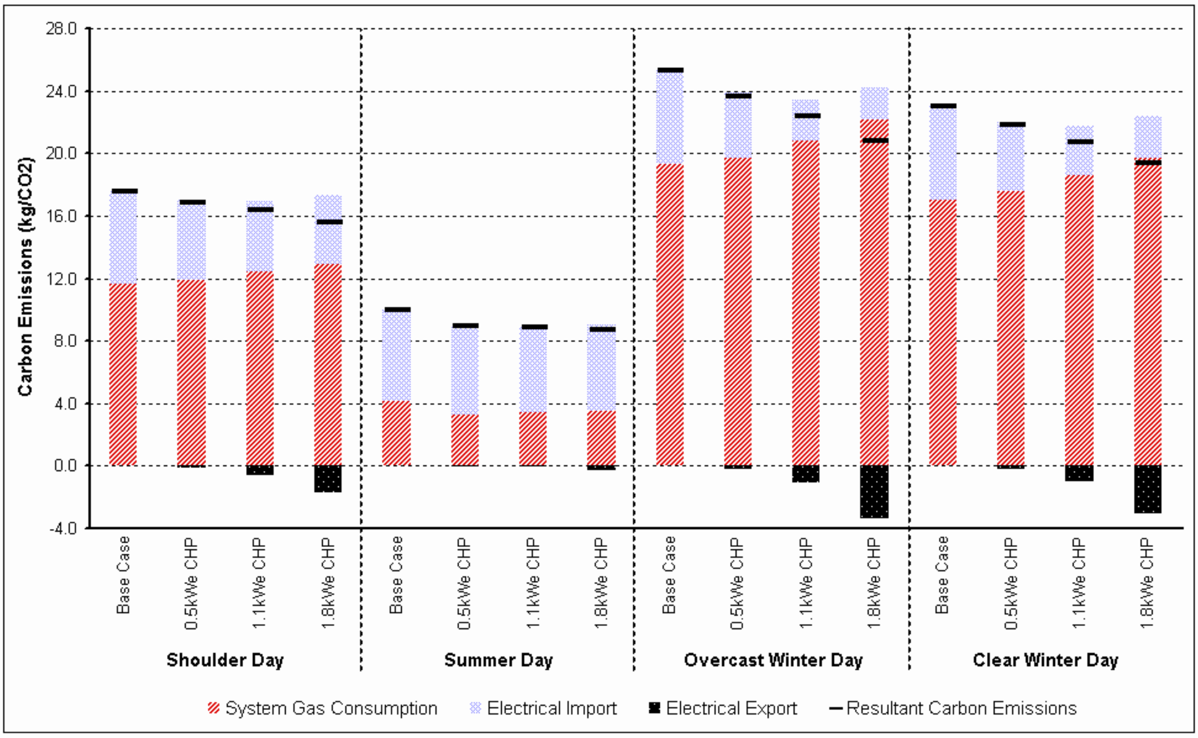

Figure 3: Carbon Emissions by source from each Generation System on each Climate Day

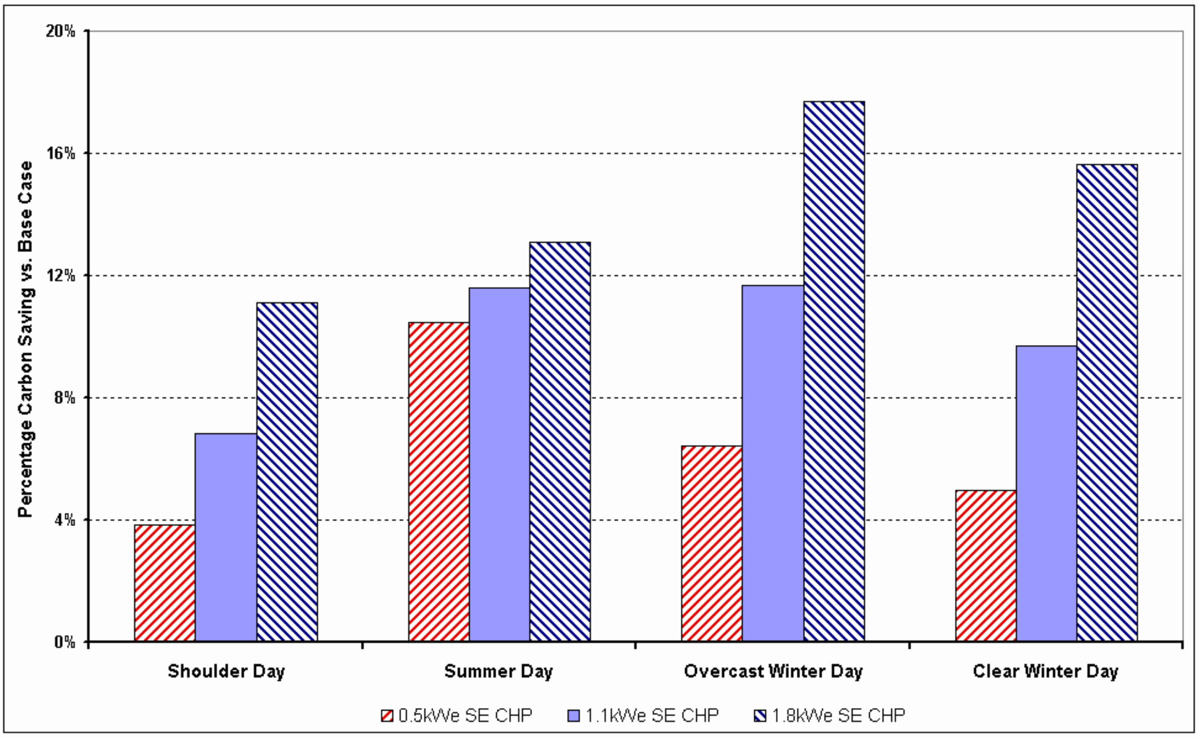

Figure 4: % Carbon Savings from Base Case from each Generation System and Climate Day

Conclusions

A transient thermal and electrical demand estimation tool was used to model the performance of four building integrated micro-generation systems within a specific dwelling during four simulation days corresponding to different climates. These systems include a base case condensing boiler and three micro-CHP systems of varying electrical and thermal capacities and efficiencies. The results of these simulation scenarios were quantified, and carbon emission figures calculated pertaining to selected operational measurements. The relative carbon savings (versus the base case) of each micro-CHP implementation scenario were presented for each simulation day to give a first order estimate of their carbon abatement potential. Although several interesting trends can be identified in these results, the primary aim of this research was to highlight the factors that affect the simulated and actual performance of micro-CHP systems in terms of carbon emissions. Further research is required to quantify the relative effect of each factor on carbon savings, and the cumulative effects on micro-CHP system sizing and design. In brief, these factors are:

- Magnitude and transient nature of thermal demand, i.e. Space Heating and DHW, including those factors that directly determine thermal demand, namely:
    - Casual gains from appliances and occupants
    - Magnitude and timing of thermal comfort requirements
    - Exterior climate
    - Dwelling construction
- Magnitude and transient nature of electrical demand, including those factors that directly determine electrical demand, namely:
    - Occupancy and appliance use patterns
    - Ownership and transient electrical load of appliances
    - Exterior climate
- Co-incidence of thermal and electrical demand, and the ratio and transient nature of such co-incidence
- Ability and efficiency to store excess electrical and/or thermal energy generated on-site
- Ability and/or desire to export electrical generation from the dwelling, and the magnitude of "carbon credit" assignable to such an export
- Thermal and electrical efficiencies of prime-mover and auxiliary generators, in steady state and start-up conditions
- Thermal and electrical capacities of prime-mover and auxiliary generators, including minimum operating power outputs and modulating ability
- Control regime of micro-CHP system, including start-up sequence, electrical and/or thermal load following ability and technology dependent on/off switching event limitations

Further research is planned to consider each factor in detail, as discussed above, in tandem with continuing development of the Building Integrated Micro-Generation model.

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Aiming at a 60% Reduction in CO2: Implications for Residential Lights and Appliances and Micro-generation

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Abstract
A number of European Governments, including the UK, have a target for a reduction in CO2 emissions of 60% by 2050 compared to 1990 levels. This paper explores the implications for residential lights and appliances and for microgeneration which are both mass produced and have the potential for significant cost reduction and market transformation.
Projected consumption for lights and appliances could be halved through a combination of new technologies, fuel switching and reduced purchasing of new and energy intensive products. A focus on energy efficiency is not sufficient.
Microgeneration devices generate heat and or power and are installed in the building or community. Typical devices include micro-CHP (both Stirling engine and fuel cell), community based CHP, biomass, heat pumps, solar PV, and solar thermal. Different technologies have potential in different types of housing. Microgeneration is developing rapidly in the UK. By 2050 the domestic sector could supply most of its heat and electricity from microgeneration, with conventional heating technologies (electric heating and gas central heating boilers) almost obsolete.
The cost of such change is discussed. In particular, 'experience curves' show that the cost of a new product is shown to fall in a predictable way with increases in volume. Applying this approach shows that payback times fall dramatically with significant levels of uptake possible. Policy to deliver such large changes through Market Transformation is discussed. The development of Energy Services Companies could help finance the required investment. Personal Carbon Allowances and information both have a significant role to play.

Introduction

The IPCC recommended that global emissions are reduced to 60% of their 1990 levels by 2050. Several governments have adopted this target as an objective, including the UK. It follows therefore, that even though there is great uncertainty over this timeframe given the rate of technical and social change, policy makers must begin to discover the implications of such radical changes.
In response to this, the 40% House report [1] postulated an internally consistent scenario whereby emissions from the UK Housing stock could be reduced to 40% of current levels by 2050, even with a 33% increase in the number of dwellings by 2050, as well as an expectation of more heat, more hot water per person, and a greater penetration of appliances. To achieve this reduction, under this scenario, requires:

- A large improvement in existing dwellings through refurbishment equivalent of moving from an average E (SAP rating of 45) to an average A on the label (SAP of 90 or more, close to zero carbon buildings, requiring all buildings have super-insulated windows, all cavities are filled and most solid walled properties remaining have external wall insulation, as well as significant microgeneration). This is
- A zero space heating demand standard for new build housing, together with significant use of microgeneration
- Significant uptake of Low or Zero Carbon technologies which provide heat and, or, electricity from devices which are integrated into the building or community (such as CHP, PV, solar thermal, building integrated wind, heat pumps etc).
- In terms of lights and appliances, the two crucial changes are that all lights are light emitting diodes (LED) because of their efficiency as well as lighting quality, and all refrigeration appliances utilise vacuum panel insulation, which reduces heat gain by these appliances to one-fifth of current levels.

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[1] The paper is based on work conducted by University of Oxford and published in 40% House, informed by further work for The Carbon Trust and the Engineering and Physical research Council as part of a project called Building Market Transformation.

Around two-thirds of the carbon saving in this scenario come from energy efficiency measures, and around one-third came from LZC technologies. Of course, this is not the only way of achieving a reduction in emissions to 40%, and it is, in no way a forecast. But it *illustrates the level of change needed* to achieve this scale of reduction. A set of policies were proposed that could transform the market and bring this scenario about, based around information, incentives (support for innovation), and regulation (appliances standards and building standards).

The work begun in 40% House is being continued in more depth in a new project called Building Market Transformation. BMT is exploring a range of scenarios, and uses sensitivity analysis to assess the impact of different assumptions for future population, household size, climate etc. BMT has taken the modeling work from 40% House, and expanded it to produce a range of scenarios, and sensitivity analysis. The main three scenarios are

- Scenario A – assumes the broad continuation of current policies including the objective of meeting Kyoto targets as well as incremental changes in technology
- Scenario B – describes a 60% reduction in carbon emissions from housing
- Scenario C – represents an extreme change, with further reductions in carbon emissions beyond 60%

The rest of this paper explores the implications of this work for components in homes that are mass produced – lights and appliances and low and zero carbon technologies- and which might therefore be subject to similar market transformation processes. Mass production may bring benefits to in terms of cost reduction if devices are made in volume (described in literature as technology learning). These two groups may be very different from building refurbishment and construction which may be much more site-specific and increasingly needs a whole-house integrated approach.

Lights and appliances

The basic driver is expected to continue to be more households (23.9 to 31.8M homes in 2050, up 33%) and wealthier households. It is possible to envision a near term future where an older, wealthier population sit in a cooled conservatory in summer, or under a patio heater outside in winter, with a laptop which gives them via broadband, phone, a television and radio in the corner of the screen, whilst they browse the stock markets on the internet. None of these products were envisioned even in work undertaken under the DECADE programme for the UK in 1997 [2].

The other major issue is smaller households. Many of the new households are one person households because we are marrying later, divorcing earlier, and living longer. In the UK, based on NHBC quarterly statistics on completions, the number of homes build as detached has reduced from 85,000 to 51,000 a year (a decline of 40%) whilst the number of new flats has increased from just over 30,000 to just under 60,000 a year (a 95% increase), all in the space of just 4 years from 2000 to 2004. This has dramatic implications for new and in due course, replacement sales of combined appliances like fridge-freezers and washer-dryers, as well as appliance ownership more generally. It cannot be assumed that traditional appliance ownership patterns will continue into the future.

There are a range of new technologies. Products are becoming more portable, with wireless communications and in future wireless power. This has several implications:

- **Always-on devices, Power supply and Standby consumption:** making devices portable (like the landline telephone) implies increased ownership (at least in the short term) of batteries and chargers. Fewer and fewer appliances –even major appliances like washing machines- have an off-switch, because it isn't required at low power demand, and the control system consumes under this level. Transformer based power supplies currently consume 1-7W, but electronic power supplies with losses of 0.1W are possible. Standby consumption could be a transitional technology.
- **New power sources:** fuel cells may power new mobile devices such as phones, MP3 players, PDA's and laptops by 2007[2]. The input fuel would thus be gas rather than electricity, with much lower carbon emissions. In due course, PV may make a comeback for small electronic goods, if efficiency improves (from 6% to 20% and even 50%), and if costs come down (eg moving away from silicon based technologies, and using polymers rather than glass as a substraight). PV will require back-up power sources either in the form of a battery or fuel cell, with both technologies making significant technical progress.

[2] Toshiba, NEC, Hitachi, and Casio have all announced protypes, see for example, http://www.engadget.com/2004/05/11/casios-laptop-fuel-cell/, and http://news.bbc.co.uk/1/hi/technology/3837585.stm

- **Fuel switching** could be a real opportunity to reduce carbon in clothes dryers, hobs and ovens, and even some portable electronic devices with fuel cells. UKDCM2 Scenario A has no fuel switching, but Scenario C does.
- **Electronics design** aimed at improved portability, will drive down power consumption both of standby modes and of associated screens.
- **LEDs for lighting**: incandescents are around 15-17 lumens per watt, CFLs around 60lpw, and whilst LEDs are struggling to match CFLs currently, progress is expected to take them to 150 lumens per watt in future. Lighting consumption could fall to a tenth what it currently is.
- **VIPs for refrigeration and hot water storage** could reduce energy consumption (from standing losses) to a quarter of what it currently is.

New product groups with changes in technology, population structure and wealth create new marketing opportunities, for example:

- More and more kitchen appliances, though increased ownership does not necessarily imply increased consumption. For example, a coffee machine when used displaces a kettle, a sandwich toaster may displace an ordinary toaster. What it does mean is that the savings from improved efficiency are harder to capture.
- Home security systems. Often systems have communications and monitoring potential. These may be combined with home control products, security products with communications capability could be two way devices not just one way.
- In a warmer climate with a wealthier population, outdoor products may become more significant, eg patio heaters (patio coolers are reportedly popular in Australia) hot tubs, outdoor lighting and conservatories.
- In a warmer climate there may also be more cooling in the home.
- increasingly products are merging. Televisions have writeable storage (currently DVDs) together with software capability for games playing. Home entertainment products and PCs are likely to come together as a single group. At the same time, phones are merging with portable computers, and even -with the advent of 3G- with televisions. Televisions are merging with PC's, given new USB-based freeview devices for PC's giving access to all digital television channels. So whilst main televisions are getting larger, second televisions could be portable or even pocket devices. The whole area of communications is merging. In practice, this happening quickly and significant change could be seen before 2010.

Figure 1 below shows 3 Scenarios developed under BMT. In Scenario A, consumption continues to rise to 120 TWh. The largest contributor to this is home electronics, but new 'outdoor products' also make a contribution. In Scenario B, consumption in 2050 is reduced to 63 TWh and in Scenario C to 54 TWh.

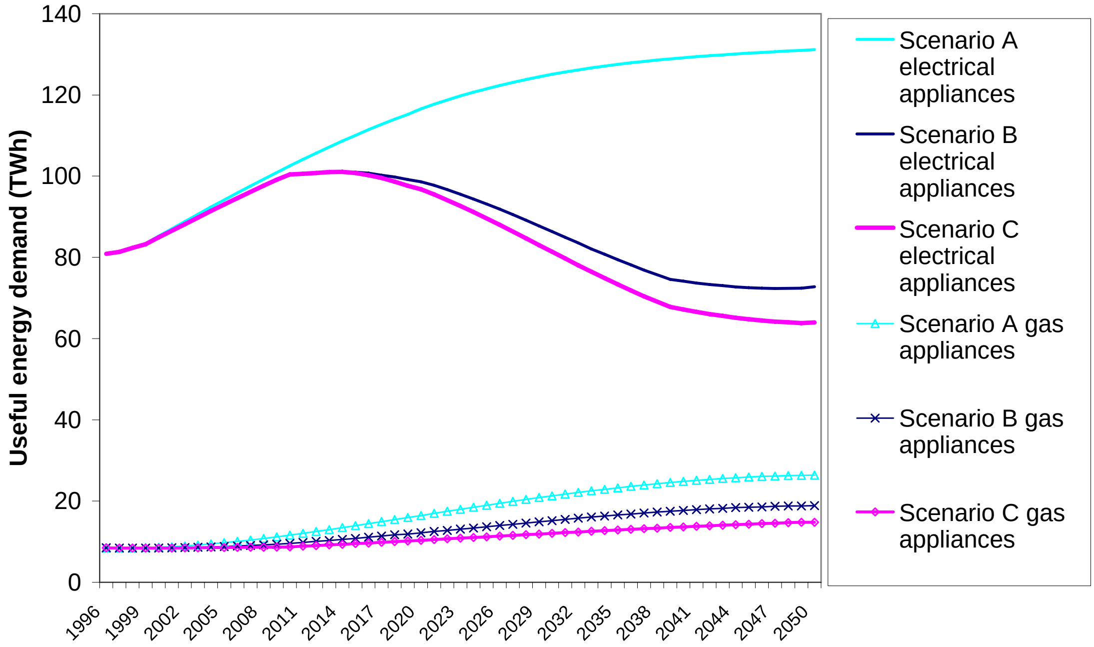

Figure 1 Three Scenarios for lights and appliances to 2050

A 56% reduction in electricity can be achieved in Scenario C compared to Scenario A by 2050. Consumer electronics (solid state power supplies, better power management and better screens) and lighting (LED's) account for over half of savings. Fuel switching in cooking and wet appliances saves more electricity than does efficiency, and in outdoor products, fuel switching and avoided high energy consumers save 14% electricity. Vacuum insulated panels in refrigeration account for 12% electricity.
If policy agreement were forthcoming in time to implement measures by 2010, most of this could be achieved by 2030, given the current rate of stock turnover. A key issue is that because lights and appliances are traded good, agreement at EU level would be needed. However development of new technology is something that the UK could play a key role in.

Low and zero carbon technologies

In the UK, Low and Zero Carbon technologies show a large potential and gas boilers (condensing or otherwise) could be very much smaller portion of the stock by 2050. The potential for LZC is broadly categorised into different types of schemes (see Table 1);

- **Combustion based opportunities** - those that generate heat and may in the process generate electricity. They would replace a conventional (gas electricity coal or oil) heating system. These again divide into group systems (community heating) or individual systems (micro CHP, or biomass). Community heating is predominantly a technology for dense urban communities. Micro CHP is essentially a suburban or rural technology.
- **Rooftop opportunities** – these capture wind or sun and may be competing for roofspace. A low cost replacement opportunity occurs in new build when a roof is installed anyway, or when a roof is replaced, which may be every 50-100 years, or when a roofspace is converted for living space.
- **Rural opportunities** – where location dictates availability such as biomass, or heat pumps which need space and are only really cost effective when a home is not on the gas network.

Table 1 Assumptions for LZC, Scenarios A, B & C

	Scenario A	Scenario B	Scenario C
Dirty fuels (direct electric heating, solid fuels)	• Electric heating is around the same level, • Coal and oil slow to decline	• Electric heating is around the same level, • Coal and oil slow to decline	• Electric heating is around the same level, • Coal and oil slow to decline
combustion based opportunities (gas and urban biomass, heat only and CHP)	• Total uptake similar to condensing boilers, so by 2050, 5% Stirling engine 5% fuel cell, 5% district heating • % biomass in micro is 5%, and in DH is 20%	• 7m homes have zero space heat. • Uptake of each technology similar to condensing boiler uptake, so by 2050 half of homes having some form of CHP (15% Stirling engine, 20% fuel cell, and 15% district heating). • Biomass is 15% of stirling engines and 25% of Community Heating	• 7m homes have zero space heat • Uptake of each technology similar to condensing boiler uptake, so by 2050 just over half of homes havesome form of CHP, but higher electrical efficiency of fuel cells, and more biomass /energy from waste (5% Stirling engine, 30% fuel cell, 20% district heating) • large scale intervention means CH good in early years, with 50% being biomass or EfW
rooftop opportunities (PV solar thermal, BIW)	• Ownership grows at half the recent growth of condensing boilers until a fifth of roofs have a device • 10% Solar Thermal • 5% PV • 5% solar thermal • No increase in output from roof devices	• Ownership grows at the same rate as condensing boilers over the last 15 years, until ownership saturates with a third of roofs having installations – eg • 12% solar thermal • 10% PV • 7% Building Integrated Wind • Some increase in output	• Ownership grows at the same rate as condensing boilers over the last 15 years, until ownership saturates with half of roofs having installations • 25% Solar thermal • 15% PV • 10% Building Integrated Wind • Significant improvements in outputs over incremental
rural opportunities (biomass and heat pump)	• 3% Heat pumps • 3% biomass	• 5% heat pumps • 5% biomass	• 5% heat pumps • 5% biomass
Total	• Gas boilers (heat-only) are still the dominant technology for space & water heating with low uptake of LZC (38% ownership in 2050)	• Uptake of LZC is higher, reaching 89% ownership in 2050	• Uptake of LZC reaches 115% ownership in 2050, but with a higher proportion of renewables relative to Scenario B

The total proportion of heat and electricity supplied under each scenario is shown in Figure 2.

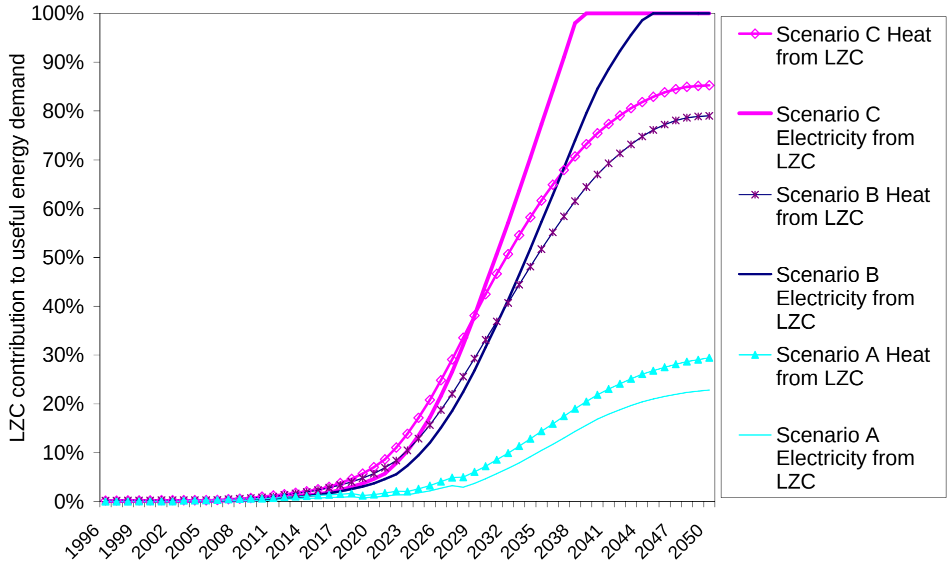

Figure 2 Three scenarios for the percentage of heat and electricity from LZC to 2050

The potential for each technology in BMT has been based on a range of existing studies.

For **Community heating**, more than 20% of UK homes could be served by Community Heating with 27% of the potential for CHP in London, and 66% in half a dozen major cities [3]. Another study explored the potential for LZC in London. PB Power, in a study for the London Mayor and Greenpeace, found that LZC could reduce carbon emissions by 28% by 2025. Of these savings, district heating made around 90% of the savings because of the density of build in the capital, and utilising a mix of natural gas, biomass and energy from waste [4]. In the report, Solar thermal, PV, and micro CHP together saved around 10% of this total. There is nothing new in the potential for district heating in large UK cities. The Department of Energy 'Energy Paper' series explored the theme several times. Energy papers 20 [5], number 35 [6], and number 53 [7] together identified significant potential in 9 major conurbations. So whilst Denmark changed its planning regime in the mid-1970s to stimulate CHP and now supplies around half of homes with CHP, the UK merely talked about it.

The potential for **biomass** heat only and in larger CHP applications has been explored by Bauen Woods and Hailes [8], RCEP [9], and Carbon Trust [10]. The potential for **Energy from Waste** in large CHP applications is separate [11].

The potential for **microCHP** was estimated by FaberMaunsell to be around 12million homes [12]. Little overlap was found with community heating because Community heating is a dense urban technology, and microCHP is a suburban technology, where density is too low to make a heat network cost effective.

The potential for **heat pumps** was identified by Hitchen [13]. The potential is limited to homes without access to gas, and where the disruption could be tolerated, such as new build or significant refurbishment (eg installation of underfloor heating and trenches outside).

The potential for **Building Integrated Wind** was estimated as being up to 5TWh by around 2020 [14]. This is of the order of 5% of residential electricity demand, depending on year and scenario.

An integrated study of **microgeneration** including Building Integrated Wind, PV and solar thermal as well as CHP below 50 kW was published by DTI [15].
Many of these studies do not take account of the reductions in energy demand through efficiency improvements, or increased number of dwellings to 2050 (usually only existing build) or changed energy prices or reductions in cost through technology learning. A key point is that the UK lags behind many other OECD countries, for example:

District heating with CHP serves less than 0.1% of UK households. In EU-15 23 million people live in homes served by district heating. In Finland and Denmark around half the population live in schemes served by district heating.

Heat pumps: In Sweden just under 10% of homes have a heat pump (as well as more than a quarter of households on district heating).

PV: the UK has supported installation of just over 1000 completed for the UK [16]. Germany has recently completed a programme of 100,000 solar roofs [17]. Japans PV programme is four times the size of Germany's. Japan has a subsidy program goal of increasing PV demand by 400 MW per year through 2010 and Germany has a goal of 100 MW per year through 2005 [18].

Solar thermal: around 80,000 solar thermal systems are installed in the UK, but over 1m are installed in the US [19].
Many countries already have higher installations for a given technology than is foreseen in Scenario C for the UK in 2050. The technology is available, it simply needs the right market framework. The extent of the bifurcation thus implied in the market place is shown in Figure 3, where the current conventional sources of energy (gas burned in heat only boilers, and electricity imported from the network) are fundamentally challenged. The policy framework to bring this potential about is discussed in a later section.

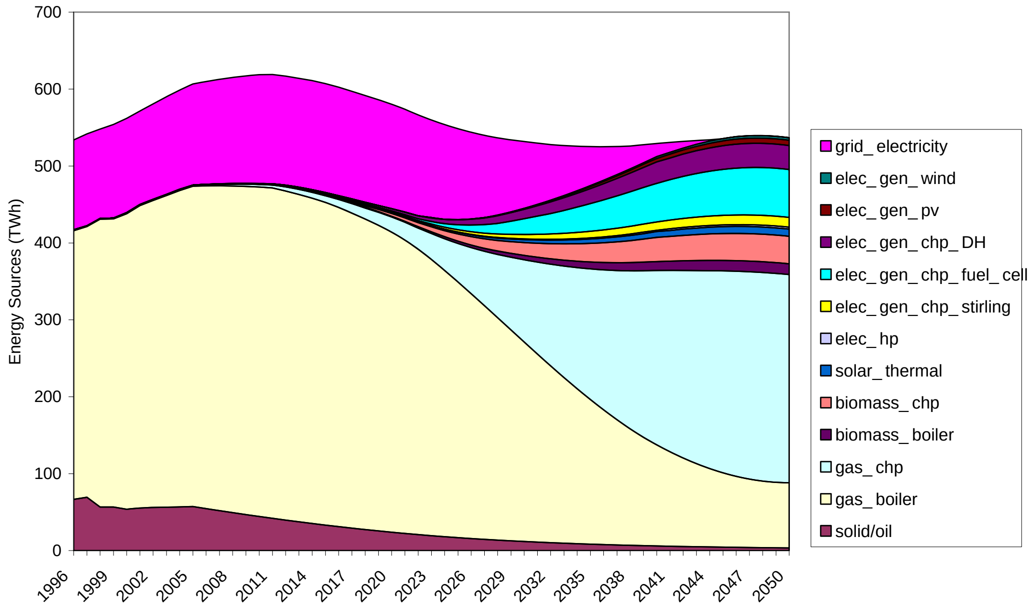

Figure 3 Changes in energy supply to homes to achieve a 60% reduction in CO2 (Scenario B)

The cost of change

At face value, the scenario proposed appears expensive. However, this is not necessarily the case. Technology learning is also known as Experience curves and in some literature as 'learning by doing'. In common parlance, the phenomena are also known as learning curves. In essence, the theory goes, for every doubling in global installed capacity or sales, there is a corresponding reduction in costs which is remarkably consistent for a given technology over successive doublings. If plotted over a log/log scale (eg price against volume of sales) the relationship becomes linear.

The phenomenon has been observed for a wide variety of products, technologies and industries over a period of time. It first made significant appearance in the management literature with Boston Consulting in 1968. Progress ratios average around 82% (i.e. prices decline to 82% of former levels after each doubling), however, progress ratios have been observed between 60% and 95% (Figure 7), with only one observation of costs increasing with volume (in the airline industry and put down to changes within the company that led to a loss of learning). The phenomena has been widely used in energy policy analysis time [20, 21, 22, 23, 24].

Under a 40% House scenario, Hinnells [25] shows that, with very high levels of installation foreseen under the 40% scenario, capital costs could fall dramatically, and paybacks could fall to less than 5 years. Thus this scenario has plausibility.

Another issue is on whom does the cost fall? Hinnells and Bertoldi [26] show that through the development of Energy Services Companies (ESCo's) that the capital cost may not fall on the householder, but be considered as an investment justified by a return.

To achieve a 60% reduction in CO2, current conventional sources of energy (gas burned in heat only boilers, and electricity imported from the network) are fundamentally challenged. One of the key learning issues might not be technical but organisational: a move towards energy services companies and a focus placed on site integrated solutions or building integrated solutions. In other words, consumers become generators, and power companies become not suppliers but enablers. Higher levels of installation of LZC would seem synonymous with the development of ESCos, and synonymous with a move away from central power generation. This kind of arrangement might foster a whole-life cost attitude to investment (where payback within the life of a technology at low discount rates makes it attractive) and a portfolio attitude to investment (eg developing a set of investments that together give a load curve that matches demand, rather than assessing investments on an individual basis).

Implementing 40% House: an action Plan timetable to 2050

The following is an indicative Action Plan for achieving scenario C, which would give a 75% reduction in CO2 by 2050 from the UK Housing stock. The plan focuses on near term actions which are necessary to avoid missing a 60% cut in 2050. Action needs to start today.
Possible framework incentives include Personal Carbon Trading (PCT) (synonymous with Personal Carbon Allowances, and investment through Energy Services Companies.

Table 2 Action Plan to 2050

	overarching issues	Housing	LZC	Lights and appliances
Policy framework	- framework incentives eg Personal Carbon Trading (PCT) - governance: devolved targets and powers - EU Directive on energy end-use efficiency & energy services	- Building Regulations - Energy Performance of Buildings Directive - government procurement - disclosure of energy and carbon emissions	- microgeneration obligation - metering - integrate LZC into building regulations - integrate LZC into Planning	- minimum efficiency standards for a wide range of products - low stand-by - solid-state power supplies
Key issues	- integrated delivery mechanisms eg Energy Service Companies (ESCOs) - metering	- unified rating system for new-build and refurbishment - 'whole-home' improvements at point of sale/rent instead of piecemeal grants	- diversity of technologies => security of supply	- lighting (phasing out the incandescent lamp) - constrain consumption in consumer electronics
2006-2009	- Ofgem consultation on domestic metering innovation reports - EU Directive on energy end-use efficiency & energy services in force by 2008- rigorous testing of technologies to identify best smart meter design(s) by 2010, including interaction with microgeneration. - existing small trials of smart meters rolled out to larger scale, including monitoring of effect on consumption and peak demand- 2 year public & stakeholder consultation process launched in 2007 to identify the optimal PCT scheme - Government establishes an independent Carbon Policy Group in 2008 tasked with setting annual emissions reduction targets - public sector projects to trial ESCos in new-build and refurbishment projects - establish a clear framework of governance & responsibilities for energy policy, with a strong emphasis on regional and local authorities	- labels to differentiate homes by 2007 based on A-G categories (Home Information Pack) - negotiations to define single co-ordinated system of standards for new build and refurbishment across all environmental impacts, incorporating Building Regulations - negotiate with industry on move towards monitoring compliance in terms of performance in use - headline performance standards for 2010, 2015, 2020 published - skills & training programmes for inspectors and HIP auditors initiated - procurement programmes for government estate launched - negotiations initiated for mandatory free access to utility data on consumption - grants/competitions established to reward innovation (based on measured performance)	- Lower Carbon Building programme launched, £ 80M capital grants, plus accreditation for products. - Microgeneration strategy includes development of roadmaps for technologies. - Microgeneration strategy will explore getting full value for exported electricity (including ROCs etc) or imposing obligation on suppliers. - Technology procurement for microchp with the major housing providers (may be at EU or IEA level) to get it onto the market. - training programmes established for installers - indicative planning requirement: specify 10% of electricity in new build to be supplied by LZC	- negotiations for energy labels revision commence - roadmaps published and cross-sectoral procurement programmes for VIP refrigeration products and residential LED lights and fixtures initiated - trials of energy display meters for cooking appliances to encourage behavioural change, linked with smart metering trials - negotiations for 2015 and 2020 minimum standards commence

	overarching issues	Housing	LZC	Lights and appliances
2010	- smart meters included in Building Regulations to cover all new homes - 5 year programme to retrofit smart meters in all households - regional trials of PCT schemes initiated in 2010 - National PCT scheme launched in 2012 - PCT integrate with European Emissions Trading Scheme for non-domestic sector - carbon disclosure information provided on sales of domestic and transport fuels - ESCos used in all publicly funded new build projects to manage energy infrastructure, including LZC - TEEC (Tradeable Energy Efficiency Commitment) implemented at national level - Local Authorities required to establish an address-specific database on energy-use in all households by 2015	- revision to Building Regulations - minimum standards implemented based on performance in use - private rental conditional on compliance with minimum standard - Housing Corporation funding conditional on zero-heat standards - all development on government-owned land to zero-heat standards - incentive programmes for refurbishment launched - utility consumption data publicly available - review status of cooling within housing stock and assess need for action	- indicative Planning framework and Building Regulations: all new homes to have 25% on-site renewables - indicitave LZC obligation on utilities: 10% by 2020 and 20% by 2025	- energy labels revised to be based on absolute consumption rather than efficiency standards - support programmes for eg VIPs, LED lighting, and fuel switching opportunities, to increase market share - minimum standard set for bulb sales: sales weighted average of around 30 lumens per Watt - 0.1 Watt minimum standard for standby set - Building Regulations require energy display meters for cooking appliances in new build - retrofit of energy display meters for cooking incorporated into the 5 year smart meter retrofit programme - agree 2015 and 2020 minimum standards, and revised labels scales for a range of goods
2015	- All existing build and new build have smart metering and billing - Carbon Policy Group reviews national PCT scheme and set next 5 year emissions reduction targets - All new housing developments to have contracted out all energy services to an ESCO for delivery.	- revision to Building Regulations: tighter standard for new-build and refurbishment - tighter standard for private-rented sector *See table 16*	- all new homes required to generate 50% of demand from LZC	- 5 year programme to install 2 LED fixtures in every household - minimum standards implemented for VIP refrigeration improved wet appliance performance and screen technologies - sales weighted average efficiency for bulbs increased to 60 lumens per Watt
2020	- Carbon Policy Group reviews national PCT scheme and set next 5 year emissions reduction targets - target of 10% of all homes to be serviced by an ESCo	- revision to Building Regulations: tighter standard for new-build and refurbishment - tighter standard for private-rented sector *See table 16*	- all new homes required to generate 100% of demand from LZC	- 20 year programme to retrofit lighting in all households - sales weighted average efficiency for bulbs increased to 100 lumens per Watt - Building Regulations require LED lighting in all fixtures in new build - second round of minimum standards take effect

	overarching issues	Housing	LZC	Lights and appliances
2025	- Carbon Policy Group reviews national PCT scheme and set next 5 year emissions reduction targets	- revision to Building Regulations: tighter standard for new-build and refurbishment - tighter standard for private-rented sector *See table 16*	- Building Regulations require that replacement boilers or electric heating must use LZC, and replacement of roofs requires solar thermal, PV or BIW if conditions are appropriate	- sales weighted average efficiency for bulbs increased to around 150 lumens per Watt
2030	- Carbon Policy Group reviews national PCT scheme and set next 5 year emissions reduction targets	- revision to Building Regulations: tighter standard for new-build and refurbishment - tighter standard for private-rented sector *See table 16*	- total ownership of LZC across total stock is 50%	
2035	- Carbon Policy Group reviews national PCT scheme and set next 5 year emissions reduction targets	Review of building regulations		- all refrigeration products in homes have VIP, and high performance energy-efficient wet appliances and TV in all homes
2040	- Carbon Policy Group reviews national PCT scheme and set next 5 year emissions reduction targets		- ownership of LZC average of 1 per home the residential sector being zero net importer of electricity, and generate 80% of heat on site	- lighting in all households converted to LED
2045	- Carbon Policy Group reviews national PCT scheme and set next 5 year emissions reduction targets			
2050	- target of 0.6 tC per capita for all energy use (Hillman & Fawcett 2004) - at least half of all homes to be serviced by an ESCo	- average space heat across stock is 6,800 kWh per annum	- LZC ownership at 115%	DLA consumption reduced by 47% compared to 1996

Conclusions

This paper explores the implications of a target of a 60% cut in CO2 by 2050 for components in homes that are mass produced – lights and appliances and low and zero carbon technologies- and which might therefore be subject to similar market transformation processes, and similar mass production with cost reduction (described in literature as technology learning). These two groups may be very different from building refurbishment and construction which may be much more site-specific and increasingly needs a whole-house integrated approach. Conclusions cover 4 areas:

- **Lights and appliances:** Consumption could continue to rise by almost a third to 120 TWh even with present policies to tackle efficiency. The largest contributor to this is home electronics, but new 'outdoor products' also make a contribution. Or consumption in 2050 could be almost halved. Improved efficiency is not enough, there has to be a focus not merely on improved efficiency but on reduced consumption. The technology learning effect of EU standards is such that efficiency standards can be had virtually for free, though perversely, efficient refrigeration appliances without the volume effects created by standards are likely to remain expensive.
- **Low and Zero Carbon Technologies:** To achieve a 60% reduction in CO2, current conventional sources of energy (gas burned in heat only boilers, and electricity imported from the network) are fundamentally challenged. One of the key learning issues might not be technical but organisational: a move towards energy services companies and a focus placed on site integrated solutions or building integrated solutions. Higher levels of installation of LZC would seem synonymous with the development of ESCos. At the more extreme levels of learning, micro CHP could in the long term be implemented with little or no cost implication over and above a gas central heating boiler. The payback period for LZC may be reduced to as low as 5 years.

- **Experience curves:** Under a 40% House scenario, experience curves suggest dramatic changes in cost effectiveness, bringing the payback of measures down to reasonable levels, thus making the scenario plausible.
- **Policy:** A policy timetable to achieve a 60% reduction is illustrated from today through to 2050. The scenario could be delivered by a combination of information, incentives and regulation known as market transformation. Overarching measures may need to include development of Personal Carbon Trading, development of the market for Energy Services Companies and improved metering and information provision. It would need to be both integrated and aggressive to achieve such levels of change.

Whilst the UK has been modeled in detail, the conclusions are likely to fit other economies developed to a similar extent and with similar space heating demands. Different economies at different stages of development and with other heating and cooling demands would need more detailed study.

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Massive Coordination of Residential Embedded Electricity Generation and Demand Response using the PowerMatcher Approach

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Abstract

Different driving forces push the electricity production towards decentralization. The projected increase of distributed power generation on the residential level with an increasing proportion of intermittent renewable energy resources poses problems for continuously matching the energy balance when coordination takes place centrally. On the other hand, new opportunities arise by intelligent clustering of generators and demand in so-called Virtual Power Plants. Part of the responsibility for new coordination mechanisms, then, has to be laid locally. To achieve this, the current electricity infrastructure is expected to evolve into a network of networks (including ICT(Information and Communication Technology)-networks), in which all system parts communicate with one another, are aware of each other's context and may influence each other. In this paper, a multi-agent systems approach, using price signal-vectors from an electronic market is presented as an appropriate technology needed for massive control and coordination tasks in these future electricity networks. The PowerMatcher, a market-based control concept for supply and demand matching (SDM) in electricity networks, is discussed. The results within a simulation study show the ability to raise the simultaneousness of electricity production and consumption within (local) control clusters with cogeneration and heat-pumps by exchanging price signals and coordinated allocation using market algorithms. The control concept, however, can also be applied in other business cases like reduction of imbalance cost in commercial portfolios or virtual power plant operators, utilizing distributed generators. Furthermore, a PowerMatcher-based field test configuration with 15 Stirling-engine powered microCHP's is described, which is currently in operation within a fieldtest in the Netherlands.

Background

Traditionally, electricity distribution infrastructures are based on a hierarchical, top-down flow and distribution of power. The infrastructures were designed and economically validated with accounting models of energy companies that typically had a time horizon of 20 to 50 year. One of the consequences of liberalisation is that power networks are being utilized with decreasing reserve capacity and investment capital preferably has a much shorter payback time horizon. This leads to an increase of smaller capacity installations operating in a distributed manner. Embedding small-scale renewable energy resources, with intermittent production, on the other hand, poses another challenge to match supply and demand of electricity in real-time at several levels in the grid. State-of-the-art information processing hardware and communication technology networks (ICT) form part of the solution for coordination and concerted control of demand and supply of electricity in these distributed environments ([1],[2],[3]).
An ongoing change in the worldwide energy supply is this growing penetration of distributed electricity generation. Distributed Generation (DG) can be defined as a source of electric power connected to the distribution network or to a customer site ("behind the meter"). This approach is fundamentally distinct from the traditional central plant model for electricity generation and delivery. Driving forces behind the growing penetration of DG are [4-7]: environmental concerns, deregulation of the electricity market, diversification of energy sources, energy autonomy, and energy efficiency.

The growing share of DG in the electricity system may evolve in three distinct stages:

- **Accommodation.** Distributed generation is accommodated in the current market. Distributed units are running free, while centralized control of the networks remains in place.

- **Decentralization.** The share of DG increases. Virtual utilities optimize the services of decentralized providers through the use of common ICT-systems. Central monitoring and control is still needed.
- **Dispersal.** Distributed power takes over the electricity market. Local low-voltage network segments provide their own supply with limited exchange of energy with the rest of the network. The central network operator operates more like a coordinating agent between separate systems rather than controller of the system.

In specific parts of the world there are already signs of the decentralization stage (see for instance [6],[7].) During the second and third stage of DG growth, the lower parts of the electricity grid are expected to evolve from a hierarchical top-down controlled structure into a network of networks, in which a vast number of system parts communicate with each other and influence each other. In this scenario, the standard paradigm of centralized control, which is used in the current electricity infrastructure, will no longer be sufficient. The number of system components actively involved in the coordination task will be huge. Centralized control of such a complex system will reach the limits of scalability, computational complexity and communication overhead.

This paper describes a novel control concept for automatic matching of demand and supply in electricity networks with a high share of distributed (co-)generation on the residential level. In this concept DG, demand response, and electricity storage are integrated using the advanced ICT technology of distributed control. The control concept opens the possibility to introduce massive scale **distributed coordination** additional to the existing **central coordination**, when the share of distributed generation increases. The coordination mechanism has the aim to increase the portion of DG that can be accommodated under normal operational conditions in the power grid.

ICT for distributed coordination

As a result of the electricity evolution, described above, the electricity infrastructure will become more and more inter-linked with ICT-infrastructure components. The architecture and algorithms of this ICT-infrastructure must be adapted to the technical structure of the (future) electricity net and the connected producing and consuming installations, but also to the structure of the liberalized energy markets. This ICT-architecture and associated algorithms must be designed using a strong system-wide viewpoint, but must also consider stakes of local actors in the system.

The PowerMatcher approach is based the computer science technologies Multi-agent Systems (MAS) and Electronic (Virtual) Markets [8-10]. The combination of these two technologies results in a combination of properties, interesting from the viewpoint of coordination in electricity networks:

- In multi-agent systems a large number of actors are able to interact, in competition or in cooperation. Local agents focus on the interests of local sub-systems and influence the whole system via negotiations with other software agents. While the complexity of an individual agent can be low, the intelligence level of the global system is high. For instance, for a temperature control system in a dwelling, the deviation from the set-point temperature is a measure for the steepness of theprice-response.
- Multi-agent systems implement distributed decision-making systems in an open, flexible and extensible way. Communications between actors can be minimized to a generic and uniform information exchange. In the PowerMatcher approach, from the appliance only a volume/price curve is sent to the coordinator/auctioneer; the auctioneer only spreads the allocations of the resource.
- By combining multi-agent systems with micro-economic principles, coordination using economic parameters becomes possible. This opens the possibility for the distributed coordination process to exceed boundaries of ownership. The local agent can be adjusted by the local stakeholder, and does not fall under the rules and conditions of an intermediate or central authority.
- Using electronic markets a *Pareto efficient* system emerges, i.e. a system that optimizes on a global level, while at the local level the interests of all individual actors are optimally balanced against each other.

Of course, the total resulting system (the electricity infrastructure plus the ICT infrastructure) must be dependable, since the power grid is a critical asset in the modern society. Most developed countries currently have a highly dependable electricity supply, and any changes to the system must not weaken it but rather strengthen it. Further, the system as a whole must be secure, i.e. hardened against hackers and cheaters.

The PowerMatcher basic concept

The PowerMatcher is a market-based control concept for supply and demand matching (SDM) in electricity networks with a high share of distributed generation. SDM is concerned with optimally using the possibilities of electricity producing and consuming devices to alter their operation in order to increase the over-all match between electricity production and consumption. In the PowerMatcher method each device is represented by a control agent, which tries to operate the process associated with the device in an economical optimal way. The electricity consumed or produced by the device is bought, respectively sold, by the device agent on an electronic exchange market. The supply-demand mechanism is explained in figure 1. Articulation of the demand response is translated into a demand curve; ability or uncertainty to shift generation is modeled into a supply curve bid. Supply and demand meet at an equilibrium point, which gives the price.

The electronic market is implemented in a distributed manner via a tree-structure of so-called *SD-Matchers*, as depicted in Figure 2 and adopted from [1,2]. An SD-Matcher matches demand and supply of a cluster of devices directly below it. The SD-Matcher in the root of the tree performs the price-forming process; those at intermediate levels aggregate the demand functions of the devices below them. An SD-Matcher cannot tell whether the instances below it are device agents or intermediate SD-Matchers, since the communication interface of these are equal. The root SD-Matcher has one or more associated market mechanism definitions, which define the characteristics of the markets, such as the *time slot length,* the *time horizon*, and a definition of the *execution event* (e.g. “every whole quarter of an hour”, “every day at twelve o’ clock”). When an execution event occurs, the root SD-Matcher sends a request to all directly connected agents to deliver their bids. The device bids are aggregated at the intermediate matchers and passed on up-wards. The root SD-Matcher determines the equilibrium price, which is communicated back to the devices. From the market price and their own bid function each device agent can determine the power allocated to the device.

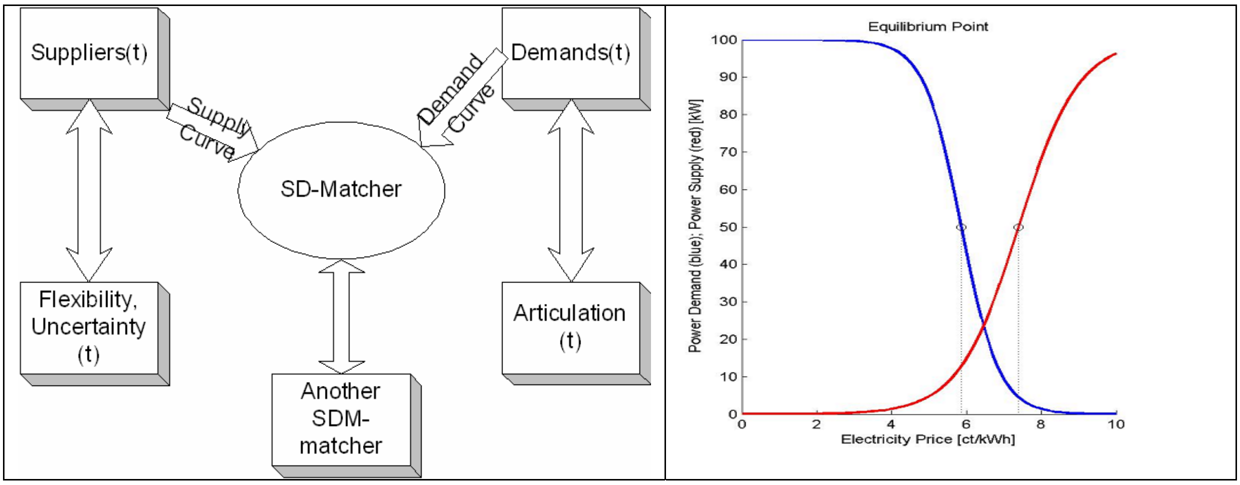

Figure 1 Principle of supply-demand matching

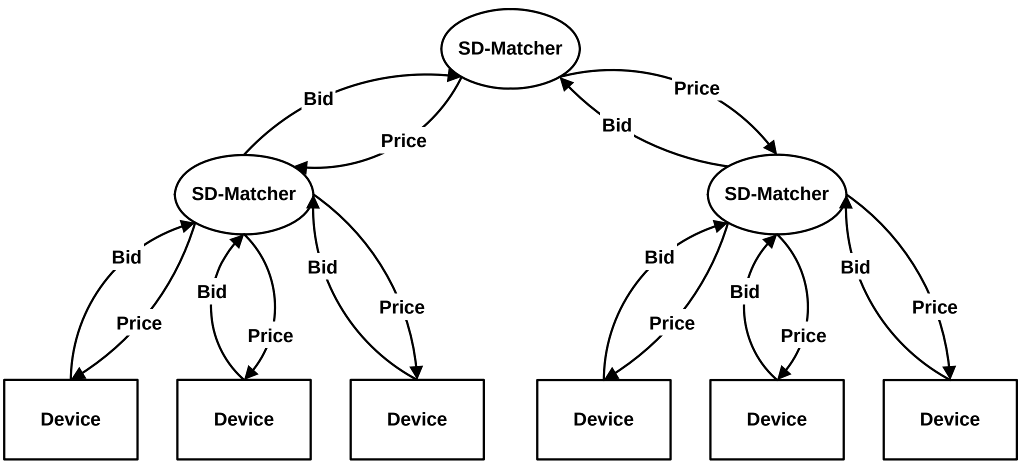

Figure 2: Hierarchy of supply & demand matchers in the PowerMatcher concept. The SD-Matchers implement a distributed electronic market.

Device agent types and strategies

From the viewpoint of supply and demand matching, devices can be subdivided according to their type of controllability into the following classes:

- **Stochastic operation devices:** devices like solar and wind energy systems of which the power exchanged with the grid behaves stochastically. In general, the output power of these devices cannot be controlled, the device agent must accept any market price.
- **Shiftable operation devices:** batch-type devices whose operation is shiftable within certain limits, like (domestic) washing and drying processes. Processes that need to run for a certain amount of time regardless of the exact moment, like, assimilation lights in greenhouses and ventilation systems in utility buildings. The total demand or supply is fixed over time.
- **External resource buffering devices:** devices that produce a resource, other than electricity, that is subject to some kind of buffering. Examples of these devices are heating or cooling processes, whose operation objective is to keep a certain temperature within two limits. Devices in this category can both be electricity consumers (electrical heating, heat pump devices) and producers (combined generation of heat and power).
- **Electricity storage devices:** conventional batteries or advances technologies like flywheels and super-capacitors coupled to the grid by a bi-directional connection. The agent bidding strategy is to buy energy at low prices and sell it later at high prices.
- **Freely-controllable devices:** devices that are controllable within certain limits (e.g. a diesel generator). The agent bidding strategy is closely related to the marginal costs of the electricity production.
- **User-action devices:** devices whose operation is a direct result of a user action. Domestic examples are: audio, video, lighting and computers. These devices are comparable to the stochastic operation devices: their operation is to a great extent unpredictable and the agent must accept any market price to let them operate.

In all described device categories, agent bidding strategies are aimed at carrying out the specific process of the device in an economically optimal way, but within the constraints given by the specific process. Note that this self-interested behavior of local agents causes electricity consumption to shift towards moments of low electricity prices and production towards moments of high prices. As a result of this, the emergence of supply and demand matching can be seen on the global system level. Device constraints and user constraints are to be dealt with and introduced in a very cautious way. E.g. micro-CHP can't be operated with too many on/off subsequent cycles in order to save overall operating time. Adequate feedback has to be given to users to meet socio-economic and acceptance requirements of partly autonomously operating devices. Using this technology may not lead to major changes in lifestyle of users without any reward.

Simulation Case

In a simulation study the impact of distributed supply and demand matching applied in a residential area was investigated. In the study, a cluster of 40 houses, all connected to the same segment of a low-voltage distribution network (an LV-cell) were simulated. Within the LV-cell an exchange agent implements the root SD-Matcher. The LV-cell is externally connected to a medium voltage network. Through this connection power can be obtained form and delivered to other parts of the distribution network.

Each home has a Home Energy Management gateway, which implements the local energy management strategy of the house. The HEM-box incorporates the intermediate SD-Matcher functionality, together with energy performance feedback to the user, and the possibility for the user to set cost and task preferences. The latter makes it possible to set agent parameters of devices without a user interface. Within the LV-cell an exchange agent implements the root SD-Matcher. The LV-cell is externally connected to a medium voltage network. Through this connection power can be obtained form and delivered to other parts of the distribution network. The electricity surplus of the cluster is delivered to an external electricity supplier, which delivers electricity to the cluster in case of local shortage. The external supplier can either be a full player on the local electronic market or set tariffs for delivery and retribution. In the latter case, the external tariffs are not influenced by the local price formation, and, typically, the retribution price will be lower than the delivery price. Then, the equilibrium price on the local electronic market will be bounded by the external tariffs. Half of the 40 simulated dwellings are heated by heat pumps (electricity consumers), the other half by micro-CHP units (small-scale combined heat-power, producers of electricity and heat). The micro-CHPs are also used for production of hot tap water. Washing machines are operated as shiftable operation devices with a predefined operational time window; electricity storage is present in the form of batteries; stochastic operation devices are present in the form of photovoltaic (PV) solar cells and small-scale wind turbines; and user-action devices are represented as lights.

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Figure 3 and 4 show the result of a typical simulation run for the LV-cell simulation case. In both plots the total consumption and the total production in the cluster have been summed into a single plotline, while production is regarded as negative consumption. The top plot shows the reference case in which all devices are free running. In this case all heating devices are on/off controlled, washing machines start their operation at the start of their operational time window, and batteries are excluded due to the absence of a real-time price signal according which they can be operated. In the bottom plot the SDM-controlled case is shown. Interesting features are:

- Around the 25th 15 minutes period there is a peak in electricity demand caused by the simultaneous starting of a number of heatpumps. Although there is also a small peak in local production at that moment, the greater part of the electricity needed to meet the peak demand is delivered from the external connection to the mid-voltage network. In the SDM-controlled case the peak in external feed-in is 30% lower, due to the reaction of different devices to the price peak on the electronic market at that moment. Consuming device agents shift part of their operation to other moments in time, producing agents shift as much as production as possible to this moment, and battery agents react by switching to discharging mode. In this particular case, consumption reduction accounts for 50% of the peak reduction, battery discharging accounts for 37%, and production increase causes another 13%. From the viewpoint of electricity distribution systems, this is an important result. The highest expected peak demand of a low-voltage net segment determines the capacity the coupling transformer and the network cables or lines. Reducing the peak demand lowers network investments in case of building new sub-networks, and defers network reinforcements in case of demand increase in existing nets.
- Introducing supply and demand matching results in a more flat and smooth profile of the electricity fed in from the mid-voltage network. Fluctuations in local consumption and local production are damped, and the mutual simultaneousness in the remaining fluctuations is high. The standard deviation of the feed-in from the MV-net in figure 3 is 58% lower in the SDM-controlled case. This means that predictability of the cluster as a whole is increased by the automatic matching of demand and supply.

Figure 4 further nicely illustrates, that the internal price development on the internal device market acts as a coordination incentive.

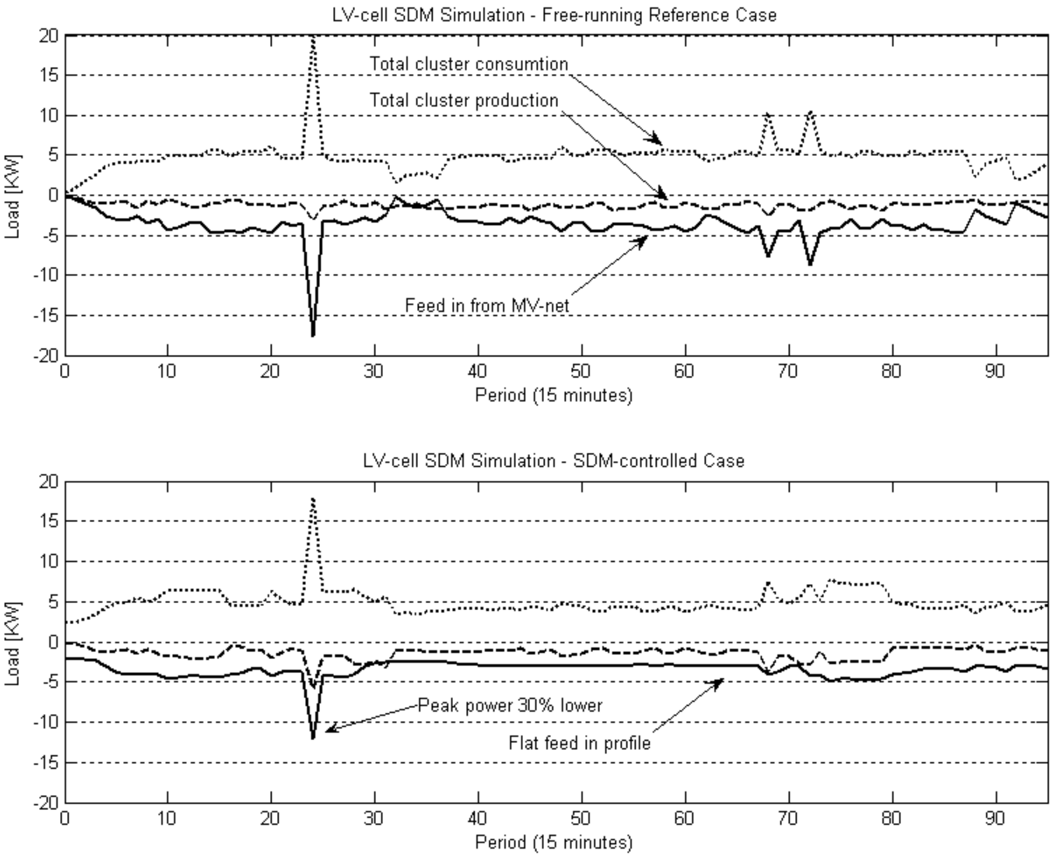

Figure 3: The result of a typical simulation run for the LV-cell simulation (see text).

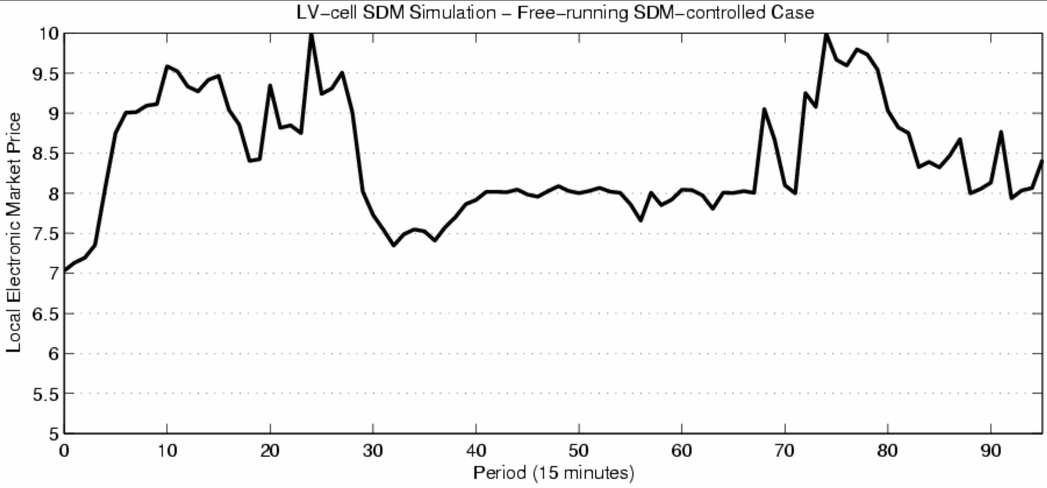

Figure 4: Internal price formation development during the internal market simulation

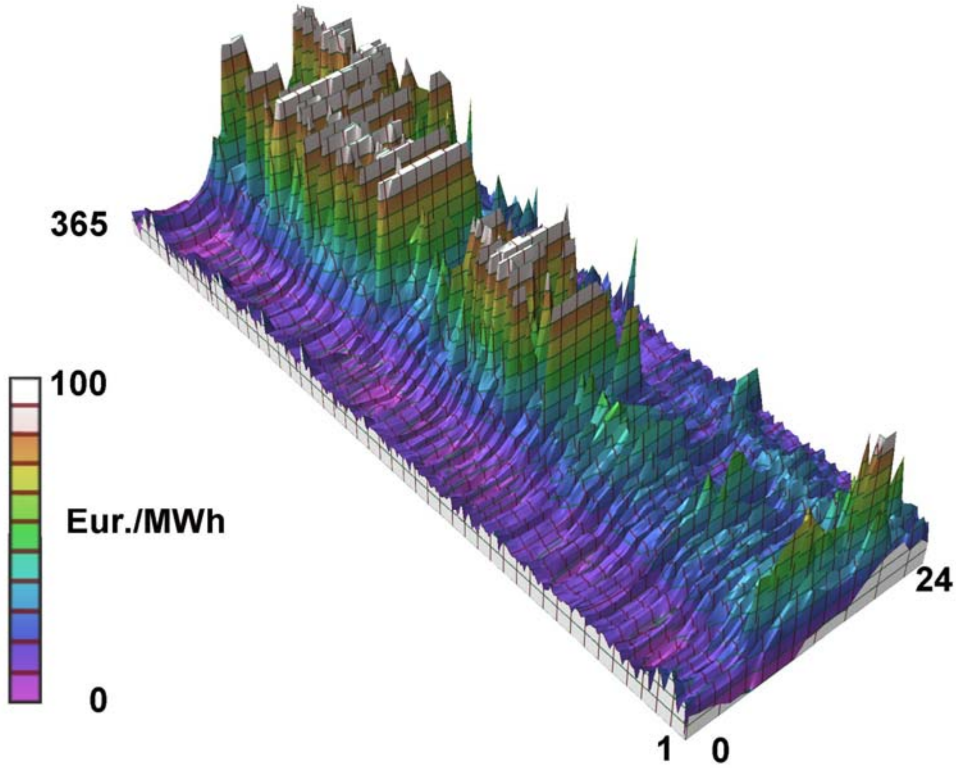

Figure 5 Price development on the APX-market in 2003 as a function of wallclock time and daynumber

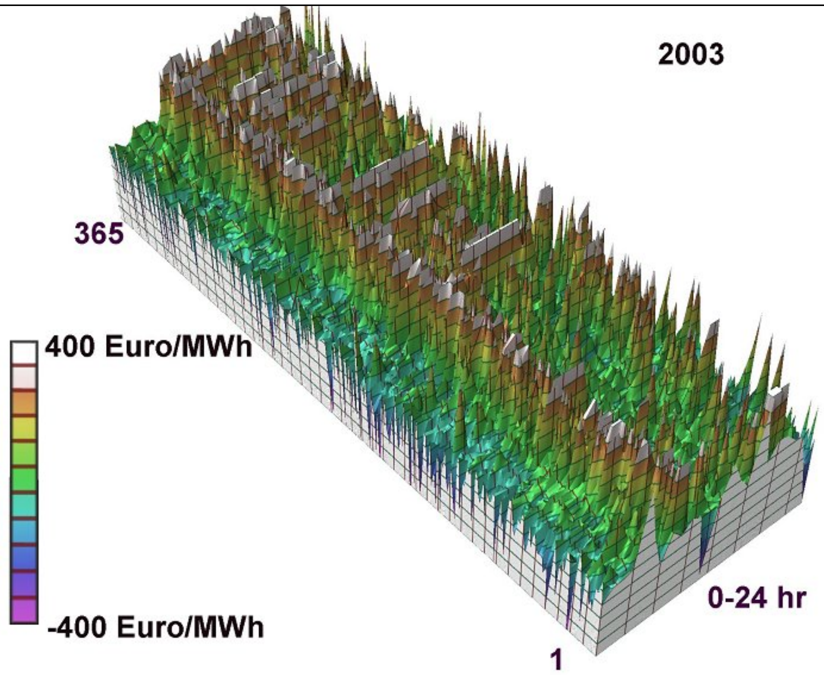

Figure 6 Imbalance (over/underrealisation compared to the programme) cost per MWh as a function of time in 2003

Utilizing distributed coordination for operating virtual power plants on markets

The flexibility in micro-CHP operation utilized by clustering in a VPP can be put into value in different ways. One might think of:

- Trading the output of the VPP on the day-ahead power market (e.g. the Dutch APX or the Scandinavian NordPool). Figure 5 shows the highly variable price development on the APX power market in the Netherlands. Actual price peaks were above 2000 Euro/MWh. The peaks round mid-day in august and at the end of the afternoon during winter provide opportunities for flexible electricity generating capacity and demand.
- Trading the output of the VPP on the imbalance or spinning reserve market. Figure 6 shows a similar 3D-plot for the imbalance market in the Netherlands. If demand/generation shiftability fits into the timeframe of this market, considerable benefits may be gained.
- Support the local distribution system operator (DSO). For instance, by reducing the local peak demand of low-voltage grid segments, to defer reinforcements in the grid infrastructure (e.g. substations and cables).

Fieldtests in a Virtual Power Plant setting

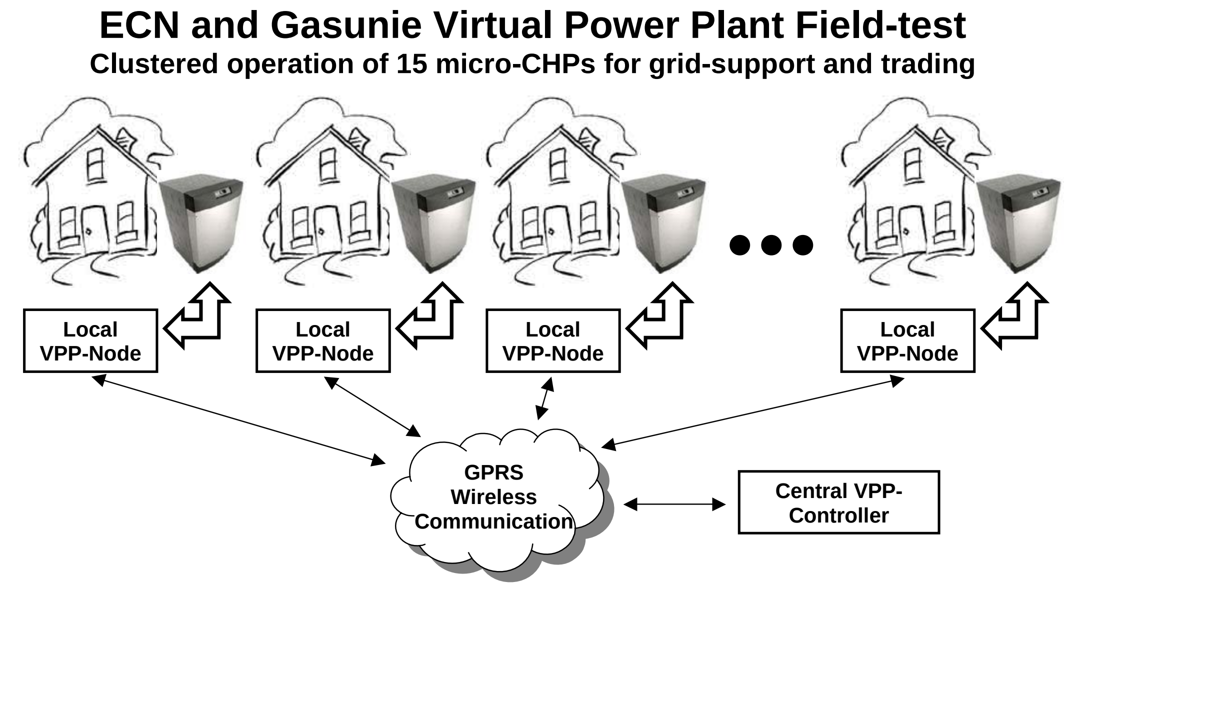

Figure 7 Fieldtest configuration with micro-CHPs

Currently a fieldtest with 15 Stirling based CHP's is in the process of rollout (see fig 6). The Dutch natural gas company Gasunie is undertaking a rollout and measurement program of domestic micro-CHP installations. A measurement project of approximately 50 microCHP installations is started. WhisperGen type installations are placed at the premises of people employed by Gasunie and a number of cooperating Dutch electricity retail companies. The primary goal of this field test is to monitor the installation in typical Dutch households and to gain user experiences. The current available micro-CHP systems are heat-demand driven, i.e. they produce heat and electricity at moments of heat demand, either from room heating or warm tap water usage. Uncoupling the electricity production from the heat demand can raise the value of produced electricity. This can be done by utilizing the inherent heat buffering capacity of the building and the warm tap water buffer. The electricity and heat functions of the CHP can be uncoupled further by adding a device for heat (or electricity) storage.

In the first half year of 2006, Gasunie and ECN cooperate to add an ICT-infrastructure and local intelligence to a series of 15 of the before-mentioned 50 microCHP's. Goal of this field test is to demonstrate the ability to act as a cluster in a Virtual Power Plant (VPP) setting to attribute to a common control goal. The PowerMatcher control concept forms the core software of this VPP.

The field test VPP is designed to support the local distribution system. Due to the open character of the control concept, flexible electricity loads (i.e. demand response) can easily be added to the system in later stages of the field trial. The field test runs under auspices of the Smart Power System-consortium, a Dutch industrial and research conglomerate developing technology and business cases for microCHP based virtual power plants.

Conclusion

Various drivers push the production of electrical power in the current electricity infrastructure towards decentralization. Multi-agent technology and electronic markets form an appropriate technology that can contribute to a solution to the resulting coordination problem. The PowerMatcher concept proposed in this article is a market-based control concept for supply and demand matching (SDM) in electricity networks with a high share of distributed generation.

The presented simulation case shows that this concept is capable of utilizing flexibility in device operation via a distributed control mechanism. Due to device reactions on price fluctuations, the simultaneousness between production and consumption of electricity in a sub-network is increased.

As a result, the net import profile of the sub-network is smoothed and peak demand is reduced, which is desired from a distribution network operational viewpoint. Two field experiments with the technology show very encouraging results as to the actual implementation and the use of price signals for smooth concerted operation of the devices due to the market equilibration mechanism. Proper socio-economic considerations are to be dealt with when constructing utility functions to be used in the agents and to assure acceptance and minimal lifestyle changes.

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Air Conditioning

Definition of Functionalities of Air Conditioners for Better Public Policies

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Abstract

To evaluate innovations and potential regulations as regards air-conditioning, it is necessary to know the exact function to which the system responds, which is not exactly an easy thing in the case of individual air conditioning. The categories are not perceived by users as they are technically. Ventilation is mixed with air conditioning, moisture is always present, and Internal Air Quality is a rising issue. Envelope and equipment interactions are perceived by the user according to many factors. Finally, last but not least, comfort is still an ambiguous concept. Any public policy has to understand and respect first the functionalities demanded by the user for equipment and space, and establish the link between those expectations and Energy Efficiency objectives. Premature judgment will lead public policies to problems.

Underlying decisions not perceived by households

The citizen of developed country lives more and more in artificial climates which are determined by market offers, regulations and policies in a very complex way. He (she) tries to perceive its environment, namely when there is discomfort, but ignores most of the determinants. However he (she) has a capacity to judge comfort (defined as the absence of any cause of discomfort). Figure 1 shows the system we are analyzing in this paper. The individual suffers from discomfort as a result of climate through the envelope (which may be altered by building codes). An installer proposes and installs equipment or the individual buys directly, maybe in an extreme situation. The utilities and national agencies interfere with equipment. Early in the process, municipal authorities can interfere with the structural choice of a more or less centralization of system. We are not developing here the significant issues existing at city scale, in town planning or utility optimization but knowledge exists [1].

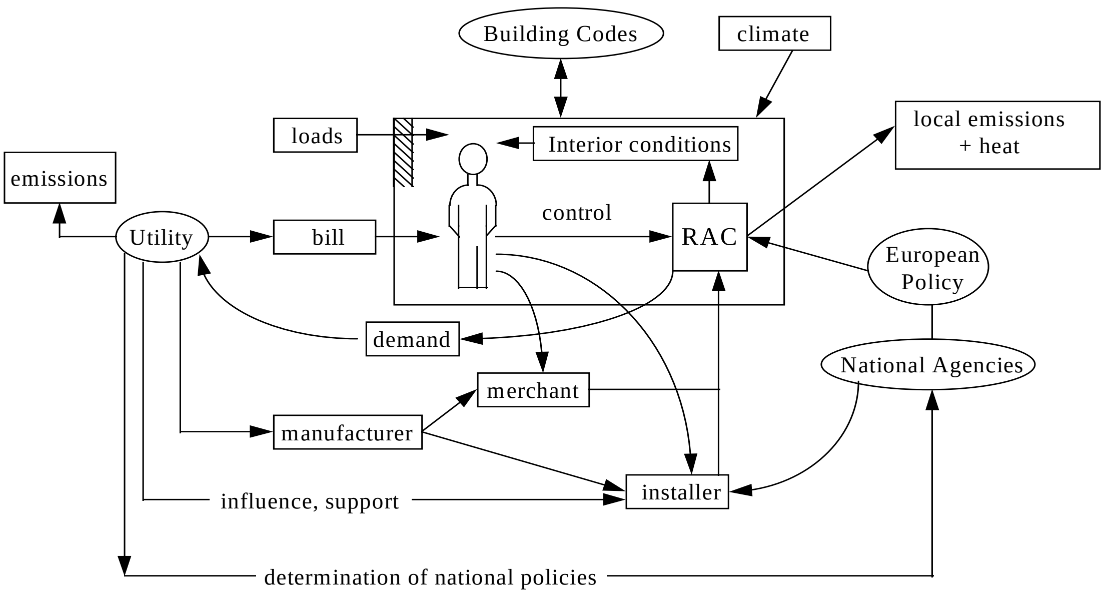

Figure1: The limited perception of air conditioning by the final user

When we speak of “air conditioners” we exclude the central systems (CAC defined hereafter).

Central Air Conditioning systems (CAC) are characterized by a central refrigerating unit operating together with an air treatment unit and make use of a fluid (air and/or water) to transport cold to the air conditioned space. They perform other functions than just refrigerating, like controlling air change, air quality and humidity. Their specifications are determined by engineers or technicians, who usually design the system and its associated energy performance without any direct influence from the final customer or user (except for the preliminary limitations on cost).

A **'Room Air-Conditioner' (RAC),** as opposed to an 'air-conditioning system' (CAC), is an individual appliance that can be bought by a household or a professional, with a direct link between the customer and the selection of the purchased good – either direct purchase by the household or through an installer with whom negotiation and specification of the appliance takes place. The existing results of EERAC [2] and a review of market features are used here as a basis for further definition of functionality problems.

Technical wording for RAC

Let us first mention systems types that are close to RAC but that the consumer will be able to separate, because he (she) can separate moisture and air treatment. **Dehumidifiers** have the same technical nature than RAC but are not designed to permit temperature control. They seem to have large market shares, especially in the UK. All RAC perform some dehumidification, in a controlled or uncontrolled way. **Evaporative cooling** is an air conditioning process where the evaporation of water is used to decrease the dry bulb temperature of the air. Some small appliances are manufactured for the domestic sector (particularly in Greece). Finally, in **desiccant cooling** systems, before being re-cooled by evaporative cooling (or a cooling coil), the air is dried. This is only used in industrial applications.

There are four main classes of individual air conditioners (RAC) that are recognised by the user as "air conditioner":

Split units (figure 2). This type of equipment is made of two packaged units (an inside and outside unit) connected by the refrigerant piping. The inside unit includes the evaporator and a fan, while the outside unit houses the compressor and the condenser. They can be connected by a fixed copper connection (made by an installer) or a flexible connection and are then said mobile split.

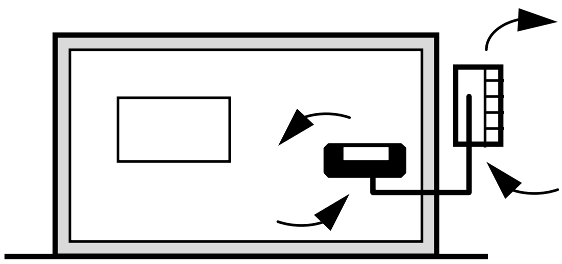

Figure 2. Diagrammatic representation of a split-packaged unit.

Multi-split units (figure 3).Multiple inside units are connected to a single outside unit. This is the rising segment in RAC sales.

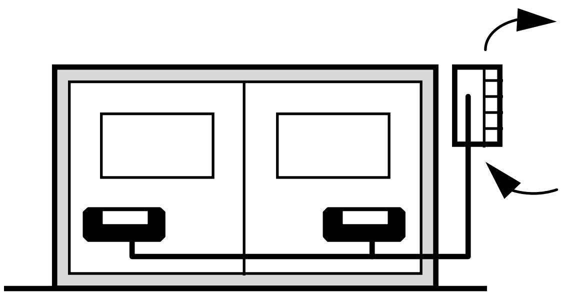

Figure 3. Diagrammatic representation of a multi-split-packaged unit.

Single packaged unit (Window units, like in figure 4). This type of equipment is made of a single packaged unit, one side of which (the condensing loop) is in contact with outside air to stimulate condensation while the other side (the evaporator loop) provides direct cooling to the inside air by forcing air over the evaporator with a fan. The two sides of the appliance are separated by a divider wall, which is insulated to reduce heat transfer between the sides.

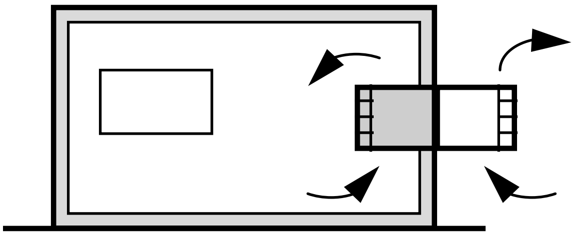

Figure 4. Diagrammatic representation of a single-packaged unit.

Single-and Dual duct air conditioners. These appliances are fully indoors and reject hot air at the condenser to the outside via a duct that is passed outdoors. They are generally movable but in order to operate they must be set close to a window or a door through which a duct eliminates hot air. In principle, a purpose built hole should be made in the building envelope for the ducting however, in practice the ducting is often hung through doors and windows, which increases the infiltration of hot air. This leads to additional thermal losses, and makes it difficult to asses the true thermal performance of single duct units. The difference between single duct and dual duct units is very large from the energy point of view because single duct units take air from the space, which in turn will demand air to other zones or outside, bringing heat (or cold) to the space. Dual duct units take air from the outside (the same air that will be rejected) avoiding this phenomenon.

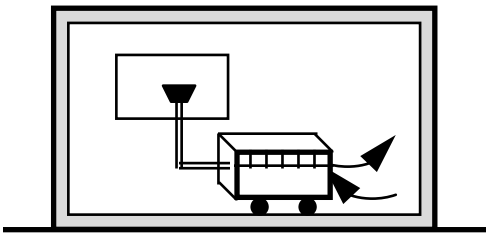

Figure 5. Diagrammatic representation of a single-duct or dual-duct unit.

Should we compare all RAC with the same grading scale in terms of energy performance?

Labeling categories of the EU Energy Label for air conditioners include the so called “single duct” and “double duct” units which are recent products for which the functional attributes are not perfectly defined, and so should be reformulated. In some way the three basic types of air conditioners (split, packaged, ducted) correspond to geometrical constraints of the users, and that’s why they were fully respected in the EU regulation (labeling directive) and looser demands were made on less efficient categories, in contradiction with EU energy efficiency objectives.
Constraints do exist that decide on the type of RAC: no access to roofs or facades for outside units of split systems, no right to open holes for packaged (door/window) units. The single or double duct air conditioners is almost the only appliance that may be installed everywhere. The installation costs become very high for Multi Splits when the user doesn’t accept individual Splits room by room and wants to hide the external units leading to longer piping, besides internal connections. One can argue that when you have a hole for a “window unit” you cannot purchase anything else than a “window unit”, and that performance of window units is to be judged relative to its geometrical constraints. In a similar way, in city centers the outside units should be prohibited for aesthetic reasons, so that single and dual duct systems should be favored in labeling categories. The extent of those constraints and the cost it would represent to introduce a performance level difficult to reach for one category within its geometrical constraint is an obvious issue. Present RAC regulation considers those constraints are absolute and that lower demands should be made on less efficient RAC types.

The reversible attribute of some air conditioners cannot be forgotten here, since it's a rising heating mode in some countries. It's a big functional issue. In Japan, the COP considered is already very often an average on cooling and heating, a point not reached in Europe.

Customer perceptions of purchase and maintenance

About the time of purchase, the questions are : what perception and understanding of the product the customers has? How far is the product specified when the consumer comes to a professional? Is really geometry the main constraint of choice? On what could we play to obtain a more reasonable functional definition?

The usual approach assumes that the choice of the user's decision is rational (based on number of kW needed). This is unlikely for individual purchase namely some Single Ducts and for directly purchased units, as for appliances sold by installers. Over sizing is the general rule.

In the case of air conditioners the purchaser is not rational about the level of residential comfort given by each type of equipment : the "functional unit" in some cases is just cooling, in other products it includes a contribution to **Interior Air Quality** (air filtration, controlled air change). New products will try to incorporate moisture control, microbiological treatment, perfume, etc. Market will pull customers in that domain of artificial product features. In a similar direction (what are the new functions, what is their value?) the **variable speed technology** provided by "inverters" represent a secondary functional benefit (overcapacity in order to make an unoccupied room rapidly comfortable?

The other way round an estimate of the lack of amenity due to the lack of a given comfort feature could be given : noise (namely for "window units"), dry air (related with some diseases, so called "sick building syndrome"), under sizing allowing temporary temperature increase. Even temperature obtained by cooling is an amenity that should not necessarily be kept constant, provided that the economic value of the discomfort (the loss of productivity, e.g.) is lower than the expenses needed to oversize or overrun the air conditioner.

As very often, **maintenance** is poorly perceived by the final user. For an individual Air Conditioning unit, changing the filter and cleaning the ducts are not expensive or long lasting technically but the consumer is afraid of doing it himself. Usually it requires the visit of a technician with a minimum charge. There is the possibility of a "contract" paid in advance but that is very expensive. A reported value = 200 Euros (two visits/year: service defined for reversible use). After some time without maintenance, energy consumption increases, as much as 20% due to fouling.

Where is the economic trade off between maintenance cost and over consumption? If the European owner of a RAC is rational, this trade off corresponds to the 20% consumption increase because this costs ten times less than the usual charge for maintenance. This means it's not economically optimal to maintain RAC in the present market situation. So that lack of maintenance means a penalty corresponding to 20% of cost of energy consumption is likely on the field.

The customer is changing: between price elasticity and awareness of global warming

We are experiencing the effect of **price elasticities**, not only on total market (already done : it became an affordable appliance) but between categories. We consider that the complete change of price positioning of the "single ducts" invalidates the assumption of a limited and temporary market for "single ducts". This type of air conditioner was initially positioned as an expensive object (expensive in Euros/kW not in Euros) for consumers under pressure buying under impulse (baby crying during a heat wave). Now we see the massive Chinese (namely under foreign license) imports positioned as first price in DIY shops (about one third of the price of previous equipment).

At the time of use we know that the consumer behavior is psychological, some people having an "**adaptative" behavior** within some limits (comfort is a difference between outside and inside). In the same conditions other people leave the equipment in full operation all the time (a recent survey in the UK shows operating time as high as 5000 hours [3] for a basic need of –say- 500 hours). There is something to expect from the new EU inspection if it is followed by efficient behavioral decisions, and maybe if some related features are included in the products, like meters easy to read. There is a cultural aspect, because "traditional" Europeans did know the thermal value of clothing, not only its aesthetical aspect, and adapted clothing to climate. The necessity of cooling in cars (due basically to noise insulation) and the fact of being used to air conditioning in (almost unregulated in terms of comfort and thermal capacity) work places, are rising the demand in residences now.

At the time of disposal, **it is essential that there is a good recovery of refrigerating fluid**, and that recycling circuits operate. Another issue at that time is to promote the purchase of more efficient

equipments at the time the consumer is ready to change, once again a point where EU inspection could be a tool.
There are two significant interactions with global policies of which the citizens and elected people have to be convinced. One is an interaction with the **urban policy** : air conditioning sales are increased by the heat island and heat wave effects (see the book "Cooling the city" [2]); air conditioners spread is unstabilising the **electrical grid** globally in Spain and Italy and generate strong regional problems in Greece, Portugal (Algarve black out) and France (PACA region reliability problems). The regional development is not uniform, and the new structure of the electricity market scatters responsibilities at peak time, two factors that could be modeled but are presently poorly known.

Envelope and equipment regulations–banning air conditoning or improving it?

In a large number of climatic zones across the European Union there is a high proportion of buildings with a clear need for artificial air conditioning, either due to climatic conditions or from a combination of thermally inefficient building design and/or high internal loads. In such situations greater energy efficiency is obtained not by preventing the use of A/C equipment but by deploying improved A/C equipment, better system design and control and through regular maintenance. Accordingly, some natio**nal building codes** in the EU aim to raise A/C efficiency through requiring more efficient A/C systems. Conversely, some building codes try to avoid active A/C energy demand altogether through the use of bioclimatic architectural practices instead of through optimizing A/C system performance and this is also sometimes presented as an approach towards raising summer energy efficiency. Yet others aim at a combined strategy of improving architectural design and raising A/C efficiency.
In fact, the limits of when the use of active A/C is desirable and when it is not, are poorly known. Such limits can be understood in terms of the physical limits of human comfort, e.g. "Is natural ventilation enough in a UK office building?", as well as in terms of economic limits e.g. "Active A/C would improve the comfort conditions in a UK office building but the cost difference is such that it is not balanced by the gains in productivity it would bring". The two types of limits should be carefully studied. We are basically facing a regulation problem between two types of solutions. To set up the rules for an optimal building code, we should internalize discomfort costs, it is to say compare the total costs of the two solutions:

- With A/C = Initial cost (of building envelope & equipment) + operating cost
- Without A/C = Building envelope initial cost + any discomfort cost

As a result of the current lack of common understanding, there are widely divergent practices and rationales in European building codes. For example one national regulation requires artificial A/C to be associated with any ventilation and another excludes it in principle. In the absence of an objective set of planning criteria, ideological views will often hold sway e.g. with some solar architects struggling for natural comfort while others will make purely aesthetic decisions, due to which A/C cost will increase.
The present contradiction will become embarrassing when efforts are made to harmonize the treatment of energy-efficiency among building codes. To outline the real limits between an effort on A/C efficiency and the domain of bioclimatic architecture is an urgent task because the application of the directive « Energy Efficiency in Buildings » opens a window for integrated measures on the building envelope and equipment. Such an integrated study is made possible by the progress of LCC analysis which apart from quantifying energy costs can also give a cost to discomfort, much in the same way as different levels of system reliability are valued in the utility business.

Comfort levels: a rising demand

The comfort level to be reached is thus an image of the **quality of the activity** which takes place **in the conditioned space**. To make rough distinctions, there is an increasing level of comfort when we move from Free Cooling, with night time over-ventilation, to Partial Cooling, separated from heating and very suitable for residential activity or non working spaces, to Total Cooling (controlled temperature) with some ventilation and an uncontrolled change in humidity level, suitable for simple work spaces, with or without heating, to Total Air Conditioning where temperature and humidity are controlled and to Advanced Air Conditioning (humidity, indoor air quality and temperature are controlled) adequate for clean rooms or other buildings with specific technical functions.
To change the level of comfort changes the consumption of energy. To make the comparison of options possible, it is necessary to give **a monetary value to discomfort**, or to estimate the cost of

the final equipment, which would give equal comfort. Often the presence of room-by-room air conditioners is a sign that comfort was incorrectly valued at the time of the building's design, thereby obliging the customer to implement local remedies. An optimal building code may avoid this for new buildings, while growing comfort expectations will still develop the room air conditioner market for existing buildings. One could develop the following approach of RAC: at least when a RAC is installed we are certain that AC has a real value and will strongly increase comfort.
The initial and running costs between the extremes may display a variation by a factor 10, but this type of choice (**who/what deserves a certain level of comfort?)** is outside the scope of a regulation. Most comparisons are to be done internally to a comfort level even if we get an idea of the relative cost of the various possible comfort levels. Due to the climatic conditions and to social habits, each country displays at a given time a given level of comfort demand, that we will accept as a data (France or Greece is more a country of Total Cooling than Spain and Italy who have chosen a Total Air Conditioning trajectory, UK accepts largely Free Cooling and Partial Cooling). The most difficult is to predict the future level of expectations, and even more the speed of change.
Changes may be quick. So one sees for example that an increase of 1 % of GNP in southern cities of the European Union leads to a 2.2 % increase of electricity use for air conditioning through individual room air conditioners available from supermarkets.
The classic concept of thermal comfort is to define temperature and humidity conditions which are acceptable by most occupants. Comfort depends in fact on outside weather conditions: in the residential sector for example, it is well-known that an environment with 18° C or 19° C will be felt comfortable in winter, but can appear cold if the outside temperature is higher than 35° C. The new standards of "**adaptive comfort**" [4] relate acceptable inside conditions to outside conditions, but no RAC behaves like this!

Some conclusions

What appears first is the difference in functionality between equipment. The final table indicates the coverage of each function by each technique ("YES")and potential of each technique to develop new functions ("Target").

Equipment type	**F1** Temperature control	**F2** Dehumidification	**F3** Humidification	**F4** Ventilation internally	**F5** Air change	**F6** Adaptative comfort target	**F7** Adaptative cooling strategy	**F8** No outside unit, no geometric constraint	**F9** Reversible heating	**F10** Movable? Mobility?
Window (packaged)	YES	Uncontrolled		YES					YES	
Split	YES	Controlled or uncontrolled		YES		Target!	Target!		YES	YES
Single or double duct	poor	Controlled or uncontrolled		YES	YES	Target!	Target!	YES	Target for DD	YES
Dehumidifier		Controlled		YES						
Evaporative cooler	poor		Poor control		YES					

The split and ducted systems seem to have specific advantages that will keep them on the market. However the controls remain poor. We are far from having "adaptive" equipment that would take into account outside conditions to build adequate inside conditions, 1- building on the outside temperature to define an adapted internal demand, 2- playing with controls on moisture and/or air velocity to generate conditions within an adapted comfort zone like the one shown on a psichrometric chart like the ASHRAE one.

Figure 6. Diagrammatic representation of an adapted control strategy aiming at an adapted comfort target

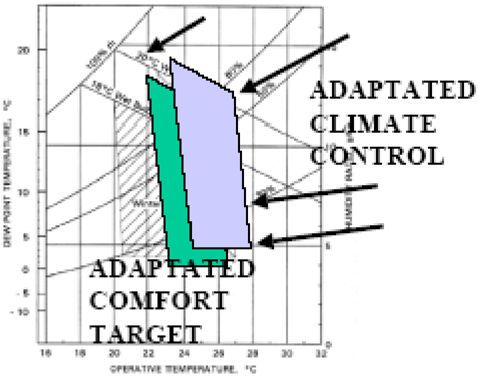

Figure 6 shows the conceptual way forward : a strategy defining an adaptated comfort target corresponding to the user and situation, and adaptated control to bring outside conditions within the comfort range, both taking into account more variables than today. This is likely to be a path of development for dual ducts and splits, the system types with a potential for energy efficiency and the highest acceptance on the other functions.

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Energy Labelling Directive, 2002/96/EC and EN 14511 Standard for Room Air Conditioners

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Eurovent

Abstract

To improve energy efficiency of room air conditioners, the European Commission decided to apply energy labelling policy through 2002/96/EC Directive. The directive refers to the standard EN 14511 for testing procedures, uncertainty of measurement and tolerances to be used for energy efficiency of room air conditioners. However, the standard in its annex A, § 4 stipulates that the allowed tolerances between the claimed and measured efficiency is 15% without taking into account that the difference between two successive classes is between 6 and 8 % which allows manufacturers to jump easily to one or even two higher classes.

Introduction

The implementation of Kyoto Protocol has a high priority for the European Union and strong measures shall be applied to achieve its target fixed for Europe as a reduction of 8% of equivalent CO2 emission between 2008 and 2012. To meet this important challenge, HVAC industry decided to be more proactive and to take relevant actions in advance before some mandatory measures are being decided by the European Commission or National Authorities.
Eurovent air conditioners manufacturers were involved in the SAVE project EERAC concerning energy efficiency of room air conditioners. This project was finalised at the end of 1999. Using the data provided by manufacturers and available on Eurovent directories, it has been realised that energy efficiency of air conditioners presented on the market varies widely: the best units have sometimes two times higher efficiency than the worst.

Two possible policies have been analysed in detail: energy labelling and minimum efficiency.

<u>Mandatory minimum efficiency</u> has been introduced in many countries outside of Europe. This is the simplest way to eliminate low efficiency products from the market but it has a very important effect on the industry and must be applied carefully. In order to avoid such regulation, Eurovent air conditioners manufacturers prepared a proposal on voluntary minimum efficiency to be supported by Eurovent certification. Implementation of this proposal started in January 2004 with the elimination of Class G products.

<u>Energy Labelling</u> as applied with success to many home appliances like domestic refrigerators was an obvious measure. However the labelling itself means only clear information to buyers – it is expected that buyers will prefer better equipment and that in this way the global, average efficiency of the products sold on the market will increase. Labelling Directive for small Air Conditioners has been prepared by the European Commission and was published in April 2002.

Full mandatory application of this Directive has been fixed for 30 June 2003. However the relevant test standard needed to serve as the reference document was missing; new revised standard EN 14511 covering all products in the scope of the Directive has not been finalised before May 2004. Following several discussions with officials from the European Commission, the Labelling Committee decided to postpone the application till just before the summer 2004.
It was expected from the application of the labelling directive to increase energy efficiency of room air conditioners. However, EN 14511 in its Annex A, stipulates that the allowed tolerances between claimed and measured efficiency is 15%. Using this tolerance, each product can jump at least one class. That means class G doesn't exist. Cleaver manufacturers and they are so many will never declare any product in class G or F because a cleaver consumers and they are so many, will always prefer to buy products with class A, B or C. In addition to this non reasonable tolerance, there is no obligation of checking by an independent body of the claimed efficiency and class.

Effect of the certification on room air conditioners energy efficiency

During the last years the energy efficiency has become an important issue for all energy consuming equipment. Eurovent manufacturers followed this trend becoming more active. As the first action, the energy efficiency of air conditioners became a certified characteristic in 2001. This action added more clarity and transparency to the users and anticipated the mandatory implementation of labelling directive for room air conditioners.
However this measure has no direct effect on improving the energy efficiency of equipment. In fact when certified data from the directory are compared with those of successive years, the global average efficiency of products appears sometime to even decrease slightly. This apparent negative effect is just the consequence of correction of wrong, exaggerated data submitted by some manufacturers, as we can see in Figure1. Each time, when a new measure is applied, we first have a decrease of efficiency than an increase.

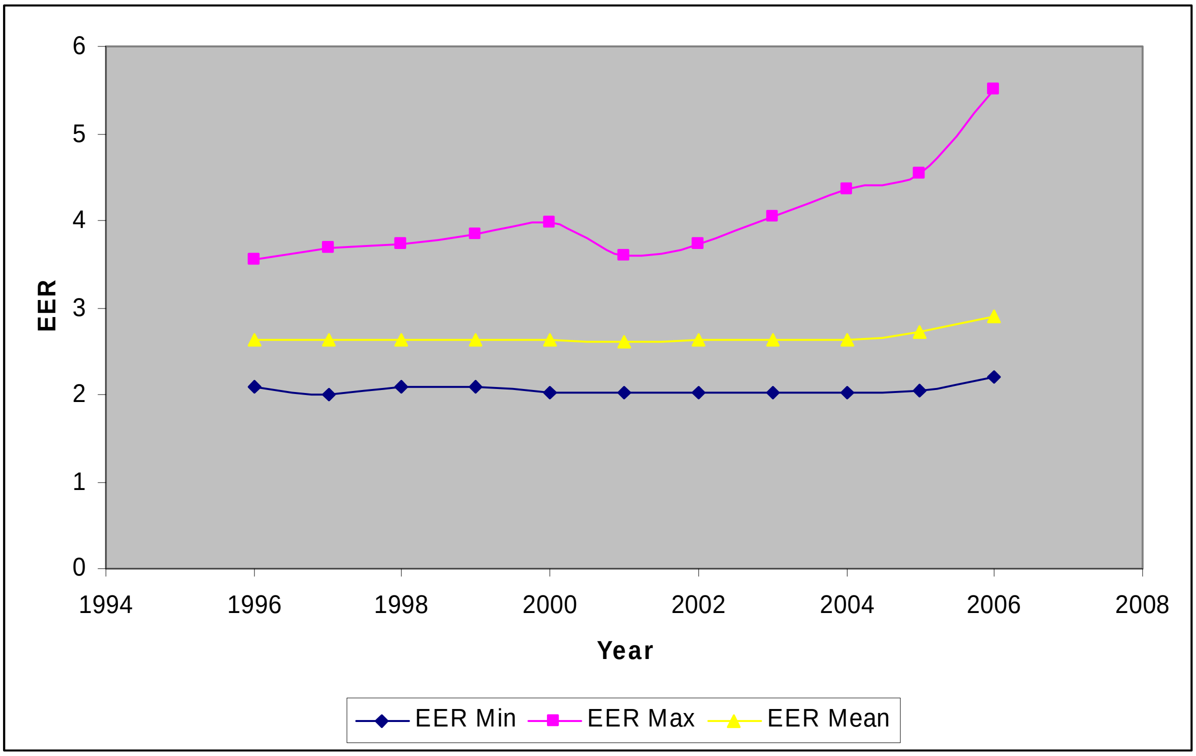

Figure 1: Evolution of EER for room air conditioners

The strongest possible action is the implementation of minimum efficiency levels as it is done by Eurovent certification. As certify all policy is applied, the lowest efficiency products under the minimum efficiency level could not be certified and they automatically disappeared from the market. At 1st January 2004, the lowest class, Class G, of room air conditioners disappeared from Eurovent directory. This was the first concrete action implemented in the certification before any mandatory minimum efficiency introduction.
The consequence of elimination of Class G appeared immediately, the average energy efficiency increased by 4% from 2003 to 2004 when the increase from 2001 to 2003 was only 1%. The minimum efficiency is 2,2. Manufacturers are presenting units with higher efficiency and the average efficiency of all air conditioners is now increasing.
The increase of energy efficiency of air conditioning is technically possible. The problem is not technical but economical. Manufacturers know how to build more efficient products but as costs are higher and there is no pressure from the market, lower efficiency products will still be found. Although a great number of users will be attracted by better products, there will always be buyers looking for lowest prices.

Effect of EN 14511 on decreasing energy efficiency of room air conditioners

With the Labelling Directive 2002/96/EC and the EN 14511 standard it is expected to improve energy efficiency of room air conditioners as it has been done for domestic refrigerators. When products are

independently checked and verified by a certification system using some reasonable realistic tolerance, performance claimed by a manufacturer is closely related to an energy class. However with 15% tolerances for EER and COP, non certified products may jump one, two or in some cases even three classes still remaining legally in conformity with the standard and therefore with the Directive. The purpose of the Directive may be completely deformed.
The following tables(1-8) to illustrate this situation for each type of product. As it can be seen for some types of air conditioners only three classes may exist instead of seven.

Table 1: Air cooled split and multi-split units - cooling mode only

Original Class	Upper limit	15%	Final class	Lower limit	15%	Final class	Average Value	15%	Final class
A	> 3,20	-	-	3,20	3,68	A	-	-	-
B	3,20	3,68	A	3,00	3,45	A	3,10	3,57	A
C	3,00	3,45	A	2,80	3,22	A	2,90	3,34	A
D	2,80	3,22	A	2,60	2,99	C	2,70	3,11	A
E	2,60	2,99	C	2,40	2,76	D	2,50	2,88	C
F	2,40	2,76	D	2,20	2,53	E	2,30	2,65	D
G	2,20	2,53	E	< 2,20	-	-	-	-	-

Table 2: Air cooled packaged units - cooling mode only

Original Class	Upper limit	15%	Final class	Lower limit	15%	Final class	Average Value	15%	Final class
A	> 3,00	-	-	3,00	3,45	A	-	-	-
B	3,00	3,45	A	2,80	3,22	A	2,90	3,34	A
C	2,80	3,22	A	2,60	2,99	B	2,70	3,11	A
D	2,60	2,99	B	2,40	2,76	C	2,50	2,88	B
E	2,40	2,76	C	2,20	2,53	D	2,30	2,65	C
F	2,20	2,53	D	2,00	2,30	E	2,10	2,42	D
G	2,00	2,30	E	< 2,00	-	-	-	-	-

Table 3: Water cooled split and multi-split units - cooling mode only

Original Class	Upper limit	15%	Final class	Lower limit	15%	Final class	Average Value	15%	Final class
A	> 3,50	-	-	3,50	4,03	A	-	-	-
B	3,50	4,03	A	3,30	3,80	A	3,40	3,91	A
C	3,30	3,80	A	3,10	3,57	A	3,20	3,68	A
D	3,10	3,57	A	2,80	3,22	C	2,95	3,39	B
E	2,80	3,22	C	2,50	2,88	D	2,65	3,05	D
F	2,50	2,88	D	2,20	2,53	E	2,35	2,70	E
G	2,20	2,53	E	< 2,20	-	-	-	-	-

Table 4: Water cooled packaged units - cooling mode only

Original Class	Upper limit	15%	Final class	Lower limit	15%	Final class	Average Value	15%	Final class
A	> 4,40	-	-	4,40	5,06	A	-	-	-
B	4,40	5,06	A	4,10	4,72	A	4,25	4,89	A
C	4,10	4,72	A	3,80	4,37	B	3,95	4,54	A
D	3,80	4,37	B	3,50	4,03	C	3,65	4,20	B
E	3,50	4,03	C	3,20	3,68	D	3,35	3,85	C
F	3,20	3,68	D	2,90	3,34	E	3,05	3,51	D
G	2,90	3,34	E	< 2,90	-	-	-	-	-

Table 5: Air cooled split and multi-split units - reverse cycle

Original Class	Upper limit	15%	Final class	Lower limit	15%	Final class	Average Value	15%	Final class
A	> 3,60	-	-	3,60	4,14	A	-	-	-
B	3,60	4,14	A	3,30	3,80	A	3,45	3,97	A
C	3,30	3,80	A	3,10	3,57	B	3,20	3,68	A
D	3,10	3,57	B	2,80	3,22	C	2,95	3,39	B
E	2,80	3,22	C	2,60	2,99	D	2,70	3,11	C
F	2,60	2,99	D	2,40	2,76	E	2,50	2,88	D
G	2,40	2,76	E	< 2,40	-	-	-	-	-

Table 6: Air cooled packaged units - reverse cycle

Original Class	Upper limit	15%	Final class	Lower limit	15%	Final class	Average Value	15%	Final class
A	> 3,40	-	-	3,40	3,91	A	-	-	-
B	3,40	3,91	A	3,20	3,68	A	3,30	3,80	A
C	3,20	3,68	A	3,00	3,45	A	3,10	3,57	A
D	3,00	3,45	A	2,60	2,99	D	2,80	3,22	B
E	2,60	2,99	D	2,40	2,76	D	2,50	2,88	D
F	2,40	2,76	D	2,20	2,53	E	2,30	2,65	D
G	2,20	2,53	E	< 2,20	-	-	-	-	-

Table 7: Water cooled split and multi-split units - reverse cycle

Original Class	Upper limit	15%	Final class	Lower limit	15%	Final class	Average Value	15%	Final classe
A	> 3,60	-	-	3,60	4,14	A	-	-	-
B	3,60	4,14	A	3,40	3,91	A	3,50	4,03	A
C	3,40	3,91	A	3,20	3,68	A	3,30	3,80	A
D	3,20	3,68	A	2,80	3,22	C	3,00	3,45	B
E	2,80	3,22	C	2,60	2,99	D	2,70	3,11	D
F	2,60	2,99	D	2,40	2,76	E	2,50	2,88	D
G	2,40	2,76	E	< 2,40	-	-	-	-	-

Table 8: Water cooled packaged units - reverse cycle

Original Class	Upper limit	15%	Final class	Lower limit	15%	Final class	Average Value	15%	Final class
A	> 3,40	-	-	3,40	3,91	A	-	-	-
B	3,40	3,91	A	3,20	3,68	A	3,30	3,80	A
C	3,20	3,68	A	3,00	3,45	A	3,10	3,57	A
D	3,00	3,45	A	2,60	2,99	D	2,80	3,22	B
E	2,60	2,99	D	2,40	2,76	D	2,50	2,88	D
F	2,40	2,76	D	2,20	2,53	E	2,30	2,65	D
G	2,20	2,53	E	< 2,20	-	-	-	-	-

Comparison test between three laboratories for three air conditioners

To evaluate the actual uncertainties of measurement using the European standard EN 14511:2004 and to demonstrate that the tolerances specified in Annex A of the standard are not reasonable, Eurovent organized a round robin test to compare the results obtained by different European independent laboratories for the measurement of the cooling and heating capacities of air conditioners and heat pumps, and of their EER and COP.
Three laboratories equipped with calorimetric room have been selected. Testing facility used in each laboratory was a balanced ambient room type calorimeter.
In the summary below, the laboratories are numbered 1 to 3. Laboratory nº 1 being the reference laboratory for the purpose of the survey

- **Standard and test method to be used:**

The tests have been performed in the same test conditions than for EUROVENT Certification testing, using the test procedures described in EN 14511-3:2004.
The test method was the calorimeter room method, including for the ducted sample, as specified in EN 14511-2:2004, Annex A.
To avoid any risk of difference in the installation of the samples in different laboratories, the maximum length of 7.5 m was used for the purpose of this round robin test.
The samples were delivered to each laboratory without refrigerant charge, and the samples charged with the quantity of refrigerant given for each sample previously to each test.

- **Test conditions:**

The test conditions were the standard rating conditions defined in EN 14511-2:2004 and reported in Table 9

Table 9: Test conditions

	Outdoor heat exchanger		**Indoor heat exchanger**	
	Inlet dry bulb temperature ° C	**Inlet wet bulb temperature** ° C	**Inlet dry bulb temperature** ° C	**Inlet wet bulb temperature** ° C
cooling mode	**35**	**not required**	**27**	**19**
heating mode	**7**	**6**	**20**	**15 max**

Three samples have been selected. The main characteristics of the samples are described in the following Table 10

Table 10: Samples tested

Sample nº	**Type of unit**	**Mode**	**Claimed capacity**
1	Split non ducted wall mounted air conditioner	Cooling	3,5 kW
2	Split non ducted wall mounted heat pump	Cooling	5,0 kW
		Heating	6,2 kW
3	Split ducted air conditioner	Cooling	6,6 kW

2- Results obtained in each laboratory

SAMPLE 1, COOLING MODE

Laboratory nº		**1**	**2**	**3**
Dry bulb temperature, air inlet, outdoor unit	(° C)	**35,07**	**34,99**	**35,0**
Wet bulb temperature, air inlet, outdoor unit	(° C)	**20,75**	**18,67**	**-**
Dry bulb temperature, air inlet, indoor unit	(° C)	**27,13**	**27,00**	**27,0**
Wet bulb temperature, air inlet, indoor unit	(° C)	**19,03**	**18,99**	**19,0**
Atmospheric pressure	(kPa)	**95,05**	**97,34**	**99,6**
Voltage	(V)	**230,7**	**229,9**	**230**
Total cooling capacity, indoor side	(W)	**3408**	**3293**	**3490**
Total cooling capacity, outdoor side (verification)	(W)	**3334**	**3306**	**-**
Dehumidifying capacity	(W)	**977**	**948**	**897**
Sensible cooling capacity	(W)	**2431**	**2345**	**2593**
Sensible heat ratio		**0,713**	**0,71**	**0,743**
Effective power input	(W)	**1223**	**1210**	**1244**
EER		**2,79**	**2,72**	**2,81**

SAMPLE 2, COOLING MODE

Laboratory nº		1	2	3
Dry bulb temperature, air inlet, outdoor unit	(° C)	**34,96**	**34,96**	**35,0**
Wet bulb temperature, air inlet, outdoor unit	(° C)	**22,27**	**20,02**	**-**
Dry bulb temperature, air inlet, indoor unit	(° C)	**27,10**	**27,00**	**27,0**
Wet bulb temperature, air inlet, indoor unit	(° C)	**19,03**	**18,99**	**19,0**
Atmospheric pressure	(kPa)	**94,87**	**96,43**	**100,3**
Voltage	(V)	**230,4**	**230,0**	**230**
Total cooling capacity, indoor side	(W)	**4962**	**4927**	**5091**
Total cooling capacity, outdoor side (verification)	(W)	**5016**	**5837**	**-**
Dehumidifying capacity	(W)	**1128**	**1194**	**889**
Sensible cooling capacity	(W)	**3834**	**3733**	**4202**
Sensible heat ratio		**0,773**	**0,76**	**0,825**
Effective power input	(W)	**1593**	**1602**	**1611**
EER		**3,11**	**3,08**	**3,16**

SAMPLE 3, COOLING MODE

Laboratory nº		1	2		3
Dry bulb temperature, air inlet, outdoor unit	(° C)	**35,06**	**35,03**		**34,8**
Wet bulb temperature, air inlet, outdoor unit	(° C)	**21,21**	**18,99**		**-**
Dry bulb temperature, air inlet, indoor unit	(° C)	**27,08**	**27,00**		**27,0**
Wet bulb temperature, air inlet, indoor unit	(° C)	**19,04**	**18,99**		**19,0**
Atmospheric pressure	(kPa)	**93,65**	**96,93**		**100,2**
Voltage	(V)	**230,7**	**230,0**		**230**
Total cooling capacity, measured indoor side	(W)	**6254**	**6239**		**6271**
Total cooling capacity, outdoor side (verification)	(W)	**6422**	**6216**		**-**
Dehumidifying capacity	(W)	**1790**	**1620**		**1587**
Sensible cooling capacity	(W)	**4464**	**4619**		**4684**
Sensible heat ratio		**0,714**	**0,74**		**0,747**
Available static pressure	(Pa)	**44**	**47**		**56**
Total power input	(W)	**2489**	**2481**		**2527**
Total cooling capacity, including corrections for the fans (final result)	(W)	**6293**	[a]	**6281** [b]	**6321**
Effective power input	(W)	**2450**	[a]	**2439** [b]	**2477**
EER		**2,57**	**2,51**	**2,58**	**2,55**

[a] no correction for the fan has been done by this laboratory
[b] estimated by the reference laboratory

SAMPLE 2, HEATING MODE

Laboratory nº		1	2	3
Dry bulb temperature, air inlet, outdoor unit	(° C)	**7,11**	**7,02**	**7,0**
Wet bulb temperature, air inlet, outdoor unit	(° C)	**6,06**	**5,99**	**6,1**
Dry bulb temperature, air inlet, indoor unit	(° C)	**20,13**	**19,99**	**20,0**
Wet bulb temperature, air inlet, indoor unit	(° C)	**12,33**	**12,27**	**-**
Atmospheric pressure	(kPa)	**94,20**	**97,85**	**99,2**
Voltage	(V)	**230,6**	**229,8**	**230**
Heating capacity, outdoor room	(W)	**6028** [c]	**6196**	**-**
Heating capacity, indoor room	(W)	**6132**	**6188** [c]	**6143** [c]
Effective power input	(W)	**1808**	**1867**	**1752**
COP		**3,33** [a]	**3,31** [b]	**3,51** [b]

[a] calculated with the outdoor side measurement
[b] calculated with the indoor side measurement
[c] final result for the heating capacity

- **Analysis of the results**

The aim of the study being the evaluation of the overall uncertainty of measurement of the capacities and efficiencies, the analysis is focussed on these parameters.
In the following page, we show an abstract of the results for the capacities and efficiencies, together with the deviation of each individual measurement with reference to the medium value of each parameter.
The main conclusion is the small differences between the results of the three laboratories.
The biggest deviation from the medium value for the capacities is 3,1 %, and 3,7 % for the efficiencies.
These deviations include not only the uncertainty of the measurement itself, but also the effect of the differences in the installation of the samples.
The conclusion of the survey is that the uncertainty of the measurement of cooling and heating capacities of an air conditioner or a heat pump by a recognised independent laboratory is fully within the maximum uncertainty required by the testing standard EN 14511-3, which is 5 %, and that the uncertainty of the measurement of the efficiencies is also inside this tolerance.

SAMPLE	COOLING CAPACITY LAB Nº 1	COOLING CAPACITY LAB Nº 2	COOLING CAPACITY LAB Nº 3	MEDIUM VALUE	STANDARD DEVIATION	STANDARD DEVIATION %	DEVIATION LAB Nº 1 (%)	DEVIATION LAB Nº 2 (%)	DEVIATION LAB Nº 3 (%)
1	3408	3293	3490	3397	99,0	2,9	0,3	-3,1	2,7
2	4962	4927	5091	4993	86,4	1,7	-0,6	-1,3	2,0
3	6293	6281	6321	6298	20,5	0,3	-0,1	-0,3	0,4

SAMPLE	EER LAB Nº 1	EER LAB Nº 2	EER LAB Nº 3	MEDIUM VALUE	STANDARD DEVIATION	STANDARD DEVIATION %	DEVIATION LAB Nº 1 (%)	DEVIATION LAB Nº 2 (%)	DEVIATION LAB Nº 3 (%)
1	2,79	2,72	2,81	2,77	0,05	1,7	0,6	-1,9	1,3
2	3,11	3,08	3,16	3,12	0,04	1,3	-0,2	-1,2	1,4
3	2,57	2,58	2,55	2,57	0,02	0,6	0,1	0,5	-0,6

SAMPLE	HEATING CAPACITY LAB Nº 1	HEATING CAPACITY LAB Nº 2	HEATING CAPACITY LAB Nº 3	MEDIUM VALUE	STANDARD DEVIATION	STANDARD DEVIATION %	DEVIATION LAB Nº 1 (%)	DEVIATION LAB Nº 2 (%)	DEVIATION LAB Nº 3 (%)
2	6028	6188	6143	6120	82,5	1,3	-1,5	1,1	0,4

SAMPLE	COP LAB Nº 1	COP LAB Nº 2	COP LAB Nº 3	MEDIUM VALUE	STANDARD DEVIATION	STANDARD DEVIATION %	DEVIATION LAB Nº 1 (%)	DEVIATION LAB Nº 2 (%)	DEVIATION LAB Nº 3 (%)
2	3,33	3,31	3,51	3,38	0,11	3,3	-1,6	-2,2	3,7

Conclusion

Implementation of energy labelling policy for small air conditioners as a first step of a general energy efficiency policy can be considered as a good starting point. However in order to achieve the purpose of this action, the European Commission should ask urgently CEN to revise the tolerances in Annex A of En14511 standard.
As shown by the survey above, the only reasonable tolerance is the one that will avoid to any product to jump from one class to another one. 8% seems to be a good compromise
In addition, the declaration of energy class is a good initiative but not a sufficient one. Europe needs to impose the checking of the characteristics claimed by the manufacturers by an independent body.
As Eurovent, we believe that without strong mandatory measures, some manufacturers will declare whatever they want.
On the other hand in order to reach Kyoto Protocol objectives and avoid becoming dustbin for the international industry, it is urgent to have a real energy policy for air conditioning systems. Europe has to combine tEnergy Labelling policy with minimum energy efficiency and to set up a schedule for the elimination of lowest efficient products.
Eurovent has been studying different possible schedules to eliminate low efficiency classes, for example the products with capacity under 4 kW, which represents more than 80% of the residential market and have a short life cycle, lowest efficiencies, E, F can be already eliminated in 2008.
By these measures, products with less efficiency will not sold in Europe and the average installed EER in Europe will increase quickly.

China Cools with Tighter RAC Standards

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Abstract

After boiling summer brought brown-out to most part of the country in 2004, China announced a new set of minimum energy efficiency standards for room air conditioners in September 2004, with the first tier going into effect on March 1, 2005 and the reach standard taking effect on January 1, 2009. This represents a milestone in China's standard setting process since the reach standard levels are significantly more stringent than previous standards for other appliances. This paper first analyzes cost-effectiveness of China's new standards for room air conditioners, and then attempts to evaluate the impact of the new standards on energy savings, electric generation capacity, and CO2 emissions reductions.

Introduction

Since 2002, China has experienced wide spread power shortage, leading to the rationing of power in 24 out of 31 provinces across country in 2004. While most observers point to the strong economic growth in China as the primary cause for such shortage, incremental air-conditioning load is also a leading contributor. It is estimated that about 30 million new room air conditioners were installed in 2004 along, adding roughly 20 GW in peak capacity, which easily eclipse the generating capacity of the Three Gorges Dam. In major cities along the eastern seashore such as Shanghai, air-conditioning load accounts for 40% of the peak summer load.

It is therefore understandable that China decided to update its minimum energy efficiency standard (MEPS) for room air conditioners. The revised standard was published in September, 2004, with the first tier going into effect on March 1, 2005 and the reach standard taking effect on January 1, 2009. This represents a milestone in China's standard setting process since the reach standard levels are significantly more stringent than previous standards for other appliances. This paper first reviews the requirements of the new Chinese standards for air conditioners, and then analyzes its cost-effectiveness, and finally attempts to evaluate the impact of the new standards on energy savings, electric generation capacity, and CO2 emissions reductions.

China's New Standard for Room Air Conditioners

China's new standard for air conditioners sets two tiers of performance requirements, with the first tier going into effect on March 1, 2005, and the second tier going into effect on January 1, 2009. The 2005 requirements are listed in Table 1.

The measured value of energy efficiency ratio (EER) of room air conditioners must be greater than or equal to the values shown in Table 1.

Table 1: Energy Efficiency Ratios (EER)

Category	Rated Cooling Capacity (CC) *W*	EER *W/W*
Single-package	-	2.30
	CC ≤4500	2.60
	4500<CC≤71	2.50
	7100 < CC ≤ 14000	2.40

In addition to setting the minimum requirement, China's new AC standard also include classification requirements for the newly established Energy Information Label, as well as the certification requirement for CECP's Energy Conservation Label.

Rating requirements (measured in EER) for specific Energy Efficiency Grades are listed in Table 2.

Table 2: Energy Efficiency Grade Specifications

		Energy Efficiency Grade EER *W/W*				
Category	**Rated Cooling Capacity (CC) *W***	**5**	**4**	**3**	**2**	**1**
Single-package	-	2.30	2.50	2.70	2.90	3.10
Split	CC ≤4500	2.60	2.80	3.00	3.20	3.40
	4500<CC≤7100	2.50	2.70	2.90	3.10	3.30
	7100 < CC ≤ 14000	2.40	2.60	2.80	3.00	3.20

For China's voluntary energy endorsement label (managed by China Standard Certification Center), the EER requirements of room air conditioners must be greater than or equal to the values shown in Table 3.

Table 3: Energy Efficiency Specification

Category	**Rated Cooling Capacity (CC) *W***	**EER *W/W***
Single-package	-	2.90
Split	CC ≤4500	3.20
	4500<CC≤7100	3.10
	7100 < CC ≤ 14	3.00

Moreover, a tighter standard goes into effects on 1 January 2009. The requirements of the 2009 standard for room air conditioners are listed in Table 4.

Table 4: Energy Efficiency Ratios (EER) in 2009

Category	**Rated Cooling Capacity (CC) *W***	**EER *W/W***
Single-package		2.90
Split	CC ≤4500	3.20
	4500<CC≤7100	3.10
	7100 < CC ≤ 14000	3.00

In order to compare the stringency of the Chinese standards, a collection of standards around the world are presented below in Tables 5 through 9.

Table 5: U.S. and Canadian Air Conditioner Standards

Category	**EER *W/W***
Window	2.87
Central	3.37
*Converted from seasonal energy efficiency (SEER) of 13. SEER is in units of Btu/Whr.	

Table 6: South Korean Air Conditioner Standards[1]

Category	**Rated Cooling Capacity (CC) *W***	**EER *W/W***
Window	-	2.88
Split	CC<4000W	3.37
	4.0 kW ≤ RCC < 10.0 kW	2.97
	10.0 kW ≤ RCC < 17.5 kW	2.76

Table 7: Singapore Air Conditioner Standards

Category	**EER *W/W***
Window	2.73

Table 8: European Union Labeling Requirements

	Energy Efficiency Grade EER *W/W*						
Category	**G**	**F**	**E**	**D**	**C**	**B**	**A**
Window	<2	2.0	2.2	2.4	2.6	2.8	>3.0
Split	<2.2	2.2	2.4	2.6	2.8	3.0	>3.2

[1] As of March 2006.

Table 9: Japanese Air Conditioner Standards

Category	Rated Cooling Capacity *W/W*	EER *W/W*	
Window		**AC-only**	**Heat pump**
	-	2.67	2.85
Split		**AC-only**	**Heat pump**
	CC<2500W	3.64	5.27
	2500-3200W	3.64	4.90
	3200-4000W	3.08	3.65
	4000-7100W	2.91	3.17
	>7100W	2.81	3.10

Where the standards cover products in several categories, the most dominant product type in China today is the split air conditioners with a cooling capacity smaller than 4500 Watts. Therefore it can be seen that the 2009 Chinese requirement for this product group will be higher than the EU label A, and only trails the requirements of Japan and South Korea. While the US standard is technically more stringent, it is set for residential central system, which carries significant duct losses.
For window air conditioners, the 2009 Chinese standard would be the highest with a minimum EER of 2.9, compared to 2.87 in the US, 2.85 in Japan, and 2.88 in South Korea.

Life-Cycle Cost Analysis of Air Conditioner Standards

One of the factors used to judge the economic feasibility of air conditioner standards is consumer life-cycle costs (LCC) savings. If a more efficient air conditioner, i.e., a unit that meets possible new standards, provides consumer LCC savings relative to a minimally compliant product, the more efficient unit is generally assessed as being economically feasible.
The LCC is the sum of the purchase cost (*PC*) and the present value of operating expenses (*OC*) discounted over the lifetime (*N*) of the equipment. If operating expenses are constant over time, the LCC simplifies to

$$LCC = PC + PWF \cdot OC,$$

where the present worth factor (PWF) is dependent on the discount rate (r) and the equipment lifetime (N) and is defined as

$$PWF = 1/r \cdot [\ 1 - 1/(1+r)^N\ ].$$

The LCC analysis described below was conducted with a 6 percent real discount rate and an equipment lifetime of 12.5 years.[2]

In order to assess the economic feasibility of increased Chinese air conditioner standards, an LCC analysis was performed on two different sized split system room air-conditioning heat pumps: 3500 Watt (W) cooling capacity and 7100 Watt (W) cooling capacity (Rosenquist and Lin, 2005). The above cooling capacity units were determined to be the most popular sized air-conditioning units in China. Table 10 summarizes the physical characteristics of the two representative units (i.e., baseline units) for which the LCC analysis was conducted. By defining baseline units, more efficient designs, otherwise known as design options, can be evaluated to determine if standards are economically feasible. Note that the rated EERs of the two baseline units have efficiencies roughly equal to the current minimum EER standards (see Table 1). At the time the LCC analysis was conducted, many air conditioner models in China had efficiencies that were roughly equal to the current minimum standards.

[2] The lifetime assumption is based on industry estimate of average lifetime of ACs in China. No benchmark discount rate is available from China. However, interest rate for loans over 5 years was 6.12% by the end of 2005.

Table 10: Baseline Characteristics of 3500 W and 7100 W Split System Room Air-Conditioning Heat Pumps

			Heat Pump Split (single evaporator)	
Rated Cooling Capacity, CC (W)			3500	7100
Rated EER (W/W)			2.57	2.55
Refrigerant			R-22	R-22
Flow Control Device			Short Tube (assumed)	Short Tube (assumed)
Evaporator		Face area (m^2)	0.206	0.303
		Fin type	Hydrophilic Slit Fin	Hydrophilic Slit Fin
		Tube type	Grooved	Grooved
Condenser		Face area (m^2)	0.381	0.502
		Fin type	Hydrophilic Slit Fin	Hydrophilic Slit Fin
		Tube type	Grooved	Grooved
Compressor		Manufacturer	Panasonic Wanbao	Copeland
		Model Number	2K23S225BUA	ZR34KH-PFJ-522
		Type	Rotary	Scroll
		Cooling capacity (W)	4000	8200
		Displacement (cm^3)	21.4	46.1
		Efficiency (W/W)	2.81	3.02
Fan	**Evaporator-side**	Air volume (m/h^3)	463	1014
		Power Input (W)	50	80
		Type	PSC	PSC
	Condenser-side	Air volume (m/h^3)	1400 (assumed)	2040 (assumed)
		Power Input (W)	75 (assumed)	150 (assumed)
		Type	PSC	PSC

Tables 11 and 12 show the cost-efficiency and LCC results for the 3500 W and 7100 W baseline units. Specific design options were added to the baseline units and their impact on manufacturer cost, consumer retail price, cooling capacity, EER, annual energy consumption (AEC), operating cost (OC), payback period (i.e., the ratio of the change in consumer retail price over the change in operating cost), and LCC were determined. Note that in Tables 11 and 12, only a limited number of design options were evaluated. For example, increases in evaporator size were not considered so as to prevent any significant changes to the indoor cabinet. In addition relatively small increases in condenser size were considered to limit the size of the outdoor cabinet.

Table 11: Cost-Efficiency and LCC Results for 3500 W Split System Room Air-Conditioning Heat Pump

		Manufacturer Cost								
No.	**Design Option**	**Incr.** ***Yuan***	**Total** ***Yuan***	**Retail Price** ***Yuan***	**Cooling Capacity** ***Watts***	**EER** ***W/W***	**AEC*** ***kWh*****/yr**	**OC**** ***Yuan*****/yr**	**Payback Period** ***Years***	**LCC** ***Yuan***
0	Baseline	-	-	2600	3299	2.57	1148	689	-	8541
1	0 +3.0 EER Compressor	40	40	2660	3307	2.75	1074	644	1.3	8214
2	1 +3.16 EER Compressor	61	101	2751	3313	2.90	1018	611	1.9	8015
3	2 + 0.419 m^2 Condenser	56	157	2834	3325	2.96	997	598	2.6	7992
4	3 +Cond^ Fan Motor +10%	20	177	2864	3325	2.98	992	595	2.8	7995
5	4 +Evap^ Fan Motor +10%	20	197	2894	3329	2.99	987	592	3.0	7997
6	5 +Cond^ Fan Motor +20%	20	217	2923	3329	3.02	978	587	3.2	7982
7	6 +Evap^ Fan Motor +20%	20	237	2953	3333	3.03	973	584	3.4	7989

* AEC based on annual operating hours of 895.

** OC based on electricity price of 0.6 yuan/kWh.

^ Cond = Condenser; Evap = Evaporator

Table 12: Cost-Efficiency and LCC Results for 7100 W Split System Room Air-Conditioning Heat Pump

		Manufacturer Cost								
No.	**Design Option**	**Incr.** *Yuan*	**Total** *Yuan*	**Retail Price** *Yuan*	**Cooling Capacity** *Watts*	**EER** *W/W*	**AEC*** *kWh/yr*	**OC**** *Yuan/yr*	**Payback Period** *Years*	**LCC** ***Yuan***
0	Baseline	-	-	5000	6814	2.57	2369	1421	-	17,254
1	0 + 3.25 EER Compressor	177	177	5264	6857	2.77	2203	1322	2.7	16,661
2	1 + 0.551 m^2 Condenser	70	247	5368	6884	2.82	2163	1298	3.0	16,557
3	2 +Cond^ Fan Motor +10%	30	277	5413	6884	2.83	2153	1292	3.2	16,548
4	3 +Evap^ Fan Motor +10%	30	307	5458	6891	2.84	2144	1286	3.4	16,548
5	4 +Cond^ Fan Motor +20%	30	337	5502	6891	2.86	2135	1281	3.6	16,548
6	5 +Evap^ Fan Motor +20%	30	367	5547	6897	2.87	2128	1277	3.8	16,556

* AEC based on annual operating hours of 895.

** OC based on electricity price of 0.6 yuan/kWh.

^ Cond = Condenser; Evap = Evaporator

Figures 1 and 2 show the LCC as a function of EER for the 3500 W and 7100 W air-conditioning heat pump units. Because a limited set of design options were evaluated, the maximum efficiency points are below the new set of standards that are to become effective in China in 2009 (see Table 3). Thus, the LCC analysis does not reveal whether the new set of standards, 3.2 EER for the 3500 W unit and 3.1 EER for the 7100 W unit, are economically feasible. Although the LCC analysis does not analyze the 2009 standard levels, the maximum efficiencies, 3.0 EER for the 3500 W unit and 2.9 EER for the 7100 W unit, do yield LCC savings. Because the maximum efficiencies analyzed are close to the new standard levels, it seems reasonable to expect that the new standard levels would be economically feasible.

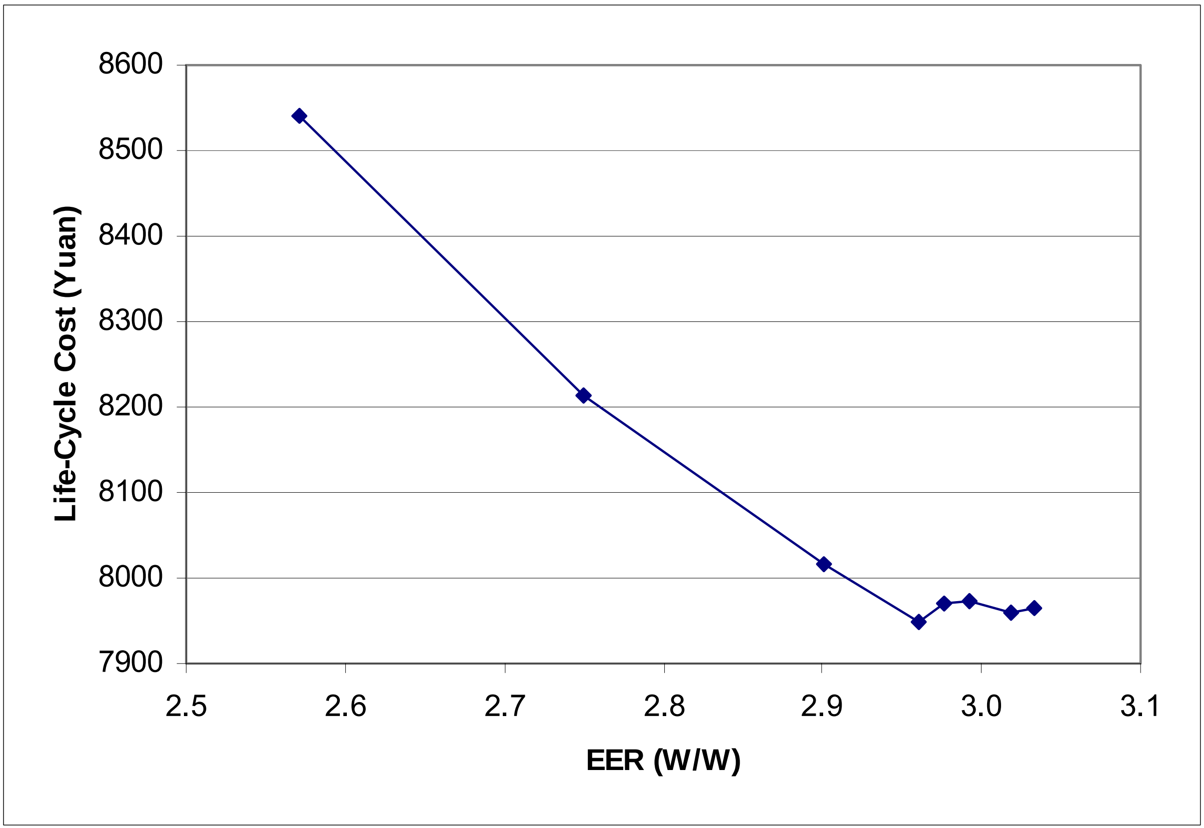

Figure 1: LCC Results for 3500 W Split System Air-Conditioning Heat Pump

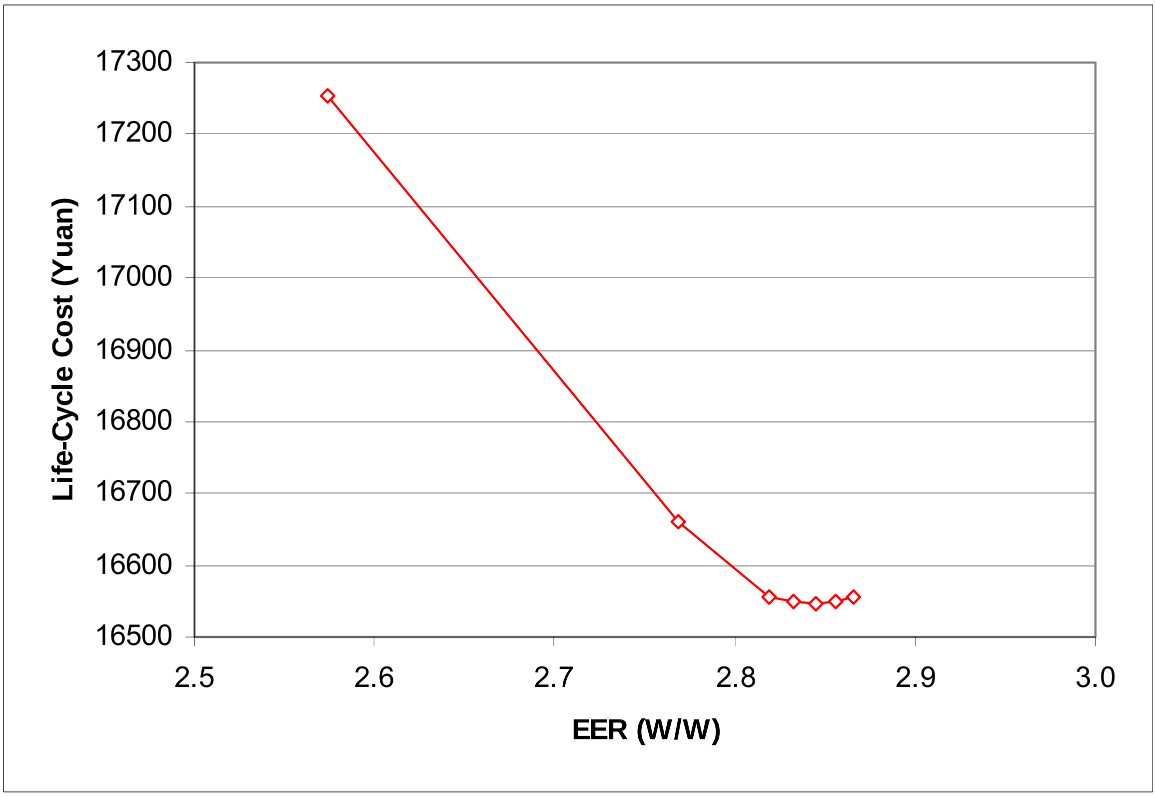

Figure 2: LCC Results for 7100 W Split System Air-Conditioning Unit

Energy Savings from the New Standard

Given that China is one of the largest consumer markets for room air conditioners in the world, the impacts of China's new standards will be very large. According to a recent report (Lin, 2005), the savings are likely to be 10 TWh of electricity and 2.7 million tons of carbon by 2010, 46 TWh of electricity and 12.3 million tons of carbon by 2020 (Table 13). Three quarters of the expected savings by 2020 stem from the more stringent reach standard to go in effect in 2009.

The peak demand reduction calculation depends on an accurate assessment of the coincident peak factor for room air conditioners in China. The reductions are likely to be about 4.5 GW in 2010 and 20.4 GW by 2020. The 2020 peak demand reduction estimate exceeds the 17 GW capacity of the Three Gorges Dam.

Table 13. Expected Energy Savings from the Room Air Conditioner Standard

Year	**Stock** *millions*	**Shipments** *millions*	**Energy Savings** *million kWh*	**CO2 Savings** *million tonnes*	**Carbon Savings** *million tonnes*	**Peak Savings*** *GW*
2000	67	17.3				
2001	85	18.3				
2002	106	21.6				
2003	133	28.2				
2004	161	29.6				
2005	189	31.0	714	0.7	0.2	0.3
2006	218	32.6	1,464	1.4	0.4	0.6
2007	248	34.2	2,251	2.2	0.6	1.0
2008	278	35.9	3,077	3.0	0.8	1.4
2009	308	37.7	6,587	6.4	1.8	2.9
2010	337	38.5	10,166	9.9	2.7	4.5
2011	365	39.3	13,817	13.5	3.7	6.1
2012	390	40.0	17,541	17.1	4.7	7.7
2013	414	40.8	21,339	20.9	5.7	9.4
2014	435	41.7	25,188	24.6	6.7	11.1
2015	453	42.5	29,034	28.4	7.7	12.8
2016	469	43.3	32,837	32.1	8.8	14.5
2017	484	44.2	36,573	35.7	9.7	16.1
2018	497	45.1	40,142	39.2	10.7	17.7
2019	510	46.0	43,360	42.4	11.6	19.1
2020	522	46.9	46,113	45.1	12.3	20.4
Cumulative Total		755	330.201	323	88	-

Conclusion

China's recent efforts to regulate the efficiency of room air conditioners have been shown to yield significant consumer economic savings as well as national benefits of avoided construction of large number of power plants and avoided emissions of GHG and other local pollutants. Relative to air conditioners that meet China's previous set of air conditioner standards, air conditioner designs with efficiencies that are just below the standards that are to become effective in 2009 yield consumer life-cycle cost savings ranging from approximately 550 yuan for 3500 W cooling capacity units to 700 yuan for 7100 W cooling capacity units. The benefits of air conditioner standards are not limited to consumers. Air conditioner standards (both the current standards and the 2009 standards) are projected to yield cumulative national energy savings of over 330 billion kWh. The resulting reduction in national energy consumption is projected to lower power plant carbon emissions by 88 million tonnes.

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An Experimental Comparison of Energy Efficiency Indicators, EER and SEER in Residential Air-Conditioners

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Abstract
A new energy-saving technology was developed for residential air-conditioners, and energy efficiency indicators, EER and SEER were compared between a conventional variable speed air-conditioner and a new one including the new technology. The new air-conditioner, called MPS (Multi Power System) consists of two constant speed compressors, an evaporator, a condenser, an accumulator and an expansion device. The system is operated in a three different mode depending on a thermal load: 1) full operation (two compressors work) 2) medium operation (lager one of the two comp. works) 3) low operation (smaller one of the two comp. works). Thus, the cooling capacity was modulated in three steps, and the energy was saved in the same way as that in the variable speed compressor driven air-conditioner. That is, when the thermal load was low, the compressors did not start and stop frequently, and start-up loss could be minimized. The energy consumption was reduced dramatically when the thermal load was minimal, and it led to SEER (Btu/hr / W) improvement. Because of this point, SEER 16.2 of the MPS was almost the same as SEER 16.8 of the inverter compressor driven air-conditioner, although the MPS showed lower EER 3.32 (W/W) than EER 3.54 of the variable compressor one. With MPS technology, it was shown that the energy saving could be achieved without adopting expensive technologies.

1. Introduction

There have been tremendous needs in air-conditioner industries to develop products protecting environment and achieving energy conservation. This has caused considerable attention toward capacity modulation that could save energy more than conventional on-off systems. There are so many capacity modulated systems nowadays and inverter type system has been in general use although its higher cost and more complex drive logic. In this article, a simpler and more efficient system, MPS, was introduced and compared with a inverter type air-conditioner with respect to their energy efficiency indicators, EER and SEER, with an emphasis on the SEER. ARI standard 210/240[1] was adopted in this article for SEER measurements. European SEER, ESEER has been mentioned in some documents such as EECCAC 2003 final report[2] and BS standard 14825:2003. But the basic concept of ESEER measurements is the same as that of SEER, and the ARI standard was followed. ESEER comparison would be carried out in our next studies.

2. Advantages of Capacity Modulation

Variable capacity modulation has been one of the most effective methods to reduce energy consumptions of air-conditioners. It is due to its several advantages. First, when the thermal load is lower than the design load, the variable capacity modulation reduces the on-off cycling loss. The on-off cycling loss is that when compressor stops, refrigerants in high-pressure side migrate to low-pressure side, and energy loss occurs. When compressor starts, there is a possibility of liquid compression, which is detrimental to compressors [3]. Also, energy consumes while building up high, and low pressures in the air-conditioner. It takes about ten minutes to reach steady running state, and the system runs at a lower efficient condition during this period. As shown in Figure 1, the constant speed system repeatedly starts and stops, depending on the room temperature setting. But the capacity modulation system minimizes on-off operation by the capacity modulating system.
Second, in lower cooling load condition, the capacity modulation system reduces the amount of refrigerant pumped out of the compressor, and it leads that the condensing pressure is reduced and that the evaporative pressure is increased. Thus, the system efficiency increases, in the capacity modulation system.
The benefit of the capacity modulation system could not be represented with the index, EER, even though the system offers a lot better benefit and saves energy consumption.

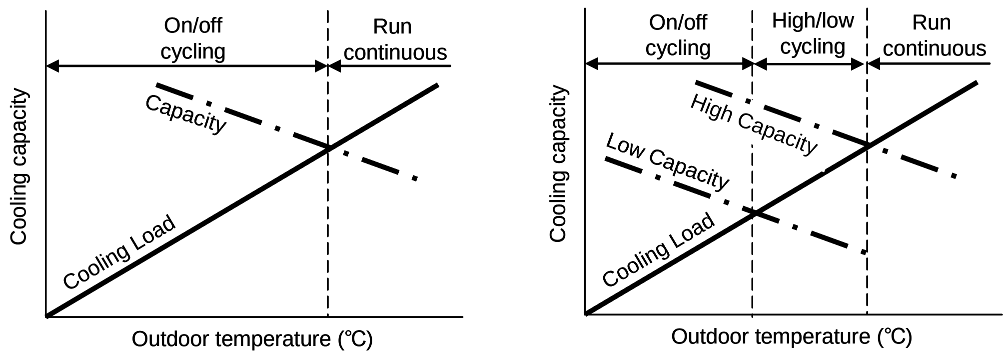


Figure 1: Operation of on/off system (left) & modulated system (right)

3. EER & SEER

EER (Energy Efficiency Ratio) is the ratio of the total amount of produced cold heat (W,Btu/hr) divided by the consumed electric energy (W) at a standard rating condition. ARI 210-240.

(1) $$EER = \frac{Q_{total}}{E_{total}}$$

SEER (Seasonal Energy Efficiency Ratio) is the ratio of the total cooling of an air-conditioner in BTU's during its normal usage period for cooling (not to exceed 12 months) divided by the total electric energy input in watt-hours during the same period.

(2) $$SEER = \frac{\sum \frac{Q(T_j)}{N}}{\sum \frac{E(T_j)}{N}}$$

According to ARI 210/240 standard, four tests named A, B, C, D are required to obtain the SEER of one or two speed system. From the C, D test, the C_D value which is used in calculation of SEER can be obtained and it can be usually omissible when user knows C_D value already. Then 0.25 times C_D value is used generally. The driving range of two-speed (or two compressors) system can be expressed as Figure 2, in three stages such as low load (case 1: only low stage on/off operation) , middle load (case 2: exchange low and high stage repeatedly), and high load (case 3: only continuous high stage operation). The values of Q and E could be obtained according to ARI STANDARD 210/240-2003 A5.1.3.1 ~ A5.1.3.4 and SEER could be calculated using eq.(2). BL (Building Load) expresses the cooling load and k means the operation step (1: low, 2: high) in Figure 2. Both of EER & SEER values describe the efficiency of the system, but EER would not be a representative of the year round energy performance of the component, nor of the seasonal energy performance of the air-conditioners.

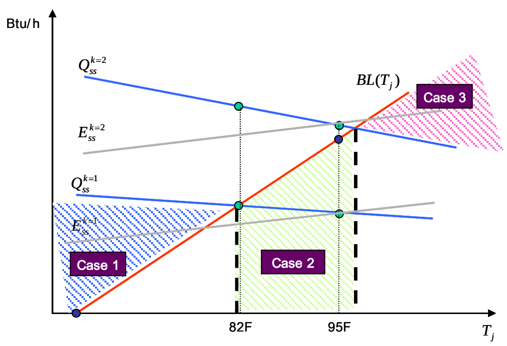


Figure 2: Performance of cooling with compressor capacity modulation

4. Main Effects of SEER

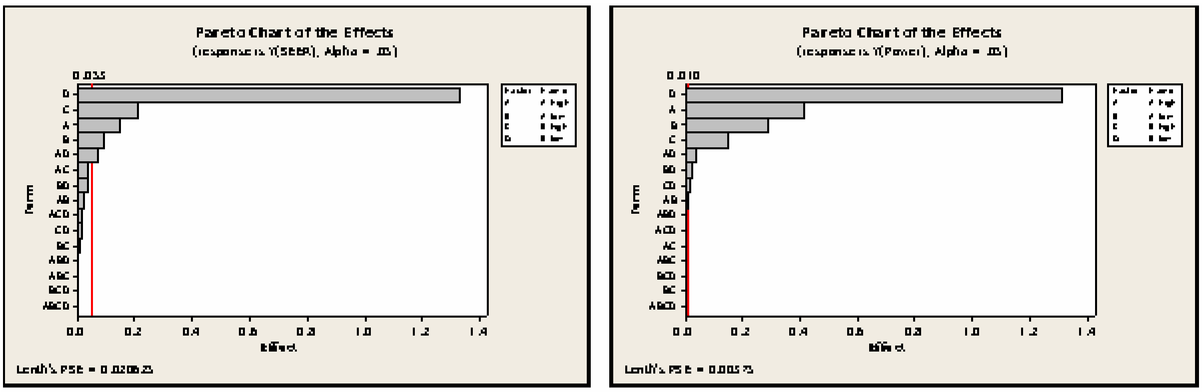
The SEER of two-speed modulation system can be obtained from A,B test at ARI standard rating condition, Table 4, by each stage (low, high) operation. Therefore, four tests were required. To examine the effect of these four test factors, 2^4 full factorial analysis was performed with a MINITAB® release 14 (commercial statistics s/w, Minitab Inc). The standard performance data was obtained by measurement at ARI A,B test with our 5RT grade unitary system that would be mentioned at chapter 6 (Measurement Set Up). Table 2 shows each 2-level of four-factors was designed to ± 5% variation of its standard performance. Performance means the cooling capacity and power consumption. Figure 3 shows the Pareto Chart (a Pareto Chart is used to graphically summarize and display the relative importance of the differences between groups of data) of 24 full factorial analysis and low stage at B test condition was identified as a dominant factor in increasing SEER. It shows the same result with both cooling capacity and power consumption. It means that PLF (Part Load Factor) is very important to actual energy efficiency. It means that the efficiency at the low cooling load is more crucial than that at the standard cooling load condition.

Table 1: Factors & Levels (2^4)

Factor	Level	
A High	-1 (-0.5%)	+1 (+0.5%)
A Low	-1	+1
B High	-1	+1
B low	-1	+1

Table 2: 2^4 DOE table

A high	A low	B high	B low
1	-1	1	1
-1	1	1	1
-1	1	-1	1
1	-1	-1	-1
1	1	1	1
-1	1	1	-1
-1	1	-1	-1
1	-1	1	-1
-1	-1	-1	-1
1	1	1	-1
-1	-1	-1	1
-1	-1	1	1
-1	-1	1	-1
1	1	-1	-1
1	-1	-1	1
1	1	-1	1



(a) Cooling capacity effect (b) Power consumption effect

Figure 3: Pareto Chart of 2^4 simulation result

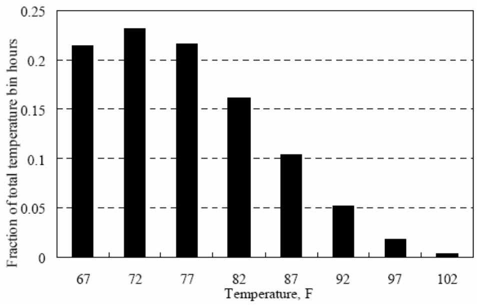


Figure 4: The distribution of fractional hours in temperature range (ARI)

Figure 4 shows the distribution of fractional hours in temperature range stipulated in ARI standard. It also shows that the PLF at low cooling loads is more important in SEER than those at higher cooling loads. The MPS system focused on this point, and the smaller compressor size of the two compressors was optimized to give the best PLF[4]. It resulted in the tremendous SEER improvement.

5. Multi Power System (MPS)

There are many ways in achieving capacity modulation, such as Multiple cylinder, By-pass, Pole change compressor, and Frequency change. Each of these methods has merits and demerits, and is used at different operating conditions. MPS is one of the methods of capacity modulation to improve SEER, with merits of simple structures and low costs. Two compressors method, which is typical example of multiple cylinder method, is shown in Figure 5. When the cooling load is high, all compressors operate to meet with high cooling load, and if the cooling load is low, only one compressor goes in working condition because the cooling load is low. Moreover, if capacities of two compressors are different, one operation step can be added. This type is expected to be high efficiency because by-pass loss in only one compressor operation is avoided in comparison with any other by-pass modulation method.[5] The test of two-compressor system has been carried out under the same conditions and only the combination of each compressor's capacity is varied.

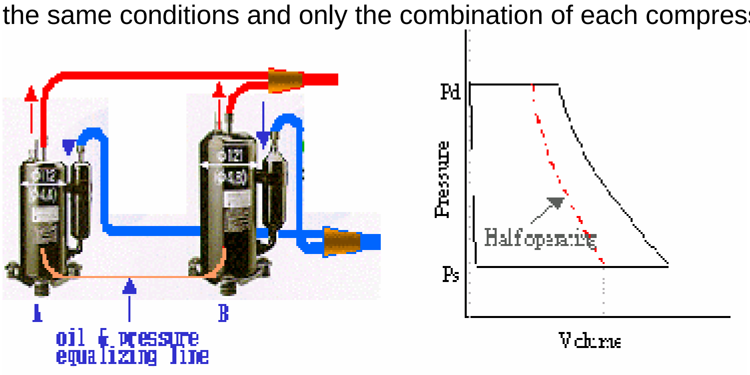


Figure 5: Two-compressor system

The expansion valve was optimally controlled to correspond with the compressors. The variation of efficiency corresponding to capacity modulation ratio(R) is shown in Figure 6. The capacity modulation ratio means the relative performance of the one out of two compressors when total capacity of the two is set to 100%. As for the equal condition, the smaller capacity compressor records the higher COP as by the left side of Figure 6. The equ.(3) and (4) for the system performance corresponding to compressor capacities has derived and we found that the optimum capacity modulation ratio makes the maximum SEER. Those equations were curve-fitted from the cooling capacity and the power consumption data.

(3) $$Q = -0.0135 \times R^2 + 2.5864 \times R - 23.519$$

(4) $$W_{com} = -0.0049 \times R^2 + 1.8229 \times R - 32.969$$

Where the COP was obtained from the equ.(5), and the power consumption of the fan was measured.

$$COP = \frac{Q}{W_{comp} + W_{fan}} \tag{5}$$

From the above result of the system performance corresponding to capacity modulation, the optimal capacity ratio of the compressors has been determined. Although the smaller capacity compressor records the higher COP as stated above, the driving range of good efficiency under smaller capacity compressor operating would be reduced relatively if the compressor capacity ratio is too small. This can bring the bad effect to SEER as shown in the right side of Figure 6. SEER is given with the each capacity ratio by KS standards (KSC9306 appendix 5.3) and the optimal capacity ratio has been found at the minimal load operation of 40% as a result shown in Figure 6.

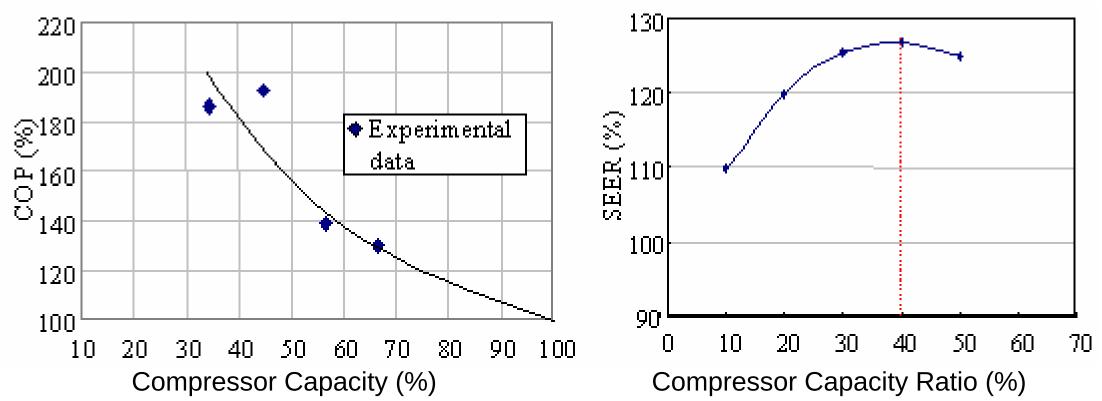


Figure 6. Performance of cooling with compressor capacity modulation

6. Measurement Set Up

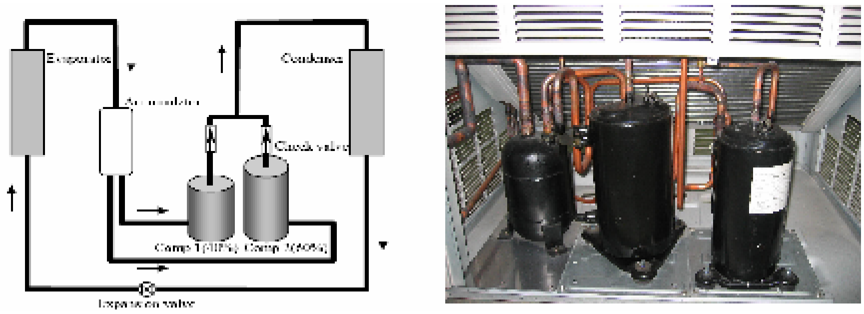
To verify the efficiency performance, MPS system with two-AC fixed type rotary was designed as Figure 7. Compressor capacity ratio was set up about 40% because of increasing SEER as result in Figure 6. A common accumulator was adapted for protection against liquid back and electronic expansion valve was used to control the mass flow at each 3 stage (low, middle, high) operation and super heat. It would be very simple structure and there is no need to equip a special circuit such as inverter drive. And it could be substitution with low cost comparatively instead of a hugely capable and expensive one compressor. But there are some cautions that should be attributable to two-compressor driving mechanism such as oil return, oil equality, pipe vibrations for reliability. All tests have been progressed with our psychrometric type calorimeter that was satisfied with ISO standard and Figure 8 shows its details. A universal air-conditioner that consisted of DC rotary type compressor was selected as another sample to compare with MPS. All the tests were performed according to the ARI standard, with the EER measurement under condition A, and the SEER measurement under conditions A and B in table 4.

Table 3. 2^4 DOE table

Sample #.	1	2
Model	MPS	INVERTER
Compressor type	AC ROTARY	BLDC ROTARY
#. of Compressors	2	1
Voltage	230V/60Hz	220/60Hz
Rated COP	3.4	3.6
Rated SEER	16	-

Table 4: Tested condition (ARI standard)

Condition		Indoor	Outdoor
A	DB	80°F	95°F
	WB	67°F	75°F
B	DB	80°F	82°F
	WB	67°F	65°F



(a) The schematic diagram (b) Compressor set up

Figure 7: MPS system with two-compressors

Verification with ETL sample test & satisfied within ±2% accuracy

Control target	Calrorimeter Range	
	INDOOR	OUTDOOR
Dry- bulb (℃)	15 ~ 45	- 20 ~ 60
Wet- bulb (RH%)	20 ~ 95	20 ~ 95
Air flow (CMM)	5 ~ 100	
Cooling (Kcal/hr)	1,000 ~ 25,000	
Heating (Kcal/hr)	1,500 ~ 32,500	

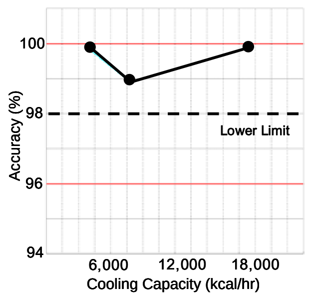


Figure 8: Details of facility that was used this study

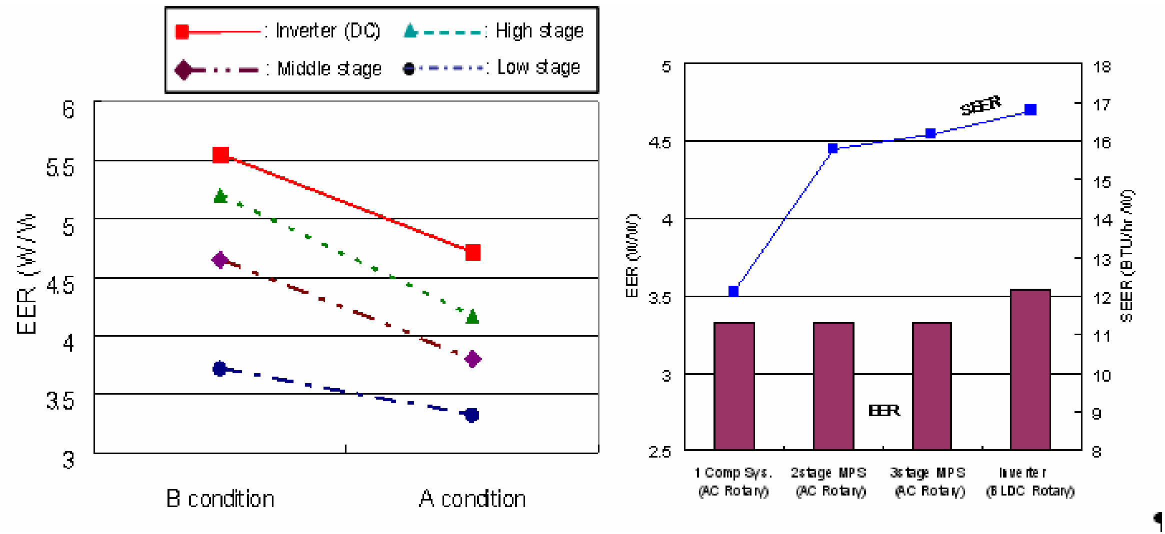
7. Efficiency Test and Results

EER & SEER test has been studied with different type of air-conditioner as follows;
[1] Inverter system with one BLDC rotary compressor
[2] MPS with two-fixed AC rotary compressors and it operates 2-stage driving (low, high)
[3] MPS with two-fixed AC rotary compressors and it operates 3-stage driving (low, middle, high)
[4]* MPS with two-fixed AC rotary compressors but it operates only 1-stage driving (high)
(* This can be regarded as just one-compressor system because it always operates full capacity.)

Table 5 shows the test results, EER and SEER, and Figure 9 describes it as graph. From the test results, the SEER 16.8 of Inverter system was highest value at this measurement and its EER 3.54 was good to the other system. But the SEER 16.2 of 3 stage MPS system was also good and similar to Inverter system although its standard EER 3.32 was equal to one-compressor system. Moreover, the SEER 12.1 of one-compressor system was very weak value compared to the other capacity modulated system. These results explain the importance of countermeasures to part load condition. As shown in Figure 9, under the lower stage operation at any temperature condition, system EER was more increased than compared to its higher stage operation. It was caused by cycle effects that the heat exchange performance would be increased when the compressor capacity was reduced with the same size of heat exchangers. This mechanism was also shown in Figure 6 and this is the key factor of why the MPS system's SEER is always higher than those of one-compressor system.

Table 5: Test result

Type of Sys.	Standard EER (W/W)	SEER (Btu- hr / W)
1 Comp Sys. (AC Rotary)	3.32	12.1
MPS Sys. (AC Rotary) with 2 stage	3.32	15.8
MPS Sys. (AC Rotary) with 3 stage	3.32	16.2
Inverter (BLDC Rotary)	3.54	16.8



(a) EER of each operation stage (b) EER & SEER of each system

Figure 9: EER & SEER test result of each type sys.

The SEER of MPS system can closely approach Inverter system when lower stage operation should be optimized to part load condition. Moreover, MPS system could be very effective air-conditioner because of its lower cost than any other capacity modulated system such as Inverter type. This can be another advantage of MPS system.

8. Conclusion

In this study, the EER and SEER were compared between the MPS and the variable compressor driven air-conditioner. The ARI standard 210/240 with A and B tests with high and low stage operation, was adopted in SEER measurements. The factorial analysis was carried out to find out the relative importance of the factors, which contribute to the SEER.

(1) From the results of 2^4 full factorial analysis, the low stage at B condition was found to be the most dominant factor in increasing the SEER of MPS system. It means that the PLF is the major factor in the actual reduction of the year round power consumption.

(2) The MPS air-conditioner with 3-stage operation was almost as good as the BLDC type inverter system with SEER 16.2 although it showed a low value of EER, 3.32, the same as that of the single compressor system. Thus, there could be an air-conditioner with low EER, but with high SEER.

Above results shows that the EER value cannot represent the actual energy consumption and the concept of the SEER should be implemented to save energy cost. From the view point of year round power consumption, this is the advantage of MPS system with its lower cost merits compared to Inverter system.

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Strategies for Improving HVAC Efficiency with Quality Installation and Service

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Robert Mowris & Associates

Abstract

Residential and commercial air conditioning use the largest share of electricity demand in the United States with approximately 33% or 344 GW and 313 TWh. Space heating uses 5.08 quadrillion Btu per year or 57.3% of total residential and commercial gas consumption in the US. There are approximately 93 million air conditioners and 35 million furnaces in the US. Each year 6 million new air conditioners and 3.5 million new furnaces are installed. Research shows 50 to 70% of heating, ventilating, and air conditioning systems have improper refrigerant charge and airflow, leaky ducts, over-sized units, mismatched coils, or improper maintenance/operation causing them to be 10 to 40% less efficient than if they received quality installation or service (QIS). Significant energy and peak demand savings can be achieved with following measures: proper refrigerant charge/airflow, duct testing/sealing, cleaning condenser coils, proper-sized coils, matching coils, economizer maintenance, and cool roofs/attics. The historic market barriers to HVAC QIS measures include: organizational practices, high start-up costs, service availability, performance uncertainty, and lack of information. Innovative strategies are required to overcome these market barriers such as customer education, marketing, incentives, standards, labels, and verification service providers to train and equip HVAC technicians to deliver QIS measures. This paper provides an overview of energy savings, market barriers, and strategies in the US to improve HVAC efficiency with QIS and transform the market.

Introduction

Air conditioning uses the largest share of electricity demand in the United States with approximately 33% or 344 GW of total residential and commercial consumption [1]. Space heating uses the largest share of gas in the US with approximately 57.3% or 5.08 quadrillion British thermal units (Btu) per year of total residential and commercial gas consumption.[1] Annual air conditioning electricity consumption is approximately 161 TWh for residential and 152 TWh for commercial. Annual space heating consumption is approximately 3.32 quadrillion Btu for residential and 1.76 quadrillion Btu for commercial. There are approximately 93 million air conditioners and 35 million furnaces in the US. Each year 6 million new air conditioners and 3.5 million new furnaces are installed [2]. Energy efficiency programs have historically provided incentives to encourage customers to purchase high efficiency equipment to reduce heating, ventilating, and air conditioning (HVAC) energy use. This only captures a small portion of potential savings. Research shows 50 to 70% of HVAC systems have improper refrigerant charge and airflow, leaky ducts, over-sized units, mismatched coils, or improper maintenance/operation causing them to be 10 to 40% less efficient than if they received quality installation or service [3, 4, 5, 6].

Significant energy and peak demand savings can be achieved with following QIS measures: proper refrigerant charge/airflow, duct testing/sealing, cleaning condenser coils, proper-sized coils, matching coils, economizer maintenance, and cool roofs/attics. This paper provides a brief description of each measure along with field measurements and supporting information. The paper provides an overview of market barriers to HVAC QIS and how these market barriers are addressed by third-party verification service providers. The paper discusses program implementation strategies to improve HVAC efficiency with QIS including customer education, marketing, incentives, standards, labels, and verification service providers (VSPs) to train and equip HVAC technicians to deliver QIS measures. The paper also provides an overview of US efforts to address QIS and how these efforts should be improved to transform the market.

[1] The British Thermal Unit (Btu) is the energy required to raise one pound of water one degree Fahrenheit.

Energy Savings for HVAC Quality Installation and Service Measures

This section provides descriptions and energy savings associated with the following HVAC QIS measures: 1) proper refrigerant charge/airflow (RCA), 2) duct testing/sealing, 3) cleaning condenser coils, 4) proper sized coils, 5) matching indoor/outdoor coils, 6) economizer maintenance, and 7) cool roofs/attics.

Refrigerant Charge and Airflow

Proper refrigerant charge and airflow improve the efficiency and longevity of split-system and packaged air conditioning systems. Average energy and peak demand savings for proper RCA are approximately 9 to 12 percent for kWh and kW based on field measurements and the 2004-2005 Database for Energy Efficiency Resources Update Study [7]. Several studies show approximately 40 to 67 percent of air conditioners suffer from improper RCA, and this reduces efficiency by roughly 10 to 20 percent [2, 8, 9]. A study of commercial units in California found 46% were improperly charged causing reduced cooling capacity and efficiency [10]. The study found 39% had very low airflow rates (< 300 cfm/ton).[2] The average airflow rate of all units tested was 325 cfm per ton or 20% less than the airflow generally used to rate efficiency. Improper charge and reduced airflow results in reduced efficiency and cooling capacity. The average energy impact is 9 to 12 % of annual cooling energy.

Most air conditioning technicians in the United States do not have proper training, equipment, and verification methods to diagnose and correct improper RCA. Consequently, many new and existing air conditioners have improper RCA causing reduced efficiency, noisy systems, and premature compressor failure. To address this problem, the California Energy Commission (CEC) adopted residential building standards in 2001 (CEC Standards) requiring either the Alternative Calculation Method (ACM), thermostatic expansion valve (TXV), or proper RCA [11]. Most air conditioners are installed using the ACM which is a computer method to show compliance with the annual energy budget requirements of the standards. The standards require inspections by Home Energy Rating System (HERS) raters to verify installation of TXV or proper RCA under the prescriptive approach or the ACM. The CEC allows a TXV to substitute for proper RCA based research findings from three laboratory studies showing improper RCA can be mitigated by a TXV [12, 13, and 14]. The studies found TXV systems only had an advantage over non-TXV systems when undercharged.

TXV-equipped systems have problems when incorrectly installed leading to a phenomenon known as "valve hunting." This can occur when the evaporator coil experiences reduced heat loads caused by low airflow, dirty or icy coils, and low refrigerant charge [15]. Under these circumstances the TXV can lose control and successively overfeed and then underfeed refrigerant to the evaporator while attempting to stabilize control causing reduced capacity and efficiency. Overfeeding liquid to the evaporator can also damage the compressor. The tendency for hunting can be reduced by correcting RCA, by relocating the TXV sensing bulb to a better location inside the evaporator coil box, and by insulating the sensing bulb. Field and factory-installed TXV sensing bulbs are often installed without insulation, without adequate linear contact, and at incorrect orientations. This practice is not recommended by manufacturers [16]. Factory-installed TXVs with un-insulated sensing bulbs inside the evaporator coil box will be influenced by mixed supply-air temperatures which are typically 10-20°F higher than vapor line temperatures. Field-installed TXVs with un-insulated sensing bulbs located in attics or garages will be influenced by attic or garage temperatures which are 50 to 80°F higher than vapor line temperatures. The three laboratory studies measured TXV-equipped air conditioners with the evaporator coil box, TXV, and well-insulated sensing bulb located in conditioned space and this is not typical of field conditions.

Field measurements for a 4-ton TXV air conditioner are shown in **Figure 1** [2]. The TXV air conditioner used 5.8 kW when overcharged and 4.8 kW when properly charged for a savings of 1 kW. The energy efficiency ratio (EER) increased by 37 percent from 7.1 EER to 9.7 EER.[3]

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[2] The "cfm" is defined as cubic feet per minute of airflow. The "ton" is defined as 12,000 Btu per hour of cooling capacity equal to the rate of extraction of latent heat when one short ton of ice (i.e., 144 Btu per pound) is produced from water at the same temperature.

[3] The energy efficiency ratio or EER is the cooling capacity in thousand Btu per hour (MBtuh) divided by total air conditioner electric power (kW) including indoor fan, outdoor condensing fan, compressor, and controls. EER is typically measured under laboratory conditions at 95°F condenser entering air, 80° F drybulb,and 67° F wetbulb evaporator entering air.

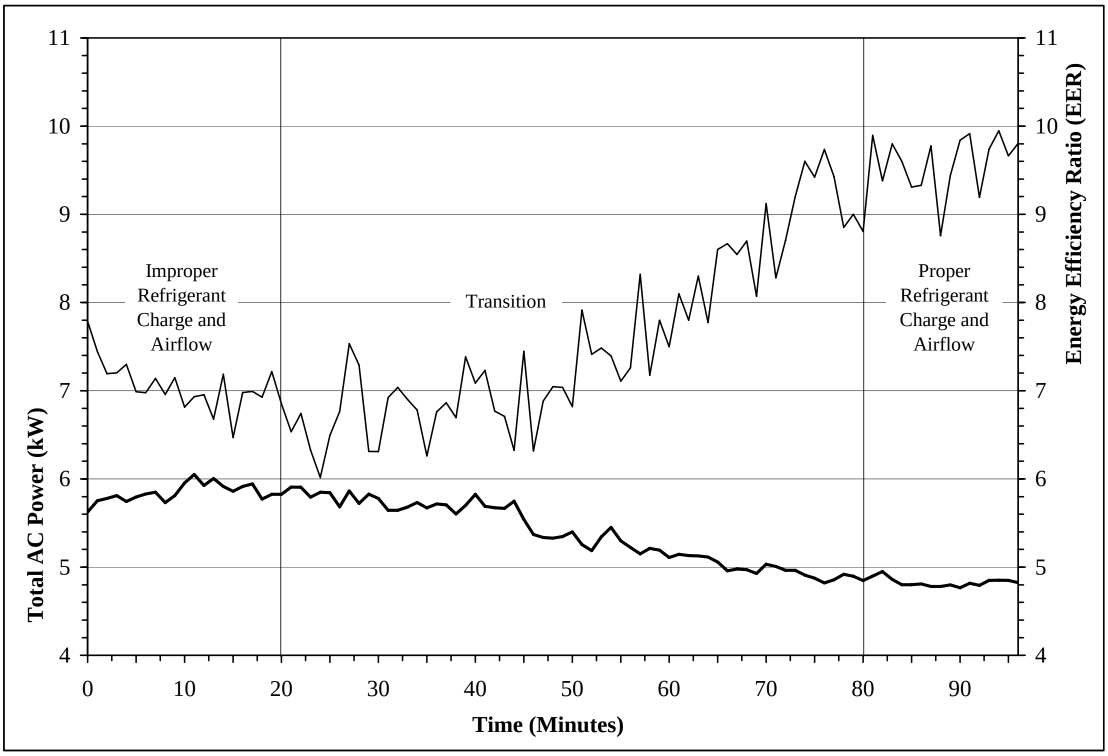

Figure 1. Measurements of a 4-ton TXV Unit with and without Proper RCA Source: [2]

Measurements of a 10-ton packaged rooftop air conditioner with and without proper RCA are shown in **Figure 2**. The 10-ton unit had a dirty/icy evaporator coil and dirty air filters and was overcharged by 14.2 ounces or 7.1 percent of the factory charge. With improper RCA the average efficiency was 5.7 EER, and average power usage was 13 kW. With proper RCA the efficiency improved to 10.3 EER, and the average power was reduced to 9.5 kW. This is consistent with the ARI rating of 10.3 EER.

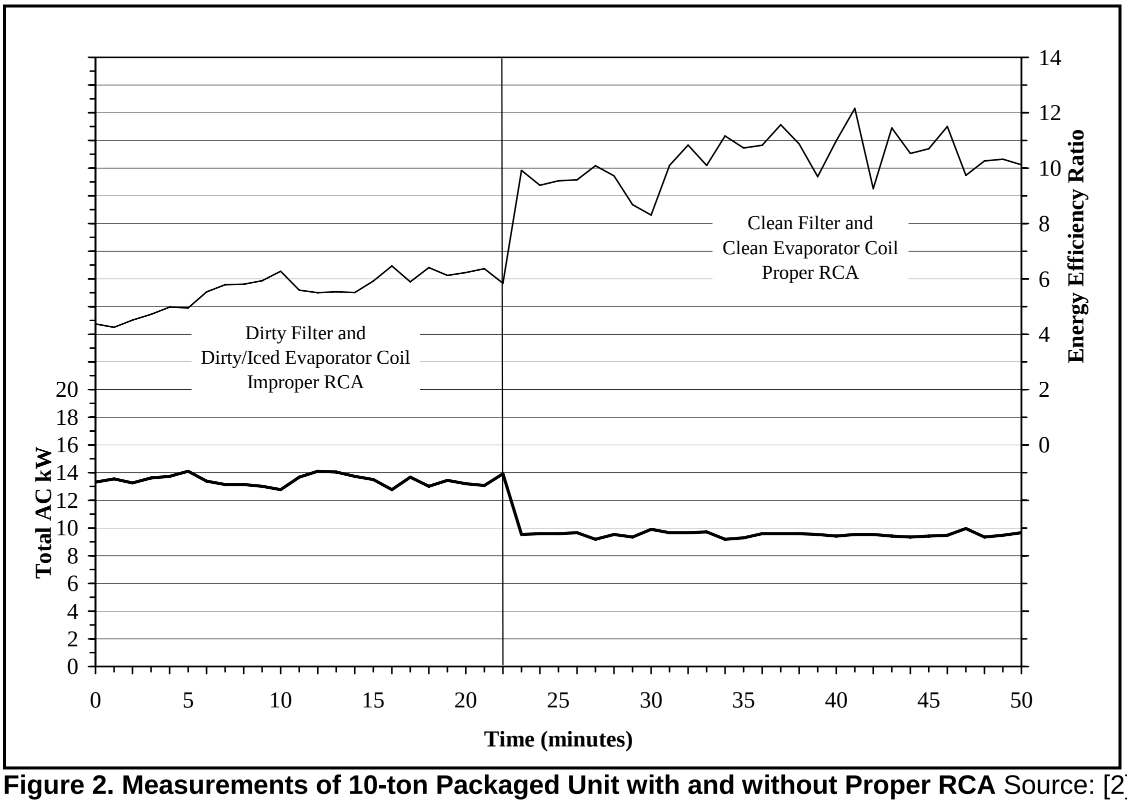

Figure 2. Measurements of 10-ton Packaged Unit with and without Proper RCA Source: [2]

Duct Testing and Sealing

Duct testing and sealing reduces duct leakage and run time and improves efficiency of heating, ventilating, and air conditioning systems. Average energy and peak demand savings for residential duct testing and sealing are 5.8 to 8.8% for kWh and 8.4 to 27.6% for therms based on the 2004-2005 DEER Study Update [7]. Research indicates that duct leakage in commercial buildings may be comparable to residential buildings [18, 19, 20]. Ducts in commercial buildings with simple rooftop package units are often located in ceiling plenum spaces that are similar to residential attics.

Duct leakage is typically described three ways: 1) Fraction of flow through the HVAC equipment that is lost, 2) Equivalent hole size, or 3) Leakage flow at a reference pressure. The latter two are often normalized by either the surface area of the ductwork or the conditioned floor area. The ductwork in small commercial buildings is leaky by all three metrics. Using the first metric, the work at LBNL indicates the average supply duct leakage for 25 Constant-Air-Volume (CAV) systems was 26% of the flow through the HVAC equipment, as compared to average supply-side leakage of 17% in residential systems [18]. Using the second metric for the 25 systems, LBNL research showed an average normalized commercial duct leakage area of 3.7 cm^2 per m^2 of floor area for supply and return ducts. The comparable residential attic duct-leakage is 1.3 cm^2 per m^2 of floor area. These results suggest that duct leakage of some light commercial duct systems can be greater than residential systems.

Cleaning Condenser Coils

Clean condenser coils provide optimal heat transfer from the condensing coil to deliver rated capacity and efficiency for split-system and packaged air conditioners. Average energy and peak demand savings for condenser coil cleaning are 8 to 12% based on the 2004-2005 DEER Study [7]. Trane found an efficiency loss of 27 percent due to conditions of accelerated fouling for multi-row coils equivalent to 8 years of typical operating conditions or annual fouling of 6.8% for commercial multi row coils [22]. Trane provided data from a study of two air conditioners operated continuously with condensers exposed to a dirty factory environment for 18 months, and this was reported as equivalent to roughly 4 to 8 years of typical operating hours. Performance measurements indicated the air conditioner with a standard plate fin coil lost 17% of its capacity and 27% of its efficiency.

Field measurements of a packaged air conditioning unit with a leaky Schrader valve and dirty condenser coil are provided in **Table 1** [23]. The AC unit was found to be inoperable due to lack of refrigerant from a leaky Schrader valve. The leaky valve was repaired and 55 ounces of R-22 was weighed in with a digital scale to achieve proper superheat within ± 5°F.[4] Technicians then combed and cleaned the condensing coil. The cooling capacity and electric power usage were measured before and after adding refrigerant charge and combing/cleaning the condensing coil. Savings from combing and cleaning the condenser coil are estimated to be 15% based on the measured EER improvement (9.0 EER with dirty coil and 10.4 EER with clean coil).

Table 1. Field Measurements of Air Conditioner Efficiency from Cleaning Condensing Coil

Description	Rated EER 95 ODT	Rated Capacity Btuh	Rated kW	Measured EER 80 ODT	Measured Capacity Btuh	Measured kW
Leaky Schrader valve no refrigerant charge	8.5	18,000	2.1	0.2	174	1.1
Repaired leaky Schrader valve and added 55 ounces of R-22 refrigerant				9.0	19,000	2.1
Post-retrofit cleaned condenser coil				10.4	21,900	2.1

Source: [23]

Proper Sized Coils (ACCA Manual J)

Proper sized coils (per ACCA Manual J) improve the capacity and efficiency of split-system air conditioners. Energy and peak demand savings for proper sized evaporator/condenser coils per ACCA Manual J are 10 to 18 percent based on field studies showing most units are significantly oversized, resulting in inefficient operation, reduced reliability due to frequent cycling of compressors, and poor humidity control [24]. Oversized systems waste capital invested in both the HVAC unit and distribution system. System over-sizing also affects the ability of the system to provide simultaneous economizer and compressor operation, and exacerbates problems with distribution system fan power,

[4] The factory charge is 55 ounces of R-22 refrigerant, for the 1.5 ton Carrier rooftop AC unit Model 585GJ018040.

since larger units are supplied with larger fans. Each time an air conditioner starts, the input energy is approximately constant, while it takes several minutes to reach full cooling capacity. Oversized units operate for a shorter cycle, and the startup time is a greater fraction of the total runtime. The startup losses are also a greater fraction of the total cooling output, reducing overall efficiency. Systems that are properly sized will run longer during each cycle, and the startup losses are small relative to total cooling output. In a study of 250 rooftop units conducted for Pacific Gas and Electric Company, the typical runtime under hot conditions was 6 minutes, with an off-time of 16 minutes [25]. This represents a 27% runtime fraction with a reduction in unit efficiency of 18%. The system efficiency is reduced as the runtime decreases. When the unit runs continuously (CLF = 1), the part-load factor is 1.0, indicating no degradation due to cycling. When the unit runs 60% of the time, the CLF is 0.6 and the unit efficiency is reduced by about 10%. If the unit runs only 30% of the time, the efficiency is reduced by about 15% [26].

ARI Matching Coils on Split System Air Conditioners

ARI matching coils provide the rated capacity and efficiency for split-system air conditioners. Energy and peak demand savings for ARI matching coils on split system air conditioners are 5 to 15 percent based on field measurements of systems with improper matching coils. Even with correct refrigerant charge many split-system air conditioners do not perform at their rated efficiency due to improperly matching evaporator and condenser coils. Condensing coil manufacturers cannot guarantee rated efficiency per Air-Conditioning and Refrigeration Institute (ARI) SEER/EER ratings with evaporator coils manufactured by independent coil manufacturers that are not listed in the ARI directory as a proper match for the condensing coil [27]. Field measurements of two new split-system air conditioners are provided in **Table 2** [28]. Pre-EER values were measured with improper RCA, and post-EER values were measured with proper RCA. The post-EER is 6.5 or 35 percent less than the 10 EER rating due to improper matching coils. This is a common problem with split system units.

Table 2. Field Measurements for Two New Split-System Air Conditioners

Site	Rated EER	Rated Capacity MBtuh	Measured Cooling Capacity Post MBtuh	Average Outdoor, Indoor Dry/Wet Bulb °F	Airflow cfm	Duct Leak cfm @ 25 Pa	Infil. cfm @ 50 Pa	EER Pre	EER Post	Service Adjust Oz.	Percent Charge Adjust per Factory Charge
#1	10	51	38.5	105/81/65	1631	19%	1830	3.9	6.5	+98.2	+49.4%
#2	10	51	41.6	105/80/64	1734	12%	1537	5.5	6.5	+12.5	+6.3%

Note: Rated EER values are based on manufacturers' data. Source: [28]

Economizer Set-up and Maintenance

Economizer set-up and maintenance reduce unnecessary air conditioning when outdoor temperatures are cool enough to provide free cooling (i.e., reduce compressor use). Average energy and peak demand savings for commercial economizer set-up and maintenance are 9 to 21% based on the 2004-2005 DEER Study [7]. A study of commercial packaged units in California with economizers generally found 64% not operating properly [24]. Failure modes included dampers that were stuck or inoperable (38%), sensor or control failure (46%), or poor operation (16%). The average energy impact of inoperable economizers is about 37% of the annual cooling energy. The 2005 DEER Study found annual savings of 21.3%.

Selection of the changeover setpoint has a major influence on the energy savings potential of an economizer. If the changeover setpoint is set too low, then mechanical cooling will operate exclusively even when the economizer is capable of meeting the cooling load [24]. Single point changeover setpoints are selected on the economizer controller according to an A, B, C or D setting. The selection of the changeover setpoint depends on the climate; humid climates require a lower setpoint than dry climates. According to the Title 24 Energy Standards, the "A" setpoint is appropriate for all climates in California. However, observations of single point changeover setpoint selection in the PIER study behind this Design Guide showed that the "A" setting was rarely used. Manufacturers may not ship their products with the "A" setting as the default, requiring a field adjustment of the controller setting. The distribution of economizer control setpoints observed in the field for single point enthalpy economizers shows only 28% of the systems in the "A" position as required by Title 24. Most systems were set in the "D" position, which results in the fewest hours of economizer operation.

Many of the economizer problems observed in the field can be avoided through careful selection and specification of rooftop unit economizer features. The following measures will improve economizer efficiency and reliability [24].

1. **Specify factory-installed and run-tested economizers**. The majority of economizers are installed by the distributor or in the field. Specifying a factory-installed and fully run-tested economizer can improve reliability.
2. **Specify direct drive actuators.** Economizers with direct drive actuators and gear driven dampers can reduce problems with damper linkages that can loosen or fail over time.
3. **Specify differential (dual) changeover logic.** Differential temperature or enthalpy changeover logic instead of single point changeover systems eliminates problems with improper setpoint and maximizes economizer operation.
4. **Specify low leakage dampers for outside and return air.** Low leakage dampers with blade and jamb seals will improve economizer effectiveness by limiting return air leakage during economizer operation and outdoor air infiltration when the unit is switched off.

Cool Roofs and Cool Attics

Cool roofs and cool attics reduce cooling loads and improve cooling capacity and reduce run time for split-system air conditioners in residential buildings. Average energy and peak demand savings are 10 to 30% based on studies by Lawrence Berkeley National Laboratory and the Florida Solar Energy Center [29, 30]. Cool attics provide similar savings using radiant barriers or attic ventilation fans. Solar-powered or conventional attic ventilation fans with thermostat control will reduce solar heat load transferred to conditioned space and attic temperatures where air conditioner evaporators and ducts are located. Cool roofs stay cooler in the sun than conventional roofs. Roofs that have high solar reflectance (high ability to reflect sunlight) and high thermal emittance (high ability to radiate heat) tend to stay cool in the sun. The same is true of low-emittance roofs with exceptionally high solar reflectance. Low roof temperatures lessen heat flow from the roof into the building, reducing space cooling electricity use in conditioned buildings. Since building heat gain through the roof peaks in late afternoon, when summer electricity use is highest, cool roofs also reduce peak electricity demand. Prior research indicates savings are greatest for buildings located in climates with long cooling seasons and short heating seasons, particularly buildings that have distribution ducts in the plenum, cool-coatable distribution ducts on the roof, and/or low rates of plenum ventilation [30]. Prior studies measured air-conditioning energy and peak demand savings from cool roofs on nonresidential buildings in California, Florida, and Texas. Cool roofs typically have measured summertime air-conditioning energy and peak demand savings of 10–30%, although savings have been as low as 2%. Cool roofs transfer less heat to the outdoor environment than do conventional roofs. The resulting lower outside air temperatures can slow urban smog formation and increase human health and outdoor comfort. Reduced thermal stress may also increase the lifetime of cool roofs, lessening maintenance and waste. The potential of cool roofs to save cooling electricity has not gone unnoticed. In its revised standards for commercial and residential buildings, the American Society for Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) included provisions to offer credits in building energy-use budgets for cool roofs [31]. In January 2001, the state of California followed ASHRAE by adopting standards to offer Title 24 compliance credit to new commercial buildings with cool roofs [11]. Georgia, Florida, and Chicago also have building codes to encourage cool roofs.

Market Barriers

There are many market barriers to HVAC quality installation and service (market barrier definitions are from 32). Performance uncertainty is an important barrier since consumers have difficulty evaluating claims about future benefits associated with unverified energy guide performance labels. Truth in advertising is important to consumers who assume new units will be installed properly. Unfortunately, many new air conditioners do not perform as advertised due to improper installation or service, and this undermines the credibility of the US energy guide labels [33]. At a minimum, the labels should include a caveat regarding SEER ratings only being valid for air conditioners installed with quality installation and service according to manufacturers' specifications. Other important market barriers include lack of information or knowledge about the importance of quality installation and service in terms of delivering rated efficiency, reducing noise, and maintaining longer life of air conditioners. Organizational practices and rules of thumb discourage quality installation such as "add or remove refrigerant until the suction line is six-pack cold" or "shows 70 psig on the suction side and less than

250 psig on the liquid line." Service availability for new air conditioners is an important barrier for manufacturers, distributors, and dealers who are generally not verifying quality installation and service due to lack of awareness and availability of cost effective and easy-to-use verification services.

These market barriers are addressed by third-party verification service providers such as: Verified™, Enalasys™, Honeywell Service Assistant™, and CheckMe™ [34, 35, 36, 37]. VSPs offer cost-effective methods to verify proper RCA, TXVs, duct testing/sealing, and other measures. Verification software is provided on several platforms: 1) Personal Digital Assistant (PDA), 2) cell-phone telephony, 3) web-enabled PDA, 4) cell phones, 5) notebook computers, or 6) telephone call-in systems. VSP programs can be deployed in any language, and since the systems are automated, the cost per verified unit is low. Verification information is collected and archived on databases where technician-supplied data is checked for accuracy and can be viewed over the internet by consumers, inspectors, dealers, and program managers. The VSP randomly inspects jobs to ensure quality results. One third-party VSP provides clearly identifiable Verified™ labels and locking, double-sealing, laser-etched Schrader caps, with tamper-proof keys for technicians. Locking caps are designed to maintain proper RCA for the life of the air conditioner. This is important since air conditioning systems are made of welded copper pipe and Schrader valves are the weakest link. Air conditioners vibrate and this causes Schrader valve cores to loosen over time and leak refrigerant. Most air conditioners have easily removable Schrader caps without integral "O-ring" seals. Safety is another reason why locking Schrader caps are important as evidenced by the deaths of two teenagers in Southern California due to inhalation of refrigerant as an intoxicant [38].

Strategies

A number of intervention strategies are required to improve HVAC efficiency with quality installation and service such as third-party verification service providers, customer education, marketing, training, incentives, standards, and labels. Third-party verification service providers are required to train and equip HVAC technicians to deliver and verify quality installation and service. Customer education, standards, and labels are important to create demand for QIS. Incentives will help motivate interest, but are insufficient by themselves to deliver HVAC QIS and transform the market. Consumers generally assume their air conditioners are properly installed. Current efficiency standards do not mention the importance of QIS, and California building standards allow a TXV to substitute for proper RCA to receive the same compliance credit. Therefore, most consumers and builders do not understand the value of proper RCA. Research studies show HVAC dealers lack interest, training, equipment, and methods to perform proper installation and service measures such as RCA and duct testing/sealing measures. To develop a robust set of supply-side market actors, Verification Service Providers (VSPs) must recruit, train, and equip local HVAC dealers to deliver HVAC QIS measures.

Several utility programs in the United States offer verification service provider incentive programs. Most programs do not include the new construction market and most programs are implemented through only one VSP. This is a problem for HVAC dealers who are trained and equipped to perform HVAC QIS with a different VSP. Switching to a different VSP to participate in a program creates unnecessary barriers and can cost thousands of dollars per technician. Having a different program in each utility service area creates problems for larger HVAC contractors who have an established VSP relationship. Classroom training on quality installation will not be effective without VSP involvement to increase participation and help transform the market for third-party verification. With greater participation, there will be more demand and competition for QIS. Competition will expand the market and drive down the incremental measure cost to the point where QIS is "standard practice" and incentives can eventually be withdrawn (i.e., exit strategy).

Utilities and government agencies should consider implementing comprehensive and consistent HVAC programs targeting new and existing residential and commercial market segments. The following measures should be considered: 1) proper refrigerant charge/airflow, 2) duct testing/sealing, 3) cleaning condenser coils, 4) proper sized coils, 5) matching indoor/outdoor coils, 6) economizer maintenance, and 7) cool roofs/attics. VSPs and Home Energy Rating System providers should work together to recruit, train, and equip HVAC contractors to help transform the market for third-party verification of quality installation and service for both new and existing construction. Programs should consider internet or database registration and permanent labels for identification and facilitation of evaluation, measurement, and verification inspections. Locking Schrader caps should be promoted for RCA measures to help maintain efficiency, promote public health and safety, encourage proper refrigerant management practices, and prevent further stratospheric ozone depletion [39]. Programs should work with manufacturers to incorporate HVAC quality installation and service standards within warranty requirements, ASHRAE, and the International Standards Organization Technical Committee 86 (ISO, refrigeration and air conditioning, www.iso.org).

Conclusions

Energy efficiency programs have historically provided incentives to encourage customers to purchase high efficiency equipment to reduce HVAC energy use, but this only captured a small portion of potential savings. Research shows 50 to 70% of HVAC systems have improper refrigerant charge and airflow, leaky ducts, over-sized units, mismatched coils, or improper maintenance/operation causing them to be 10 to 50% less efficient than if they received quality installation or service. With approximately 93 million air conditioners and 35 million furnaces in the US and 6 million new air conditioners and 3.5 million new furnaces installed each year, the estimated potential energy savings from HVAC QIS are significant. These savings can be achieved through a number of intervention strategies aimed at downstream, midstream, and upstream market actors including: education, marketing, training, incentives, standards, and labels. One of the most important strategies for success is developing and supporting a robust supply-side verification service provider network to train and equip HVAC technicians to deliver and verify quality installation and service. Utilities and government agencies should encourage manufacturers, distributors, and HVAC dealers to work with VSPs to improve HVAC efficiency with QIS. Utilities and government agencies should also motivate consumers to demand HVAC QIS through education, marketing, incentives, standards, and labels.

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Posters

The Panpower Transformer

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Abstract

Target:
To develop an energy- and cost-efficient linear power supply transformer that will meet future requirements on low no-load (standby) power consumption and high efficiency rate during load.

Method:
To combine the advantages and to eliminate the disadvantages of existing technologies, the EI-core transformer and the Toroidal-core transformer. The low production cost of the EI-core transformer is combined with the superior electrical performance of the toroidal-core transformer. Winding of a straight bobbin which is formed to a circular shape after the winding is completed and after that insertion of the electro-steel core-band into the toroidal bobbin.

Result:
- The PanPower toroidal (circular) shaped high performance linear power supply transformer which easily can be produced in small sizes down to 1VA output or even less.
- A linear power supply transformer that will meet future requirements on low no-load (standby) power losses and high efficiency rate during operation.
- A simple and fast manufacturing process in combination with less materiel use resulting in lower total cost than even the conventional EI-core transformer.
- A low cost and energy efficient linear power supply transformer with small size and low weight generally available for all transformer manufacturers.

Conclusions:
Future requirements on reduced no-load (standby) power losses and increased efficiency rate during operation will be unachievable for the today most commonly used transformer, the EI-core transformer. The superior conventional toroidal transformer is too expensive. A new linear transformer technology is needed to meet future market and legal demands. The new high performance linear power supply transformer, the PanPower transformer meets future requirements on energy saving at very low cost to the benefit of the environment and the end user.

General situation

During the last decade the marked for external power supplies and battery chargers has in a literal sense exploded. Mobile phones, portable A/V-products, laptop PC's, numerous of IT products, power tools etc. are powered by external power supplies "EPS".
Many of these EPS-units suffer from poor performance both in terms of far too high standby power consumption and too low efficiency rate in operation mode.
A large number of these EPS are permanently connected to the mains, also when not in use, resulting in energy waste.
Also a large number of internal power supplies "IPS" suffer from poor performance with especially too high standby power consumption.
Energy saving is on the agenda almost everywhere and future regulations on reduction of the standby losses and increased efficiency are expected to come all over the world.

Power supply technologies

Most EPS and IPS units are based upon either the linear technology or the switching technology. Both technologies have their advantages and disadvantages.
During the last decades almost all R&D-work on power supplies has been focused on the switch mode power supply (also called electronic transformers) while very little or almost nothing has been done for improvement of the linear power supply (conventional transformers).
The result is large quantities of poor linear EPS/IPS units still in use causing energy waste.
Already several years ago PanPower AB understood the intolerable situation and decided to seek for ways for improvement of the linear transformer.

Linear technology

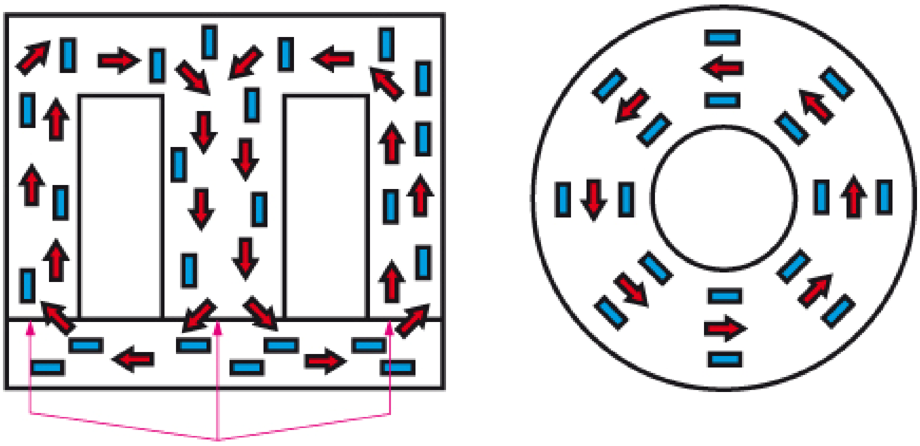
Why use linear technology

In certain sizes the linear power supply (EPS & IPS) is a low cost alternative for the benefit of the end consumer.
The linear transformer is robust and solid making it very durable, reliable and almost immune against incoming transients. Suitable for markets with poor mains network and severe (i.e tropical) weather conditions.
For AC/AC operation linear is the only low cost technology available.

Types of linear power supplies

Almost all linear EPS units are based upon two types of transformers, the most commonly used, the EI-core transformer (> 95%) or the less used Toroidal-core transformer (< 5%).

EI Core **Toroidal Core**

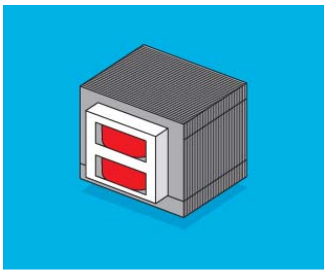


air-gaps resulting in lower performance

orientation of the magnetic flux in the core material

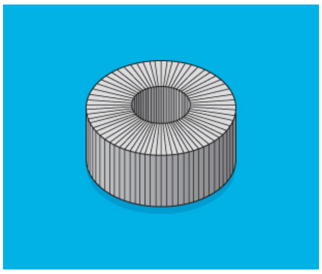
orientation of the magnetic domains in the core material

To use the core material in the best way, the magnetic flux and the magnetic domains shall have same orientation.



Characteristics of the EI-core transformer

- Low production cost, simple and fast production.
- Poor geometrical configuration of the iron-core leading to energy waste.
- Air-gaps in the iron-core also leading to energy waste.
- High standby energy loss.
- Low efficiency rate in operation mode.
- Robust against transients, incoming disturbances.
- Large size and weight.
- Difficult to meet future requirements on energy saving.



Characteristics of the Toroidal-core transformer

- High production cost.
- Not suitable for high volume mass production because of time-consuming production.
- Perfect geometrical configuration of the iron-core and no air-gaps resulting in low energy waste.
- Lower standby energy loss.
- Higher efficiency rate in operation mode.
- Robust against transients, incoming disturbances.
- Smaller size and lower weight.
- The winding method using a shuttle making production of small size transformers <15VA impossible.
- Will meet future requirements on energy saving.

The PanPower linear transformer

Overall targets

- To develop a new generation of low cost energy efficient linear transformers available for the open market and which shall replace the EI-core transformer.
- The transformer shall allow very fast and simple high volume mass production.
- The transformer shall be suitable for both manual and automatic production.
- The transformer shall meet future market requirements in terms of both low standby energy loss and high efficiency rate in operation mode. The target shall be to meet the requirements primarily in the Energy Star and as far as possibly in the European Code of Conduct programs for EPS. Reference to below table.
- The transformer shall be possible to produce in small sizes down to around 1 VA.
- Weight and size shall be less than what is typical today, limited use of raw materials and no material waste in production.
- Lower price compared with existing technologies.
- The targets shall normally be possible to reach even when using standard low cost non-oriented silicon-steel.

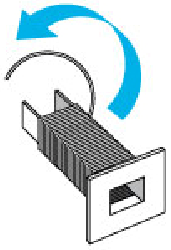
Energy Star and Code of Conduct no-load (standby) power loss and efficiency rate limits.

Output power	**Max no load power consumption**		**Efficiency rate**
	Energy Star	**Code of Conduct**	
1 VA	0.5 W	0.3 W	49 %
2 VA	0.5 W	0.3 W	55 %
5 VA	0.5 W	0.3 W	63 %
10 VA	0.5 W	0.3 W	70 %
15 VA	0.75 W	0.3 W	73 %

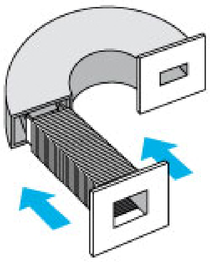
Method

Because of the energy saving targets PanPower AB decided to focus on the toroidal-core technology. The general idea has been to make use of and combine the advantages of the EI-core and Toroidal-core transformers and to eliminate all their disadvantages.
The target was to keep and even reduce the low production cost of the EI-core transformer, to overcome the time-consuming production method of the Toroidal-core transformer and to make production of small size transformers, commonly used in EPS, possible.

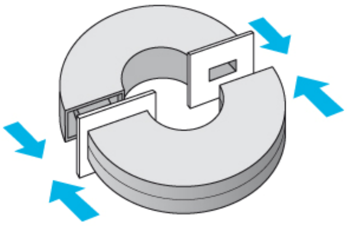
By deleting the conventional toroidal winding method using a shuttle and replace it with conventional winding of a straight bobbin, the production speed can be increased more than 100 times compared with the production time of a conventional toroidal transformer and it will allow production of small sized transformers.
To make this possible we had to develop a completely new production method for the toroidal-core transformer which can be described as follows:



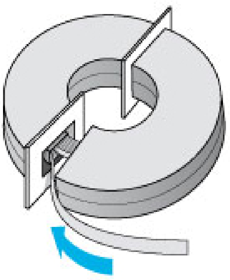
1. **To make a straight winding on a slave-bobbin using a conventional high speed winding machine. There will be separate bobbins for the primary and secondary windings.**



2. **To transfer the straight winding from the slave-bobbin to a toroidal shaped master-bobbin. The master-bobbin is divided in two parts, one for the primary and one for the secondary windings.**



3. **The two master-bobbin halves are connected to each other to form a complete toroid.**

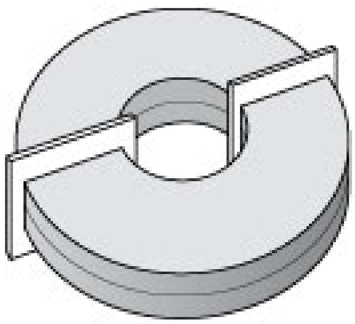


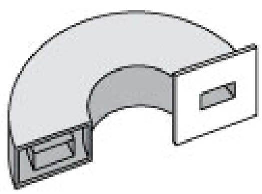
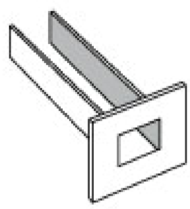
4. **The electro-steel core-band is inserted into the cavity of the two bobbin halves to make a complete toroidal transformer.**

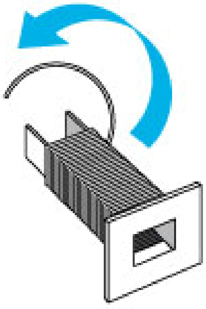
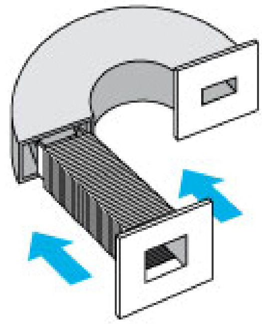
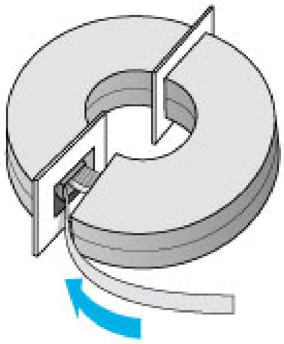
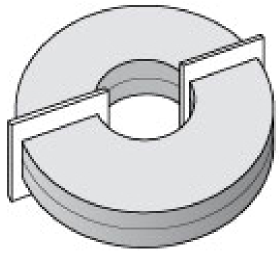
Result: The PanPower Transformer

- Simple high speed winding of a straight bobbin.
- Simple high speed production process, low cost production.
- Allowing simple near to market production.
- Possible to produce in small sizes down to 1 VA or even less.

- The window area (centre hole) can be reduced to a minimum resulting in smaller size, less material use and lower energy loss.
- Low standby energy loss and high efficiency rate in operation mode.
- No stamping of core material, no material waste.
- Small size and low weight.
- Low price, even lower than for the EI-core transformer.
- A robust, solid, low cost transformer with a long lifecycle and which will meet future global requirements on energy savings, in most cases even when using standard non-oriented low cost silicon-steel.
- An energy efficient low cost linear transformer for the benefit of the environment and the end consumer.
- A new generation of linear power supply transformers replacing the EI-core transformer.
- The PanPower transformer is expected to go into first mass production during the 2^{nd} half of 2006 and will be available for the open market on license basis.



	
1. MASTER BOBBIN	**2. SLAVE BOBBIN**

	
3. SLAVE BOBBIN WITH WINDING	**4. INSERTION OF SLAVE BOBBIN WITH WINDING INTO MASTER BOBBIN**
	
5. INSERTION OF STEEL CORE-BAND INTO THE MASTER BOBBIN CAVITY	**6. THE COMPLETE PANPOWER TRANSFORMER**

Contributions and Expectations of Energy Efficiancy Correlated with Sustainable Developement

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Abstract

The paper intends to present some important strategical actions for energy efficiency improvement, correlated with the principles of sustainable development. Also, Romania is now a country in the process of integration in the European Union.
Considering all these, Romania undergoes a process of harmonization of national legislation with the Community provisions, with a view to fulfill the commitments assumed for accession to European Union.
The Law 199/2000 has been enacted, regarding the efficient use of energy. This law intends to create the necessary legal framework for establishing and applying a national policy of efficient use of energy, according to the provisions of the Treaty of Energy Charter.
As for the energy used in the domestic sector, its evolution was remarkable in the last years. The domestic customers can choose from a large range of tariffs, unique all over the country.
Economic agents can also choose their favorite tariff, according to their energy behavior, in order to obtain the lowest average return prices.
Another principle, that suits both energy efficiency improvement and a sustainable development, is to supply consulting services to customers. The cost of electricity strongly depends on the moment and type of energy consumption. Customers' satisfaction is not the only goal. The company also gains customers' loyalty, which in the long run leads to a long partnership.
On a competitive energy market, elements like energy efficiency and sustainable development are major attributes for ensuring the market evolution in a socio-economical environment where all participants to market can benefit.

Introduction

Romania's integration in the European Union requires the achievement of significant progress in the field of efficient energy use. By using energy in an efficient manner, the energy consumptions can be reduced, thus allowing the use of less primary resources, which leads to an increase of energy supply security and the support of economical and social development, decreasing the level of financial efforts related to import of resources.
The basic elements of the process of Romania's accession to the European Union are the adoption and transposition of the "acquis communautaire". When adopting the "acquis communautaire", the following three components were considered:

a. adopting the "acquis communautaire" and drawing the secondary legislation;

b. implementation of national law by creating an institutional framework;

c. performing market monitoring activities.

The approximation of laws is limited to the essential requirements which place the products on the Community market. These requirements should be met in order to allow the products to benefit from the right to free movement in the Community market [1].

1. Legal framework

The Romanian energy legislation has been substantially enriched when the ***Law No. 199/2000 on efficient energy use,*** *republished,* was enacted. The law has in view to create a legal framework that is necessary in order to draw and apply a national policy for efficient energy use, according to the provisions of the Energy Charter Treaty, to the Energy Charter Protocol on energy efficiency and related environmental aspects and to the principles that underlie the sustainable development.

The ***Law No. 199/2000,*** *republished,* defines as a main goal of the national policy of efficient energy use obtaining the maximum benefit in the whole energy chain of generation, conversion, storage, transmission, distribution and consumption of different forms of energy. This law has been made in order to eliminate two types of restrictions noticed in the promotion of energy services

- lack of a legal basis for investments made by energy companies at the end-users, by means of applying DSM principles; in this regard, the Article 14 (1)(c) sets into a legal context the information, consulting and financing actions, as well as the execution of works for increasing the efficient use of fuels and energy in the end-users installations;
- lack of incentives for ESCO-type companies, that would make up for the negative effect of the low energy prices, which is a reason why private investments in this sector are quite unattractive; this is why Article 18 introduces a series of fiscal facilities, later cancelled by Law No. 414/2002.[2]

The Romanian law, in harmonization with the European law, sets the following principles:

- The labels and the card that accompany the electrical home appliances has to state the energy consumption and the energy efficiency class;
- The producers of electrical home appliances, their authorized representatives and the importers of such appliances have the responsibility to ensure the appropriate technical documentation.

The National Strategy for energy efficiency and the action plan related to it, approved by the Government Decision No. 163/2004, provides opening of financing for national energy efficiency programs.

The Romanian Energy Regulatory Authority – ANRE – set up a legal framework based on the respect of the energy efficiency, even if doesn't have directly competences for improvement energy efficiency.

ANRE elaborates, establishes and perform control for application of the national obligatory settlements necessary to work energy market efficiently, competitively, transparently and to assure protection of the customers.

Also according to legal arrangements, the useful efficiently of the electricity stays on the base to establish the prices and the tariffs of the electricity and the heat produced through co-generation.

At the same time, EU Directives with directly implications in energy efficiency, were transposed in Romanian legislation, in principle by the following:

- The Commercial Code of electricity market approved by ANRE Order no. 25/2004, which establishes fundamental elements, rules and mechanisms which refer to tariffs calculation and relationships between participants of the market.
- Government Decision 443/2003 regarding to promotion production electricity by renewable sources.

According to the legal provisions, the *Romanian Agency for Energy Conservation* -ARCE- is entitled to monitor the application of energy efficiency legislation, having precise duties regarding information, checking, control, but also the obligation to warn economic agents and other categories of energy end-users who don't follow the specific provisions in this field.

In order to improve energy management in industry, the Ministry for Economy and Commerce has issued the ***Order MEC No. 245/2002*** regarding the approval of the Regulation on the authorization of natural and legal persons who are entitled to make energy balances and the Regulation for testification of persons with energy management responsibilities.

Also, the following guides have been drawn and approved:

- Guide for making and analyzing energy balances - ***Decision No. 56/28.05.2003 of ARCE;***
- Guide for preparing and examination in the field of energy balances, with a view to apply the Regulation on the authorization of natural and legal persons who are entitled to make energy balances - ***Decision No. 57/28.05.2003 of ARCE;***
- Guide for preparing and examination in the field of energy management, with a view to apply the Regulation on the authorization of persons with responsibilities in the field of energy management - ***Decision No. 58/16.05.2003 of ARCE.***

2. Implementation of national law in order to create the institutional framework

With a view to apply the provisions of the proposal of the Directive of the European Parliament and Council on promotion of energy efficiency at end-users and of energy services, a very important role is held by the power supply and distribution companies. The following are taken into account:

- increase of participation of energy companies, without the obligation to supply energy services themselves or to become ESCOs; the proposal provides acceptable forms of participation, like sharing the responsibilities, outsourcing, etc;
- actions of energy suppliers and distributors, in order to help the customers to shift their energy demand towards energy services and to make a step ahead from the simple sale of kWh;
- directing the national and regional energy efficiency funds to the power companies and to other suppliers of energy services; opening competition.

The ***Law No. 199/2000,*** *republished,* includes, in Chapter VI, under the title "Obligations for energy consumers", the following general provisions, which we quote here in order to emphasize some particular aspects:

- according to Article 12 (1): „Energy consumers, legal persons, have the obligation to observe the technical regulations in force regarding the design, manufacture, operation, maintenance, repair of own installations and of energy receivers, as well as providing them with measurement and control devices."
- according to Article 12 (2): „Energy consumers, legal persons, have the obligation to have their own energy consumption recording and monitoring system and to make available for authorized institutions all information regarding energy consumptions and energy efficiency indicators."
- in the industrial energy sector, energy balances (for both electricity and fuel) are made; these regard industrial assemblies, machines, sections, enterprises, and highlight the methods to decrease the energy consumptions. By applying the suggested measures, important energy savings are achieved.

The ***Law No. 199/2000,*** *republished,* includes specific provisions for economic agents with activities of fuel and energy generation, transmission or distribution, as well as for the promotion of using solar, wind, geothermal, biomass and household waste energy [Fig.1].

After agreement with consumers, the producers and suppliers of electricity and thermal energy can engage in activities of information, consulting, financing, as well as execution of works with a view to increase the efficiency of use of fuels and energy in their installations.
These general provisions represent the basic elements needed to ensure the security and continuity of operation of installations, machines and equipments in the energy sector. The design, engineering and operation norms for all components and functional assemblies are strictly regulated.

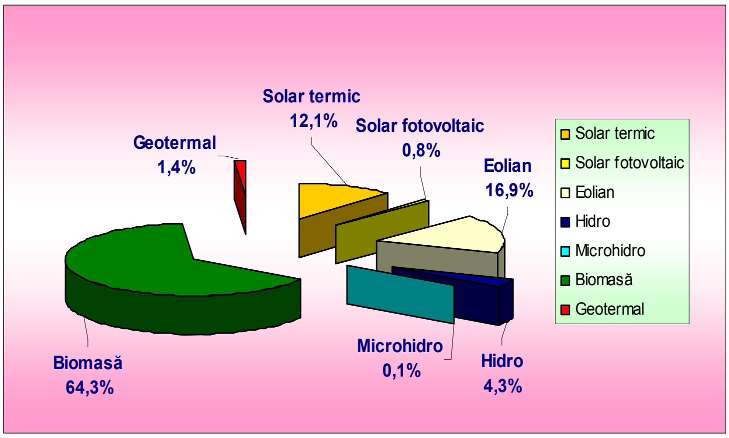

Figure 1: Annual potential of renewable energy sources [10].

3. Efficient energy management at end-users, as specific form of energy service

Demand side management represents a service dedicated by energy supply and distribution companies to their end-users, with a view to make energy savings, as al alternative to capacity modernization or replacement, in the case of development of power distribution networks. The energy services have to be considered by the suppliers as a possibility to modify the old energy sales model, by shifting from a product sale to a service sale.

As energy efficiency policy started to be considered of public interest, the key of success of the DSM policy, especially in the context of liberalization of energy market, is the political perception on its legitimacy. A way of proving this legitimacy is to analyze the distributive impact (who benefits from the DSM program, who and how much will have to pay for this benefit, what costs will be transferred to the electricity companies). Either it's reflected in a grant from the state, or in regulations for DSM promotion, it is necessary to justify the legitimacy of the support of public interest. [3]
In this context, the role of those who make the energy policy is to prove to the public, to the industry, to politicians, the fact that it is possible to achieve important energy savings, that energy savings are competitive in terms of costs with the conventional sources and they can be distributed in a fair manner. The energy efficiency indicators are the quantitative expression of the following strategic objectives:

- monitoring of targets referring to energy efficiency and to the programs of CO_2 level reduction at national and international level;
- evaluation of energy efficiency policies and programs;
- planning of future actions, including research & development programs;
- setting the basis for energy strategies;
- comparing the performances achieved on an international scale.

The increase of activities efficiency represents a strategic option for any company. In general context, efficiency can be appreciated by means of global indicators, which mainly refer to *the economic aspects of the company* (specific costs, specific revenues), or to aspects regarding *company marketing* (quality of service or product, company's market share).
In the same time, energy efficiency improvement can be appreciated by means of evolution energy intensity [Fig.2] [11].
Awareness and education of suppliers and customers in terms of energy efficiency and the relation to quality of electricity represent important options in the process of making efficient the activities, knowing that these elements motivate the staff and improve the company's performance.
The theme is approached from both sides: electricity consumer and power supplier.

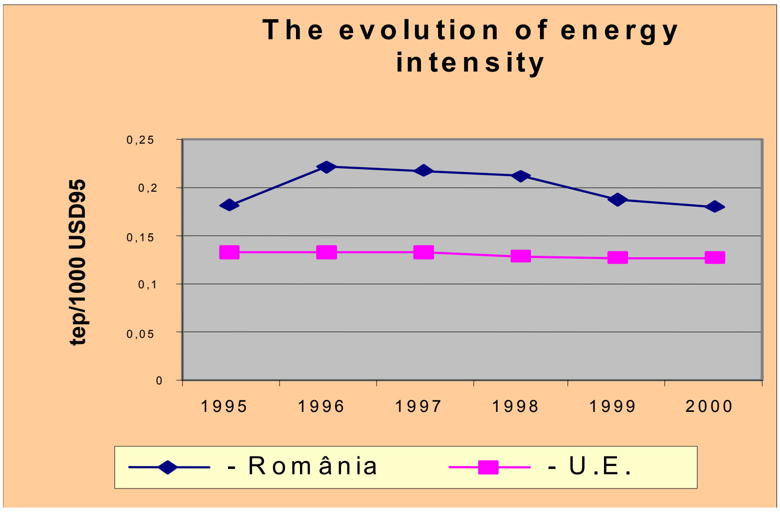

Figure 2: The evolution of energy intensity in Romania and the EU.

4. Market control activities

Market control represents an instrument for competent authorities, allowing them to implement the regulatory actions that adopt European directives. For this, the competent authorities assign structures responsible for market monitoring and control whether:

- the products are according to the provisions of the national law that applies to them;
- actions are taken to bring the products from nonconformity to conformity;
- fines are applied when the products prove not to be according to the essential requirements set in the regulatory actions.

In this regard, the Ministry of Economy and Commerce, through the Romanian Agency for Energy Conservation, applying the government decisions and in collaboration with ANPC (the National Authority for Customer Protection), monitor and control the observance of provisions of technical regulations on energy efficiency labeling for electrical home appliances (refrigerators, washing

machines, combined washer/dryers, lamps, dryers with cylindrical drum, dish washers, electrical ovens, ballasts for fluorescent lamps, air-conditioning appliances.
The labeling of electrical home appliances is made according to their energy efficiency, which is determined on the base of the power consumption of appliances, measured in the conditions set by the Romanian norms (harmonized with the European ones). These standards establish methods for measuring the performances of electrical home appliances, that apply to each category of appliances.
The activity of market monitoring has three main stages [1]:

- dissemination of information until the harmonized legislation entry into force;
- monitoring the conformity of products that enter the market with the requirements of national law that applies to them;
- taking measures to ensure conformity, if applicable.

In order to monitor the products that enter the market, in an efficient manner, the authorities responsible for market control have the authority, capacity and resources to:

- visit the production sites and the places where the products are stored or sold, as appropriate;
- take samples and examine/test them;
- ask for any relevant information regarding the product.

The corrective actions depend on the degree of nonconformity, which is set on a case-by-case basis. The producer or the person responsible for introducing the products on the market has to take steps to solve nonconformities and to make the product according to the requirements that apply to it.

Conclusions

Romania has to harmonize its energy policy to the one of the European Union. Special attention has to be given to security, efficiency, environmental protection and consumer protection, using the mechanisms of competition and a balanced statement regarding energy efficiency. In this regard, the home appliances have an important role, because they are used on a wide scale.
In a society who wishes to implement the concept of sustainable development, considerable efforts have to be made not only for obtaining stable energy resources, as well as for increasing the efficiency of the processes that use these resources.
The energy efficiency of home appliances is a key action of the policy of implementing the Kyoto Protocol, as well as a subject of many directives and programs. All the countries that adopted the EU regulations on energy efficiency have lower energy consumptions and reduced their CO_2 emissions.
Indeed, the energy efficiency improvement in all stages of conversion of primary energy into useful energy leads both to the a lower social-economical impact and to a lower impact on environment associated to the activities in the human society. A great number of economical and political sectors contribute to the implementation of these actions, from those who bring to best value the primary energy sources to the political decision factors.
The main characteristic for the present situation of Romanian energy sector is the fact that energy saving is the cheapest energy resource available, in the context of integrated resource planning.

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Decision Support Model for Energy Companies' Operational Environment in the EU New & Candidate Member States

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Abstract

One of the current energy policy's goals in the European Union (EU) is the exchange of knowledge and experience between the EU-15 member states and the new as well as the candidate countries in issues regarding the development of Renewable Energy Sources (RES) and the promotion of Energy Efficiency (EE). Nowadays, the liberalization of energy markets and the deterioration of the climate, in combination with the non-stop crude oil price increase, have had a decisive influence on the development of the above sectors. Indeed, one of the most important elements for the RES and EE development is the enhancement of energy producers by RES and ESCOs respectively. These companies' success is based on the formulation of a modern environment in each EU member state. However, the environment of the new and candidate member states is less mature than the environment of the EU-15 member states, as it is still in its development phase. In this context, the main aim of this paper is to present a "multidimensional" decision support model for the formulation of modern energy companies' operational environment, which also incorporates the "new parameters" that enter the energy market, namely the liberalization and the climate change. This model is used so as to assess the environment of the energy companies in the fourteen (14) new and candidate member states of the EU.

Introduction

The development potential of the Renewable Energy Sources (RES) in the new and candidate member states of the European Union (EU) is high [1]. As a result, the expectations for a significant increase of RES contribution to the primary energy supply reach 26% in the year 2030 [2], from 10% in the year 2003 [3] in the overall EU. Moreover, the increase of energy consumption, as well as the CO_2 emissions in these countries is an inevitable outcome of social and economic development. As a result, it is clear that Energy Efficiency (EE) can be improved in these member states.

Nowadays, the European Commission (EC) aims to facilitate the exchange of knowledge and experience between the EU-15 member states and the new as well as the candidate countries in order to enhance RES development and promotion of EE.

The developing countries, which can be benefited from the experience and knowledge of the most developed ones, are constituted of the ten member states (Cyprus-CY, Czech Republic-CZ, Estonia-EE, Hungary-HU, Lithuania-LT, Latvia-LV, Malta-MT, Poland-PL, Slovenia-SL, Slovakia-SK), which joined the European Union (EU) in 2004, Bulgaria-BG and Romania-RO, that are going to join the European Union in 2007, as well as Turkey-TR and Croatia-HR that have recently started negotiations with EC.

One of the most important parameters for the RES development is the enhancement of involved producers. These producers can be either companies deriving from utilities producing energy from conventional sources that have decided to be activated in the field of RES or Independent Power Producers (IPPs). These companies can be either newly entering companies or companies already engaged in the construction and trade of renewable energy technical equipment that have decided to enter the market as IPPs. In addition to this, Energy Service Companies (ESCOs) have been developed and their role is crucial for the promotion of EE.

The success of the above energy companies is based on the formulation of a modern environment in each EU member state. Generally, Chandler [4] outlines that the operational environment of companies determines substantially the main long-lasting objectives and aims of each company, fires a line of action and determines the necessary means for the realization of these objectives. Johnson and Scholes [5] note that the environment directs decisively the activities of a company in the long run. In addition, Ansoff [6] supports that the existence of the companies' operational environment is the base of creation of common lines between the activities of a company.

In this context, each member state needs to formulate an up-to-date energy company's environment, which has to be enhanced, giving thus the opportunity to more companies in these member states to be properly activated.
However, the environment of these member states is less mature than the environment of the EU-15 member states and it is still in a developing phase, due to the lower social acceptance, the public awareness, the fact that the Kyoto Protocol is not top priority yet as well as the absence of appropriate national financial sources.
Based on the international literature, a large body of literature examines the external factors of the energy companies – in terms of policies, regulations and financing support schemes of these states. For instance, Bechberger in 2003 [7] and Patlitzianas et al. in 2004 [8] presented general renewable energy overviews of candidate countries. In 2005, Streimikiene [9] described the RES and EE development in the Baltic States and Reiche [10] presented an investigation of the driving forces for a further promotion of renewable energies in the accession states in 2006. However, these papers do not take into consideration the recent developments, regarding the EC's accession negotiations with Turkey and Croatia. In addition to this, there are no papers investigating the operational environment of energy companies in an integrated way as presented above.
The main aim of this paper is to present a "multidimensional" decision making model for the formulation of modern energy companies' operational environment, which also incorporates the "new parameters" that are introduced into the energy market, namely the liberalization [11] and the climate change [12]. This model is used so as to assess the environment of the energy companies in the fourteen (14) new and candidate member states of the EU.
In this context, the paper is structured in four sections as follows:

- After an introduction, the second section provides a short description of the adopted model.
- In the third section this model is applied in assessing the energy companies' environment in the EU new and candidate member states. In particular, this section describes the inputs, including concrete facts and figures obtained in the data collection process and the outputs of the procedure as well as their discussion.
- The last section presents the conclusions, which summarize the main points that have been brought up in this paper and outlines perspectives for the development of the companies' environment in the region.

Brief Description of the Model

The description of the energy companies' operational environment is the aim of the model (**I.M.E.C.O.**) that is constituted by the following five components:
Component 1 – Identification
This component concerns the identification, based on the experience, of seventeen actions, in each one of the environment's dimensions. In particular, the dimensions (D_i) of the environment can be categorized in four dimensions, the political/ legal, financial, social/ cultural and technological (i=1,2,3 and 4) taking into consideration the literature that is related to the company's environment and its strategy [13-16].
Based on the relative literature review [17-21], the necessary actions towards the formulation of a modern energy companies' operational environment (A_{ij}) are categorized and illustrated in the following Table 1.

Table 1: The Actions

Dimension	Actions	
D_1: Political - Legal	$A_{1.1}$	Legislation on the support of energy production from RES
	$A_{1.2}$	Verification system for energy service companies
	$A_{1.3}$	Standardisation of energy services contracts
	$A_{1.4}$	Political support of RES-EE
	$A_{1.5}$	Political promotion of international energy cooperation
D_2: Financial	$A_{2.1}$	Economical support of RES project
	$A_{2.2}$	Economical support of energy management projects
	$A_{2.3}$	Economical support of EE projects
	$A_{2.4}$	Promotion / Support of new financing sources
D_3: Social – Cultural	$A_{3.1}$	Employment for RES-EE fields
	$A_{3.2}$	Social acceptance for the RES-EE fields
	$A_{3.3}$	Education support actions for RES – EE
	$A_{3.4}$	Development of new energy companies in the region
D_4: Technological	$A_{4.1}$	Support actions of R & D on the energy sector
	$A_{4.2}$	Support actions of R & D on new innovative technologies of energy production by RES
	$A_{4.3}$	Support actions of R & D on new energy efficiency's technologies
	$A_{4.4}$	Support actions of the commercial exploitation of the research results

Component 2 – Modeling

The second component concerns the modeling of the energy companies' operational environment, via the development of a group of appropriate indicators. The development of this component is based on the use of existing indicators, identified after a detailed literature review. In this framework all the past efforts made for the development of energy indicators in the RES and EE sectors from EC, OECD, IEA and APERC [22-29] were detected. In any case, the aim is not the development of new indicators but the use of the already existing ones, in order to measure on a common basis the necessity of an intervention.

The selected indicators belong to two basic categories: qualitative and quantitative indicators. In particular:

- Seventeen (17) Basic Indicators (B_{ij}, i- 1,2,3 and 4, j=1,2,…,a) were selected based on the appropriate literature survey. These indicators present the most essential information regarding the diagnosis of the country's performance, in terms of the energy companies' environment. The basic indicator is the key means of decision making for the necessity of taking intervention measures or not.
- Some other indicators create a new pool that includes the Secondary Indicators S_k, (k=1,2,…,m). The secondary indicators act accessory to the estimation of the weaknesses of the energy companies' environment. These indicators are focused on specified issues of the weaknesses of the energy companies' environment and describe specific activities for selected aspects of the sectors they examine. The selected secondary indicators are forty one (41).
- A third pool of indicators is created, representing the effects that the "New Parameters" of the companies' market involve in the decisions of their operational environment's formulation N_l, (l=1,2,…,n). The new parameters' selected indicators are twenty-two (22).

Component 3 – Estimation

The third component concerns the estimation of the necessity for each Action (A_{ij}) of the companies' environment. Concretely, the Basic Indicator is related to a group of Secondary Indicators. Moreover, a second group of indicators, reflecting the impact of "new parameters", is related to each one Basic Indicator. As a result, there are selected:

- The pool of the correlated indicators of "New Parameters" (N_{ilx}, x=1,2,3,…,b).
- The pool of the correlated Secondary Indicators (S_{ijy}, y=1,2,3,…,c).

In this way, a "pool of decision indicators" is being created, the price control of which portrays the estimation of the "existence of the necessity or not" for improving the companies' environment.

Component 4 – Choice

After the estimation of the action's necessity, the model investigates the intervention choices, based on the evolution indicator's DB_{ij} values. This indicator illustrates the evolution of the Basic Indicator's performance during the past year. The value of the above mentioned indicator is estimated according to appropriate thresholds and the existence or not of appropriate measures in the last year is examined. In this context, the continuation of the existing measures (I), their modification (II) or the formulation of new measures (III) is proposed.

Component 5 – Order

The last component receives as input the results of the previous components, in order to evaluate the direct actions to be done for the development of energy companies' environment in each country and involve a methodology of quantifying multiple qualitative judgments based on the multicriteria decision making method (Ordered Weighted Average) [17].

The six criteria are selected so as to incorporate all the needs of the companies' operational environment as well as the emerging needs and opportunities of the "new parameters", which determine the final decision. In addition to this, the member states' performance to each one of the criteria is based on a 1-5 order qualitative scale, with "1" illustrating an insignificant progress of the country regarding the particular criterion, "2" a low, "3" a moderate, "4" a high and "5" a very high progress of the member state regarding the particular criterion. The criteria are presented in the Table 2:

Table 2: The Criteria

Category	Priority Criteria
Basic Needs	C_1: Contribution to the increase of the RES proportion
	C_2: Contribution to the increase of the EE
	C_3: Contribution to the security of supply
	C_4: Contribution to the sustainable development
New Parameters	C_5: Progress regarding the liberalization of the energy market
	C_6: Contribution to the reduction of the greenhouse gases

The algorithm of the model appears in the following Figure 1.

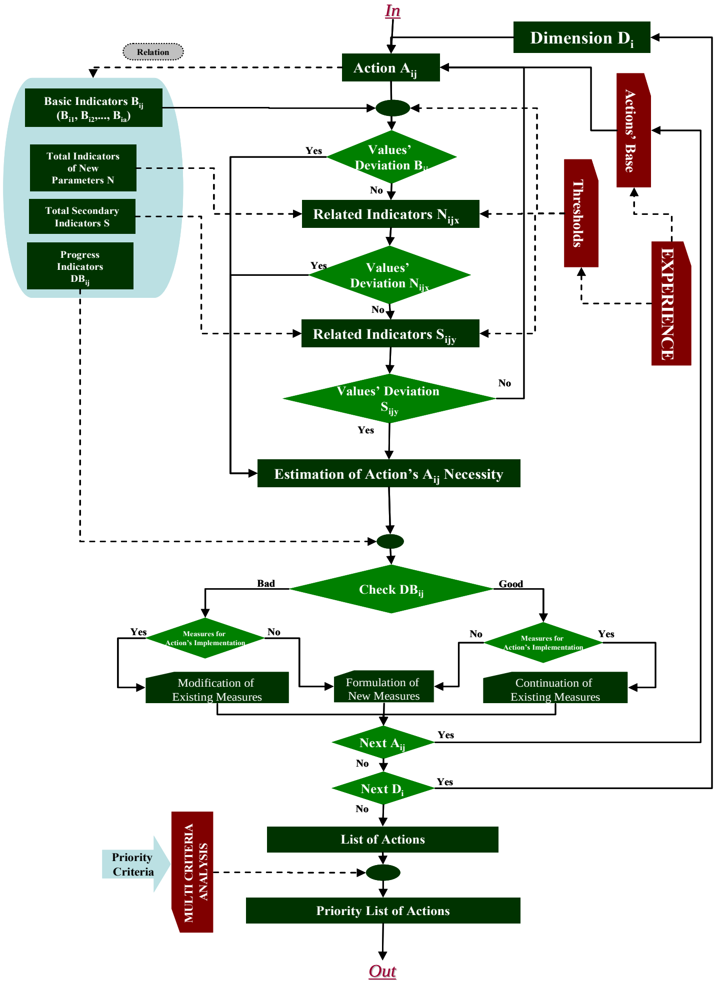

Figure 1: The Algorithm of Model

Case Study in the EU New and Candidate Countries

Inputs

The inputs are firstly based on the results of a project funded by the ALTENER programme of the EC [18]. In addition to this, the collected information was enhanced and updated, through the implemented events and the initial outputs of the on-going FP6 project, funded by EC [19]. Finally, the related - implemented events in the region [20] as well as the reports written by EREC (European Renewable Energy Council) [1] and other relevant sources [21-25] were taken into consideration.
Based on the above sources, some indicative data obtained in the process of data collection for the indicators used are illustrated in the following Figures.
Based on Figure 2, it is clearly illustrated that in most of the examined countries RES primary production is mainly based on biomass and on a secondary basis on hydro. Even though photovoltaics (PVs) and wind options are already considered to be mature enough, their penetration in the energy market of these countries remains very limited. In addition to this, countries which have a significant RES primary production due to their resources are Turkey, Poland and Romania.

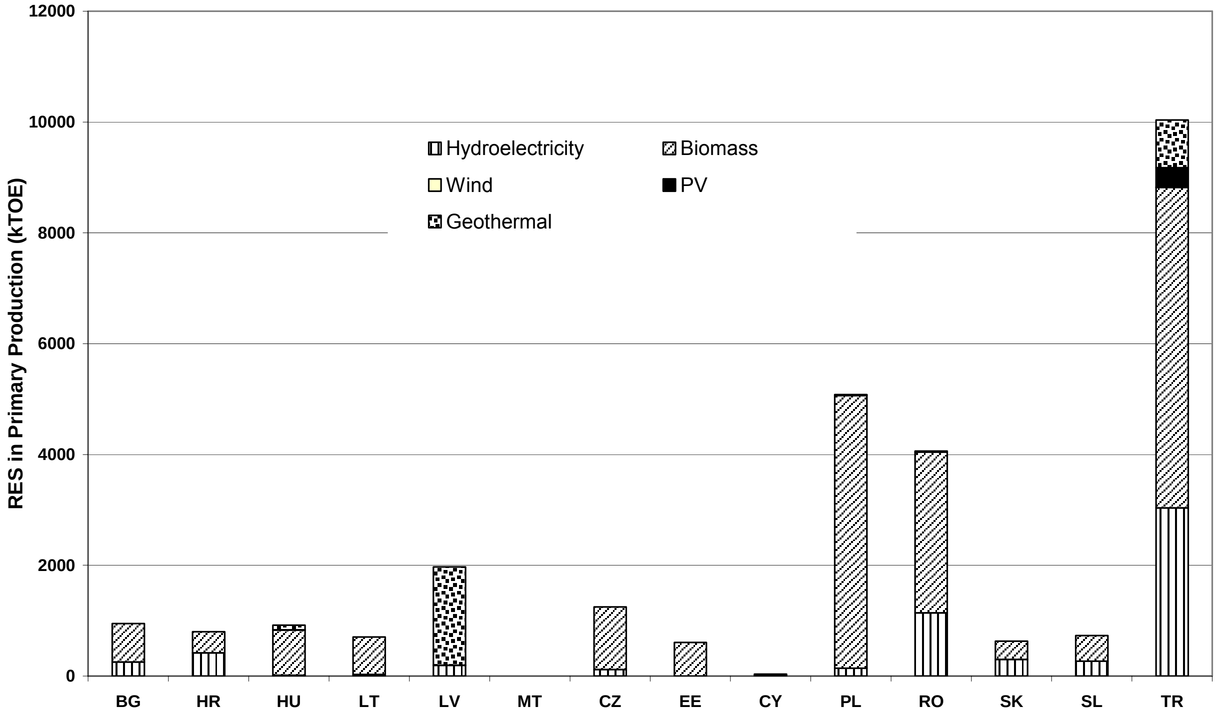

Figure 2: RES in Primary Production – 2003

In Figure 3 it is clearly depicted that there are a number of countries like Turkey, Poland and Romania, where RES production corresponds to thousands of ktoe annually. However, this doesn't necessarily means that in these same countries the RES percentage in GIC is particularly high, as it doesn't exceed ~13%. On the contrary, a number of countries with exceptionally high percentage of RES contribution in GIC are Latvia, Slovenia, Lithuania and Estonia.

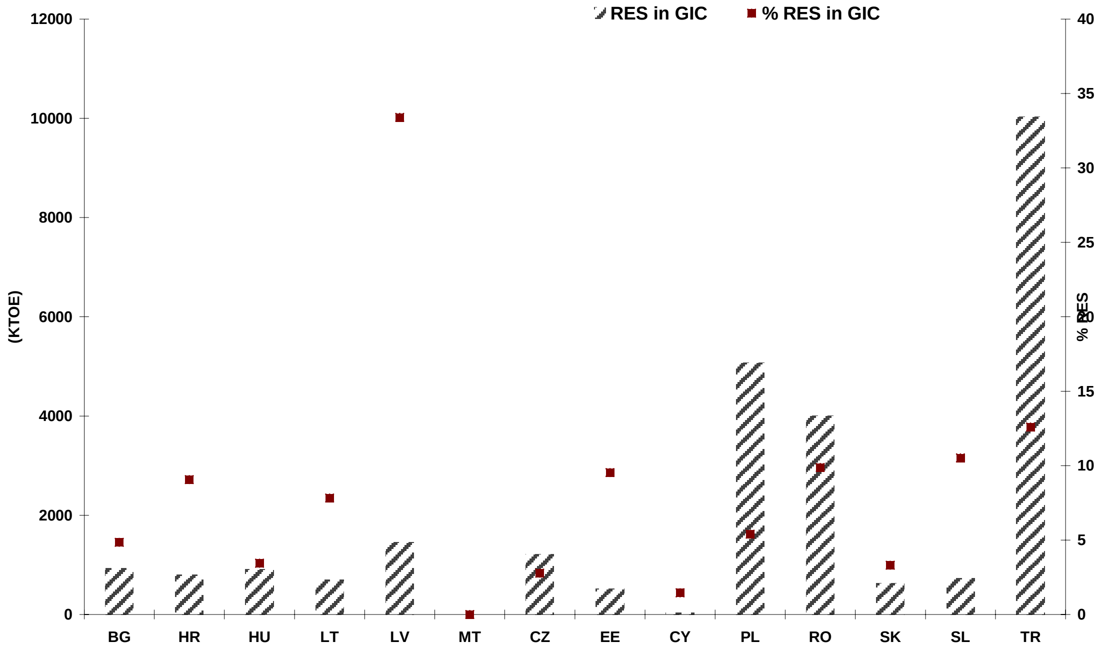

Figure 3: RES in Gross Inland Consumption – 2003

Moreover, from the following Figure 4 can be outlined that RES percentage in the electricity generation remains limited in most countries, with the exceptions of Hungary and Latvia that possess significant biomass and geothermal production respectively.

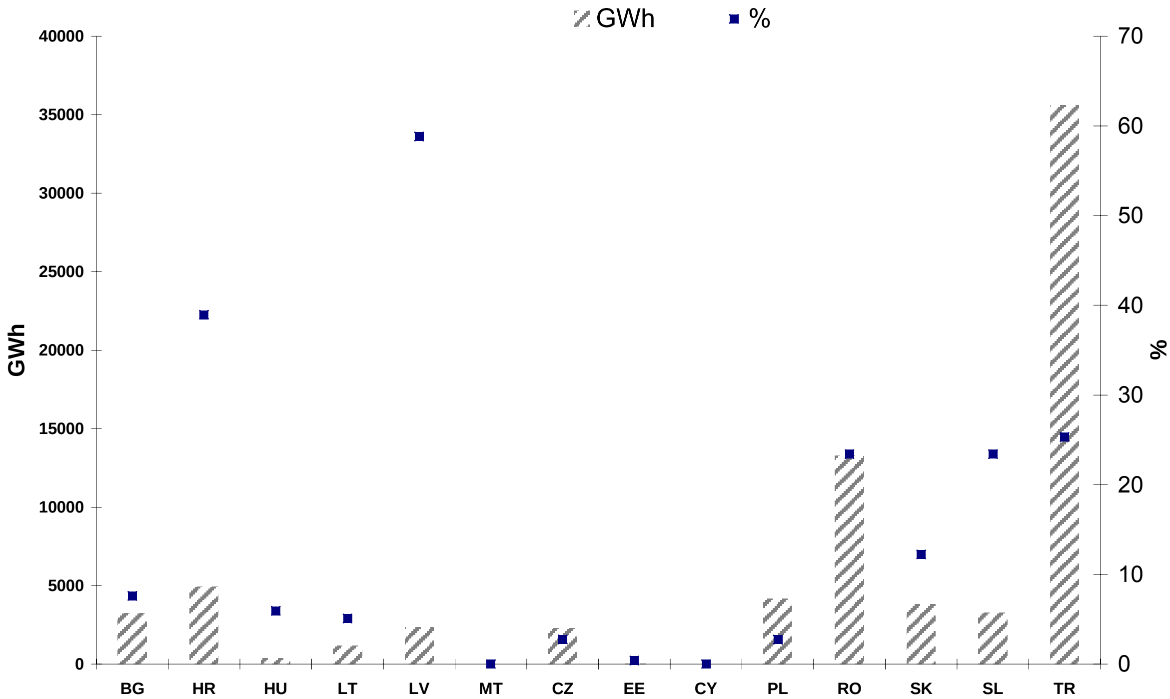

Figure 4: RES in Electricity Generation – 2003

Based on Figure 5 it can be easily concluded that the countries with the greatest penetration of RES in GIC per 1.000 persons are the ones with the lowest population, like Slovenia, Latvia and Estonia.

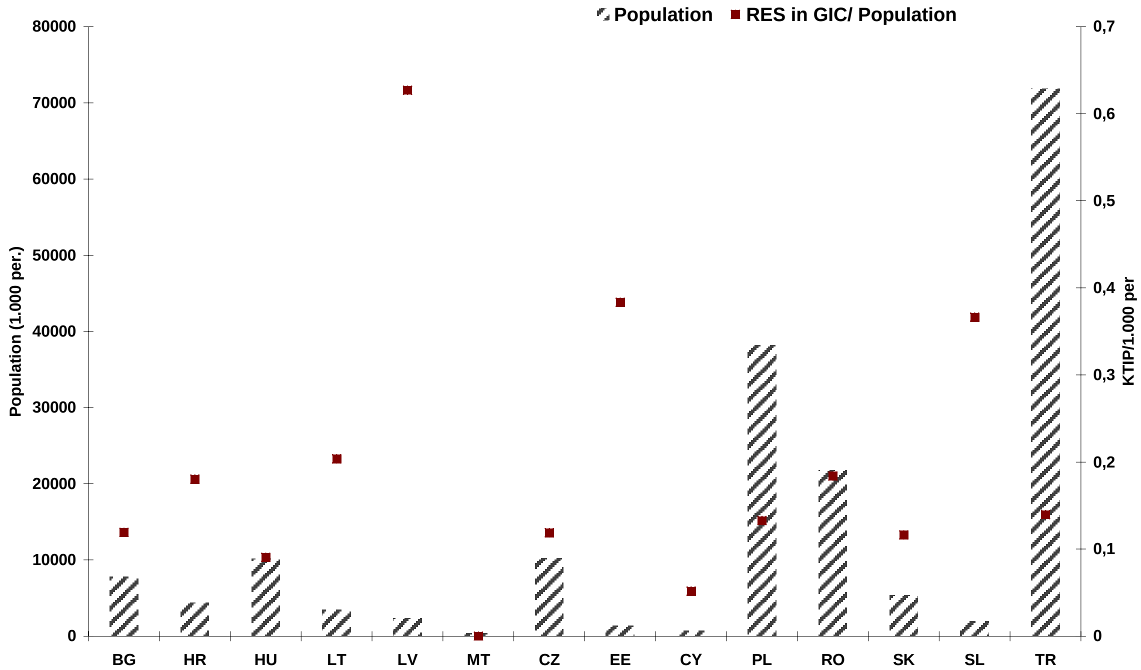

Figure 5: RES per population – 2003

In addition to this, the increase of energy consumption as well as the CO_2 emissions in the majority of these countries as an inevitable outcome of social and economic development is clearly illustrated in the Figures 6 and 7. As a result, it is clear that EE could be improved in these member states.

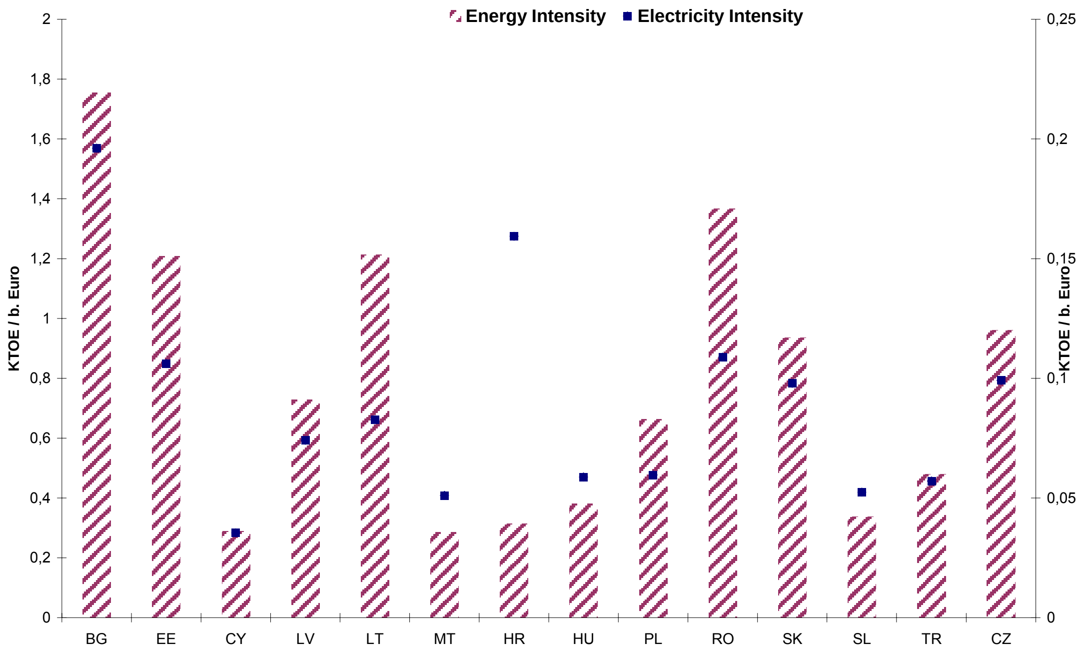

Figure 6: Energy Intensity – 2003

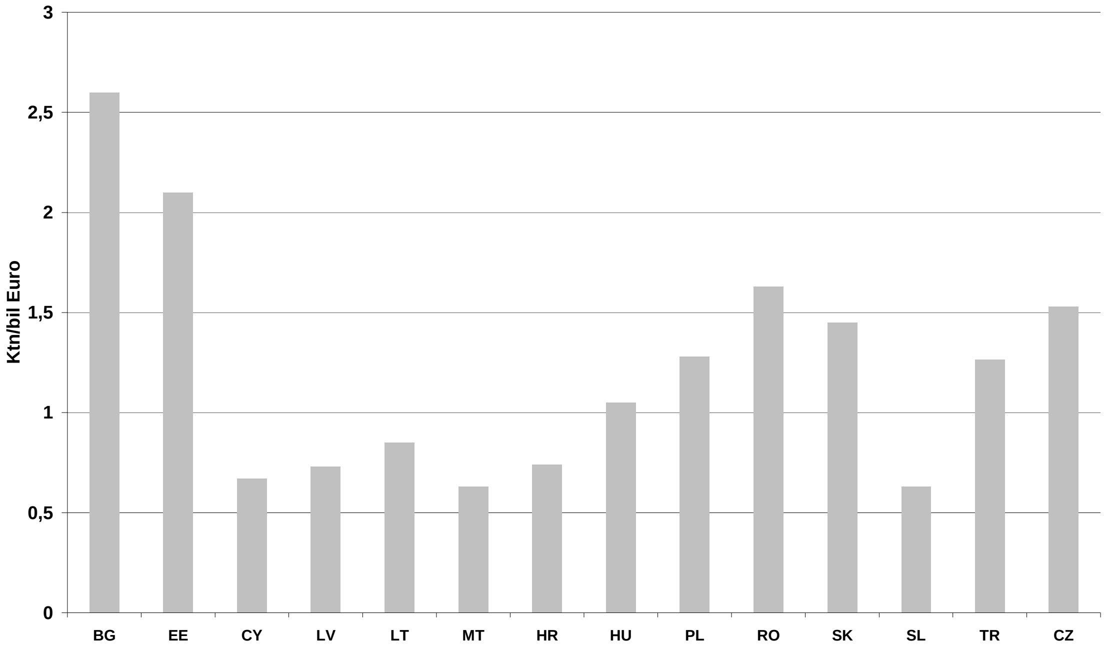

Figure 7: CO_2 Intensity (ktn CO_2 / billions Euro)

Moreover, there is a great number of countries that will have difficulties in meeting their Kyoto target for 2010. In this framework the countries that will probably not achieve their goal are Estonia, Latvia, Lithuania, Slovakia and the Czech Republic. On the other hand, countries that will easily meet their target are Croatia and Slovenia, while countries that will meet their target with difficulties, as in 2003 they were very far behind, are Bulgaria and Hungary.

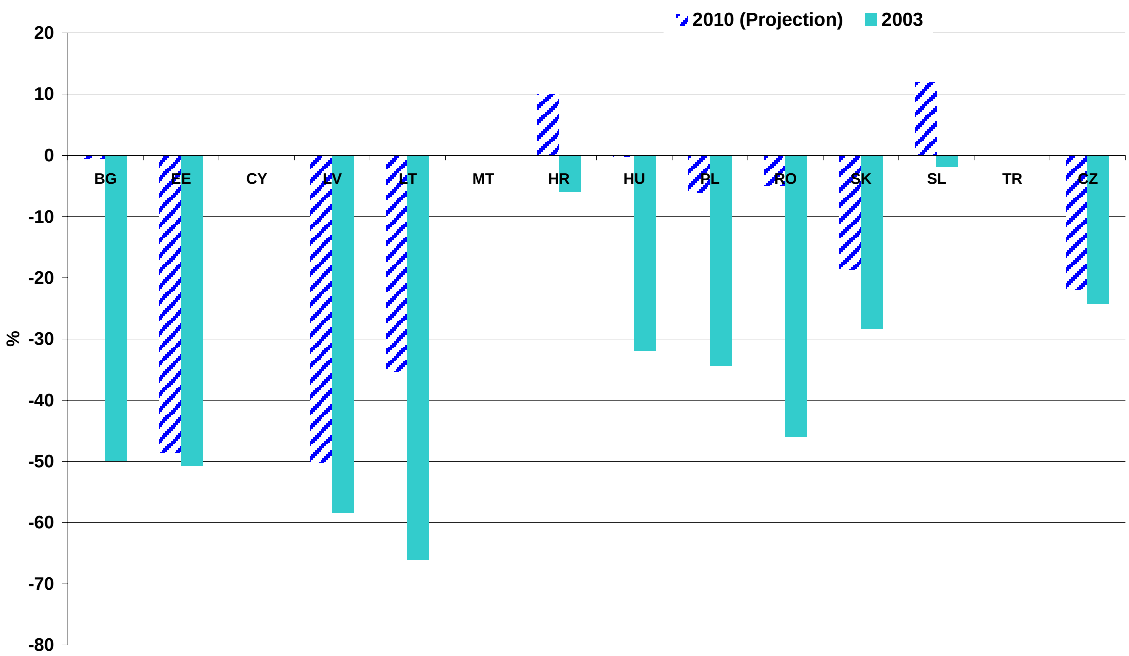

Figure 8: Distance from the Kyoto Protocol Target

In addition to this, a significant amount of money has recently been devoted to the R & D in the RES and EE sectors in some of the examined countries, such as Bulgaria, Hungary and Romania. However, as depicted in Figure 9, these countries are still lagging behind from the EU-15 member states in terms of technology progress and innovation production, which is also obvious taking into consideration the lack of domestic manufactures of RES and energy conservation equipment.

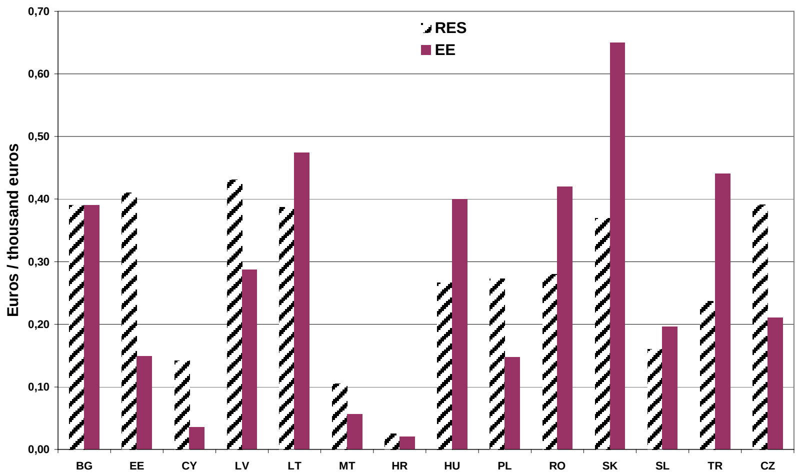

Figure 9: R & D in RES & EE - 2003

Outputs and Discussion

The results of the proposed model's application in the 10 new and 4 candidate member states are presented in the following Table 3. In particular, the actions examined are ranked, from the most necessary to the ones of lowest priority.

Table 3: The Outputs

Member State	***Actions***
BG	$A_{3.2}$ (I) > $A_{3.3}$ (III) > $A_{1.1}$ (II) > $A_{3.4}$ (II) > $A_{2.1}$ (I) > $A_{1.5}$ (I) > $A_{2.2}$ (I) > $A_{1.3}$ (I) > $A_{2.3}$ (II) > $A_{4.4}$ (III) > $A_{4.1}$ (I) > $A_{4.3}$ (II)
CY	$A_{2.4}$ (III) > $A_{4.4}$ (III) > $A_{1.2}$ (I) > $A_{4.3}$ (II) > $A_{1.3}$ (III) > $A_{3.3}$ (I) > $A_{4.2}$ (I) > $A_{1.5}$ (I) > $A_{2.1}$ (I) > $A_{4.1}$ (II)
CZ	$A_{2.2}$ (II) > $A_{3.4}$ (III) > $A_{2.1}$ (I) > $A_{4.2}$ (I) > $A_{2.4}$ (I) > $A_{4.3}$ (II) > $A_{2.3}$ (II) > $A_{1.4}$ (I) > $A_{1.1}$ (I)
EE	$A_{1.4}$ (III) > $A_{2.1}$ (II) > $A_{3.4}$ (III) > $A_{4.3}$ (I) > $A_{2.2}$ (II) > $A_{2.3}$ (I) > $A_{2.4}$ (I) > $A_{4.1}$ (I) > $A_{3.2}$ (II) > $A_{1.2}$ (I)
HR	$A_{1.1}$ (I) > $A_{2.1}$ (I) > $A_{1.4}$ (III) > $A_{1.5}$ (I) > $A_{2.3}$ (II) > $A_{2.4}$ (III) > $A_{1.2}$ (I) > $A_{1.3}$ (III) > $A_{4.3}$ (III) > $A_{4.2}$ (III) > $A_{4.1}$ (I) > $A_{3.2}$ (I) > $A_{3.1}$ (III) > $A_{3.4}$ (II)
HU	$A_{3.1}$ (I) > $A_{4.2}$ (I) > $A_{3.4}$ (III) > $A_{4.4}$ (II) > $A_{2.1}$ (I) > $A_{2.3}$ (III) > $A_{1.5}$ (II)
LT	$A_{2.3}$ (I) > $A_{2.2}$ (I) > $A_{2.4}$ (III) > $A_{1.4}$ (III) > $A_{1.3}$ (III) > $A_{3.4}$ (III) > $A_{4.3}$ (III) > $A_{2.1}$ (I) > $A_{1.5}$ (I) > $A_{3.2}$ (II) > $A_{3.1}$ (I)
LV	$A_{3.3}$ (I) > $A_{1.3}$ (III) > $A_{3.1}$ (I) > $A_{2.1}$ (I) > $A_{2.2}$ (I) > $A_{4.1}$ (II) > $A_{3.4}$ (I) > $A_{4.3}$ (II) > $A_{4.4}$ (III) > $A_{1.5}$ (I) > $A_{1.1}$ (I) > $A_{2.3}$ (I) > $A_{2.4}$ (III) > $A_{3.2}$ (I)
MT	$A_{1.1}$ (I) > $A_{4.1}$ (II) > $A_{4.2}$ (II) > $A_{1.4}$ (II) > $A_{1.5}$ (I) > $A_{2.1}$ (II) > $A_{2.3}$ (II) > $A_{1.2}$ (I) > $A_{1.3}$ (III) > $A_{3.2}$ (I) > $A_{3.3}$ (III) > $A_{4.3}$ (II)
PL	$A_{4.2}$ (I) > $A_{4.3}$ (II) > $A_{4.1}$ (I) > $A_{2.1}$ (I) > $A_{3.2}$ (III) > $A_{3.4}$ (III) > $A_{1.4}$ (III) > $A_{1.3}$ (III) > $A_{2.3}$ (I)
RO	$A_{1.1}$ (II) > $A_{1.4}$ (III) > $A_{1.3}$ (II) > $A_{3.1}$ (II) > $A_{3.3}$ (III) > $A_{3.4}$ (III) > $A_{2.1}$ (II) > $A_{2.3}$ (I) > $A_{2.2}$ (I) > $A_{3.2}$ (III) > $A_{4.4}$ (II) > $A_{2.4}$ (II) > $A_{1.2}$ (I) > $A_{1.5}$ (I)
SK	$A_{3.1}$ (III) > $A_{3.3}$ (III) > $A_{4.3}$ (III) > $A_{4.4}$ (III) > $A_{3.4}$ (III) > $A_{2.1}$ (I) > $A_{2.3}$ (II) > $A_{2.4}$ (III) > $A_{2.2}$ (I) > $A_{1.4}$ (III) > $A_{1.1}$ (I)
SL	$A_{4.1}$ (I) > $A_{4.2}$ (II) > $A_{4.3}$ (I) > $A_{1.4}$ (III) > $A_{1.3}$ (III) > $A_{4.4}$ (III) > $A_{2.3}$ (I) > $A_{2.1}$ (I) > $A_{3.2}$ (II) > $A_{3.4}$ (II) > $A_{3.1}$ (II) > $A_{1.2}$ (I)
TR	$A_{1.1}$ (II) > $A_{1.4}$ (III) > $A_{1.5}$ (I) > $A_{1.2}$ (II) > $A_{2.1}$ (II) > $A_{3.4}$ (III) > $A_{1.3}$ (III) > $A_{4.2}$ (II) > $A_{3.1}$ (II) > $A_{3.2}$ (III) > $A_{2.3}$ (I) > $A_{3.3}$ (III) > $A_{4.1}$ (II) > $A_{4.3}$ (II).

The main points that can be drawn up from the results of the current model's application are the following:

- *Political - Legal Dimension:* In most countries the necessary actions to be regarded as medium priority concern the political support for the RES and EE sectors as well as the promotion of energy co-operations. Few countries have to emphasize on the enhancement of the energy companies' certification system and the standardization of energy services' contracts, such as Croatia, Malta, Slovenia and Turkey. Countries which seem to have made adequate efforts in this dimension of the companies' environment are Hungary and Poland.
- *Financial Dimension:* The insufficiency of financial resources for the support of RES, as well as of EE, is particularly obvious, even if the percentage of RES in the accession members'

electricity market was above the average of the EU-15 members. In most countries, energy companies' environment development is lagging behind in terms of its financial dimension. In particular, the necessity for subsidies for appropriate projects and energy management activities is evident in the majority of the countries. Moreover, all countries need to promote modern financing sources, apart from Cyprus and Turkey, countries in which related activities have already occurred.

- *Social - Cultural Dimension*: Actions of this dimension are considered to be of high priority in Estonia, Hungary, Poland Latvia and Bulgaria. Drawbacks, such as low number of specialised employees, limited amplification of employment, lack of educational policy and limited activities for promoting the benefits of RES - energy conservation, create problems of establishment and acceptance of the energy companies' concept.

  In this context, environmental awareness is developed only in a low level in the EU accession member states and therefore the related actions can be considered to be of significant importance, with the exception of Cyprus and Latvia. In addition, in all countries, the necessity for the related employment support was derived. Furthermore, in Bulgaria, Czech Republic, Estonia, Hungary, Malta, Poland, Slovenia and Slovakia high priority has to be given in actions concerning the growth of regional new energy companies' development. Moreover, the need to support the education for RES – EE appeared for all countries besides Bulgaria, Croatia, Poland and Slovenia.
- *Technological Dimension*: The support of R& D in the energy sector generally seems to be an action recommended to the majority of the countries, besides Hungary. Especially, necessity for actions of the R& D support for the new RES innovative technologies is presented in all countries, apart from Bulgaria and Romania, where significant efforts have been implemented recently. In addition to this, the need for R& D support of the new EE innovative technologies in the rest of the countries is evident. This is realistic since, in most accession countries, a lack of domestic manufactures exists, apart from some specific cases such as Latvia, Slovenia and Turkey (industries for boilers' equipment and water turbines). Moreover, the manufacture of solar collectors is rapidly increased in Cyprus as well as Hungary, Slovakia and Poland. Finally, the necessity for supporting the commercial exploitation of the research results for the RES-EE sectors exists in all countries. On the other hand, technology for specific RES technologies (e.g. hydroelectric energy and biomass) for heating reasons is constantly developing and already has been used in many of the accession states. With regard to geothermal energy, Hungary, Turkey and Poland show a relatively satisfactory technological growth.

Conclusions

After taken into account the outcomes, the key points are presented in the following way:

- Their political/legal environment has not developed yet, compared with the corresponding environment of the 15 member states but specifically in some cases (such as Slovenia, Lithuania, Latvia, Estonia, Hungary, Poland and Czech Republic) a significant progress has been observed. In addition to this, there is a great number of countries that will have difficulties in meeting their Kyoto target for 2010.
- These states have had a century-long tradition in the utilization of renewable energy, primarily in biomass and hydropower. RES percentage in the electricity generation remains limited in most countries, with the exceptions of Hungary and Latvia that possess significant biomass and geothermal production respectively. As a result, the financial environment of most accession member states should be enhanced.
- The social/cultural brings a different outcome to one's attention, especially in the middle places. Cyprus ranks relatively high, showing their high social RES awareness in that way. Nevertheless, it can be concluded that countries (Latvia, Estonia, Poland, Lithuania and Hungary) which are active and evolving carry the crowds along with them. A significant amount of money has recently been devoted to the R & D in the RES and EE sectors in some of the examined countries, such as Bulgaria, Hungary and Romania.
- In the technological environment, Poland and Latvia surpass the rest, due to their traditional technological know-how and an already developed "heavy" industry, followed in a close distance by Estonia, Hungary, Lithuania and Czech Republic.

As a result, decision making support models, such as the one presented in this paper, are needed to identify, diagnose, and order the appropriate actions in a consistent way, as well as to assist policy making and formulate a modern energy companies' operational environment. In addition, the model's procedure assisted the specific decision making problem and the outcome might have been quite different if different indicators and criteria had been chosen. However, the model's conceptual can provide a sufficient framework for supporting other decision making problems.

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Energy Efficiency in Romanian Residential Sector – Present Situation and Perspectives

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Abstract

From the energy consumption point of view, the residential sector is the second largest sector in Romania. Yet, the use of almost all types of energy (electricity, thermal energy, oil petroleum products, natural gas, coal) used in households decreased in the last years, following the same trend in energy consumption as all other sectors. This is the case of households owned by the people (unfortunately to many, today) with the income less than the ones of so-called “middle class”. Of course, people with greater income, affording greater energy consumption, improved their way of living having new greater houses, including by buying and using many household appliances.

However, there is a great potential for efficient use of energy in Romanian homes taking into account the followings: there are over 8,1 millions of households within almost 4,85 millions of buildings; over 50% of them are more than 40 years old, 37% have the length of service between 20 and 40 years and 10% are less than 20 years old.

Furthermore, great steps were also made in Romanian legislation regarding energy efficiency, most of them being in accordance with European legislation (EC Directives).

The paper presents official data about the present situation, the savings potential, what was done (programs, projects, grants), what is to be done (politics, objectives, goals, actions plans, information campaigns), different scenarios (needed financial resources, estimated impact) in order to obtain efficient use of energy in Romanian residential sector.

Because energy efficiency is not only a great challenge but also a must when Romania wants to be an equal partner within European Union.

Present situation

General aspects

Romania is slowly recovering from an economical declining period, which was also reflected in the reduction of energy consumption specific to transition process.

In the last decade of the 20th century, energy efficiency policy and programs were not implemented on a large scale in Romania.

However, in the last years, having in mind the goal of integration in European Union, energy efficiency became an important part of Romanian national energy policy.

Some basic statistics

According to the 2002 national census, Romania has a population of about 21,68 millions inhabitants and a dwellings stock of about 8,15 millions.

It results the average number of persons per household of 2,7, of which:

only 1,1 are active persons (40,8%);

1,6 are inactive persons (59,2%), of which: 0,6 are retired people (23,4%); 0,5 are pupils and students (17,4%); 0,5 are other persons (unemployed people, such as housewives etc.) (18,4%).

The average net salary is about 230 EUR / month.

From the total number of 8,15 millions dwellings:

- 53% are older than 40 years;
- 37% have the length of service between 20 and 40 years;
- 10% are under 20 years old.

In the urban zones, the most of dwellings are in block of flats (81,5%) and the villages 91% represent singular dwellings (houses).

From the property point of view, 97,5% of total number of dwellings is in private property, owner-occupied, and only 2,5% is owned by the state.

Energy consumption and energy intensity

According to [24], for residential sector, in 2005, there was registered an energy final consumption of about 7,97 thousands equivalent tones of petroleum which means about 32% of total energy final consumption in Romania.

In the ranges, the situation is as follows:
- electricity (9,2%);
- thermal energy (34,7%);
- petroleum (19%);
- natural gas (35,2%);
- coal (0,1%);
- others (renewable resources or offal – 1,8%).

In the residential sector, thermal energy is used for heating, preparing warm water and food cooking. Speaking in general, the efficiency of this thermal energy use is only 43% (63% in Bucharest – the capital of Romania).
Because of poor conditions of some centralized heating systems and the lack of metering systems at all block of flats or at individual levels, many consumers, especially from towns areas, preferred individual heating systems using natural gas.
As for energy intensity in Romanian residential sector, this is over 8 times bigger than the mean value from European Union countries, varying between 6,6 (compared to Great Britain or Germany) and 12,8 (compared to Spain). Mainly, this results from the less efficiency of district heating and poor thermal insulation of most apartments situated in block of flats.

Legislation regarding energy efficiency

Important data regarding basic legislation

February 1997. Ratification of "Energy Charta Treaty and the Protocol regarding Energy Efficiency and Environment Aspects"
According to [1], these contain stipulations such as:
- correlation of energy efficiency policies of different countries;
- development of cooperation between countries, by energy efficiency programs;
- estimation of energy efficiency potential;
- creation of specialized national structures for energy efficiency;
- application of energy efficiency measures;
- facilitation in introduction on market of energy efficiency technologies and services;
- new approaches and methods for financing energy efficiency investments.

November 2000. Law regarding efficient use of energy
This law, [2], was created for application of Energy Charta Treaty. Besides above-mentioned stipulations, accent is put on the followings:
- complying of international conventions in which Romania is part of;
- Romanian Agency for Energy Conservation (ARCE in Romanian language) is the national authority for energy efficiency;
- watching the market in order that technical regulations on energy efficiency are respected;
- compulsoriness of using high energy efficiency materials and equipments in all domains of activity;
- compulsoriness of making energy surveys (by authorized persons or firms) for economical firms;
- possibility to obtain exemption from taxes for equipments to be used in energy efficiency projects;
- granting of loans (with 25% lower interests from banks) for energy efficiency projects;
- financial stipulations for activities that lead to energy efficiency increase;
- firms with energy consumption greater than 1000 equivalent tones of petroleum / year and local administrative authorities for towns with more than 20000 inhabitants are obliged to have special energy efficiency programs;
- fining the minor offences of law.

Methodological Norms for application of this law were created in 2002 (according to [9]). In these norms, an entire chapter refers to firms of energy management and services. A special accent is put on energy efficiency indicators for this kind of projects.

February 2001. Ratification of the "Kyoto Protocol for United Nations Convention on Climate Changes" (Signed in 1997)
So, according to [3], Romania is committing itself in:
- application and/or elaboration of energy efficiency policies;
- cooperation with other countries;
- changing information.

June 2003. Guidebook for training and testing specialists for energy administration
In this norm, according to [15], the following fact is stressed:
Professional experiences, required for those who want to be authorized for energy survey, differ depending on category. This category differs in accordance with:
- survey type (electrical, thermal, complex);
- analyzed equipments power.

June 2003. Guidebook for training and testing specialists for activities regarding energy surveys
In this guidebook, according to [16], a distinct domain is present: “Labeling and standardization. Energy Efficiency”

June 2003. Monitoring procedure for activities regarding energy surveys
According to [17], it is stipulated that energy surveys give the necessary information about following aspects:
- energy consumptions;
- situation of equipments operating and control;
- applicable measures for making optimum the energy parameters.

July 2003. Energy Law
In this law, according to [18], it is written that activities within energy sector must to be carried out to fulfill some basic objectives, one of them being the following: “transparency of tariffs, prices and taxes for electricity within a tariff policy, the goal being the increasing of energy efficiency in production, transport, distribution and use of electricity”.

August 2003. Energy Road Map for Romania
According to [19], the basic scenario regarding energy efficiency is that in which total energy intensity must be reduced with 30÷50% until 2015, by means of changing high-energy consumption technologies, restructuring national economy. Alternative scenario foresees a reduction of only 25%, based on a slow development of Romanian economy caused by influences of global economy.

February 2004. National Strategy regarding Energy Efficiency
It is according to [22].

National authorities

Romanian Agency for Energy Conservation (ARCE in Romanian language)
According to [11], among its main attributes there are the followings:
- drawing up norms and technical settlements for energy efficiency increasing of equipments, outfits used for energy production, transport, distribution and consumption in buildings and other fields of activity;
- technical assessment and approval of projects investments from the special fund of energy system development;
- free of charge expert advice in drawing up and carrying out.

Romanian Fund for Energy Efficiency (FREE in Romanian language)
It was created, according to [10], for financing projects from two sources: internal (Romania) and external (international bank, especially).

Specific legislation for energy efficiency domestic appliances

Between 2001 and 2003, a series of energy efficiency norms for different domestic appliances (for household use) appeared by Governmental Decisions. There are referring to settling energy efficiency, energy and ecological labeling requirements for: refrigerators ([20]), clothes-washing machines ([4]), combined clothes-washing and drying machines ([5]), electric clothes driers with cylinder ([7]), dish-

washing machines ([8]), electric ovens ([12]), air-conditioners ([14]), electric lamps ([6]), ballasts for fluorescent lighting sources ([21]).
It must be noticed that in these norms there are references to each applicable European Norm (in most cases – adopted as Romanian Standard).
In December 2005, a law regarding energy performances of buildings ([23]) was promulgated, containing aspects regarding:

- construction;
- heating and cooling;
- ventilation;
- lighting;
- energy consumption.

Some examples regarding Romania's participation in different energy efficiency programmes

Agreements for grants

These were concluded between Romania and the following institutions:

- International Bank for Reconstruction and Development (in 2002);
- European Commission (PHARE 1 Program – in 2000): energy efficiency improving in district heating systems;
- European Commission (PHARE 2 Program – in 2002);
- European Commission (in 2003): technical assistance for preparing the projects for environmental sector in some towns from Romania – Baia Mare, Botosani, Drobeta Turnu Severin, Galati, Deva, Hunedoara).

Participation on multi-national level

1998÷ 2002 – ALTENER Program for renewable energy resources in Europe;
1998÷ 2002 – SAVE Program for energy efficiency in Europe

Cooperation between Romania and only one other country

France. SIENE Symposium on energy and environment theme (in Romania: Cluj Napoca in 1997, Timisoara in 1999)
The Netherlands (in 1998). Economic cooperation
Switzerland (in 1999). Projects referring to thermal energy in Buzau Town and Pascani Town, Romania
Norway (in 2001). Modernization of district heating system in Fagaras Town, Romania
Sweden (in 2001). Cooperation regarding energy and environment
Bulgaria (in 2002). Regional development of energy policy
Germany (in 2002). Cooperation in the field of energy

Opportunities

Taking into account all the above-mentioned data and experience from different programs, there are some ways of energy efficiency in residential sector:

- thermal rehabilitation of buildings (dwellings);
- increasing the efficiency of heating systems, lighting systems;
- using efficient "white goods".

The needed investment is about 167 EUR for an annual economy of 1 equivalent tones of petroleum. It results a total investment of 6,17 billions EUR.

Perspectives

Within its Energy Strategy on Medium Term and Energy Road Map, it is emphasized that, when it becomes member of European Union, Romania assimilated and applies European Community Acquis, Romanian market becoming a part of the united Europe large market.
Romanian energy policy has to be synchronized with the European Union one. Accents must be put on safety, efficiency, environment and consumers' protection, using competition mechanisms and an equilibrated settlement of energy efficiency. Not to forget the information campaigns that must be carried out in mass media, shops, schools.

For the residential sector, it is estimated that the maximum value of annual economy of final energy is about 3,6 thousands equivalent tones of petroleum, which represents an economy of primary resources of 4,3 thousands equivalent tones of petroleum.
Considering 133 EUR for 1 equivalent tone of petroleum, it results an economy of 0,57 billions EUR / year for primary resources acquisition. Not to mention the impact on the environment.

Conclusions

Better use of energy leads to economical development. So, DSM ("Demand Side Management") is not anymore an option, but a necessity, especially for Romania, which has a large potential for this. Especially in residential sector that represents an important sector regarding energy consumption.
In now a days Romania, one of the most important conditions of progress is to reduce so-called "energy intensity" and, in order to do this, efficient use of energy is "a must".
In order to gain its place among high-developed countries, Romania has to develop its economy further on. For this, the focus is on following objectives:

- providing for energy resources and safety;
- energy efficiency;
- utilization of renewable resources;
- environment protection.

One can see that energy efficiency has an important role. Specific actions have to be done for a better preparation in carrying out conditions required by the European Community Acquis in this domain.
Romania is also hoping that international community will support its efforts by different means (grants, know-how, sharing experience).
Because today Romania wants to let, to the future generations, a country with high life standard, less pollution and better use of different forms of energy.

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The Bottom Line of Green is Blue: How ENERGY STAR is Transforming Home-Building While Generating Economic and Environmental Impacts

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Abstract

In the US, the traction gained by the ENERGY STAR residential energy efficiency program and its highly-recognizable cyan-blue logo illustrates how a voluntary program can stimulate innovation, transform markets, and conserve greenhouse emissions. From light bulbs to heating equipment, American homes are becoming more efficient as a result. When the EU instituted home energy ratings, the business of residential energy auditing began to emerge. As this industry takes hold, learning the lessons of ENERGY STAR is critical.

In 2006, the US Environmental Protection Agency's (EPA) ENERGY STAR Guidelines for New Homes will align with recent changes in federal residential energy efficiency standards. An estimated 2,000,000 new housing starts annually could be affected by these changes. Reliance on "branding" is one way to achieve continued program participation, yet alignment of state programs with these new guidelines is no easy task.

This paper describes ENERGY STAR's outreach aimed at ensuring builder and rater retention, identifies the impacts on the stakeholder sectors, and details innovations like the Indoor Air Package (under pilot in 3 states) and the highly-contentious Thermal Bypass Checklist that assures builders address areas prone to envelope inefficiency. This research compares the consequences and emissions reductions of more energy-efficient homes across eight climate zones and fifty states, analyzes the barriers faced and concludes with programmatic solutions and lessons learned as these radical changes to a national program (and mindset) seek to green the American dream.

Background

According to conservative estimates, the United States could save up to 0.70 quads by 2010 by implementing simple energy efficiency measures in buildings, if mandated by specific policy changes. And forty billion pounds of CO_2 could be prevented from entering the atmosphere if only 10 percent of US homes were able to meet ENERGY STAR's guidelines for new construction.

Today, 90 percent of new US homes are found in large developments in suburban settings and the 2000 US Census found that the majority of Americans now reside in those suburban areas. Urban sprawl and the development of all rural areas are worsening. For example, from 1985 to 1997, the US population grew 16 percent while the area of land developed grew 47 percent. In addition, the average single-family home size has increased more than 700 square feet since 1970.

Inefficiency, increasing home size, and urban sprawl are three factors that have led to an unsustainable situation. To impact the energy use of all new homes and prevent the resultant environmental degradation due to ever-increasing home sizes and escalating urban sprawl, the US Environmental Protection Agency (EPA) began its new homes initiative in 1995.

The ENERGY STAR for New Homes program continues today as a voluntary program under the EPA ENERGY STAR suite of programs aimed at environmental preservation through market transformation. This program has had the aggressive goal of transforming the U.S. housing market to energy efficient construction in the residential sector. What began as a modest initiative in 1995, today has gained traction in every state in the union through a network of more than 90 utility partners, 2,900 builders, and 360 providers and rater (verification) organizations.

To achieve the sweeping market transformation in the residential sector envisioned by the ENERGY STAR for New Homes program, the EPA worked with an implementation team at ICF International for marketing, sales, and technical support services to builders, subcontractors, and broader international stakeholders including Home Energy Raters (HERs), mortgage lenders, utilities, and product manufacturers. This singular team construction has lent the ENERGY STAR for New Homes program the robustness of a government-backed program and the corresponding budget security coupled with the market-based approach of a consulting firm that has expertise in all relevant areas from product labeling to home-building.

Figure 1: ENERGY STAR Qualified Home Label

For a home to be labeled as ENERGY STAR qualified, the New Homes team has worked through builders and third-party verifiers (Home Energy Raters or HERs raters) to authenticate the energy efficiency of each ENERGY STAR home. Figure 1 shows the ENERGY STAR qualified homes label. Figure 2 illustrates how homes may be labeled under the ENERGY STAR process.

The Strategy

The ENERGY STAR new homes team works through the vehicle of ‘account management’ to provide technical and market support to all target regions and target groups identified. The team lends support to all relevant stakeholders in that target area. For example, there may not be a utility program, or a rating infrastructure in a particular target area. The team will work with the utility (or provider) to train raters and assist them in starting their businesses providing building science consulting to local builders who seek to participate in the ENERGY STAR New Homes program. Builders, too, must be convinced to participate in the program. As shown in Figure 2, the builder begins this process by signing a Partnership Agreement with EPA.

Thus far, the ENERGY STAR for New Homes program has targeted large production builders (those who build more than 300 homes a year) as its primary catalysts in the marketplace. Small builders, too, are welcomed to the program, however, their impact is limited by their size. Through a program of sales training, marketing support, co-branding, and “advertising partnerships” with local builders, the ENERGY STAR program has flourished, with nearly 3,000 builders participating presently.

Through training, capacity-building, advertising support, co-branding with the ENERGY STAR logo, and a host of other support mechanisms, the ENERGY STAR for New Homes program has labeled more than 500,000 homes across the United States as having achieved the targeted energy efficiency levels. **Table 1** shows how the energy efficiency of the typical US home has increased since 1993.

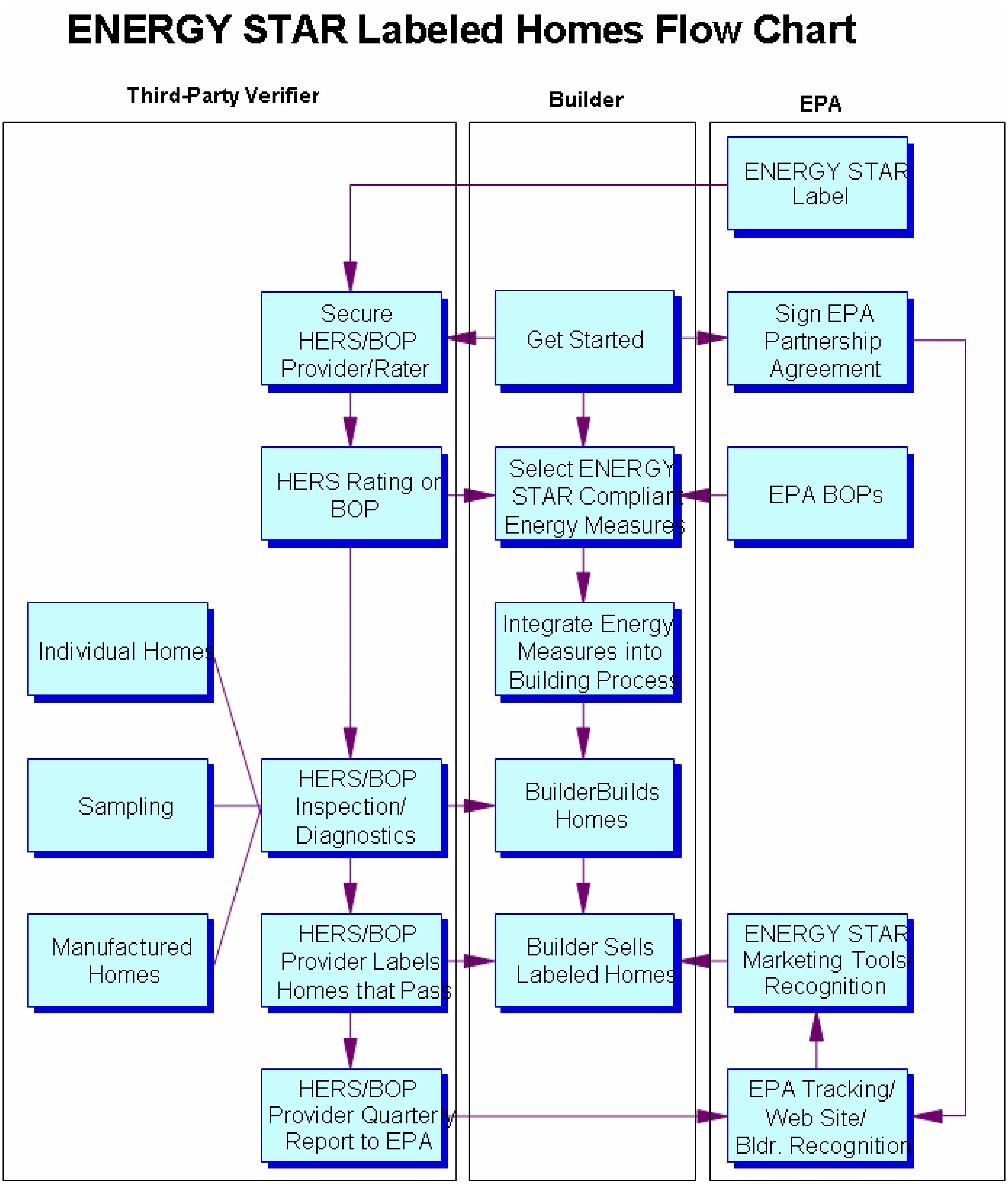


Figure 2: Process of Rating a Home as ENERGY STAR Qualified

Key Features of the Program
The key features and activities of the ENERGY STAR for New Homes program include developing regional strategic plans for supporting ENERGY STAR New Homes within the various stakeholders in each region, identifying, recruiting, and cultivating program champions (like utilities or providers) in each local market considered of interest to the goal of nationwide market transformation. Additionally, the ENERGY STAR for New Homes team has worked to foster strategic alliances between partners, conducting and/or facilitating meetings, seminars and workshops, and developing tools and materials aimed at strengthening recruiting and account management. Since its inception in 1991, the ENERGY STAR program has conserved emissions equal to the removal of 150,000 cars from US highways and has the goal to prevent carbon emissions of 9 million metric tons by 2012. The ENERGY STAR for New Homes program expects this initiative will account for another 1,000,000 new homes being built efficiently by the end of the decade. So the need to retain program partners is clear.

Table 1: Increase in Energy Efficiency of Various Home Building Components 1993-2006

		Hot Climate		Mixed Climate		Cold Climate	
		1993 MEC	2006 ENERGY STAR	1993 MEC	2006 ENERGY STAR	1993 MEC	2006 ENERGY STAR
Shell Information							
Wall Insulation	(R-Value)	13	13	21	13	21	19
Door	(R-Value)	5	1.33	5	2.5	5	7.75
Attic Insulation	(R-Value)	30	30	38	38	49	49
Slab Insulation	(R-Value)	0	0	5	10	5	10
Window U-Value	(U-Value)	0.68	0.55	0.49	0.4	0.33	0.4
Window SHGC	(SHGC)	0.38	0.35	0.58	0.45	0.88	0.55
Infiltration	(nach)	0.35	0.46	0.46	0.4	0.55	0.33
Systems Information							
Cooling Efficiency	(SEER)	10	14	10	13	10	13
Heating Eff.	(AFUE)	78	80	78	90	78	90
Heating Eff.	(HPSF)	n/a	8.2	6.8	8.5	6.8	8.5
Duct R-value	(R-Value)	5	6	5	6	5	6
Duct Loss	(cfm/cfa)*	~8	4	~8	4	~8	4
Thermostat Type		Man.	Prog.	Man.	Prog.	Man.	Prog.
Water Heater Fuel Typ		Gas	Gas	Gas	Gas	Gas	Gas
Water Heater Efficiency	(EF)	0.56	0.61	0.56	0.61	0.56	0.61
Evaluation Location							
City		Phoenix, AZ		Baltimore, MD		Minneapolis, MN	

Present Challenges in the ENERGY STAR Program

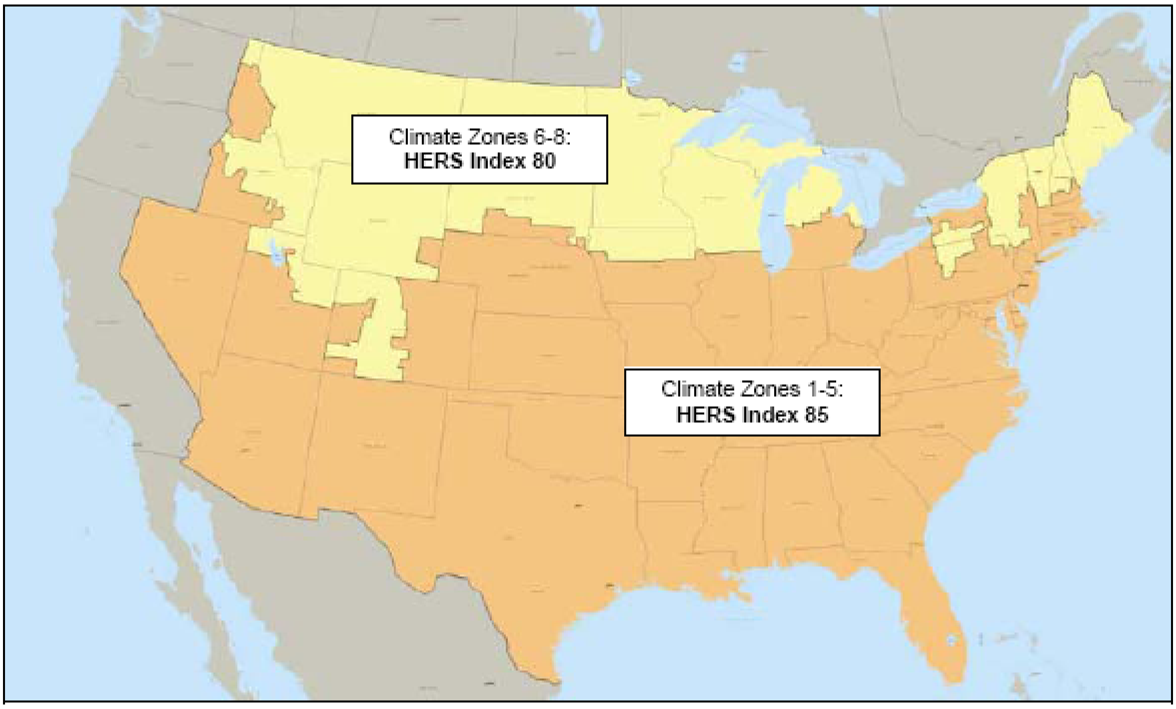
As markets for energy efficiency mature (e.g., the US market began with the 1973 Energy Conservation Act) various elements must adapt to keep pace with technological and practical changes. During the past few years in the US, the Home Energy Raters (HERS) guidelines were amended to be based on the International Energy Conservation Code (IECC) beginning in 2006.
The national requirements for air conditioners, too, were changing, to require a 13 SEER (a more efficient unit). Additionally, the IECC became the standard for performance over the older Model Energy Code (MEC). Some of those code changes are that the insulation requirements are now defined by the 2004 IECC not MEC 93; the operating assumptions are now matched with the 2004 IECC; and equipment efficiencies in the Reference Home were updated to reflect air conditioning/heating industry changes like the aforementioned upgrade from a 10 to a 13 SEER air conditioner, from 6.8 to 7.7 HSPF for heat pumps, and increased water heater efficiency. Even the HERs Index was changing to reflect a much different system of measurement where "zero" energy use was the preferred score (0) and 100 now constituted a code-built home (the least efficient). And there were even revisions to the Reference Home used by the IECC upon which to base this index.
In short, the industry was changing and the EPA guidelines for ENERGY STAR qualified homes

needed revision to reflect these shifts.
The ENERGY STAR team began modeling the impacts and effects of various scenarios, using Department of Energy (DOE-2) modeling software. These changes to the guidelines were announced in early 2005, with the request from EPA to builders, raters, utilities, and providers to submit written comments back to the ENERGY STAR team. Those comments were received, reviewed, and incorporated into the final guidelines issued in December 2005.
In 2006, the ENERGY STAR for New Homes program guidelines will go into effect, to align all stakeholders with recent changes in federal residential energy efficiency standards, making it more important than ever to right-size equipment, seal the building envelope, ensure clean indoor air quality, and secure emissions reduction. An estimated 2,000,000 new housing starts annually could be affected by these changes in the ENERGY STAR guidelines. Continued compliance was seen as key to ongoing success of the program.
Reliance on "branding" was seen as one way to achieve continued program participation, however, alignment of state programs with these new guidelines remains a challenge. In some states, equipment manufacturers pose a potential obstacle to widespread implementation of this long-standing and highly successful voluntary program (as manufacturers of more efficient equipment fail to release pricing information so critical to builders seeking to incorporate this equipment into their procurement strategies, for example). The single-most important challenge to the ENERGY STAR New Homes program is still how to ensure retention of key partners (and their trust) as this well-known program transformation is being rolled-out to thousands of implementing agencies across the US in the coming months.

Strategy to Effectuate These Changes

The goals of the new guidelines were to respond to industry changes, use tried-and-true energy efficiency improvements to make those changes, balance energy efficiency with cost-effectiveness, integrate more ENERGY STAR qualified products into the homes and promote their use, and create equivalent construction improvement requirements across the country. This last goal is likely the most interesting and relevant to the EU market, where each country has its own standards for construction and not unlike the US states, often has very different regional and climate-sensitive approaches to home-building.
The new ENERGY STAR guidelines are effective immediately, but contain a grandfather clause, allowing homes that have been permitted before July 1, 2006 or that have been enrolled in a utility program before December 31, 2005, to continue to be labeled using the old guidelines until January 1, 2007. And there are essentially two paths by which a home may be labeled ENERGY STAR. The first is the "performance path" that allows any efficiency of equipment to be used as long as the overall performance target is reached. The lower the efficiency of the equipment, the more upgrades need to be made. The second path is the "builder option path" otherwise known as the BOP. The BOP prescribes the efficiency levels of equipment needed to comply. Both paths require the accompaniment of a completed "Thermal Bypass Inspection Checklist".
Since the United States covers such a vast landmass, there was the need to divide the country into "climate zones". There are eight climate zones used by the present EPA guidelines, as well as numerous other agencies. Different climate zones may use the Builder Options Package (BOP) to comply with the ENERGY STAR guidelines. That BOP includes heating and cooling equipment ratings, energy efficient windows specifications, maximum duct leakage and insulation requirements, maximum envelope leakage requirements, and completion of the mandatory Thermal Bypass Inspection Checklist (TBC).
Different climate zones may opt to use the Performance Path to comply with the ENERGY STAR guidelines for new homes. In that case, builders in various climate zones would ensure envelope tightness using the Thermal Bypass Inspection Checklist, ensure maximum duct leakage was not exceeded, and include at least one ENERGY STAR qualified product category within the home to achieve a HERs Index, as specified by each climate zone. **Figure 3** illustrates the various HERs Indices required in each climate zone.

Minimum HERS Index Required to Earn the ENERGY STAR[1]



Note: Due to the unique nature of some state codes and/or climates, EPA has agreed to allow regionally-developed definitions of ENERGY STAR in California, Hawaii, and the Pacific Northwest to continue to define program requirements. The States of Montana and Idaho may use either the requirements of the national program or the regionally-developed program in the Pacific Northwest.

Figure 3: Climate Zones and HERs Indices

Thermal Bypass Inspection Checklist

Completion of this thermal bypass checklist is mandatory for either path taken by a builder in any climate zone. This checklist covers the sixteen areas known to cause energy inefficiency in homes. Preventing thermal bypass in those areas, the ICF modeling showed, will result in home energy efficiency that is within the limits acceptable to EPA. Each builder must use a HERs rater to verify that the builder has, in fact, avoided thermal bypass in these problem areas. The checklist provoked immediate and strong reaction from builders and raters alike after it was formulated. The comments from utilities, state energy offices, HERs providers and raters, as well as interested stakeholders were considered by the ENERGY STAR team, acted upon, and then posted on the ENERGY STAR Web site to ensure transparency of all actions resulting from this feedback. In general, stakeholders were in favor of the checklist however some worried that it might increase costs or require additional site visits by raters. Upon resolution of these concerns, the checklist was agreed and approved, becoming part of the new guidelines to builders.

To prove that thermal bypass has not occurred in the home's construction, the rater will test each home, or may sample "batches" of homes. And because some inspections cannot be completed in one or two visits by a rater, the builder is allowed to check up to four items on the list. Completion of this checklist ensures that the home buyer receives a third-party quality check of the home; and the builder gains the advantage of fewer "callbacks" and reduced warranty costs for each home sold. The subtler effect of this checklist may be a harmonization of construction practices for these problematic areas in residential construction, such that more efficient homes become the norm.

The ENERGY STAR program has used numerous business tactics and market leverage to reach builders, raters, realtors, and manufacturers. Consequently, there has been an increase in the visibility of concepts like quality assurance and quality control. And in the marketplace, consumers are increasingly requesting "green" homes, as witnessed through green programs like Environments for Living, USGBC LEED-H, and Southface's Earthcraft initiative. EPA foresaw this increased focus and developed the timely Thermal Bypass Inspection Checklist (in 2006) and the Indoor Air Quality Package to answer the need for quality construction as well as address the need for baseline "green" using ENERGY STAR guidelines as the threshold.

Another market impact has been that utility-funded programs continue to rely on selling ENERGY STAR to their customer-base through rebates and have not yet begun to sell the “added value.” This gap in sales strategy has made it difficult for utility-based programs to help consumers understand not just the “added value” aspects but also the “added cost” requirements. Yet builder partners around the country have become sensitized to the need to reduce callbacks and insurance claims to remain competitive in an increasingly competitive homebuilding market; so the climate for going “green” using ENERGY STAR program has continued to be successful. And in part, the cooperative advertising builders are able to use, that depicts them as part of the ENERGY STAR family carrying this cyan-blue logo has continued to hold sway.

Present Challenges in the EU Residential Program

The EU Energy Performance of Buildings Directive (EPDB) became law in January 2003. Like the US regulatory mechanisms mandating energy efficiency, the EU Directive has far-reaching implications for the owners, operators, and developers of all buildings—homes and offices alike. European experts estimate that more than US$17 billion (13 bl Euro) in potential costs savings could be captured by 2015 if energy saving measures (like insulation, window replacement, etc.) were undertaken in all building stock. In the residential sector, the average EU household could easily save a range of 200 to 1,000 Euros per year, according to its consumption level.

Not unlike the ENERGY STAR new homes program, the EU directives require that new homes be benchmarked using a whole building energy performance calculation and be certified by a “suitably qualified and/or accredited expert in an independent manner”. (The EU version of a HERs rater, the third-party verifier). The major difference between the EU and the US approach to achieving energy efficient homes and ratings is that the US ENERGY STAR program is voluntary and provides substantial cost-effective rationale and support to the process of building and rating energy efficient homes. The EU approach is via a mandatory mechanism—leaving the pathway for “getting to” energy efficient homes (and the rating of those homes) largely up to the builders and raters.

The next significant difference lies in the approach to market transformation. ENERGY STAR’s consumer outreach was aimed at generating a “market pull” for energy efficient homes, thereby creating business opportunities for both the sales of new energy efficient homes (by ENERGY STAR qualified builders) as well as a ready market for the services of the certified raters (by the ENERGY STAR qualified builders who seek to have their new homes labeled and who will hire the raters to do so).

Rating Scales in the UK

The two EU countries that presently exhibit the most developed home energy ratings infrastructure are Denmark and the UK. In the UK, there are two energy scales for rating homes. The first, Standard Assessment Procedure (SAP) utilizes a scale from 1-120, with 120 being excellent. A SAP rating is required for all new buildings like homes, as well as those existing ones being retrofit. Like the changes to the US HERs index, in 2005, the SAP 2005 will be introduced (effective April 2006) as the basis for the implementation of the Energy Performance in Buildings Directive.

Similar to the ENERGY STAR’s more stringent guidelines being rolled out in 2006, the SAP 2005 differs from SAP 2001 in that it takes account of building integrated renewable energy systems and fixed internal lighting. And to make it more difficult for raters, the SAP scale will change to be 1 to 150, not 120.The second method of home energy rating afoot in the UK is the National Home Energy Rating (NHER) scale. The National Home Energy Rating (NHER) has a 0 -10 scale and provides an estimate of the amount of carbon dioxide emitted each year as a result of the home’s energy use.

The two energy scales (SAP and NHER) measure slightly different things: the SAP looks at the fixed elements of the home and is the same wherever the property is located in the UK. (All homes built to the same design should have the same SAP). Whereas, the NHER includes various location-specific elements (including whether the home is South-facing or sheltered from wind by other buildings), occupancy patterns and cooking. And so the NHER reflects actual running costs—much like the US HERs index. However, unlike the UK system, the US system standardized on one scale, the HERs index (which, as previously mentioned, has recently been amended to reflect current industry conditions). Standardization and agreement on one system of scoring is highly recommended for the EU, to prevent misalignment of energy efficiency labeling of similar homes in different countries.

The UK Homes Label

Both the SAP and the NHER scales produce a label for rating homes in the UK and are based on the BREDEM (Building Research Establishment Domestic Energy Model). The UK label uses a logarithmic scale (e.g., increasing an NHER rating by one point will reduce the energy bills by a more or less constant percentage). Not only are the US and UK (EU) systems different, but the home labels (certificates) too, differ. The ENERGY STAR label (as a voluntary program) specifies that the home was rated, the date, and the rater's name. The UK building certificate (as part of a mandatory program) goes much further in that the certificate shows the watts per square meter of energy used, the kg of CO_2 per square meter of net area per year, the rated performance of each mechanical component, and the expected performance summary for the home (or building).

There are many features of the building certificate that are more detailed than the ENERGY STAR label. While it is unlikely that the voluntary ENERGY STAR label would benefit from adding these features, the Energy Guide label (also used in the US) to denote actual energy use of equipment might benefit from comparison with the UK building certificate which incorporates such innovations as "decibel levels" of the operating equipment. As US consumers become more informed about ergonomic stressors like noise pollution, learning from the EU experience is also recommended.

The UK Rating Infrastructure

Not unlike the US HERs raters, the UK NHER raters are trained by a central organization (National Energy Foundation), a registered charity that also developed the National Home Energy Rating Scheme for British homes. In the US, all raters are certified through the organization known as the Residential Energy Services Network (RESNET). Although RESNET began as an organization serving the mortgage industry, today it provides a critical link to the rating infrastructure of the US. The ICF team assisted RESNET five years ago to revise the RESNET Vision Statement to more closely align with this growing rating industry. ICF continues to participate on RESNET's technical and procedural committees in an advisory capacity. RESNET's vision has changed since its inception and its role has changed, too. Now RESNET certifies raters and works closely with the ENERGY STAR team to standardize rater qualifications and training, track rating transactions, and provide mechanisms ensuring the quality of all home energy ratings.

Unlike the US guidelines, the EU directives require that a valid energy performance certificate be produced for all dwellings when they are rented out. And while much uncertainty remains over exactly how the EU Directive will be implemented in the rental sector, the use of the EU home labels is highly innovative in scope. The EU Directive is similar to the ENERGY STAR for new homes program in that the EU Directive mandates that an energy certificate be provided for all homes. But it is dissimilar in that the ENERGY STAR program does not mandate the prominent display of this energy certificate. Precisely where to locate the ENERGY STAR label on a home remains a point of discussion to this day and is largely up to the discretion of the HERs rater.

Experts believe the average home in England would currently receive an NHER rating of between 4.5 and 5.5 (with 10 being excellent). A home meeting the current Building Regulations would probably score higher, perhaps around 8.0 or more, these experts claim. Yet in 2006, a new version of the NHER will be introduced to model lighting and appliances more accurately. And its scale will also be extended from 0 to 20! Before these latest alignments, refinements, and adjustments occur, the lessons learned by the ENERGY STAR for New Homes program may be instructive.

Conclusions and Lessons Learned

Probably the most important benefits of retaining ENERGY STAR partnerships with builders and the rating infrastructure have been the constant communication from the field and feedback between EPA and the various stakeholders who will implement the new guidelines. The back-and-forth dialogue that allowed partners to vent frustration, vet the new guidelines, and become vested in the new specifications has led to maintained partnership in key areas. Additionally, this collaboration has proven beneficial in achieving greater stakeholder "buy-in" of the new guidelines.

The next important aspect has been the ongoing issuance of guidelines updates and increased partner training in the changes to the guidelines. When the new ENERGY STAR guidelines were originally changed, a shorter implementation period was envisioned. However, numerous complaints from stakeholders and a near "crises of confidence" on their part led to a more reasonable timeline, along with a grandfather clause, allowing builders to make the change in construction once all homes permitted had been completed.

The presence of a strong rating infrastructure has proven beneficial (and perhaps necessary) to make inroads into new markets through ENERGY STAR across the US. Support to this rating infrastructure in terms of training and capacity-building has meant that ENERGY STAR's best proponents to "sell" the program to builders were on-board with the new shifts in the guidelines at a time when their retention was crucial.

The continued improvement trajectory of the ENERGY STAR New Homes program through vehicles like the Indoor Air Quality Package and the Thermal Bypass Inspection Checklist has increased the public presence of the ENERGY STAR brand and captured a whole new audience of consumers searching for "green homes". As builders relay this new product to their customers, the knowledge about the integrity, quality factors, and benefits of the purchase of an energy efficient home (and ENERGY STAR in particular) increase exponentially. And the reduced callbacks and warranty costs to builders help reinforce their decision to remain ENERGY STAR partners and practitioners.

Homebuyers the world-over seek answers to immediate questions and want to avoid searching through onerous and technically-challenging information to get those answers. Over the years, consumers have "looked for the ENERGY STAR label" as in indicator of quality. The one-stop shop of ENERGY STAR provides US consumers with a central clearinghouse for information on how to make more informed choices. Much attention has been given by the EPA team to the challenge of simplifying the buying decisions for consumers and making program participation by industry stakeholders economically-justifiable as well as pragmatic from an implementation standpoint.

It is important to note that the ENERGY STAR program has been built upon market transformation principles. The ENERGY STAR program has been adopted by utilities, state energy offices, and program champions across the US. Some locales and states have even made ENERGY STAR the threshold for their residential building codes. Yet as the program matured and the market began to be transformed, the ENERGY STAR team (both within EPA and at ICF) found they needed to carefully target which markets were "ready" for ENERGY STAR, which messages resonated with new partners, which tactics needed revision, and how to best nurture the program through the identification and use of champions or "market mavens". As the EU program grows, similar strategy adjustments will no doubt be required.

As the US housing market changes and US builders attempt to "go green" with energy efficiency, there is real opportunity in the decades-old ENERGY STAR brand. As home buyers have higher expectations, do more research, and are increasingly time-poor, prospective home buyers search the Internet and look through the websites of many builders before they ever encounter a salesman. Savvy builders realize this, and will continue to follow this known brand. As the EU rating infrastructure grows alongside the implementation of the new directives for homes, European consumers will benefit from the trail blazed by this decades-old program and be able to foreshadow the coming adjustments to the SAP and NHER home energy rating systems by seeing that the bottom line of green is probably blue.

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Promoting actions for lighting energy efficiency and saving in residential buildings in Romania

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Abstract

Both in European Union countries and in Romania, the residential sector represents an important potential for the reduction of energy consumption. The energy consumption in this sector is focused on lighting and domestic appliances and heating/air conditioning/hot water. The efficient use of electricity is still a neglected issue, with a lack of the necessary statistic data.
The Lighting Engineering Center of the Technical University of Cluj-Napoca (LEC UTC-N), Romania is involved in two programs for promoting lighting energy efficiency and energy saving measures in residential buildings: **ENERLIN - European efficient residential lighting initiative,** an EIE - SAVE program to promote Compact Fluorescent Lamps (CFL) in the residential sector, and **CREFEN – Integrated software system for energy efficiency and saving in residential sector,** a Romanian CEEX program.
Market research has indicated that in order to substantially increase the use of CFLs in the residential sector, it is essential to develop and market attractive and good quality CFLs. The ENERLIN EIE SAVE program has set out to propose and validate robust scenarios for CFL promotional campaigns on European, national and regional levels. The aim of the CREFEN project is to achieve an integrated software system for reducing the energy consumption and promoting an advanced energy management in residential buildings in Romania. The software applications are focused on the electric energy efficient use and saving in residential sector.

ENERLIN – European efficient residential lighting initiative

The European Climate Change Programme (ECCP) identified residential lighting as an important area to CO_2 emission reductions. After a considerable number of promotion and rebate schemes, about 135 million CFLs are used today in European homes. However, only 30% of EU households have at least one CFL, with those households that own them having an average of three or four. The ENERLIN EIE SAVE program is aiming at promoting to all the stakeholders a quality charter to assure that the CFL that are marketed and promoted can deliver savings which last overtime and meet the customer expectations of high quality lighting, and the ultimate objective of the program is to substantially increase the efficiency of residential lighting in a number of Member States and Candidate Countries.
In the context of the Kyoto Agreement, the European Community and individual Member States are looking for cost-effective measures to reduce CO_2 emissions and combat climate change. The residential lighting market is still dominated by inefficient Incandescent Lamps (GSL – General Service Lamps). Market research has indicated that to achieve durable market transformation and to substantially increase the use of CFLs in the residential sector, it is essential to develop and market attractive and goods quality CFLs. The ENERLIN EIE SAVE program proposes to develop and validate robust scenarios for CFL promotional campaigns in European, national and regional levels. Concerning energy savings from CFLs, assuming that there is 150 million households in Europe the energy economy by replacing only one additional 75 W GSL by one 15 W CFL is in the order of 22.5 TWh or 4 MTEP per annum, this corresponds to 1.2 Mtonnes of less CO_2 per annum. We should add at these savings that a high quality CFL has a life span higher than 10,000 work hours, compared to 2000 work hours for a GSL.
The European Union initiated numberless campaigns to promote compact fluorescent lamps with the purpose of increasing the market share of compact fluorescent lamps at 15%. In this case, the estimated energy saving would amount to 15 TWh per year. This energy saving is similar to a reduction of annual CO_2 emissions of about 800 kTones CO_2.

Objectives of the ENERLIN action. Improving the energy efficiency is a central theme of energy policy within the European Community, as indicated in the White Paper “An Energy Policy for the European Union”, since improved energy efficiency meets all the three goals of energy policy, namely security of supply, competitiveness and protection of the environment. Lighting represents an important part of building energy consumption in the EU – around 10% of the total electricity consumption, ranging from 5% (Belgium, Luxemburg) to 15% (Denmark, Netherlands, and also Japan).

The global electric lighting energy use may be split in four sectors: services 48%, residential 28%, industrial 16% and street lighting and other 8% [Mills 2002].

Overall electric appliances in households, industry and the tertiary sector represent 40% of the EU’s total electricity consumption, its generation being one of the most important sources of CO_2 emissions. Within the EU, the households and private and public services sector buildings are important power consumers. In both cases lighting represents a large part of their energy consumption. Several EU and National Initiatives and Directives tented to promote energy efficient lighting for services sector buildings. These efforts can be judged as very successful because nowadays the Compact Fluorescent Lamp (CFL) market share represent 20% of the global European market whereas the same figure in world scale is limited to 17%. The rate of the households owning a CFL covers the range from 0.8 CFLs per household in UK to more than 3 CFLs per household in Denmark; the SAVE projects have found that there is at least room for 8 CFLs per home [Kofod 2002, Loe & Jones 2002, *DELight* 1998]. An analysis on the lighting pattern in 100 Danish homes denotes that the monthly average lighting consumption varies between 5% and 21% of the total respective monthly consumption, and 24% of the lamps are energy efficient lamps (linear fluorescent lamps or CFLs). However, the same market analysis from Lighting Companies show that in Western Europe energy inefficient incandescence lamps (including halogens) still represent 30% of the sales [9]. The bulk of these inefficient light sources concern the residential sector.

There are several reasons explaining that residential sector still use a large amount of incandescence lamps:

- It seems difficult to convince individual customers that the payback time is so rapid.
- There are still many customers unaware of the environmental and economic benefits of CFLs
- Low quality (and probably lower cost) CFLs are widely available in the European markets, the customers buying these devices due to the attractive price are very rapidly disappointed by the reduced lifetime, bad lumen output due to wrong information from manufactures about how to replace incandescent lamps, and bad lumen maintenance of these lamps.
- Older generation of CFLs were almost unable to offer to customers an acceptable ambiance within the residence, this due to poor colour rendering index, limited choice of colour temperatures, ungracious shapes and aesthetic incompatibility with luminaires; most of these inconveniences are now overcame but there is still a large part of customer unaware of that progress.
- For households lighting can be purely practical or a very architectural feature or a combination of both, therefore energy efficiency is often just one consideration and probably not the prevailing one.
- CFL lamps are not suitable for applications with short on-off cycles as this reduces lamp life; therefore it is necessary to educate the customer on how to use them effectively.
- The warm up time of the CFL before full lumen output does that the user should not use in a staircase or elsewhere where they need the full lumen output immediately.
- The common CFL lamps are very sensitive to voltage variation; of course, in many countries the mains voltage is very well regulated, but in other countries and especially eastern European regions the voltage may fluctuate and this is still an important issue for CFLs.
- Finding luminaires with nice design, suitable for CFLs, is in nearly all countries, a difficult issue; many nicely designed luminaires for incandescent lamps do not look equally nice if they are used with CFLs.

Promoting CFLs by using solid argumentation, which answer to the specific individual questions and fears of the customer and then add imitative measures seems to be the right way to act. It should be noticed here that “rational” arguments are not appropriate for all customer segments. To reach the last customer segment we need new CFL solution and new control features that create added value. To identify all possible reasons of using CFLs, compile them and provide the good answers (scientifically proved) and then translate them to a clear and understandable argumentation for the non-specialist,

is the main barrier that needs to be addressed. Furthermore, barriers to information about energy-efficient technologies (including lighting) exist on several levels, each of which has implications for penetration rates. The most widespread problem in many countries, to varying degrees, is that of a lack of awareness of energy efficiency. Members of the general public simply cannot define what it means for a technology to be energy efficient. Information barriers are important to policy makers as well.
The ultimate objective of this program is to substantially increase the efficiency of residential lighting in a number of Member States and Candidate Countries, and this can be done by offering them good arguments necessary to overcome the above cited barrier. It is also important to promote the wide-scale availability of a high spectrum of low-cost CFLs suiting a wide range of needs including different sizes, shapes, colour rendering, wattage (particular problem in some counties like Hungary is that the typical good CFLs are of lower wattage and therefore provide limited illumination levels), and bases. Furthermore, to achieve successful residential market transformation we should promote that both light fixture outlets as well as design and specialty stores display their luminaires with CFLs (good and aesthetic ones) rather than GSL. At the same time the program is aiming at promoting to all the stakeholders a quality charter to assure that the CFL that are marketed and promoted can deliver savings which last overtime and meet the customer expectations of high quality lighting.
The major part of the program will design implement and evaluate a common promotional campaigns for CFLs that meet the European CFL Quality Charter along with dedicated fixtures. These national or regional campaigns shall be conducted in collaboration with lamp manufacturers, retailers, consumer and environmental organisations, and electricity utilities. On the other hand the elaboration of the argumentation should be based as deep as possible to quantitative and scientific arguments. This last, may lead to the creation or/and use of independent test facilities allowing to examine different proposed solutions before adopt them in the final argument list.
All the program objectives will lead to a higher market share for the most efficient CFLs and dedicated luminaires. The main stakeholders concerned by this program are manufacturers' associations, consumers' associations, buyer's groups, energy agencies and other intermediates, utilities, training institutes, retailers, installers and other professions. The final beneficiaries will be end-users of equipment mainly in domestic sector.

ENERLIN Consortium. 14 partners from 14 countries constitute the proposed consortium, covering a large part of Europe form north to south and from east to west. This is an important issue; because, concerning lighting the reaction of the individual customers is quite different form a country to the other (north countries prefer low colour temperatures lamps –hot ambiance- and south countries are more sensitive to high colour temperatures –cold ambiance-). The consortium includes western countries with high GDPs compared to eastern countries that they just integrated EU (Poland, Hungary, Czech Rep., Latvia and Estonia). These countries are in full market transformation at this moment. Finally, two candidate countries (Bulgaria and Romania) are also members of the consortium. The ENERLIN consortium is strongly cross-disciplinary including, National or Regional Energy Agencies (ADENE, KAPE, ENEA, SEC, SEVEn, BE), one ESCO in Belgium, academic institutions (France – the coordinator CPAT - University Toulouse 3 -, Hungary and Romania), a values-based consultancy focusing on sustainability (Respect) as well as independent consulting SMEs (Ekodoma, Energy Saving Bureau). Each partner has solid experience with EU projects (especially from DG TREN), and strong links with international organisms like CIE and projects like ELI, other European networks (COST-529) and programs (GreenLight). Some consortium partners are quite influential for policy-making bodies in both national (regional) and European levels.

CREFEN – Integrated software system for energy efficiency and saving in residential sector

The **CREFEN project** aims to creating an integrated software system-tool focused on the applications concerning the electric energy efficient use and saving in residential sector in Romania. The project integrates the consumption assessment and prognosis methodologies, consumption scenarios, consumers' guidance and training to the advanced technologies, sustainable electric energy management and the economical, social and environment impact, as well. A special issue is to develop the necessary databases of equipment and endowments from residential sector, using the market surveys and questionnaires.
The project aims to develop an advanced modeling and simulation software system-tool of electric energy consumption in residential sector and of economical effects, to implement an application with databases, an interactive educational application and electronic book related to the energy efficiency

use in order to influence the consumers' options in selecting energy efficient appliances for environmental protection by reducing the CO_2 emissions.

The **National Strategy in the energy efficiency field** adopted by the HG 163/2004 underlines that the residential sector has a primary energy saving potential at 3.6 millions tones equivalent petrol through 6.8 million tones of the total final consumers; it means more than 50%. This potential can be capitalized by the rehabilitation of the buildings thermic insulation, the improvement of the heating and lighting systems and of the electric domestic appliances. The legislative frame was created and is on line with the EU acquis, the EU Directives related to labeling of the energy parameters for many electric appliances.

The **Governmental Program** on the following years 2005-2008 states the necessity to accomplish the legislative and institutional frame in order to apply the flexible mechanisms adopted by the Kyoto Protocol, to pursue the implementation of the technical and economical measures for the reduction of the gas emission with the greenhouse effect, in accordance with the features of the National Plan for the Allocation of the Emission Quotas, the development of the National Plan for Climatic Changes Action, the improvement of the energy efficiency and the promotion of regenerate energies.

The **specific objectives** of the CREFEN project are:

- Drawing up of scenarios and prognosis of electric energy consumption in residential sector;
- Achievement of an advanced modeling and simulation software system-tool of electric energy consumption in residential sector and of economical and environmental effects;
- Using a tool for defining the potential of energy saving, prognosis and scenarios of consumption evolution;
- Improvement of the degree of taking into consideration by the consumers, decision factors and specialists of the opportunities, advantages of promoting new technologies in electric energy consumption in residential sector, in the framework of a sustainable development integrated at the European level;
- Designing and implementation of a web application with databases for domestic and lighting appliances available on the Romanian market, which include information from the energy label and sheet;
- Designing and implementation of the software for an interactive system and an electronic book.

The project is connected with energy efficient use according to EU directives from one side and with the implementation of database applications using web-based technologies for assisting and influencing the consumers decision in selecting the domestic and lighting appliances from the other side, that leading to sustainable environment management. The last aim of the project is for environmental protection by reducing the CO_2 emissions.

The software application architecture will be a modular one, with the possibility of its extension with new functionalities, without perturbing the other components or requiring the reorganization of the system data.

LEC UTC-N work in the CREFEN project aims: (1) to analyze the Electric Lighting component in the energy balance of the dwelling; (2) to elaborate a simplified mathematical model for calculation of the inside electric lighting; (3) to present the IT system to technical background users groups (students, designers, dealers and retailers); (4) to contribute with the chapter Electric and Natural Lighting of the design specification for IT system; (5) to analyze the direct energetic and educational benefits and evaluate the importance and the impact of the improvement of the domestic users education; (6) to design consumption evaluation scenarios based on the evolution of the technological performances of the new lighting equipments (for 5 and 10 years); (7) to print an informing flyer concerning the electric and natural lighting component; (8) to promote the project achievements by workshops, the 'Ingineria Iluminatului' (Lighting Engineering) journal and the ILUMINAT international conference.

Analysis of electric lighting energy consumption in the residential sector in Romania.

The statistic data [10] for the period 2000 – 2004 allow us to determine the variation of total household consumption – Figure 1 -, total number of household consumers – Figure 2 -, average consumption per household consumer – Figure 3 – and of the specific consumption per m^2 – Figure 4.

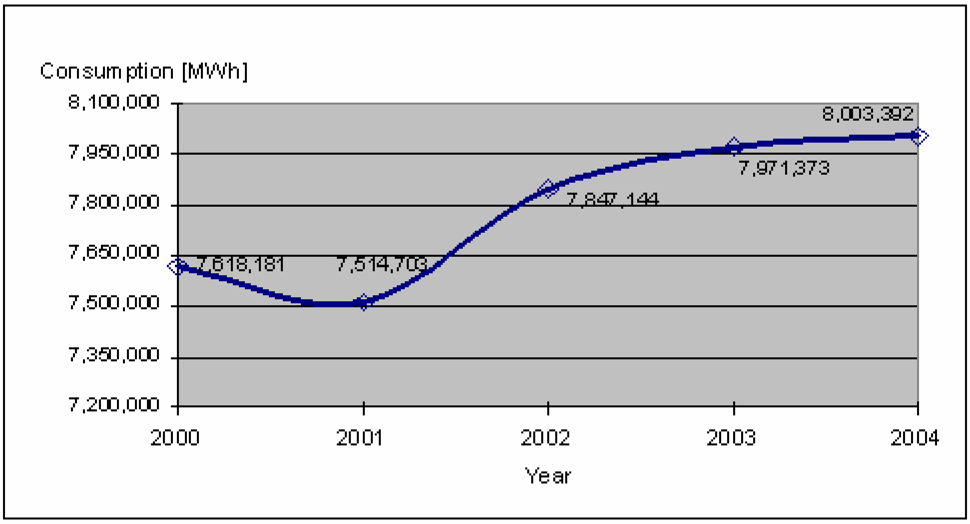

Figure 1: Variation of total household consumption in Romania between 2000-2004 [MWh]

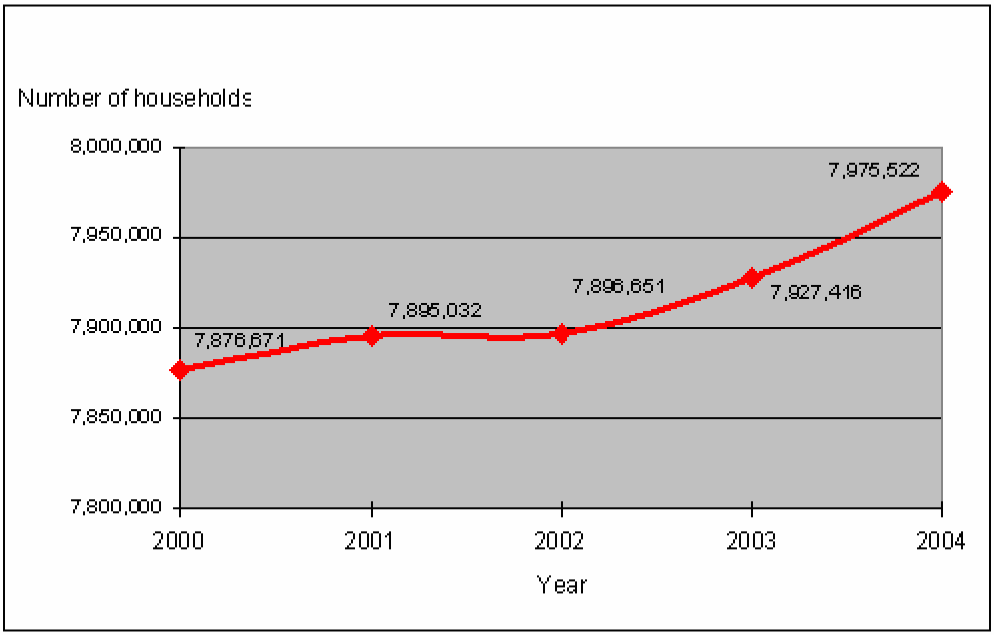

Figure 2: Variation of the total number of household consumers in Romania between 2000-2004

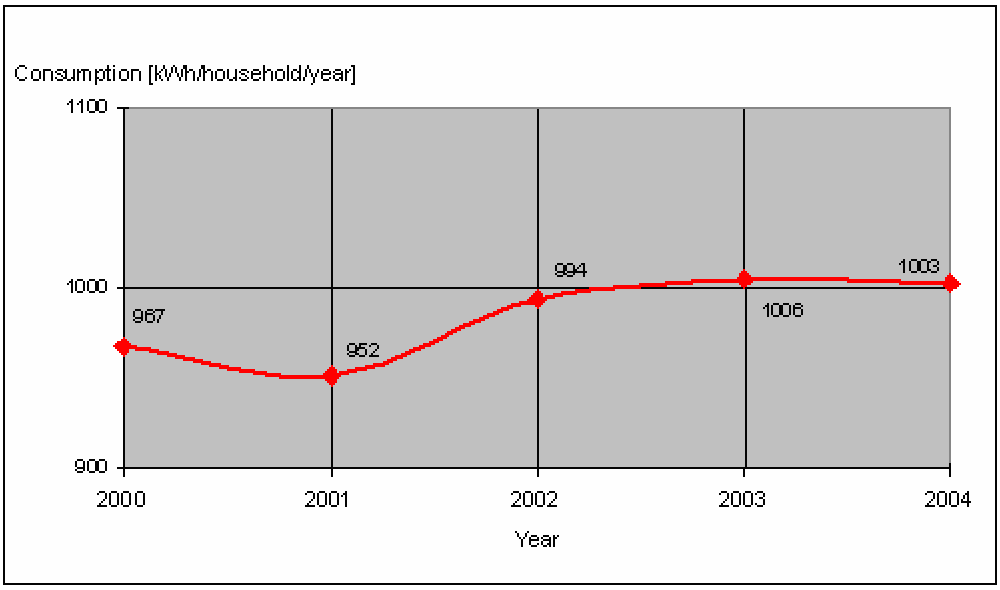

Figure 3: Average energy consumption between 2000-2004 [kWh/household consumer/year]

At the level of the EU, according to “Energy efficiency indicators in Europe” – Odysee [1], the residential consumption in 2003 was of 2533 kWh/household/year. We remark that in Romania this consumption is of about 40% of the EU level.

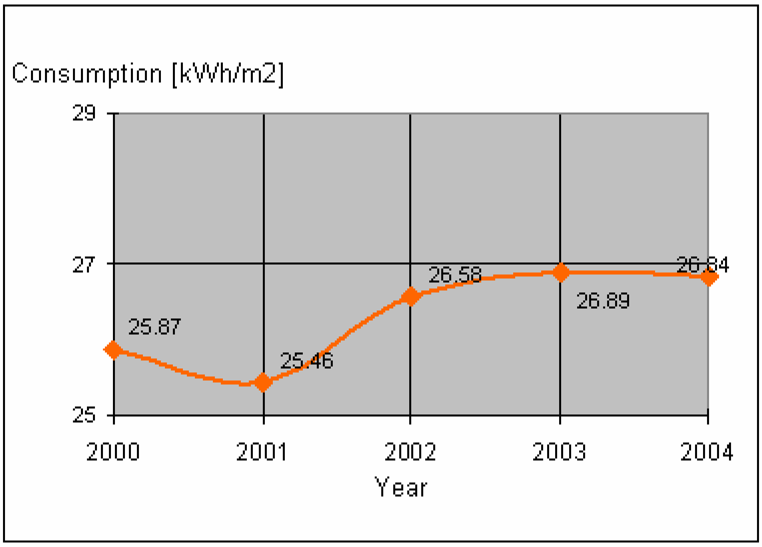

Figure 4: Household consumption per m^2 in Romania (kWh/m^2) – the average value of 37.39 m^2 per household in Romania has been considered.

We currently have little information with respect to the electric lighting contribution to the total energy consumption of the households in Romania. As estimation, we may count on the results of the study [4], according to which the electric lighting consumption represents around 25% of the total electric energy consumption of the studied households.

The analysis of the presented data allows us to estimate a few characteristics of electric energy consumption of households – Table 1.

Table 1: Characteristics of electric lighting energy consumption in households in Romania.

Year		2000	2001	2002	2003	2004
Total annual electric lighting consumption	[MWh]	1,938,000	2,028,000	1,996,000	2,028,000	2,036,000
Annual electric lighting consumption per household	[kWh/household /year]	246	257	253	256	255
Annual electric lighting consumption per m^2	[kWh/m^2/year]	6.58	6.87	6.76	6.84	6.83
Annual cost of electric lighting consumption per household	[Euro/household /year]	38.57	39.57	39.19	39.47	39.42

Note: The total annual household consumption in Romania has been determined considering the sales of Electrical National Company towards the household consumers and the average contribution of the consumption on the lighting circuits (25%); The annual electric lighting household consumption per m^2 was determined based on the average household surface in Romania in 2002 – 37.39 m^2/household; An average exchange rate of 3.50 RON/Euro.

A comparison of the information presented in [5] to the data presented in this study is shown in Table 2.

Table 2: Characteristics of electric lighting energy consumption in the residential sector in Romania – comparative study based on data in [1] and [5].

	DELight 1998	UTC-N 2005
Electricity consumption		
Total electricity consumption (TWh/an)	60.0 (1996)	33.8
Residential electricity consumption (TWh/an)	7.1	8.001
Residential lighting electricity consumption (TWh/an)	n.a. (1996)	~2.036
Household lighting – Information		
Household lighting electric energy consumption (kWh/an)	n.a. (1995)	~255.3
Number of lamps per household	9	n.a.
Average number of CFL per household	0.006 (1995)	n.a.
Household ratio using CFL	0.5 (1995)	n.a.
Average number of CFL per household using CFL	1.1 (1995)	n.a.
Number of luminaires per household	5.5	n.a.
Households – Information		
Number of households (x10^6)	7.78 (1995)	7.97
Number of persons per household	2.91 (1994)	2.63 (2002)
Average surface (m^2)	n.a.	37.39
Prices	1996 (ecu)	2005 (Euro)
Price of electric energy per kWh 0 – 50 kWh	0.008	0.38
50 – 100 kWh	0.019	
>100 kWh	0.041	0.0921
	ecu	Euro
Price of GSl	0.3	0.43
Price of CFL	13.2	4.3

Note: The average exchange rate of 3.50 RON/Euro has been used

The increase in the annual household electric lighting energy consumption in 2004 vs. 2000, of 3.61%, correlated with the continuous increase of the number of household subscribers in Romania of 1.24% (2004 vs. 2000) – Figure 2, determine the necessity to adopt measures of energy efficiency in the household lighting of Romania.

The total energy consumption dropped from 60 TWh/year in 1996 [5] to 33.8 TWh/year in 2005, according to the data received from the national company of electricity. For the same period, the weight of the residential consumption increased significantly, partly due to the massive reduction of industrial consumption after 1989, but as well, to a continuous increase of the number of household subscribers.

Figure 5 shows the spreading of different types of lamps used in household lighting in a few countries in Europe – New Member States and Candidate Countries. [2]

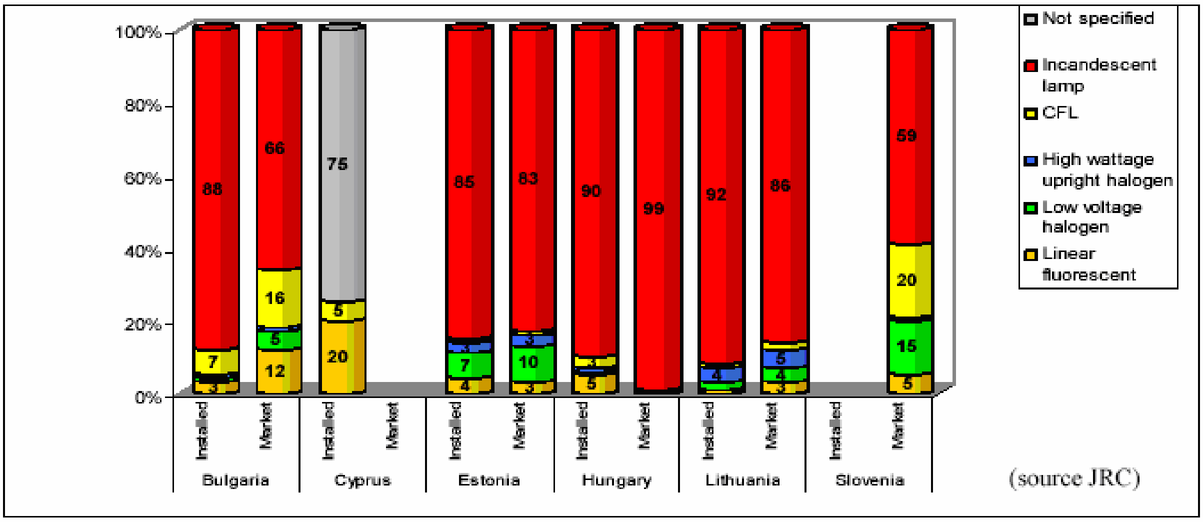

Figure 5: Residential electric lighting in a few countries in Europe – spreading of different types of lamps, Source JRC

The cost of CFLs mainly depend on their life span, the cheapest having a life of 3 years, the typical cost in Romania being between 2.9 – 4.3 Euro, and the more expensive ones have a life span of 8-10 years and a price of 8.6 – 11.4 Euro. Since the electric energy consumption of these lamps is much lower and has a much smaller cost (only 20% of the cost of GSL, the cost of the initial investment may be recovered in 3 – 12 months, depending on the cost of the CFL, after which up to 8.0 – 9.0 Euro per lamp per year is saved.

The use rate of CFLs is from 0.8 units per household in Great Britain up to over 3 units per household in Denmark. Projects from the SAVE programme consider as a reasonable upper limit the use of up to 8 units per household. An analysis of the residential lighting, realized in 100 households in Denmark, shows a lighting consumption of between 5% and 21% of the total monthly electric energy consumption of the household and the use of 24% saving lamps – linear fluorescent lamps and compact fluorescent lamps.

During November 2005 a study has been realized using feed-back reply forms concerning the usage degree of GSL and CFLs in households in Western Romania. We received 295 replies, namely 220 apartments (with 1–4 rooms) and 75 houses (with 2–more than 7 rooms). The light source equipment in these households is presented in Table 3.

Table 3: Light source usage statistics for GSL and CFLs in Romanian households.

Household		**GSL**		**CFL**		**Installed power**
Type	No.	Units	Average	Units	Average	kW
Apartment	220	2624	11.98	367	1.67	0.770
Single-family house	75	1088	14.51	196	2.61	1.028
Total	295	3712	12.58	563	1.91	0.835

The variation of the number of lamps of type GSL and CFL on household type, based on the number of rooms (living room and bedrooms), is represented in Figure 1 – for apartments, respectively Figure 2 – for single-family houses.

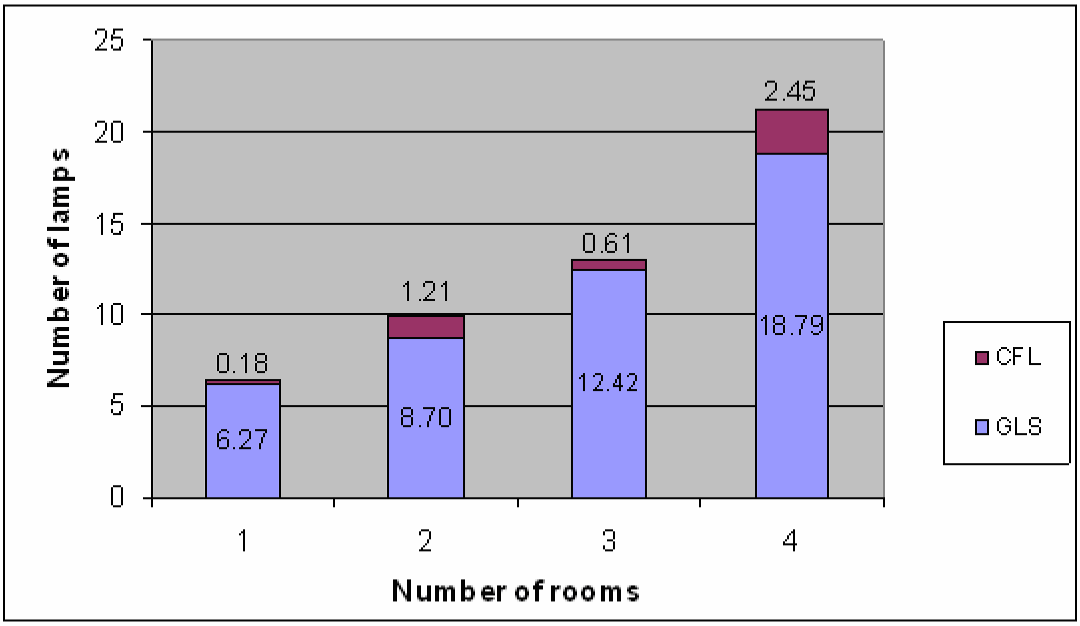

Figure 6: Variation of the number of lamps on apartments with the number of the rooms (living room and bedrooms)

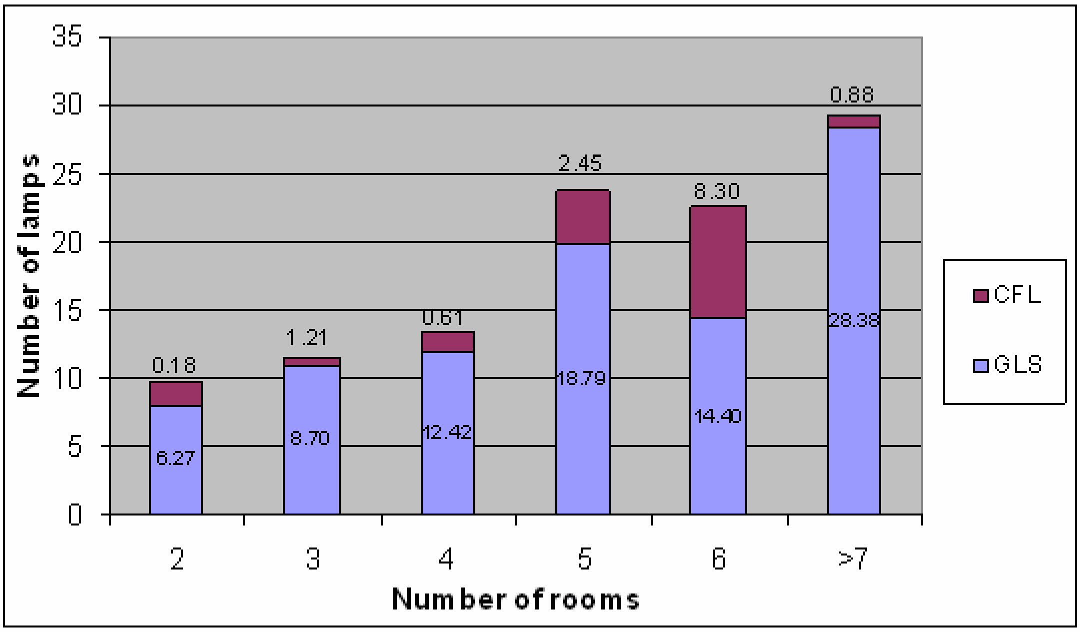

Figure 7: Variation of the number of lamps on single-family houses with the number of the rooms (living room and bedrooms)

The installed lighting power has an average value of 0.835 kW/household.
From the analysis of the data presented above we may conclude that the CFL energy saving lamps are bought by people with high earnings, which own houses.
We consider the equipping degree with CFLs of approximately two units per household is high, and this denotes the interest of Romanian consumers for buying energy saving lamps.

Conclusions

The estimative values of total electric energy consumption and the total lighting energy consumption in the residential sector, presented as a conclusions of our study, are of 255.3 kWh/household/year, and 25% of the total household electric energy consumption, values that fit in the limits presented by the specialty literature.

The mounting of a single CFL in each household of Romania would lead to a decrease of the household electric energy consumption of around 45,246 MWh/year. The estimation has been realized on a theoretical evaluation, based on 2,036,000 MWh/year (the household electric lighting energy consumption - 2004) divided to 9 (average number of lamps per household in Romania (Table 2) and then to 5 (the ratio between the electric energy consumption of a CFL and a GSL with the same luminous flux). This value corresponds to a saving in the CO_2 emissions of about 2.5 kTones CO_2

(1 kWh = 0.0536 kg CO_2 according to the average values considered for European countries).

Other than achieving important electric energy savings and cuts in costs and in polluted emissions, the introduction of efficient lighting technologies in the case of household consumers presents a different, important advantage, namely the reduction of the maximal absorbent power in the morning and evening consumption peaks.

The predicable economic impact of this study will be established by the adoption of policies towards an electric energy consumption reduction, both locally and nationally. It is essential to increase the awareness of the energy efficiency problem both by users and by the electric energy providers, in order to reduce the consumption peaks that are specifically due to lighting.

Acknowledgments

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Lighting Efficiency in China

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Abstract

Lighting accounts for about 13% of the electricity used in China, and lighting is probably the largest and most rapidly growing use for electricity in China. Over the decade from 1988 to 1988, it is estimated that electricity used for lighting in China increased from 44 TWh per year to 152 TWh per year. Over the past ten years, China has become the largest producer as well as the largest exporter of lighting products. The efficiency and quality of Chinese lighting products has major impacts on global energy use, sustainability and greenhouse gas emissions. The China Green Lights program was established to address barriers to the development, production and sale of high quality and efficient products in China. This paper examines the growth of lighting products and estimates the impact of efficient lighting products on electricity use and carbon dioxide emissions.

Introduction

Lighting accounts for about 13% of the electricity used in China, and lighting is probably the largest and most rapidly growing use for electricity in China. Over the decade from 1988 to 1988, it is estimated that electricity used for lighting in China increased from 44 TWh per year to 152 TWh per year, and lighting use has increased rapidly in the residential, commercial and industrial sectors. Key factors leading to increased lighting electricity consumption include: increased residential use of lighting with rising incomes; large numbers of commercial buildings built to international standards; better illuminated factories; and intensive development of street and large area lighting [1, 2, 3].

Over the past ten years, China has become the largest producer as well as the largest exporter of lighting products. The efficiency and quality of Chinese lighting products has major impacts on global energy use, sustainability and greenhouse gas emissions. Initial exports of Chinese lighting products, including CFLs in particular, often had unreasonably high rates of premature failure and of premature decline in lighting efficacy. This appeared to be due to use of low quality glass and electrical components combined with poorly training workers and inadequate attention to quality control.

The China Green Lights program was established in October 1996, with the assistance of the United Nations Development program, to address barriers to the development, production and sale of high quality and efficient lighting products in China. This initial program invested some US $36 million to improve both the demand side and the supply side of the Chinese lighting market. Key planned program outcomes were increased purchases and market share of CFLs and efficient fluorescent tubes, reduced electricity consumption and reduced greenhouse gas emissions.

This paper uses quantitative methods to examine the impact of the China Green Lights program on production of lighting products, electricity use and emission in China. The approach used here draws on the small but developing literature on quantitative analysis of demand side management programs, which emphasizes the use of econometric models to overcome the need to estimate market effects such as free riders and spillover.

Several previous studies have used econometric methods to analyze the impact of market transformation programs. Duke and Kammen [4] found that accounting for feedback between the demand response and production response for electronic ballasts increases the consumer benefit cost ratio. Horowitz [5] found that coordinated national electronic ballast programs were more cost effective than local efforts. Horowitz and Haeri [6] found that the cost of energy efficiency investments was fully capitalized in housing prices and that purchasing an energy efficient house was cost effective. Jaffe and Stavins [7] found that insulation levels in new residential housing appropriately reflect energy prices.

An outline of the paper is as follows. The next section provides a review of the methodology used in this study. This is followed by individual sections covering production, exports and sales of incandescent lamps, halogen lamps, low voltage lamps, standard fluorescent tubes, efficient fluorescent tubes, compact fluorescent lamps and other lamps. The penultimate section provides estimates of reduction in electricity use and carbon dioxide emissions due to the China Green Lights program. The last section offers the study's conclusions.

Model and Estimation

It is convenient to view a single lamp or tube market (such as the market for compact fluorescent lamps or energy efficient fluorescent tubes) in isolation and abstract from linkages to other markets or general equilibrium effects. Consider the following simple four-equation model where (1) is the demand curve for a specific lighting product, (2) is the stochastic process for the path of income over time, (3) is the supply curve for the lighting product, and (4) is the stochastic process for import prices over time, and the error terms have been suppressed for convenience.

(1) $\text{quantity}_t = a + b^* \text{ price}_t + c^* \text{ income}_t + d^* \text{ dummy}_t$

(2) $\text{income}_t = e + f^* \text{ time}_t$

(3) $\text{price}_t = g + h^* \text{ world price}_t + i^* \text{ dummy}_t$

(4) $\text{import price}_t = j + k^* \text{ time}_t$

In these equations, quantity_t is domestic market demand for the lighting product at time t, price_t is unit price of the lighting product at time t, income_t is total domestic income at time t, time_t is the year t, world price_t is the per unit at time t, and dummy_t is a shift variable that takes the value “0” in the pre-China Green Lights program period and the value “1” in the China Green Lights program period.

Equation (1) represents the demand curve in year t. It says that market demand for the lighting product is a linear function of product price, total domestic income and a preference variable, which represents a shift in consumer demand towards the product of interest. This demand shift could be driven by program advertising and promotional activities or by other factors, but in any event reflects consumer views of relative value of the product compared to other products. Equation (2) represents the path of income over time. It says that the path of income can be adequately represented by a (stochastic) linear trend. Over the relatively short period of data available, this is a reasonable assumption.

Equation (3) represents the supply curve for a lighting product in year t. It says that that lighting product price is a linear function of the world price and a supply shift variable. The supply shift variable represents a shift in domestic supply towards higher efficiency products (or away from lower efficiency products) as a result of changes in producer preferences, perhaps as a result of marketing initiatives, or the effect of a subsidy. Equation (4) is the world price which is constant over a given year but decreases over time due to experience curve effects and increased competition due to market transformation.

Substituting for income in (1) and substituting for price in (3) yields a simple structural equation model with two equations in two variables, quantity and price. Solving this model for price and for quantity, yields in turn the reduced form of this structural model as follows:

(5) $\text{quantity}_t = \alpha + \beta^* \text{ time} + \chi^* \text{ dummy}_t$

(6) $\text{price}_t = \delta + \phi^* \text{ time} + \gamma^* \text{ dummy}_t$

Equation (5) represents the reduced form equation for quantity. Note that it has been rearranged so that quantity depends on a constant plus a time trend plus a term that represents program impacts. Equation (6) represents the reduced form equation for price, which in this model is the same as the supply equation. Note that it has been rearranged so that price depends on a constant plus a time trend plus a term that represents program impacts. We provide estimates of equations (5) in the next section.

The study approach is as follows. First, information from local surveys and data sources are used to build a database of domestic consumption for various lighting products. Second, regression discontinuity models (sometimes referred to as interrupted time-series models) are applied to this data to understand the impact of the China Green Lights program on quantities of lighting products produced. In the regression models, it is assumed that all non-program factors are captured by a time-trend term so that the coefficient on a dummy variable for the program period measures program impact. Third, using engineering data, algorithms are used to estimate the energy savings for each efficient technology as well as the impact of energy savings on emissions. Time-series information on product sales is invaluable in understanding market transformation, and this is often done by using the ordinary least squares regression model. But time-series data on sales of products is often characterized by the first-order auto-regressive process where the errors between periods are not independent. Applying the usual ordinary least squares evaluation framework in this context can potentially provide misleading results. For references see Dhrymes [8], Johnston [9], Malinvaud [10] and Theil [11].

Overview of Chinese Lamp Production and Performance

Chinese production of lighting products for the period 1988 to 1998 is shown in Table 1. Production is reported in millions of lamps per year. Lamp types include GLS or standard incandescent, halogen, low voltage or primarily vehicle lamps, T5 to T-8 efficient fluorescent tubes, T9 to T12 standard fluorescent tubes, compact fluorescent lamps and other lamps, which includes high intensity discharge lamps.

Table 1: Lamp Production (million units)

	GLS	Halogen	Low voltage	T5-T8 tubes	T9-T12 tubes	CFL	Other	Total
1988	1,303	30	50	0	156	8	214	1,761
1989	1,437	40	55	0	171	9	309	2,021
1990	1,747	50	61	4	208	10	396	2,476
1991	1,993	80	89	6	212	11	437	2,828
1992	2,264	90	131	8	278	18	551	3,340
1993	2,217	100	399	20	238	38	574	3,586
1994	2,559	189	567	14	282	52	880	4,543
1995	2,900	278	666	18	328	66	1,244	5,500
1996	3,413	300	650	50	364	120	1,498	6,395
1997	3,053	350	650	70	423	150	1,337	6,033
1998	2,624	400	650	84	336	180	1,334	5,608

Source: China Association of Lighting Industry, various years. Note that 1994 data are author's interpolations. Fluorescent tube shares by type, before 1995, are based on discussions with industry officials.

Chinese lamp performance is compared to international standard performance for the mid-1990s in Table 2. Wattage refers to the range of available lamps in watts. Efficacy refers to lamp efficiency in terms of lumens per watt. Life refers to average hours of lamp life under normal conditions. Lamp types included in the table are incandescent, halogen, linear fluorescent, compact fluorescent, metal halide and high pressure sodium.

Table 2: Chinese and International Lamp Performance

	China			International		
	Wattage (W)	Efficacy (lumens/W)	Life (hours)	Wattage (W)	Efficacy (lumens/W)	Life (hours)
Incandescent	15-1000	7-18	100-1000	10-1500	5-25	100-2000
Halogen	50-2000	14-28	50-1500	10-1000	15-30	50-2000
Linear fluor	6-125	25-40	3000-5000	4-200	40-100	10000-20000
CFL	4-28	40-65	1000-3000	5-55	50-70	5000-20000
Metal halide	150-1500	70-80	3000-8000	30-2000	50-125	2000-10000
HPS	35-1000	60-100	4000-12000	30-1000	50-150	10000-25000

Source: Min, Mills and Zhang, 1995.

Incandescent Lamps

An incandescent lamp consists of a thin, frosted glass envelope filled with argon and/or nitrogen gas. Electricity heats a tungsten filament to about 2500°C causing the tungsten to emit visible light and heat. The incandescent lamp is inefficient because most of the energy is used to produce heat, and it is short lived because the tungsten evaporates and is deposited on the glass before a thin spot is formed on the filament and breaks. China produces a wide variety of incandescent lamps, but medium-base Type A lamps predominate. As shown above in Table 2, China in the mid-1990s produced a narrower range of wattages for incandescent lamps than was available on the international market. Lamp efficacy in terms of lumens per watt and length of lamp life were both significantly worse in China than internationally.

Production, export and apparent domestic consumption of incandescent lamps in China for 1995 to 1998 are shown in Table 3. Production and domestic consumption of incandescent lamps appears to have peaked in 1996 with declines in production and domestic sales in 1997 and 1998. Exports show a generally upward pattern, but the export share of production is lower for incandescent lamps than for certain other products such as CFLs.

Table 3: Incandescent Lamps: Production, Exports and Domestic Use (million units)

	Production	Exports	Apparent Consumption
1995	2900	150	2750
1996	3413	142	3271
1997	3053	98	2955
1998	2624	423	2201

Source: China Association of Light Industry, various years.

Determinants of Chinese lamp production are explored in Table 4. We use a simple econometric model, where sales in millions of units are a function of GDP in trillions of constant 1995 yuan and of a dummy variable for the Chinese Green Lights program (which are the years 1997 and 1998). From a statistical perspective, both regressions fit the data well. The explanatory power of both regressions is very high at over 85%. Auto-correlation is not a major problem with either regression, although the maximum likelihood regression slightly improves the estimated auto-correlation.

In the ordinary least squares regression (OLS), a one trillion increase in GDP increases annual sales of incandescent lamps by 520,000 units. The China Green Lights program reduces annual sales of incandescent lamps by 857 million units. This is about one-quarter of the peak sales of incandescent lamps of 3,053 million units in 1996. In the maximum likelihood regression (ML), a one trillion increase in GDP increases annual sales of incandescent lamps by 530,000 units. The China Green Lights program reduces annual sales of incandescent lamps by 861 million units. Results of the OLS and ML regression are similar.

Table 4: Incandescent Lamps: Determinants of Sales (millions of units)

	Ordinary Least Squares Regression			Maximum Likelihood Regression		
	Coefficient	St. Error	Significance	Coefficient	St. Error	Significance
Constant	-104	315	0.75	-112	304	0.71
GDP	0.52	0.069	0.00	0.53	0.067	0.00
Green Lights	-857	272	0.01	-861	267	0.00
R-squared	0.87	-	-	0.89	-	-
D-W	1.70	0.15	-	2.19	-0.09	-

Note: Standard errors are shown in parentheses beside the regression coefficients and estimated auto-correlation is shown in parentheses beside the Durbin-Watson statistic.

Halogen Lamps

A halogen lamp uses a tungsten filament, but the envelope is made of quartz with a higher melting point than silicon based glass, and it is relatively small. The gas inside the envelope comes from the halogen group, allowing the filament to burn hotter thus improving lamp efficiency. At high temperatures, the released tungsten combines with halogen and is re-deposited on the filament, which increases the length of life of the filament. China produces a range of halogen lamps comparable to the international market. Lamp efficacy in terms of lumens per watt and length of lamp life were close to international standards in the mid-1990s.

Production, export and apparent domestic consumption of halogen lamps in China for 1995 to 1998 are shown in Table 5. Production steadily increased over this period. Exports show a generally upward pattern, but the export share of production is lower for incandescent lamps than for certain other products such as CFLs.

Table 5: Halogen Lamps: Production, Exports and Domestic Use (million units)

	Production	Exports	Apparent Consumption
1995	278	180	98
1996	300	200	100
1997	350	230	120
1998	400	265	135

Source: China Association of Light Industry, various years.

Determinants of Chinese halogen lamp production are explored in Table 6. Sales in millions of units are a function of GDP and of a dummy variable for the Chinese Green Lights program (which are the years 1997 and 1998). From a statistical perspective, both regressions fit the data well. The explanatory power of both regressions is very high at over 97%. Auto-correlation is a major problem with the OLS regression, and the ML regression substantially improves the estimated auto-correlation. In the ordinary least squares regression (OLS), a one trillion increase in GDP increases annual sales of halogen lamps by 81,000 units. The China Green Lights program increases annual sales of halogen lamps by 16 million units. In the maximum likelihood regression (ML), a one trillion increase in GDP increases annual sales of halogen lamps by 82,000 units. The China Green Lights program increases annual sales of halogen lamps by 11 million units. The results of the OLS and ML regression are very similar.

Table 6: Halogen Lamps: Determinants of Sales (millions of units)

	Ordinary Least Squares Regression			Maximum Likelihood Regression		
	Coefficient	St. Error	Significance	Coefficient	St. Error	Significance
Constant	-228	32	0.00	-230	38	0.00
GDP	0.081	0.0070	0.00	0.082	0.0082	0.00
Green Lights	16	28	0.58	11	29	0.40
R-squared	0.97	-	-	0.97	-	-
D-W	1.38	0.31	-	1.63	0.19	-

Note: Standard errors are shown in parentheses beside the regression coefficients and estimated auto-correlation is shown in parentheses beside the Durbin-Watson statistic.

Low Voltage Lamps

Most low voltage lamps produced in China are used in motor vehicles. Most vehicle headlights use halogen bulbs, but some headlights use high intensity discharge lamps, including mercury vapour lamps with xenon added to reduce the start-up time. Motor vehicle lamps produced in China appear to generally meet international standards

Production, export and apparent domestic consumption of low voltage lamps in China for 1995 to 1998 are shown in Table 7. Production and domestic consumption of low voltage lamps appears to have peaked in 1995 with declines in production and domestic sales in 1996, 1997 and 1998. Exports show a generally upward pattern, but the export share of production is lower for incandescent lamps than for certain other products such as CFLs.

Table 7: Low Voltage Lamps: Production, Exports and Domestic Use (million units)

	Production	Exports	Apparent Consumption
1995	666	80	586
1996	650	100	550
1997	650	120	530
1998	650	120	530

Source: China Association of Light Industry, various years.

Determinants of Chinese low voltage lamp production are explored in Table 8. Sales in millions of units are a function of GDP in trillions of constant 1995 yuan and of a dummy variable for the Chinese Green Lights program (which are the years 1997 and 1998). From a statistical perspective, both regressions fit the data well. The explanatory power of both regressions is very high at about 95%. Auto-correlation is not a major problem with either regression.

In the ordinary least squares regression (OLS), a one trillion increase in GDP increases annual sales of low voltage lamps by 210,000 units. The China Green Lights program apparently reduces annual sales of low voltage lamps. This particular result makes little sense and is due to the rapid ramp up of production of low voltage lamps in the period before the program. In the maximum likelihood regression (ML), a one trillion increase in GDP increases annual sales of low voltage lamps by 220,000 units. The China Green Lights program again apparently reduces annual sales of low voltage lamps. The results of the OLS and ML regression are very similar.

Table 8: Low Voltage Lamps: Determinants of Sales (millions of units)

	Ordinary Least Squares Regression			Maximum Likelihood Regression		
	Coefficient	St. Error	Significance	Coefficient	St. Error	Significance
Constant	-639	92	0.00	-656	84	0.00
GDP	0.21	0.020	0.00	0.22	0.018	0.00
Green Lights	-251	79	0.01	-268	75	0.00
R-squared	0.94	-	-	0.95	-	-
D-W	2.02	-0.01	-	2.11	-0.06	-

Note: Standard errors are shown in parentheses beside the regression coefficients and estimated auto-correlation is shown in parentheses beside the Durbin-Watson statistic.

Standard Fluorescent Tubes

A fluorescent lamp consists of a sealed glass tube which is coated on the inside with a phosphorous powder. The tube contains mercury, an inert gas such as argon, and two electrodes. This mechanism is used to excite atoms using a chemical reaction rather than by heating a tungsten element, as in an incandescent or halogen lamp. Using a chemical rather than a thermal process increases the efficiency of the lamp and greatly lengthens lamp life. The range of fluorescent lamps produced in China in the mid-1990s was fairly wide, but lamp efficacy and lamp length of life were substantially below international standards.

Production, export and apparent domestic consumption of T9-T12 fluorescent lamps in China for 1995 to 1998 are shown in Table 9. Production and domestic consumption of T9-t12 lamps appears to have peaked in 1997 with declines in production and domestic sales in 1998.

Table 9: Standard Fluorescent Tubes (T9-T12): Production, Exports and Domestic Use (million units)

	Production	Exports	Apparent Consumption
1995	328	-	328
1996	364	-	364
1997	423	-	423
1998	336	-	336

Source: China Association of Light Industry, various years.

Determinants of Chinese T9-t12 lamp production are explored in Table 10. Sales in millions of units are a function of GDP in trillions of constant 1995 yuan and of a dummy variable for the Chinese Green Lights program (which are the years 1997 and 1998). From a statistical perspective, both regressions fit the data well. The explanatory power of both regressions is high at about 82%. Auto-correlation is not a major problem with either regression.

In the ordinary least squares regression (OLS), a one trillion increase in GDP increases annual sales of T9-T12 lamps by 52,000 units. The China Green Lights program reduces annual sales of T9-T12 lamps by 16 million units. In the maximum likelihood regression (ML), a one trillion increase in GDP increases annual sales of T9-T12 lamps by 55,000 units. The China Green Lights program reduces annual sales of T9-T12 lamps by 21 million units. The results of the OLS and ML regression are very similar.

Table 10: Standard Fluorescent Tubes: Determinants of Sales (millions of units)

	Ordinary Least Squares Regression			Maximum Likelihood Regression		
	Coefficient	St. Error	Significance	Coefficient	St. Error	Significance
Constant	21	47	0.45	11	32	0.74
GDP	0.052	0.010	0.00	0.055	0.0070	0.00
Green Lights	-16	41	0.71	-21	30	0.48
R-squared	0.82	-	-	0.83	-	-
D-W	2.22	-0.11	-	2.34	-0.17	-

Note: Standard errors are shown in parentheses beside the regression coefficients and estimated auto-correlation is shown in parentheses beside the Durbin-Watson statistic.

Efficient Fluorescent Tubes

Efficient triphosphor tubes use significantly less energy than halophosphate tubes and suffer far less degradation in light output levels over time. Detailed information on production of fluorescent lamps by efficiency level is not available, so for our purposes T5-T8 lamps are viewed as efficient while T9-T12 lamps are view as standard.
Production, export and apparent domestic consumption of incandescent lamps in China for 1995 to 1998 are shown in Table 11. Production and domestic consumption of incandescent lamps appears to have increased through 1998.

Table 11: Efficient Fluorescent Tubes (T5-T8): Production, Exports and Domestic Use (million units)

	Production	Exports	Apparent Consumption
1995	18	-	18
1996	50	-	50
1997	70	-	70
1998	84	-	84

Source: China Association of Light Industry, various years.

Determinants of Chinese T5 and T8 lamp production are explored in Table 12. Sales in millions of units are a function of GDP in trillions of constant 1995 yuan and of a dummy variable for the Chinese Green Lights program (which are the years 1997 and 1998). From a statistical perspective, both regressions fit the data well. The explanatory power of both regressions is very high at about 93%. Auto-correlation is not a major problem with either regression, although the ML regression substantially improves the estimated auto-correlation.
In the ordinary least squares regression (OLS), a one trillion increase in GDP increases annual sales of T5-T8 lamps by 11,000 units. The China Green Lights program increases annual sales of T5-T8 lamps by 33 million units. In the maximum likelihood regression (ML), a one trillion increase in GDP increases annual sales of T5-T8 lamps by 10,000 units. The China Green Lights program increases annual sales of T5-T8 lamps by 39 million units. The results of the OLS and ML regression are very similar.

Table 12: Efficient Fluorescent Tubes: Determinants of Sales (millions of units)

	Ordinary Least Squares Regression			Maximum Likelihood Regression		
	Coefficient	St. Error	Significance	Coefficient	St. Error	Significance
Constant	-36	10	0.01	-32	8	0.00
GDP	0.011	0.0023	0.00	0.010	0.0018	0.00
Green Lights	33	9	0.01	39	8	0.00
R-squared	0.93	-	-	0.94	-	-
D-W	2.32	-0.16	-	2.13	-0.06	-

Note: Standard errors are shown in parentheses beside the regression coefficients and estimated auto-correlation is shown in parentheses beside the Durbin-Watson statistic.

Compact Fluorescent Tubes

China is currently the largest supplier of compact fluorescent lamps, which are fluorescent tubes folded on themselves to minimize space requirements. In the mid-1990s many Chinese produced CFLs lasted little longer than incandescent lamps, but product quality and lamp life of Chinese manufactured CFLs have improved substantially over the past decade. Many lower end Chinese factories have ceased production. Chinese now produces CFLs in a wide range of wattage levels and styles.

Production, export and apparent domestic consumption of CFLs in China for 1995 to 1998 are shown in Table 13. Production and domestic consumption of incandescent lamps have steadily increased through 1998 and exports show an upward pattern, and the export share of production is very high compared to other types of lamps.

Table 13: Compact Fluorescent Lamps: Production, Exports and Domestic Use (million units)

	Production	Exports	Apparent Consumption
1995	66	39	27
1996	120	70	50
1997	150	80	70
1998	180	100	80

Source: China Association of Light Industry, various years.

Determinants of Chinese CFL production are explored in Table 14. Sales in millions of units are a function of GDP in trillions of constant 1995 yuan and of a dummy variable for the Chinese Green Lights program (which are the years 1997 and 1998). From a statistical perspective, both regressions fit the data well. The explanatory power of both regressions is very high at about 96%. Auto-correlation is not a major problem with either regression.

In the ordinary least squares regression (OLS), a one trillion increase in GDP increases annual sales of CFLs lamps by 29,000 units. The China Green Lights program increases annual sales of CFLs by 45 million units. In the maximum likelihood regression (ML), a one trillion increase in GDP increases annual sales of CFLs by 28,000 units. The China Green Lights program increases annual sales of CFLs by 50 million units. The results of the OLS and ML regression are very similar.

Table 14: Compact Fluorescent Lamps: Determinants of Sales (millions of units)

	Ordinary Least Squares Regression			Maximum Likelihood Regression		
	Coefficient	St. Error	Significance	Coefficient	St. Error	Significance
Constant	-92	17	0.00	-88	15	0.00
GDP	0.029	0.0037	0.00	0.028	0.0033	0.00
Green Lights	45	15	0.02	50	14	0.00
R-squared	0.96	-	-	0.96	-	-
D-W	2.04	-0.02	-	2.11	-0.05	-

Note: Standard errors are shown in parentheses beside the regression coefficients and estimated auto-correlation is shown in parentheses beside the Durbin-Watson statistic.

Other Lamps

Other lamps include low pressure sodium (widely used for street lamps in China), high pressure sodium, mercury vapor, metal halide and a variety of specialty lamps. In the mid-1990s, a wide range of high pressure sodium and metal halide lamps were produced. But lamp efficiency and lamp life for these high intensity discharge lamps were at perhaps two-thirds of international levels.

Production, export and apparent domestic consumption of other lamps in China for 1995 to 1998 are shown in Table 15. Production and domestic consumption of other lamps appears to have peaked in 1996 with declines in production and domestic sales in 1997 and 1998. Exports show a generally upward pattern, but the export share of production is low.

Table 15: Other Lamps: Production, Exports and Domestic Use (million units)

	Production	Exports	Apparent Consumption
1995	1,244	4	1,240
1996	1,498	6	1,492
1997	1,337	8	1.329
1998	1,334	12	1,322

Source: China Association of Light Industry, various years.

Determinants of Chinese lamp production are explored in Table 16. Sales in millions of units are a function of GDP in trillions of constant 1995 yuan and of a dummy variable for the Chinese Green Lights program (which are the years 1997 and 1998). From a statistical perspective, both regressions fit the data well. The explanatory power of both regressions is very high at over 96%. Auto-correlation is a problem with then OLS regression, although the ML regression improves the estimated auto-correlation.

In the ordinary least squares regression (OLS), a one trillion increase in GDP increases annual sales of other lamps by 560,000 units. The China Green Lights program reduces annual sales of other lamps by 485 million units. In the maximum likelihood regression (ML), a one trillion increase in GDP increases annual sales of other lamps by 55,000 units. The China Green Lights program reduces annual sales of other lamps by 477 million units. The results of the OLS and ML regression are very similar.

Table 16: Other Lamps: Determinants of Sales (millions of units)

	Ordinary Least Squares Regression			Maximum Likelihood Regression		
	Coefficient	St. Error	Significance	Coefficient	St. Error	Significance
Constant	-1,453	204	0.00	-1,436	215	0.00
GDP	0.56	0.045	0.00	0.55	0.047	0.00
Green Lights	-485	177	0.03	-477	181	0.01
R-squared	0.96	-	-	0.97	-	-
D-W	1.62	0.19	-	2.00	-0.00	-

Note: Standard errors are shown in parentheses beside the regression coefficients and estimated auto-correlation is shown in parentheses beside the Durbin-Watson statistic.

Impact on Energy Use and Carbon Dioxide Emissions

Energy savings are estimated in Table 17 for compact fluorescent lamps and for energy efficient fluorescent tubes. Energy savings for the first two years of China Green Lights are defined as unit change in load multiplied by average annual hours multiplied by twice the estimated program impact on sales. For screw-type lamps, it is assumed that a 13 watt CFL replaces, on average, a 40 watt GLS lamp leading to a change in load of 27 watts. Average hours of use are assumed to be 4.0 hours per day or 1,460 hours per year. For fluorescent tubes, it is assumed that a 36 watt T8 tube replaces, on average, a 40 watt T12 tube leading to a change in load of 4 watts. Average hours of use are assumed to be 5 hours per day or 1,825 hours per year.

The unit savings results are shown below. Estimated savings per unit are 39.4 kWh for a CFL replacing an incandescent lamp and 8.0 kWh per year for a T5 to T8 lamp replacing a T12 lamp. These results are the estimated savings that would be experienced at the customers' meters. At the system level, savings would be about ten percent higher to allow for transmission losses and distribution losses.

Annual energy savings from two years of China Green Lights are 4,426 GWh using the OLS regressions and 4,954 GWh using the ML regressions. Carbon dioxide reductions are 2,753 kilotonnes using the OLS regression and 3,081 kilotonnes using the ML regressions.

Table 17: Annual Energy and Carbon Dioxide Savings at the Meter and at the Generation Busbar

	Base lamp (W)	Efficient lamp (W)	Unit demand savings (W)	Hours (per year)	Unit meter savings (kWh)	Line loss factor	Unit busbar savings (kWh)	Total busbar savings (GWh)	CO_2 savings (GWh)
Ordinary Least Squares Based Estimates									
CFL/GLS	40	13	27	1,460	39.4	1.10	43.3	3,898	2,425
T8/T12	40	36	4	1,825	7.3	1.10	8.0	528	328
Total								4,426	2,753
Maximum Likelihood Based Estimates									
CFL/GLS	40	13	27	1,460	39.4	1.10	43.3	4,330	2,693
T8/T12	40	36	4	1,825	7.3	1.10	8.0	624	388
Total								4,954	3,081

Source: Min, Mills and Zhang, 1995 and regressions. Emissions factor of 0.622 kilotonnes of carbon dioxide per GWh of electricity and loss factor were provided by the China Green Lights program.

Conclusions

Lighting accounts for about 13% of the electricity used in China, and lighting is probably the largest and most rapidly growing use for electricity in China. Over the decade from 1988 to 1988, it is estimated that electricity used for lighting in China increased from 44 TWh per year to 152 TWh per year. Over the past ten years, China has become the largest producer as well as the largest exporter of lighting products. The efficiency and quality of Chinese lighting products has major impacts on global energy use, sustainability and greenhouse gas emissions.

The China Green Lights program was established to address barriers to the development, production and sale of high quality and efficient products in China. This paper examines the growth of lighting products and estimates the impact of efficient lighting products on electricity use and carbon dioxide emissions.

Estimated savings per unit are 39.4 kWh for a CFL replacing an incandescent lamp and 8.0 kWh per year for a T5 to T8 lamp replacing a T12 lamp. Annual energy savings from two years of China Green Lights are 4,426 GWh using the OLS regressions and 4,954 GWh using the ML regressions. Carbon dioxide reductions are 2,753 kilotonnes using the OLS regression and 3,081 kilotonnes using the ML regressions.

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Energy Efficiency Testing Facilities of Home Appliances in Egypt

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Abstract

Egypt is heavily depending on fossil fuel (oil and natural gas) to meet its growing energy demand. This has led to limited hydrocarbon exports, one of the main sources of national income. The Energy Strategy as one of the main components of the Egyptian Economical Development Strategy targeted to decrease the growth rate of Energy Consumption using fossil fuel from 9% to 5.25% by the year 2017, through different Energy Efficiency Programs.

The Energy Efficiency Improvement and Greenhouse Gases Reduction Project (EEIGGR) is a main project financed by UNDP/GEF to assist Egypt in reducing long term growth of GHG emissions from Electrical Power Generation through a range of activities which include Standards & Labeling Program. One of the building blocks of this program is the establishment of accredited testing facilities with appropriate testing procedures. The EEIGGR has successfully developed the energy efficiency standards for the three home appliances with the highest market penetration in Egypt namely: Refrigerators, Washing Machines and Air Conditioners. Relevant Testing Facilities have been recently built at New and Renewable Energy Authority (NREA) affiliated to Ministry of Electricity and Energy.

This paper will present the Egyptian Experience at NREA in performing Energy Consumption Tests to Refrigerators and Washing Machines according to International and Egyptian Standards. This paper will describe the main features of Testing Facilities, Capacity Building of Staff, Mechanism implemented to ensure the enforcement and compliance with the standards and labels. The Accreditation Process, Verification of Results with European Labs in addition to Impact on National Trade Balance will also be presented.

Introduction

Egypt's economic development outlook for the next decade calls for a challenging growth in Gross Domestic Product (GDP) exceeding 6 % on average requiring almost similar increases in energy supply. Since Egypt is an oil and gas producing country ,it is heavily dependent on fossil fuel to meet the current growing energy demand. This is consequently increasing the rate of energy utilization to cope with ambitious goals of economical growth especially with subsidized prices. This will constrain hydrocarbon exports, one of the main sources of national income, and foreign currency. The rising trend in energy consumption levels is likely to turn Egypt to a net oil importer soon. National studies predict that the demand for crude oil is expected to double by 2017 but annual production will be reduced by half. Although natural gas production is increasing, unless domestic consumption levels and patterns are managed more effectively, Egypt's supply of natural resources will be threatened and so, its economic growth plans. [1]

Energy Efficiency in Egypt

- With the economic reform in Egypt in the early nineties, Energy efficiency awareness has increased, especially with the annual growth rate of 5.5 % in energy consumption where statistics has shown that this rate may reach 7 %, by the year 2017. Many studies have been conducted by national and international experts which concluded the following: [2],[3]
  - Any increase in economic activity by 1 %will eventually increase energy consumption by 1.3%
  - Investing in Energy efficiency projects will lead to economic growth (Economic Multiplier ~ 2.32$) more than investing in production of energy (Economic Multiplier ~ 1.48$)
  - With the Implementation of Energy Efficiency Projects a new market of related equipment will arise accompanied with new skills and job opportunities (~ 25,000 to 100,000) in O & M of those equipment, in addition to job opportunities in the field of consultancy services.
  - Investment in Energy efficiency in industry will decrease operating costs and consequently will increase global competitiveness of product.

- The saving is not only as a result of reduction of energy demand but also by reducing the investment required to meet the steadily increasing energy demand to meet economical development objectives.
- The income to the facilities from energy saving can be reinvested in Human Resource Development or in purchasing new equipment and facilities.
- In order to organize and coordinate efforts towards energy efficiency improvement, a regulatory body becomes necessary.

o The Energy Strategy -one of the main components of economic and social development strategy till 2017 - has been reviewed and formulated to include a strategy of energy efficiency improvement. The overall objective is to decrease the annual growth rate of energy consumption from 9 % to 5.25 % and to improve demand for oil and natural gas from 1770MTOE in 1998 to 1175 MTOE by the year 2017saving about 110 $ Billion (estimated for $ 25 barrel price).

o The current economic conditions in Egypt are creating a suitable climate for investing in energy efficiency. Different Energy Efficiency Programs using proven technologies are being introduced to the business community every day. These programs are usually nationally financed or implemented in cooperation with international organizations. For example:[1]
- Cogeneration to generate electricity and steam
- Highly efficient lighting systems including local manufacturing of energy efficient lamps
- Power factor improvement using locally manufactured capacitors
- Efficient internal combustion engines, efficient combustion in boilers and improved thermal insulation
- Waste heat recovery and reuse
- Energy Management systems in buildings

Energy Efficiency Improvement and Green House Gas Reduction Project

o The Energy Efficiency Improvement and Green House Gas Reduction Project (EEIGGR) is one of the main energy efficiency projects implemented by Ministry of Electricity and Energy (MOEE) and financed by UNDP/GEF, to assist Egypt in improving energy efficiency and reducing long term growth of GHG emissions from electric power generation. One of the main activities of this project is the standard and labeling program which has successfully developed in 2003 Egyptian Energy Efficiency Standards to the home appliances with highest market penetration in Egypt namely: Refrigerators, Washing Machines and Air Conditioners.[4]

o **Main features of Egyptian Energy Efficiency Standards**

Those standards aim at improving of energy consumption in appliances that have been selected according to a certain criteria. These criteria included: penetration level in the Egyptian market, average monthly energy consumption and amount of energy savings that may result from such improvement. Refrigerators, Washing machines and Air conditioners testing requirements and procedures have been set up for the standards which include also test conditions, measuring equipment and max allowable values of energy consumption. Energy label that indicates monthly energy consumption and levels of energy efficiency are now issued, where manufacturers are committed to stick the label on the appliance to allow to the customer to select the appliance with less energy consumption. It has been decided that these Energy levels should be reviewed every two years for efficiency improvement. [5]

o **Energy Efficiency Testing Facilities at NREA**

One of the building blocks of standard and labeling program is the establishment of accredited testing facilities to perform energy consumption testing to home appliances following the issued standards. New & Renewable Energy Authority (NREA) as independent entity was selected to host those testing facilities and will be responsible for conducting energy efficiency tests according to Egyptian Standards and to the regulatory decree issued to enforce the standards and labels . NREA affiliated to MOEE acts as the national focal point for expanding efforts to develop renewable energy technologies to Egypt on a commercial scale together with the implementation of related energy efficiency programs. Through its Testing and Certification Center performance tests are performed for the evaluation of renewable energy equipment performance as well as other equipment for energy efficiency purpose. [6]

o The UNDP has complemented the ongoing UNDP/GEF national and standards and labeling by providing assistance to establish the energy efficiency testing facilities. NREA contracted -for a turn key job- an Egyptian Supplier who designed the system and supplied the relevant equipment for Refrigerators and Washing Machines according to technical specifications prepared by an

International Consultant from the Collaborative Labeling and Appliance Standards Program (CLASP). The equipment was imported from different well known European and American suppliers. [7]

Refrigerators Testing Facility at NREA

- This testing facility performs energy consumption tests on refrigerators with capacity up to 1100 liters and on freezers up to 850liters. Locally manufactured or imported refrigerators and freezers can be tested according to International Standards (ISO5155, 8187 and 8561) and Egyptian standards (ES 3794) which comply since 2005 with International standards. The test room is fabricated from fiberglass material and is thermally insulated up to 30 º C and its size (3 * 4 * 2.85) is sufficient for testing two Units Under Test (UUT) simultaneously.[8]
- Power supply to each UUT (with 1350 VA max. power) is controlled to provide voltage in the range from 0 v to 270 v and frequency in the range from 45 HZ to 500 HZ with accuracy ± 1% [1] .The power supply is equipped with a power transducer with error reading 0.2± 0.04FS with maximum error 0.8watt to measure electrical parameters supplied to the UUT.
- **Test Room Preparation and Testing Conditions**
    - The room ambient temperature is adjustable from10 ° C to 55°C within an accuracy ± 1° C. It is controlled to maintain temperature within 25C ± 1° C with gradient < 1°C and accuracy 0.2 % of span via PID controllers used to activate heater or cooler. Temperature measuring devices are shielded so that the indicated temperature is not affected by the operation of condensing units.
    - Humidity of test room is maintained at the standard range where it can be increased using steam generator activated by a solid state relay to control humidity in the range from 45% to 75% with accuracy 2% .
    - Air speed inside the test room is controlled using a high efficiency distribution system. Air is restricted to flow along the walls and floor and away from the space occupied by the UUT. This technique is used to ensure that air circulation in the vicinity of the UUT is constant and does not exceed 0.25m/s. Fig. (1)

Figure 1: Air circulation in refrigerator test room

In table (1) and table (2) we compare accuracies required for measurements and instruments as specified in ISO 8187 & ES 3794 with those provided by the testing facility [9], which shows how we exceeded those accuracies in supplied equipment

[1] In this testing facility we can test locally manufactured refrigerators that can be exported to those countries that have got 220 v or 60 Hz supply

Table 1: Comparison between accuracies of measurements required in standards with accuracies of measurements provided by the testing facility

	Test Room Conditions	Required accuracy according to ISO Standard	Required accuracy according to Egyptian Standard	NREA Measurement Accuracy
1-	Voltage	± 1%	± 1 Volt	± 0.13 Volt
2-	Frequency	± 1%	———	± 0.05 HZ
3-	Ambient Temperature	± 0.5 ° C	± 1 ° C	± 0.24° C
4-	Humidity	———	———	± 2 %
5-	Power	———	———	± 0.4 W

Table 2: Comparison between accuracies of instruments required in standards with accuracies provided by the supplied equipment of the testing facility

	Test Room Instruments	Required accuracy according to ISO Standard	Required accuracy according to Egyptian Standard	NREA Instrument's Accuracy
1-	Voltage Transducers	———	± 0.5 % of reading	± 0.25 % of F.S
2-	Frequency Transducers	———	———	± 0.1% of Span
3-	Current Transducers	———	———	± 0.25 of F.S
4-	Energy	± 1 % of F.S	± 2 % of reading	± 0.2 of reading + 0.04 of F.S
5-	Ambient Temperature Controller	———	———	± 0.25 % of Span
6-	Humidity Controller	———	———	± 0.25 % of F.S for Voltage ± 0.7 % of F.S for Current
5-	Temperature Sensors Inside The Refrigerators	± 0.3 ° C	± 0.5 ° C	± 0.1 ° C

- **Test Unit Preparation**
  - A wooden platform and separators painted dull black have been provided to hold the UUT at 30 cm height from floor and 60cm from sides, ensuring free air circulation around the UUT according to standards.
  - Temperature sensors of RTD type (4wire, 0.1° C accuracy) are connected to test loads distributed in the freezer and cabinet according to standard, as shown in Fig.(2). Storage and equivalent volume of the UUT are calculated according to relevant testing procedure[2]
    It is preferred to operate the UUT in an entry room for about 6hours before introducing it inside the test room. Thermostats or temperature control devices are adjusted before the test at the manufacturer recommended positions. If the UUT has got an ice making unit, it must also operate during the test period.
  - Before the software starts logging data and calculating energy consumption , the UUT must reach steady state equilibrium testing conditions indicated by:
    Temperature inside the cabinet at half thermostat = +5° C,
    Temperature inside the freezer = - 6° C to - 18° C depending of no of stars mentioned in the fridge operating manual,
    Compressor operates for two or three on-off cycles

[2] For ES 3794: equivalent volume = storage volume of cabinet + correction factor * storage volume of freezer (correction factor is function of ambient temperature and temperature of cabinet and freezer), for ISO 8187: equivalent volume = storage volume of cabinet * correction factor + storage volume of freezer * correction factor (correction factor is function of cabinet temperature)

Figure 2: Distribution and connection of RTD's to thermal loads in refrigerator cabinet and freezer

- **Data Acquisition System (DAS) and Software Features**
  The facility is supported by a DAS to collect the data from sensors .Before reaching steady state all on line data are shown namely voltage, current frequency, temperature and humidity inside the test room in addition to the temperature transmitted via RTD's .As soon as we set up Test period, Standard Type for test (ISO or ES) and type of fridge (with or without defrosting) , we can then start logging data. All above data are monitored in addition to on-off cycles of compressor and ratio of total time of compressor operation to total test period named Run Time Ratio [3],as well as Power Factor with logging interval that starts from 1 sec[4]
- **Determination of UUT Energy Consumption and Class Level**
  At the end of the test we get total energy consumption during the test period .Energy consumption for the whole year is calculated (E annual = E daily * 365) as well as the class according to both Egyptian and ISO standards [5]

Table (3) compares results obtained from intercomparison laboratory tests conducted during the Acceptance Tests of the testing facility, where a difference of 1.53 % of results shows the level of reliability and reproducibility of the testing facility

Table 3: Intercomparison laboratory test results: NREA laboratory and SLG Pruf-Und Zertifizierungs GmbH Testing laboratory

NO.	Item	SLG Pruf-Und ZertifizierungsGmbH Testing lab.	NREA Testing lab.
1-	Test duration	24 : 00 : 00	24 : 04 : 48
2-	Energy consumption per day	1728.06 wh without defrosting	1701.77 wh with defrosting
3-	Annual energy consumption	630.74 Kwh/year	630.74 Kwh/year
4-	Average Temperature in The Cabinet	5.1	5.11
5-	Average Temperature in The Freezer	-18.83	- 17.24
6-	Percentage Running Time	48 %	45.9 %
7-	Class	C	C

Washing Machines Testing Facility at NREA

This testing facility performs energy consumption tests to automatic or half automatic washing machines with capacity up to 10kg. Locally manufactured or imported washing machines can be

[3] In 8187standards this ratio excludes period of heater in operation
[4] PF < 1when compressor is operating, PF = 1 indicating that it is the period where the compressor is OFF and the heater is ON during defrosting period, PF = O in case of UUT without defrosting.
[5] In ES 3794: Class = annual energy consumption / equivalent volume (KwHr/L) ,In ISO 8187: Class = (Annual Energy Consumption/Standard Energy Consumption) * 100

tested according to international standard (IEC 60456) and Egyptian standard (ES 4100) which complies since 2005with international standards.[8]

- **Test Room Preparation and Testing Conditions :**
  - The test room is thermally insulated and has same dimensions as the refrigerators test room and is capable of testing two UUT's simultaneously Fig (3). Washing Machines testing facility is equipped with two power supplies with same capabilities as in refrigerators but with max power 3000 VA, to set electrical parameters needed to operate the UUT.

Figure 3: Washing machine testing facility showing also temperature and humidity sensors

- In Washing Machines Testing Facility we don't have any restrictions regarding air flow around UUT. Consequently, we control ambient temperature inside the test room using normal air conditioner to provide room temperature around 25 ° C as specified with accuracy ± 0.6 º C
- Water Pressure inside washing machine is set to 240 Kpa, a pressure transmitter detects the difference between measured and required pressure of water activating a frequency inverter used to control the speed of a pump in the range from 0.5 to 3 HP with accuracy 0.1%.
- Temperature of water pumped to the UUT is controlled within specified values [6] [6]using a water tank where detected low temperature water can be heated via a pump and heater. For detected high temperature water, a refrigeration system with a timer shall operate to cool the water and do the circulation of water inside the tank.

In table (4) and table (5) we compare accuracies required in standards for measurements and instruments with those provided by the testing facility [9], which shows how we exceeded those accuracies in supplied equipment

Table 4: Comparison between accuracies of measurements required in standards with those provided by the testing facility.

	Test Room Conditions	Required accuracy according to IEC Standard	Required accuracy according to Egyptian Standard	NREA Measurement Accuracy
1-	Voltage	± 2 % (4.4 Volt)	± 2 % (4.4 Volt)	± 0.95 Volt
2-	Frequency	± 1% (0.5 HZ)	+ 1% (0.5 HZ)	± 0.025 HZ
3-	Ambient Temperature	± 5 ° C	± 5 ° C	± 0.6° C
4-	Humidity	———	———	± 2 %

[6] For ES 4100: temperature of water inside the UUT = 25 ° C, For IEC 60456 temperature of cold water inside the UUT= 15 ° C and temperature of hot water inside the UUT= 60 ° C.

Table 5: Comparison between accuracies of instruments required in standards with those supplied by the testing facility

Test Room Instruments		Required accuracy according to IEC Standard	Required accuracy according to Egyptian Standard	NREA Instrument's Accuracy
1-	Voltage Transducers	———	± 0.5 % of reading	± 0.25 % of F.S
2-	Frequency Transducers	———	———	± 0.1% of Span
3-	Current Transducers	———	———	± 0.25 of F.S
4-	Energy	———	± 2 % of reading	± 0.2 of reading + 0.04 of F.S
5-	Ambient Temperature Controller	———	———	± 0.25 % of F.S for Voltage ± 0.7 % of F.S for Current
6-	Humidity Controller	± 3 % of F.S	———	± 0.25 % of F.S for Voltage ± 0.7 % of F.S for Current
5-	Temperature Sensors Inside The Washing Machine	± 0.5 K	± 0.5 ° C	± 0.1 ° C
6-	Water Flow	± 1 % of F.S	± 2 % of F.S	± 0.3 % of F.S
7-	Water Pressure Controller	± 5 % of F.S	———	± 0.25 % of F.S for Voltage ± 0.7 % of F.S for Current
8-	Mass	± 0.1 % of F.S	± 0.3 % of F.S	± 0.01% of F.S
9-	Water Temperature Controller	± 1 K of F.S	———	± 0.25 % of F.S for Voltage ± 0.7 % of F.S for Current

- **Test Unit Preparation**

  The test is run on UUT without detergent where it is set for fully automatic cycle for cotton fabric at 60 º C without pre-washing cycle. The UUT is loaded [7] by textiles that are pre-washed at least 20 cycles and not more than 60cycles .The UUT is subject to five complete tests for every complete washing cycle according to standards. Average annual energy consumption (for 240cycle /year) is determined[8]. The class is determined as the ratio of energy consumption to the capacity of UUT in Kwhr/Kg

In table (6) we compare results obtained from intercomparison laboratory tests conducted during the Acceptance Tests, where a difference of 6.4 % of results shows the level of reliability and reproducibility of the testing facility

[7] Maximum capacity for full automatic and 75 % for half automatic

[8] A correction factor is mentioned in the standard to calculate energy consumption for full automatic machines with no control switch of temperature equal to 0.6 or those which having a non separated pre- washing program equal to 0.85

Table 6: Intercomparison laboratory test results tests: NREA laboratory and DEA laboratory

NO.	Item	DEA Testing Lab.	NREA Testing lab.
1-	Test duration (Time of Program B)	02 : 07 : 12	02 : 14 : 36
2-	Inlet water temperature	22 ° C	25 ° C
3-	Water pressure	270 Kpa	245 Kpa
4-	Water consumption	——	77.968 L
5-	Heater Current	7.88 A	8.05 A
6-	Motor Current	1.2 A	1.17 A
7-	Motor stage pressing current	2.9 A	2.48 A
8-	Power of electric heater	1.68 Kw	1.779 Kw
9-	Power of electric motor	0.26 Kw	0.22 Kw
10-	Weight of wear	5.44 Kg	5.14 Kg
11-	Temperature of washing machine water	60 ° C	50.09 ° C
12-	Average Energy Consumption from Program B	1.03 Kwh	0.9842 Kwh
13-	Average Energy Consumption from Program B/Kg	179.1 Wh	191.49 Wh
14-	Class	C	D

- **Data Acquisition System (DAS) and Software Features**
  The facility is supported by a DAS to collect the data from sensors .On the PC we can monitor the same parameters mentioned in the refrigerators testing facility namely electrical parameters, room temperature and humidity. Pressure and temperature of water inside the UUT are also displayed at the set log interval that starts from 1 sec. Fig. (4)

Figure 4: Data acquisition system of washing machine test facility

Common Features

- **A Calibration Kit has been supplied to calibrate different parameters used in the system including the following:**

- A Pressure calibrator used to calibrate: Pressure Transmitters (P-I and P-V), Pressure Converters (P-P and I-P), Pressure switch and relief valves
- A Multifunction Calibrator to calibrate electrical parameters in the range of the supplied equipment, pressure in the range from (- 1 to2O bar),humidity from (0 % to100 %), Thermocouples and RTD's an also be calibrated in the range from (-50° Cto 650° C)

o Each Testing Facility has been equipped with a manual system (0.05 % accuracy) supplied as backup to the computerized system.. This system can record all parameters data for 24 hrs and calculate daily energy consumption .This manual system has also 64analog channels and 64 alarm set points. It has also 48 digital inputs and 48alarm relay outputs in addition to an event alarm system. Fig. (5)

Figure 5: Back up manual system supplied to record all measured parameters in parallel with computerized system

- The Testing Facility has safety features including a fire alarm system, in addition to an "under and over temperature alarm" to shut down the whole system. The software has a flashing lighting in case of out of range parameters or in case of turn off of any equipment. Moreover, as soon as we start logging data to calculate energy consumption human intervention is not allowed to stop logging data.

Mechanism adopted for Enforcement of Standards and Labeling

o An agreement with Egyptian Organization for Standards and Quality EOSQ -as a regulatory body- is being reviewed where NREA will receive Refrigerators or Washing Machines randomly selected by EOSQ at the manufacturer site .This mechanism is expected to ensure the enforcement of standards and labeling The quality management system established since 2004 at NREA Testing and certification center ensures effective lab management according to ISO9001/2000 requirements.

o The reports issued from NREA will indicate the energy consumption and the class of the appliance for the manufactured model. Those data should be mentioned on the label that will be issued by the manufacturer prior to distribution in the stores. This label will be subject to investigation in retail shops by another regulatory body affiliated to Ministry of Internal Trade

Accreditation Process

o The Industrial Modernization Program financed by EU has adopted accreditation of the new testing facilities. Quality management system according to ISO 17025 requirements has been established including quality manual and testing procedures.

o Work instructions, Inventory and log file of all testing equipment, maintenance plan and records of troubleshooting, Calibration records are currently applied. Accreditation of the testing facility is expected by July 2006.

- NREA is now seeking international accreditation to save high fees paid by manufacturers to test locally manufactured appliances abroad prior to exporting

Capacity Building

Three engineers and two technicians have attended a classroom and on-site factory training to learn operating and calibrating testing equipment and to get acquainted with Egyptian and international standards of testing procedures. An on-the-job-training has also been conducted during the installation phase and during commissioning to perform the complete test according to both standards in addition to O&M procedures. They have also been trained to monitor and analyze test results and issue reports, in addition to a hands-on training to calibrate testing parameters of the whole testing facility using supplied calibration equipment. Accreditation requirements according to ISO 17025have been taught to testing engineers including methods of calculation of uncertainty as one of the main requirements of testing credibility.

Impact on National Economy

- Testing of locally manufactured appliances has shown the application of improved technologies that have dramatically improved their energy efficiency. [2]
    - For the refrigerators: use of high efficiency compressors and increased insulating material width results in savings around 40 % of the current energy consumption.
    - For the washing machines: one of the local manufacturers uses Water Jet system instead of the normal system with results obtained showing 20 % saving of energy consumption .Other improvements include using highly efficient compressors, special sensors to control water consumption, and decreasing inter drum space. These improvements can provide almost 30 % energy and 20.8 % water savings
- Moreover by applying standards and labeling to home appliances we expect a great impact on national economy as following:
    - The Egyptian market will be protected from low energy efficient products and consequently will create a competitive market for highly efficient products.
    - Bringing benefits to the consumer through less spending on electric bills
    - Decrease of GHG emissions.
    - Reduction of investment costs needed to build Power plants to meet growing requirements of energy
    - Improved national balance of payments due to savings of fossil fuel for exports and petrochemical industries

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Residential Gateway Standardisation

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Abstract

This paper will present the standardisation work being done in ESTI, with NGN@Home and TISPAN and work done within the CENELEC SmartHouse Project.

To be able to understand the residential gateway concept we have to look into today's residential access environment with different network access technologies coming to the home via the existing twisted pair telephone network (xDSL), the coax (and fiber) cable TV networks and emerging wireless access. Coupled with this today we also have a direct broadcast satellite networks, switched digital video networks, PCS networks, and probably others. These are probably not all at the same place and same time and also these are not only competing networks, but they are incompatible at various levels of the OSI model. This would mean that they are incompatible in more than their basic physical interface characteristics.

This incompatibility and competition among those networks that we have are in functions, price, availability, which means that the residential customers will have to work with a complicated connections and switching problems. So, the solution is to design a technology-based solution that will handle this function and hide the complexity from the consumer.

Home Networking Trends

Broadband gateways are devices of the future and they have much to offer but at the moment they are still in the laboratories and for some time to come. The innovations in telecom industry have reshaped the way we communicate, our nature will still ask for more connectivity, more bandwidth, more services, and more scalability and what we want is everything, not just certain elements. If we have a high-speed Internet access at work, than why can't we also have it at home?

The demand goes not only for a high-speed access, but also other applications such as linking telecommuters with corporate offices, to controlling a home alarm system from the other side of the country, turning the dishwasher ON from the office, or downloading a movie from one computer to another within our homes.

Reliable broadband services delivered to the home will enable a variety of applications that will enrich our quality of life with new multimedia services for voice, video, videoconferencing, interactive gaming, high speed Internet access, telecommuting; services for white goods, metering, health care for the ill, elderly and disabled, security, monitoring and intelligence.

While aiming for more functionality out of a high-speed connection, the challenges service providers are facing is finding a way to uniformly serve customers with different demands. Many providers are turning to broadband gateways as a solution that could bring together multiple technologies without compromising the end user service. This new "digital home" is the converging point of multimedia, computing, Internet and telecommunication industries.

The Home Residential Gateway market could be separated into three types of device:

- Home Residential Gateway - addresses entertainment (video and audio), communications (telephony), high-speed data access, and control and monitoring (HVAC, security, lighting, etc.) functions.
- Internet Residential Gateway – This is intended to connect multiple computers, multiple high-speed access problems in the home.
- Set-Top Box Residential Gateway – Are the CATV digital solutions. They are new generation boxes that came from the analogue TV set-top box with more capabilities and features.

The Home Residential Gateway has a control function between external networks and in-home networks and devices. It serves as a traffic control and routing device and has these key functions:

- The location to terminate all external access networks to the home, with multiple residential services being delivered over any type of access network.
- The location to terminate all home networks, such as telephone, television, computing, alarm, telemetry, data, etc.
- To seamlessly interconnect those public and private networks

The network interface units are selected to match the appropriate external network. The customer premises interfaces are selected to match internal home networks or specific home appliances. The processor serves to operate the back-plane as a switching point to allow highly flexible translations and interconnections while hiding the complexity from the customer
The residential gateway enables consumers to connect electronic devices such as PCs, kitchen appliances, audio/video equipment and security systems to their phone service and high-speed Internet access. By connecting the electronic devices, consumers can perform tasks such as adjust heating or air conditioning via a home computer. The home networking products came out a while ago, but what we are missing is the home residential gateway to tie everything together. Using the home residential gateway, users can share a single broadband connection for all PCs in their home and share that connection, by setting up home LANs, share files and play interactive games.
The concept of Intelligent Homes and Business is intended to provide solutions for automation in homes, buildings and related areas to assist people in their living environment. Standardized solutions will make it easier to supply services and networking, together with numerous new applications including remote control of home automation, alarm systems and assistance to people with special needs. Communications' infrastructures will form an essential part of the support to these applications.

Home Area Networks
The Home Area Network is a short-range communications system designed for the residential environment and is independent of the home network physical (PHY) layer medium, where this may include, but is not limited to:

- Co-axial cable
- CAT 5 and CAT 6 cable (twisted pairs - balanced)
- Telephone wire (unbalanced)
- Power line communications
- Optical fibre
- Radio Frequency (RF) wireless
- Infra Red (IR) wireless

The home network physical layer protocol and data link protocol may include, but are not limited to:

- Bluetooth™
- Ethernet or IEEE 802.3
- HomePlug™(Home Powerline Alliance)
- HomePNA™(Home Phoneline Networking Alliance)
- HomeRF™(HomeRF Working Group)
- IEEE 802.11a/802.11b

As can be seen from the above list, there are many network technologies; it may not be possible to deliver all Home services over the network technologies listed above.

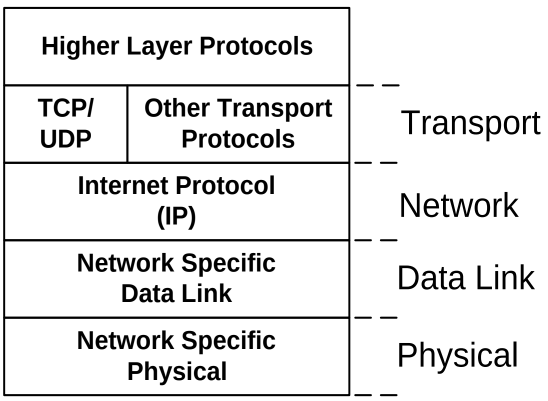

Figure 1: Home Network Protocol Stack

Typically, devices within a home network communicate with each other using a peer-to-peer architecture as opposed to the client/server model that is used in corporate networks. In peer-to-peer networks, devices can connect to each other directly without a server as an intermediary. In client/server architecture, all devices connect to a central server, which provides services like Internet access, applications and file sharing. Many more devices can connect in a client/server network than in a peer-to-peer network.

Existing Communications Cabled Infrastructure "No New Wires" Networks

Phone Line Networks
This technology uses a home's internal phone wiring to connect one device to another. Most phone line networks require that all devices be connected to the same phone line (i.e., the same pair of wires). A phone line can carry multiple signals at different frequencies, which is why one can talk on the phone and still use a DSL modem for Internet access. Network traffic over phone lines uses frequencies higher than DSL or voice bands. This, de-facto industry standard for this technology, is set by the HomePNA a Phone-line Networking Alliance offering a quality of service (QoS), which enables real-time audio and video precedence over other data.

Power Line Networks
Since power outlets are more widespread in a home than phone jacks, a network that makes use of electrical wiring could be more practical. Power line networks send data signals through existing AC power lines. The challenge is that data transmission on the AC power lines is highly susceptible to interference and noise generated by household appliances (e.g., hair dryers, dishwashers, etc.). The HomePlug Alliance sets the industry standard for higher data rate networking over home AC wiring. This consortium is developing standards for a second generation of power line network products with 10 Mbps transfer rates and increased reliability. The HomePlug Alliance has several focus areas: HomePlug 1.0 + AV (in-home connectivity, including digital home and consumer electronics applications), HomePlug BPL (to-the-home, Broadband-over-power line applications) and HomePlug Home Automation (command-and-control applications).

Wireless Networks
IEEE 802.11 is growing in popularity and support as prices continue to fall and as consumer awareness grows through the efforts of the Wi-Fi Alliance (an organization established to promote interoperability between IEEE 802.11 devices and to bestow certificates of conformance to those devices implementing a baseline subset of IEEE 802.11). It also supports other computing devices such as PDA's. Wi-Fi IEEE 802.11 is also being adopted for wireless connectivity in public places, college campuses and the workplace, using the same network adapters one would use in the home or in business.
Bluetooth is one of the latest protocols that came into the wireless arena. Imaginatively named after a Viking King, this short-range wireless protocol is not aimed solely at the home network but the personal area network (PAN). Bluetooth is primarily meant to reduce the number of cables required to interconnect small devices like mobile phones, PDAs, laptops, keyboards and headsets to each other. Bluetooth network can connect to access points in pre-existing networks within a range of about 10 m (30 ft) with the data transmitted at a maximum of 1 Mbps.

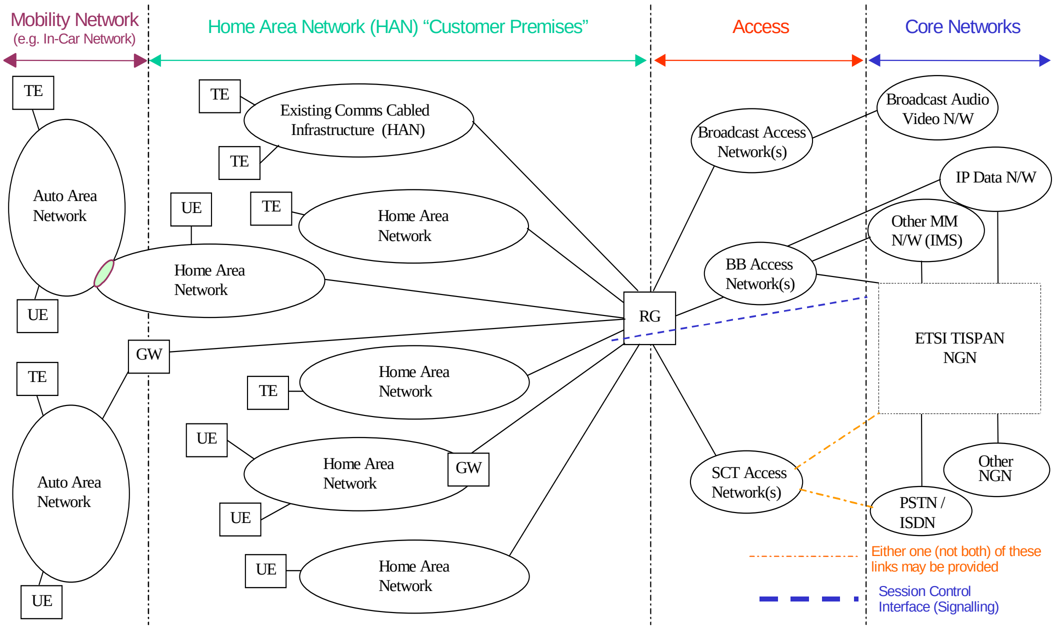

Figure 2: NGN @ Home Interfaces

There are multiple interfaces at the boundary to the Home Area Network and within the HAN.

Access Networks

The definition of the access network(s) is outside the scope of NGN @ Home. However, the interaction between the HAN and access network has to be managed at several levels to:

- Ensure privacy within the Home domain;
- Provisioning of end devices that may be required for specific services;
- Requests from end devices for resource allocation (QoS aspects);
- User profile management;
- Service level management;

NGN @ Home is required to support access networks of diverse technologies and capabilities. Regardless of the type of access network technology, the NGN @ Home communications and services are required to be available to all end users.
Whilst profiling the specific characteristics of the various access networks is within the scope of the NGN @ Home work, the QoS and Security specifications under Release 1 will only cover the following access network technologies:

- Switched Circuit Technology (SCT) – PSTN/ISDN/GSM
- Digital Subscriber Line (xDSL)
- Hybrid Fibre Co-ax (HFC)
- Satellite and Terrestrial Broadcast
- WLAN (used in local loop) – IEEE 802.11x

Access Network Assumptions/Requirements

The access network is defined as a collection of network entities and interfaces that provides the underlying IP transport connectivity between the device and the NGN core entities. Examples of "Access Network" are given below. It should be noted that this list is not an exhaustive list and other access network may be considered.

- xDSL: this includes ADSL, SDSL and VDSL transport systems and supporting concentration/multiplexing technologies. The TISPAN NGN will provide direct support for this access requirement through interfaces to control resources (QoS) and coherent authentication.
- Wireless LAN networks are required to be supported by the TISPAN NGN. For Release 1 they are regarded as just another type of access network. The TISPAN NGN interface to the wireless LAN network will be at a fixed (not radio) point. Requirements for this support are similar to the support for XDSL access networks.

- Cable networks may be supported as another type of access network, but no interworking requirements are placed. TISPAN NGN will not control resources or authenticate access to this network by terminals and users.
- Fixed IP Connection (e.g. Gigabit Ethernet link to corporate network). TISPAN NGN assumes that this interface is a direct connection to a customer owned and managed LAN or MAN. Control is limited to admission control. Example scenarios also include FTTC (Fibre to the curb) and FTTH (Fibre to the home).
- 3GPP PS domain. TISPAN NGN shall support the 3GPP PS domain at the same interface point as other access networks, see Figure 2. Network attachment and associated functionality is supported in exactly the same way as in a 3GPP network. In this sense a TISPAN_ NGN supports any 3GPP IP-CAN. TISPAN NGN does not support the CS domain as an access system. All interfaces between the PS domain and the IMS are maintained unchanged in the TISPAN NGN. The 3GPP PS domain is not re-documented as part of TISPAN NGN specifications.

All NGN capable access types are required to offer IP connectivity.

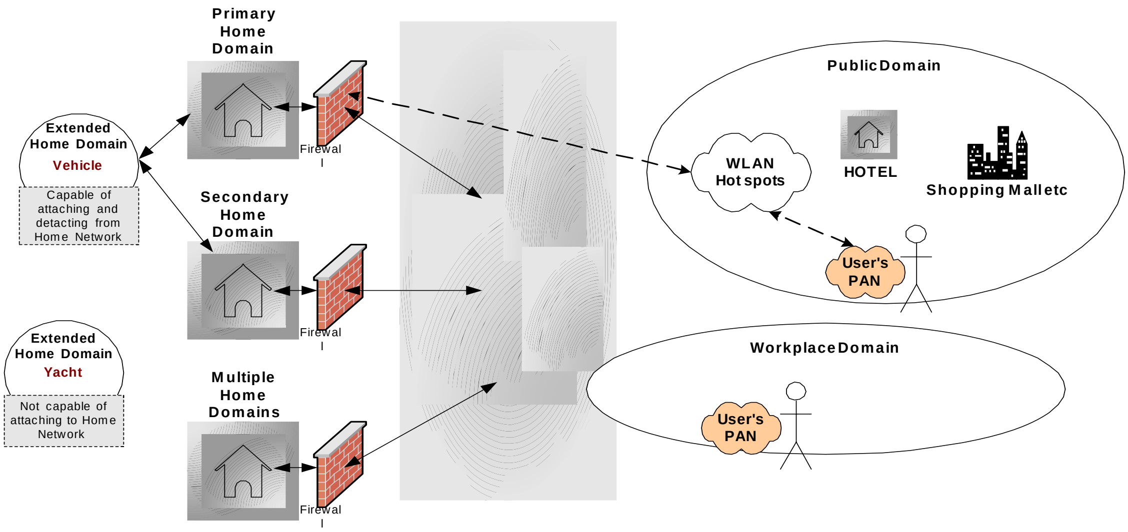

Figure 3: Multiple Home Domains

Home Residential Gateway is an IP based device that *enables* a Service Provider to offer enhanced set of home network services with QoS, Device and Service Discovery, Security, Firewall, Provisioning & Management. It also enables users *to connect* devices like PCs, kitchen appliances, audio/video equipment and security systems to a high-speed Internet Access.
At the same time Home Residential Gateway enables users *to share* a broadband connection for all PCs, by setting up home LANs, share files, printers and play interactive games and also is able *to provide* solutions for automation in homes, buildings and assist people in their living environment.

Home Residential Gateway Reference Architecture

The Next Generation of in-home network should support a multiple of different home networks based on IP but also the other non-IP based networks that should be interconnected into one overall structure, represented in Figure 3. Connection to the Wide Area Network should be done through a single Residential Gateway Architecture that on one side would support different access technologies and on the home side it should connect to other home routers/switches but also legacy networks through separate gateways.

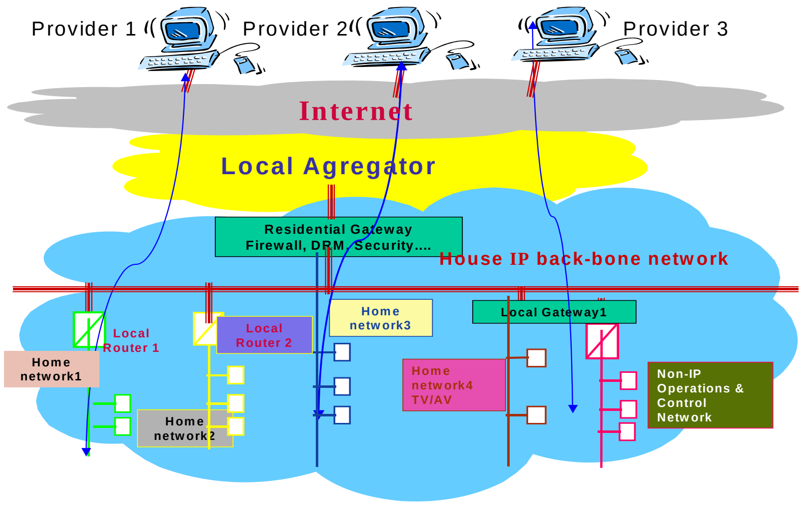

Figure 4: Home and Access Network Model

From the Figure 3, it is clear that there are four fundamental areas that are the key to the NGN @ Home:

- Multiple Access Networks (using both IP and non-IP native access technologies)
- Multiple Home Area Networks (including the control domain, the transport domain, and the applications environment)
- Multiple Services and Service Providers (multiple content streams and formats)
- Multiple End User Devices and Terminal Equipment connected within the Home Area Network

The NGN@Home Project areas:

- ***General Model.*** The Home Network Architecture targets at supporting a wide range of services, from legacy telephony to new generation services, such as: audio, data, video broadcast and conversational services, streaming services, interactive gaming.
- ***Functional Architecture Model***. A distributed functional architecture with the use of a new set of protocols to control user sessions (identification, authentication), resource allocations and QoS, the traffic (policing, enforcement), services and applications, between various entities within the home network, Packets filtering (depending on "IP address/port", i.e.; firewall functionality), Packet marking, Resource allocation and Bandwidth reservation, Allocation and translation of IP addresses and port numbers (NAPT), Throughput limitation, and optionally Media Ciphering/Deciphering, Media Trans-coding, Media flows topology (conferencing, redirection of flows, etc.), User Authentication, Usage metering, IP address allocation.
- ***End-to-end Quality of service***
- ***Service platforms*** (including APIs)
- ***Network Management***
- ***Security & DRM/CA***

The NGN@Home Project functions and features:

- ***Easy to acquire, store, and access digital music.*** From anywhere in the home access to digital music collection stored on multiple, network-enabled devices, including PCs, “virtual jukeboxes” and portable audio players and for playback on any network-enabled playback device in the home.
- ***Easy to manage, view and share digital photos.*** The wireless download feature transfers all the photos to a media archive on a PC that will distributes the photos to photo frames, PC screensavers, TV adapters, and other devices throughout the home. It even securely sends the images across the Internet to friend or family.
- ***Distributed, multi-user content recording and playback***. Using a universal remote, access any of the network-enabled set-top boxes, PCs, or TVs in the home and select programs for viewing, or for recording and later playback, utilizing available tuner resources embedded in network-enabled TVs, dedicated PVRs, set-top boxes, and PCs.

In order to deliver on digital interoperability in the home, it is required to support:

- Transparent connectivity between devices inside the AV Home Network;
- Unified framework for device discovery, configuration and control;
- Interoperable media formats and streaming protocols;
- Interoperable media management and control framework;
- Compatible authentication and authorization mechanisms for users and devices;
- Home control, communications, and more advanced entertainment scenarios.

End users can:

- Select the service provider independent of the access mechanism;
- Different end users within the same HAN can select different service providers;
- Roam between delivery networks, based upon their subscription profile with the selected service provider.

For example: a user can register with the service provider for delivery of content when connected via neighbours' HAN.
The objective is to define an open network architecture enabling the provision of services to the users in its home and in nomadic situation. The basis for a multi-service home network based on a Home Residential Gateway (HRG) that acts as a service platform for the end user needs to be defined. The HRG has embedded Agent that could allow a remote management of the home network by the home network service operator.

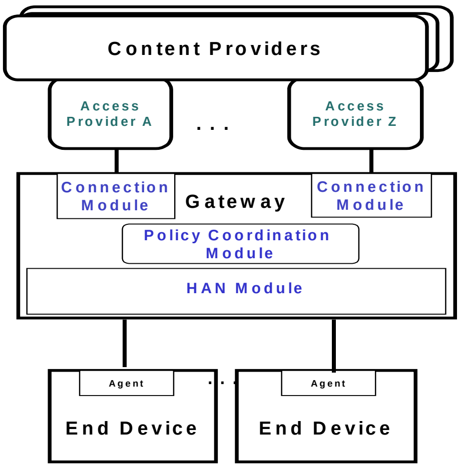

Figure 5: Home Gateway Architecture overview

Home Residential Gateway coordinates shared access to the Internet for all of its End Devices. It has four physical/logical modules: Connection Module, Access Module, Policy Coordination Module and HAN Module.

A: Connection Module. Provide content to End Devices, through Access Provider(s) and through out-of-band Broadcaster.

B: Access Provider Module. Provide Access to Internet for the Connection Module(s) on the Gateway coming via: xDSL, HFC, PLC, xTTH, FWA, GPRS, UMTS, or any other new access technology. He may provide local advertisement insertion.

C: Policy Coordination Module coordinates changes amongst the other modules. It handles NAT, DHCP, IP Routing, DRM and CA Rights, Multicast optimisation, Network Address Translation, Quality of Service & Security. It makes appropriate adjustments to the other Modules as needed.

D: HAN Module. Home Access Network (HAN) module might be separate hardware like a Hub, bridge, switch, access point. It ties the various home networking media together. It should support Ethernet, PLC, IEEE 1394, 802.11, HPNA, Bluetooth, USB, coaxial cable. Its role is to notify the Policy Coordination Module of pertinent changes.

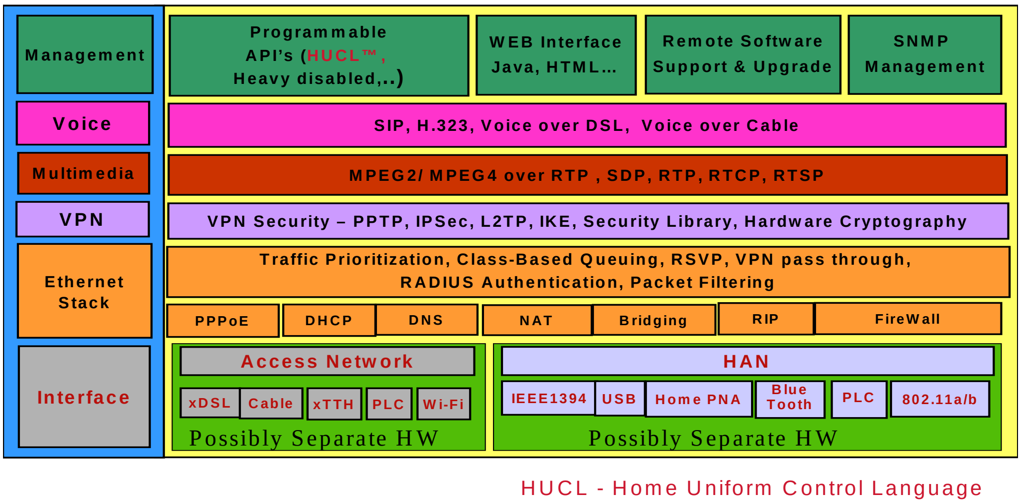

Figure 6: Home Gateway Stack (example)

The Home Residential Gateway is to enable the delivery of new services to devices within the home with the goal to interact with IP (and non-IP via specific GW's) based home devices. This would give a Service Provider a management, provisioning, QoS and Security to the Home Residential Gateway together with the LAN messaging, prioritised QoS and simple remote diagnostics for all home devices in his domain of management.

Quality of Service (QoS) Requirements and Functions

The meanings of QoS include two aspects: service performance and service differentiation [ITU-T E.800]. The key parameters of service performance are bandwidth, delay, jitter, and packet loss. The guarantee of service performance should be end-to-end, consistent and predictable, at a level equal to or above a guaranteed minimum [RFC2990]. Service differentiation means providing different performance guarantee for different service applications. And some key services should be carried with accurate and unaffected QoS guarantee even under heavy load. Especially for voice services, the IP network should be capable of providing a carrier-class QoS that is equivalent to the legacy PSTN.

1. The end-to-end QoS architecture should:

- Encompass CPEs
- Be independent of access technology
- Accommodate multiple administrative domains
- Support varying services, such as real-time multimedia communications and VPN
- Support convergence of connectionless and connection-oriented networks and technology
- Support proactive (e.g., admission control) and reactive mechanisms (e.g., congestion control) based on measurements

The Home Residential Gateway is an environment that enables home networking applications to utilize QoS resources. These resources provide a management mechanism that prioritises data flows to support real-time application traffic, such as VoIP, A/V streaming, and video gaming, by using prioritised media access and queuing.

The Home Residential Gateway QoS:

- Enable home networking applications to establish prioritized data transmission among Hosts as well as between the Hosts and the Residential Gateway using compliant messaging.
- Enable home networking applications to establish prioritized data sessions between the Access Node and the Home RG device.
- Home Residential Gateway device supports a transparent bridging functionality for QoS messaging from/to home compliant applications
- Ability to assign traffic priorities (differentiated media access) to specific applications

- Ability to prioritize queuing in the Home Residential Gateway device in conjunction with the packet handling functionality.

The Home Residential Gateway QoS-enabled services:
The NGN@Home should be able to support a wide range of QoS-enabled services. To offer these QoS services, it is necessary to define:

- Bearer service QoS Classes
- QoS Control mechanisms
- QoS Control Architecture
- QoS Control Signalling

The provision of NGN@Home QoS mechanisms should take account of different QoS control mechanisms corresponding to different technologies and possibly different business models. The following three scenarios have been identified:

- <u>Proxy QoS with policy-push:</u> The client's terminal or Home gateway does not itself support native QoS signalling mechanisms. It requests a specific service to the Application Manager, which determines the QoS needs for this service (as in xDSL network).
- <u>Client-requested QoS with policy-push:</u> The client is able to request its QoS needs and the terminal or the Home gateway is capable to send QoS requests over signalling and/or management protocols for its own QoS needs, but requires prior authorisation from an Application Manager (as in Mobile Network).
- <u>Client-requested QoS with policy-pull:</u> The client terminal or Home gateway is capable of sending QoS Request over signalling and management protocols for its own QoS needs, and does not require prior authorisation.

This approach is in conformance with PacketCable multimedia Architecture Framework (PKT-TR-MM-ARCH-VO1-030627) as endorsed by ITU-T J.179.

VPN Service Requirements
VPN services constitute an important piece of the current service market for the service/network providers and estimations indicate their value will continue to grow. The required VPN service features will also continue to grow with the evolution of application scenarios and enabling technologies and also looking at Service Providers' increasing variegated set of network and service environments.
Some significant evolving requirements are like: simultaneous data/voice/video support, multicast support, QoS support, enhanced security, mobility integration (nomadicity, roaming), increased access technologies diversification, increased interworking scenarios, customer-on-demand capabilities, multi-layer VPN services (L1/L2/L3) and related features (multi-layer resource control), multi-provider and other complex connectivity scenarios, IPV6/IPV4 support, migration scenarios, VPN OAM, ubiquitous user identification. A number of these requirements are common to other services whose support is required by future NGN and NGN@Home architectures.
At the same time, some of the inherent characteristic of the VPN services, like service-transport layer separation, virtualisation of resource, multipoint connectivity, auto-discovery capabilities, make them particularly interesting looking at some general characteristics required by future NGN and NGN@Home architectures.

Security
The ability to guarantee secure communications and to block unwanted traffic or access to a terminal is beneficial for almost all types of basic service capabilities.
To support the Home user security requirements, there are security functions that reside within the Home Residential Gateway Security Domain, that is on a per-home basis that include servers used for key distribution, encryption, and authentication as well as some other client functions.

1. **Home Security Portal (HSP)**. The HSP communicates with Network or Service Provider security servers, and includes functions that provide client side participation in the authentication, key exchange and certificate management processes. Other security functions include management message security, participation in secure download processes, and remote firewall management
2. **Firewall (FW).** The Firewall provides functionality that protects the home network from malicious attack.

3. **Key Distribution Centre (KDC) Servers**. The key distribution centre (KDC) servers provide security services to the CSP and include functions that participate in the authentication and key exchange processes.

Basic network security issues have changed very little over the past decade. Protecting the confidentiality of information, preventing unauthorized access and defending the network against attacks remain primary concerns for network security specialists. Making network security significantly more challenging is wide spread remote access by and the high number of increasingly sophisticated attacks.

The network has been placed in a vulnerable position and will remain that way based on several key trends.

- Changing levels of trust: An ever-widening range of network access is being granted to different users that is making the network increasingly vulnerable
- Ubiquitous access to the Internet: The availability of the Internet has made every home, office or business partner a potential entry point for an attack. This ubiquitous access allows sophisticated attacks to be launched against the corporate network by deliberate attackers or unknowingly by remote users logging onto the corporate network.
- Attack sophistication: New types of attacks that target application vulnerabilities have been added to the long list of viruses, worms and Trojan horse attacks that need to be defended against.

Security components describe the different security layers and their intended use:

- Virtual Private Network (VPN). Protect communications between sites and/or users with an encrypted, authenticated communications session.
- Denial of Service (DoS). Protect against denial of service type attacks
- Network Firewall. Protect the network by controlling who and what can have access to the network
- Application Aware Firewall. Combination of network and application level protection detects and stop application level attacks
- Intrusion Prevention. Dedicated technology designed to protect against a wide range of sophisticated application level attacks
- Antivirus. Protect against virus attacks at the desktop, gateway and server levels
- Personal Firewall. Protect content on personal computers and in turn, keeps corporate networks safe.

Possible services to be supported:

- Home Residential Gateway device authentication
- Secure management messages between the WAN access link and the Home Residential Gateway
- Secure download of configuration and software files
- Optional configuration file for security
- Remote Home Residential Gateway firewall management
- Standardized firewall configuration and reporting
- Simple parental control
- Secure Residential Gateway management messages
- Secure QoS on the WAN access link

Billing, charging and accounting

NGN In-Home should enable all possible types of billing arrangements, as well as accounting (between providers). This includes also e-commerce arrangements. Billing, charging and accounting will be based on the collection of information from any appropriate entities in the form of Charging Data Records (CDRs).

Security Authentication Requirements and Copy Protection

An NGN In-Home Network should provide security from network operator and user perspective. It should provide the possibility to establish trust relationships with other networks and with users. This includes the capability of the network to authenticate and authorize a single user and another

network. A user should have the possibility to authenticate the network. The IP multimedia applications should be provided in a secure manner.
The NGN Home Network should allow for a user to register with multiple terminals in parallel and multiple users to register with the same terminal. At any time the NGN Home Network should be able to verify the identity of users and terminals.
Additionally it should be able to check the authorization of the user to use resources of the NGN Home Network and to access services offered by it. Identities of NGN Home Network users, used e.g. for authentication, authorization and routing, could be administered by the network operator.
A user profile, that is a collection of user related data, is provided for support of:

- Authentication
- Authorization
- Service subscription information
- Location
- Charging

The NGN Home Network should support mechanisms for the network operator to guarantee the authenticity of a user identity presented for an incoming call to a user where the call is wholly within that operator's network.

NGN@Home Network Mobility Support
The ability for the user to communicate and access services irrespective of changes of the location of user or terminal, i.e., independent of the network access point, and of changes of the terminal type. The degree of service availability may depend on the Access Network capabilities, as well as any service level agreements between the user's home network and the visited network.

- ***Terminal Mobility***, where the same terminal equipment is moving or is used at different locations. The ability of a terminal to access telecommunication services from different locations and while in motion, and the capability of the network to identify and locate that terminal.
- ***Personal Mobility***, the user changes the terminal used for network access at different locations. The ability of a user to access telecommunication services at any terminal on the basis of a personal identifier, and the capability of the network to provide those services delineated in the user's service profile.
- ***Service Mobility*** is applied for a specific Service, i.e. the ability of a user to use the particular (subscribed) service irrespective of the location of the user and the terminal that is used for that purpose.

One of the crucial requirements for NGN and NGN@Home is to provide the mobility management for users and terminals so as to ensure the roaming across the heterogeneous networks and also the seamless mobility for on-going sessions in the networks.

Possible user requirements for mobility:

- Users should be able to gain access from any network access point. This includes all the access technologies (fixed, mobile radio, WLAN, WLL, etc.) and users are able to access their services through other networks (roaming). These possibilities may be limited by subscription and roaming arrangements among various service providers.
- Users should be able to get their services in a consistent manner, which is dependent on the constraints they experience in their current situations (ex. terminal capabilities, bandwidth limitations etc.). This is required for services provided by the network operator as well as services provided by a third party.
- Users' availability and reachability should be known to network functions and possibly, to services and applications, including those provided by a third party.

NGN@Home Network Applications Support
In a NGN Home Network it should be possible to offer and support standardized and non-standardized applications. The support of non-standardized services is defined by service capabilities.

The NGN Home Network should support capability negotiation of IP multimedia applications to identify and select the available media components and resources, QoS etc. of IP multimedia sessions. It should be possible for the capability negotiation to take place on invocation, acceptance and during an IP multimedia session (e.g. following a change in terminal capabilities, change in media types etc.). The user, the operator or an application on behalf of them may initiate capability negotiation.

In order to support the user's preferences for IP multimedia applications, the capability negotiation may take into account the information in the user profile whenever applicable. This includes the capability to route the IP multimedia session to a specific terminal, when multiple terminals share the same NGN service subscription.

The NGN Home Network should support a rapid service creation and deployment using service capabilities, which enables maximum flexibility for the end user devices and network & application servers.

This would give an operator possibility to efficiently deploy IP multimedia applications without having to wait for these applications or additional enabling technology to be standardised in the NGN environment or somewhere else. For example download of client software from a 3rd party repository.

The NGN Home Network should support regulatory requirements especially with respect to emergency communications and lawful interception.

The NGN Home Network should provide mechanisms that allow presenting the identity of the connected party to the session originator, if this is not restricted by the connected party or the network. It should be possible for the user or the network to identify an alternative destination for an IP multimedia session or individual media of an IP multimedia session.

The sending party, receiving party or the network on their behalf, may initiate redirection to alternative destinations. It should support more than one IP multimedia session to be run by a user in parallel and also activation of concurrent IP multimedia applications within IP multimedia sessions.

Energy Efficiency in the Refurbishment of High-Rise Residential Buildings: Mapping Out an Integrated Policy Approach

Pedro Guertler, Winton Smith

Association for the Conservation of Energy

Abstract

In the context of pressing and frequently conflicting environmental, economic and social policy objectives, energy efficiency investment is repeatedly found to be a cost-effective and reconcilable component of energy policies. High-rise residential buildings are a particularly salient issue in this regard as their poor energy efficiency is regarded as a "moderate" to "major" problem by 18 out of 27 housing ministries who responded to a Europe-wide survey [1]. Yet no previous research exists on the Europe-wide picture of the potential for energy efficiency improvement in high-rise buildings, nor on ways to achieve this potential.

Taking into account the present EU (25) plus Bulgaria, Romania and Turkey, this paper – based on research funded by the International Energy Agency and the European Alliance of Companies for Energy Efficiency in Buildings – briefly illustrates the scope for increased energy efficiency in high-rise buildings and the benefits investment in energy efficiency in these buildings can provide, including the cost-effectiveness and CO_2 mitigation cost of this investment. Following this assessment of the current situation and potential, and based on a map of the political, economic, social and legal opportunities for and barriers to financing and implementing the necessary energy efficiency investment, policy steps are identified and proposed which form the integrated policy approach needed to exploit the energy-saving potential in this sector.

Introduction

Some 36 million European households are in high-rise residences, one in six of all households [1], and yet many of the buildings are in urgent need of refurbishment. This paper highlights a Europe-wide cost-effective energy saving potential of 28% from energy-efficient refurbishment of the high-rise residential building stock. Attainment of this potential would imply a 1.5% reduction of Europe's total final energy demand and CO_2 emissions savings of 35Mt. In practice only the less efficient buildings need to be refurbished to realise these stock-average savings and for these buildings typical savings in heating energy from refurbishment of between 70% and 80% are identified.

Buildings in general suffer from a variety of barriers that tend to prevent their occupants from maintaining and refurbishing them to the levels of comfort and energy performance that would be justified over the longer term, but collective housing is particularly susceptible to market failures. Many occupants do not own the property while their landlords usually have little motivation to finance improvements. Refurbishment requires collective agreement on a capital investment, which is difficult to establish especially when some occupants expect to live in the building over the longer-term but others only for the short-term. Furthermore, in most cases the occupants of high-rise residences are not among the wealthier members of society and they find it difficult to raise capital for longer term investments. It is not surprising, then, to find that this section of the building stock is the most neglected and that there remain significant cost-effective opportunities for it to be refurbished in a way that improves comfort, saves energy, reduces CO_2 emissions and significantly improves the urban environment.

This paper, based on a research project funded by the International Energy Agency and EuroACE (the European Alliance of Companies for Energy Efficiency in Buildings) [2], investigates the potential for energy savings in high-rise residential buildings in Europe – defined by the 3rd European Housing Ministers' Conference on Sustainable Housing, in Genval, Belgium in 2002, as multi-family buildings with more than four storeys [3]. It then maps out an integrated policy approach for the incorporation of energy efficiency improvements into widely needed overall refurbishment as a central element of sustainable refurbishment. The 28 countries covered by the project were organised into eight groups, according to socioeconomic category ('old' EU members (EU15), 'new' (EU10) and accession (AS3) states) and climate (using three heating degree day bands) as shown in Figure 1 and Table 1.

Table 1: Categorisation of countries into base regions

	EU15	**EU10**	**AS3**
Warm climate *<2700 heating degree days (HDDs)*	(A) France Greece Italy Portugal Spain	(B) Cyprus Malta	(C) Turkey
Moderate climate *2700-3700 HDDs*	(D) Belgium Ireland Luxembourg Netherlands United Kingdom	(E) Czech Republic Hungary Slovakia Slovenia	(F) Bulgaria Romania
Cold climate *>3700 HDDs*	(G) Austria Denmark Finland Germany Sweden	(H) Estonia Latvia Lithuania Poland	

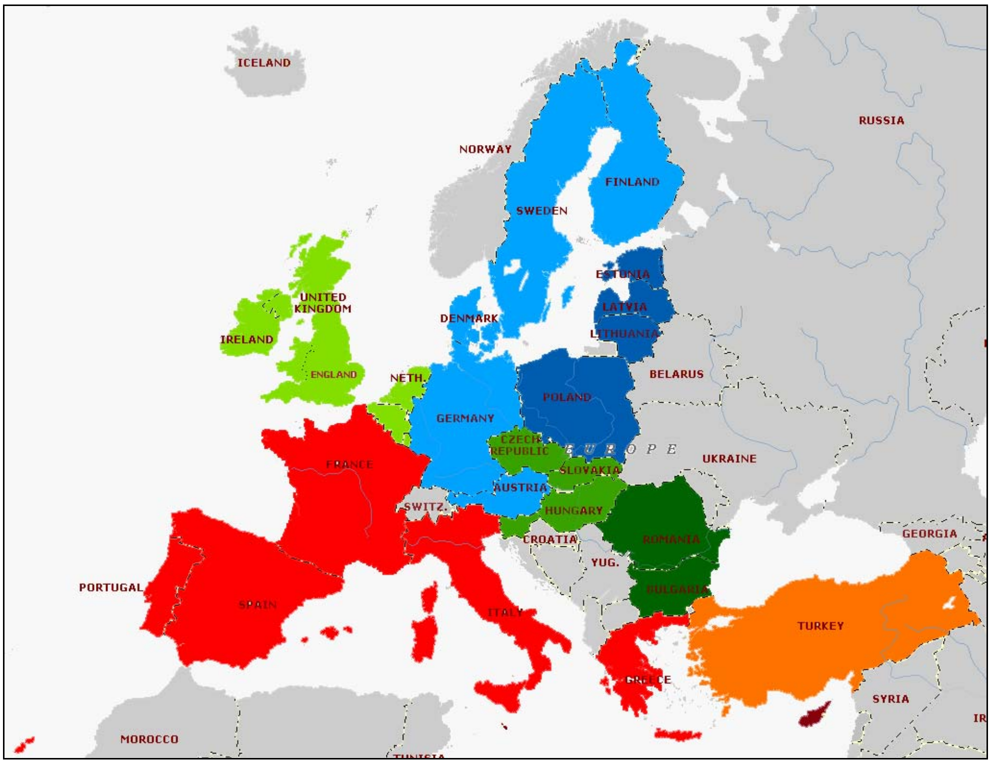

Figure 1: Base regions

Not all possible energy efficiency improvements were considered quantitatively. The quantitative modelling assessment incorporated wall, roof and floor insulation, window replacement, and improvements to the heating system – all in terms of their effect on reducing heating demand. Many other measures, including external solar shading and the effect of insulation on reducing cooling energy demand (potentially significant in reducing energy demand in hot, humid climates), passive solar design, ventilation strategies, the reduction of internal heat loads and lighting play an important role in reducing energy demand in high-rise buildings, but fell outside of the scope of the quantitative assessment examining the cost-effectiveness and amount of energy and CO_2 savings.

Assessing the situation – findings for individual base buildings

Using data from a variety of European projects[1] and based on commercial data from EuroACE members, it was possible to create eight representative (of those in need of refurbishment) high-rise buildings with construction and energy features typical for buildings in each group of countries. The main findings from modelling the chosen measures in these individual 'base buildings' are shown in Figure 2 through to Figure 5, covering a range of key indicators.

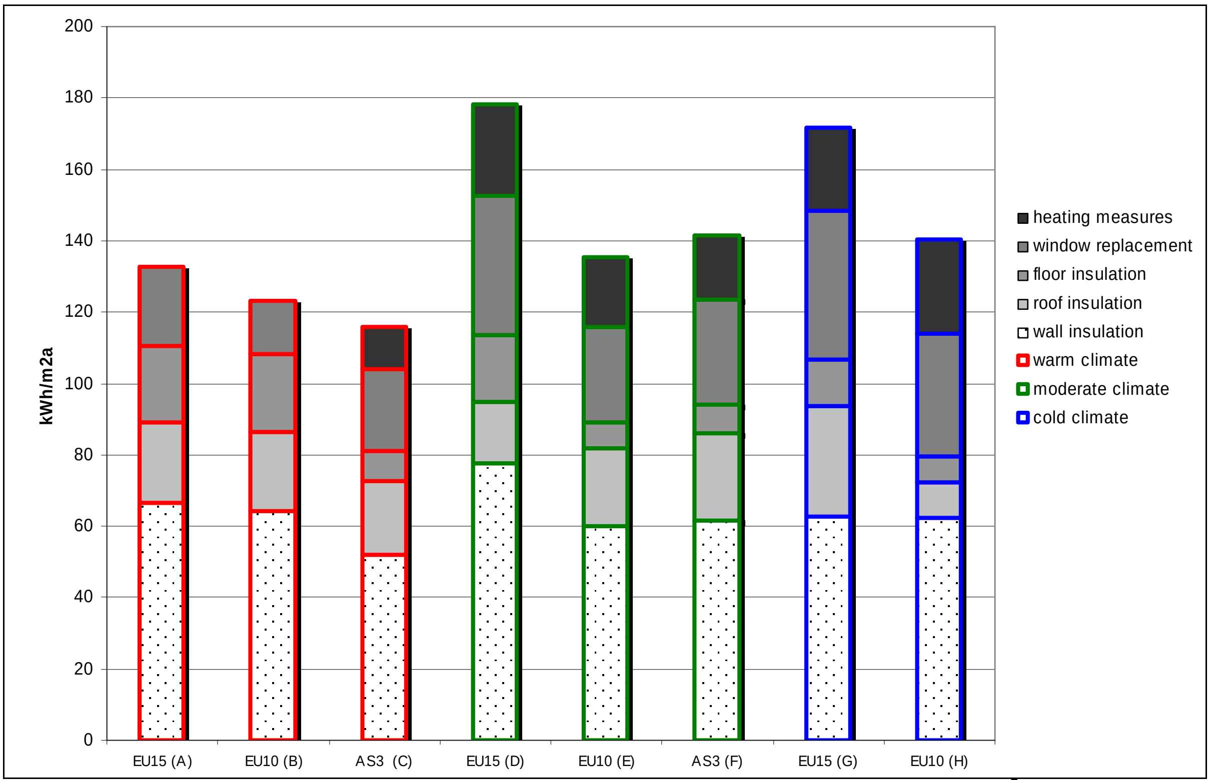

Figure 2: Reduction of heating demand – contribution of all modelled measures[2]

- Achievable energy savings are substantial, ranging from approximately 70% to 80% of heating demand.

[1] see [1], [4], [5], [6], [7] amongst others

[2] The stacks in each column, read from top to bottom, correspond to the top-down order of the measures in the legend.

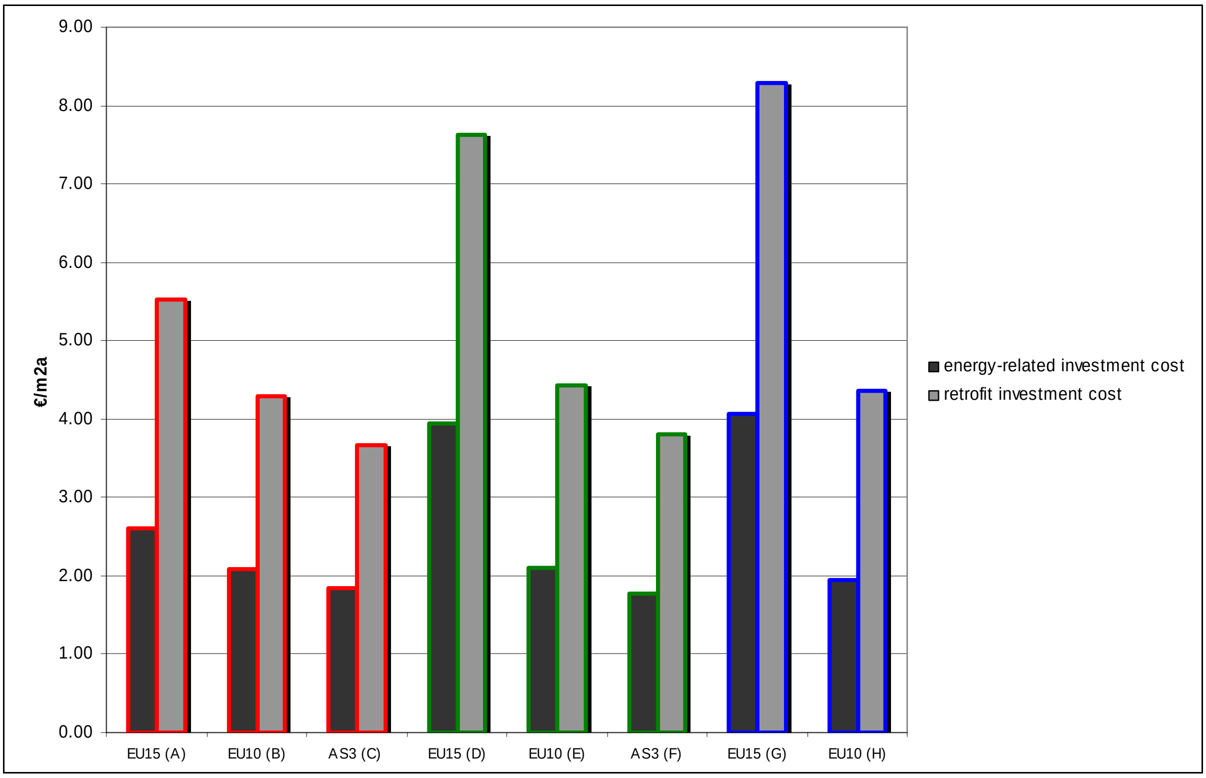

Figure 3: Energy-related and retrofit investment cost

- The energy-related investment cost – i.e. the additional cost of making refurbishment that needs to take place anyway as energy efficient as is reasonably practicable – is approximately half what it would cost to improve energy efficiency separately from general refurbishment (i.e. 'retrofit').
- The cost of energy efficiency investment is lowest in EU10 and AS3 countries, mainly due to lower labour costs.

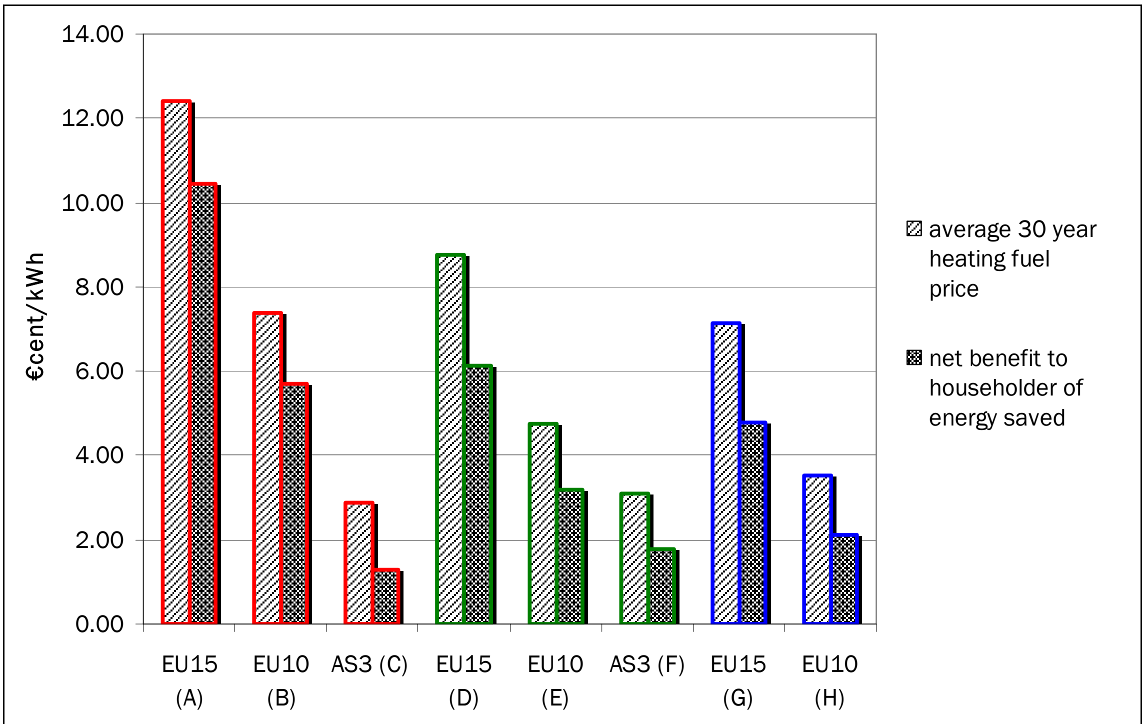

Figure 4: Energy prices and household benefit of energy saved[3]

[3] Energy prices taken from [8].

- Energy prices are (still) much higher in EU15 countries than in EU10 and AS3 countries.
- Taking reduced energy expenditure for households into account, there is a net benefit as a result of investment for all base buildings; the net benefits are highest in EU15 countries. Though net benefits in EU10 and AS3 countries are lower, as a proportion of households' disposable income, the benefit is often greater than for EU15 households.

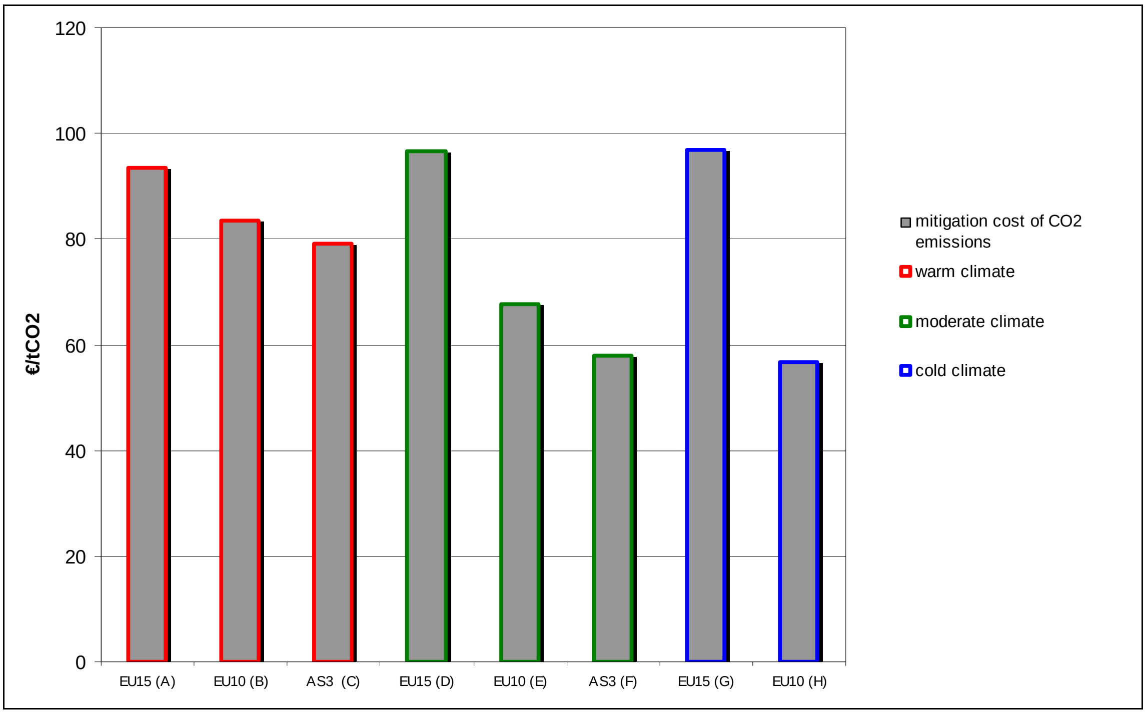

Figure 5: CO_2 mitigation cost

- Net CO_2 mitigation costs (i.e. after taking reduced household energy expenditure into account) are lowest in EU15 countries [2]; more importantly, from a policy-maker's perspective, gross CO_2 mitigation costs, illustrated in Figure 5 are lowest in EU10 and AS3 countries.

Assessing the situation – findings for the high-rise stock

With respect to overall CO_2 emissions there is scope for substantial reductions from the entire European high-rise building stock; this part of the assessment, unlike the results presented so far, is not based on the modelling of individual base buildings, but on a survey of European housing ministries about their stock [1]. Figure 6 illustrates the annual CO_2 savings possible from the high-rise stock according to the ministries surveyed, based on their estimates of energy saving potential.

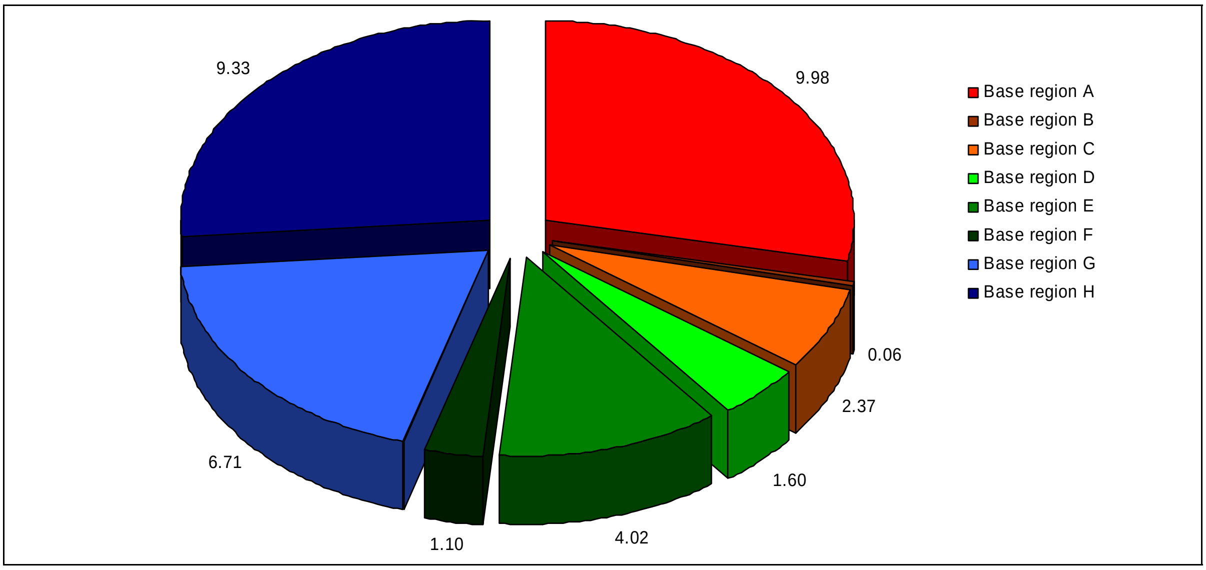

Figure 6: CO_2 savings potential according to national housing ministries [$MtCO_2$]

The highest energy saving potential is in Eastern Europe; 39% in base region E and 34% in base region H. Europe-wide, the energy saving potential is 28%, implying a reduction of Europe's total final energy demand of 1.5%, and a corresponding approximate emissions reduction of 35 $MtCO_2$. The lower stock-wide energy saving potential compared to the potential in individual base buildings (see Figure 2) is because each base building is assumed to be refurbishable with respect to every energy efficiency measure considered, an assumption that holds true for many buildings, but of course not across the whole of a country's or region's high-rise stock.

In addition to the financial payback and reduced CO_2 emissions, the less tangible benefits of improved energy security (in terms of avoided investment in energy generation and distribution, increased system reliability, resource conservation and enhanced energy price stability [2]), employment gains [2, 9] and improved residential comfort and wellbeing [2, 10] also need to be balanced against the required energy efficiency investment cost.

Six case studies, covering the various climatic and socio-economic regions and carried out as part of the research underlying this paper [2], highlight many practical approaches for appropriating the benefits outlined above, and carry a number of their own findings. For energy efficiency in the refurbishment of high-rise buildings overall, the mapping of an integrated policy approach begins below.

Mapping opportunities for and barriers to an integrated policy approach

Having identified that there are substantial benefits associated with improving the energy efficiency of high-rise residential buildings, in practice the realisation of the significant energy and emissions saving potential is faced with a number of institutional, economic, legal and social barriers, but also opportunities. A comprehensive assessment identified the following opportunities and barriers as significant, needing to be exploited or addressed collectively in order to develop an integrated policy approach.

Politically and institutionally,

The capacity to gain an accurate picture of the state of high-rise buildings, to administer financial instruments and ensure best practice is applied in the refurbishment of the high-rise stock is crucial. A number of important European projects, notably OPET Building [6], SUREURO, LOCOSOC and the project underlying this paper can contribute to filling gaps in knowledge and know-how.

Rapid privatisation and the much higher proportion of privately owned housing in EU10 and AS3 countries [2] poses specific (but not exclusively) institutional challenges to refurbishment, requiring new approaches and partnerships. Public-private partnership approaches to refurbishment could hold much promise, though experience is thin on the ground.

Financially and economically,

Energy prices are a key determinant of the attractiveness of energy efficiency investment. With the lowest European prices likely to rise more rapidly than others, the incentive to save energy should

strengthen and the target groups of new and existing financial instruments to promote energy efficiency in high-rise buildings would become more receptive to them. In this context, there is an important opportunity in the extensive European body of knowledge surrounding the design and implementation of effective financial instruments.
Flat-rate tariffs associated with district heating provision in EU10 and AS3 countries in particular, so common in the high-rise stock, pose a significant barrier in that they do not create any incentive on the part of the householder to save energy and thus undermine the effectiveness of financial instruments. In these cases, incentivising district heating suppliers to save their customers' energy by providing a full energy service or third-party financing agreements may supply another means by which to improve high-rise energy efficiency.
Financial incentives designed to link to the Energy Performance of Buildings Directive's (EPBD) certification requirements – and to the Energy End-use Efficiency and Energy Services Directive (ESD) – present a powerful opportunity to strengthen the case for incorporating energy efficiency improvement into refurbishment.
The effect of the economic cycle and interest rates on housing expenditure and competing priorities for investment [11] – in particular for public funds – serve to highlight the fact that most investment in high-rise buildings is needed where the least is forthcoming, mainly in EU10 and AS3 countries [1], as illustrated in Figure 7.

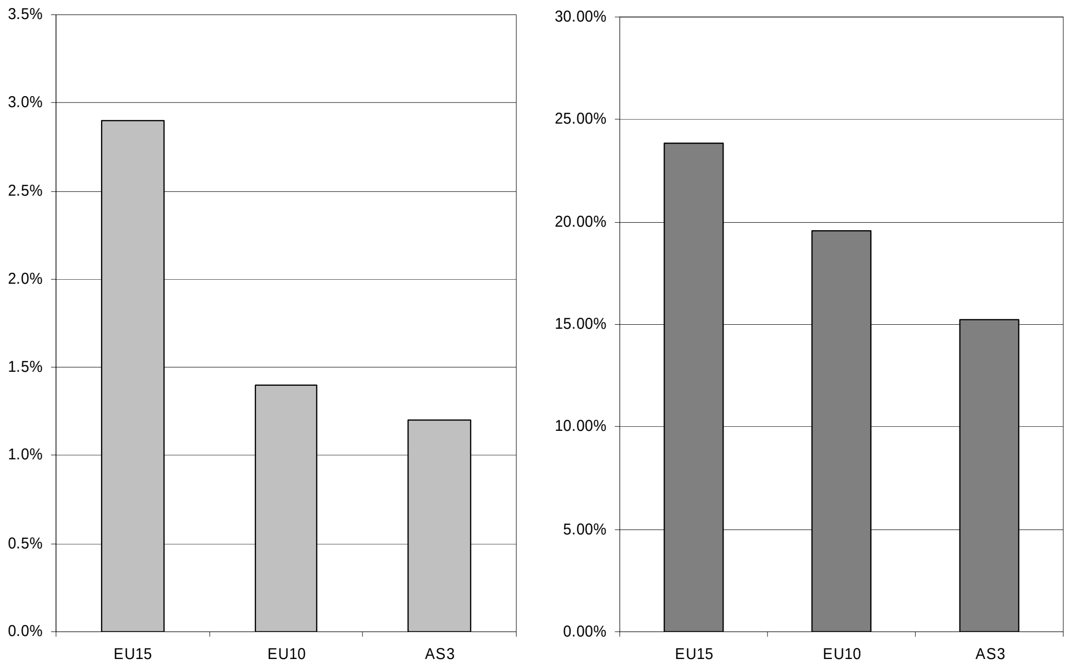

Figure 7: Percentage of state budget and percentage of household budget spent on housing

Legally,
The EPBD's transposition into Member States' legislation offers a central legal opportunity to drive the improvement of high-rise energy efficiency as part of the refurbishment cycle. The Directive stipulates that whenever a building with a total useful floor area of over $1000m^2$ undergoes major renovation, its energy performance must be upgraded to meet minimum requirements. This fits the profile of high-rise buildings and matches the argument for integration of energy efficiency into refurbishment: the chance must be taken to ensure the transposition of the Directive interprets it this way.
The ESD addresses a wide range of barriers, including the removal of competing incentives in the interests of saving energy, the creation of a market for energy services and the requirement to introduce individual metering and billing for each end-user. Potential synergies with the EPBD exist, and the opportunities these present must be investigated further.
Widespread inadequate legislation or procedures governing the collective ownership of, and decision-making about high-rise buildings or estates pose a significant barrier to implementing energy efficient refurbishments [2]. Effective laws or codes of conduct are essential. Figure 8 [2, 1] shows the inadequate coverage of rules governing occupants' decisions about high-rise buildings in EU10 and AS3 countries.

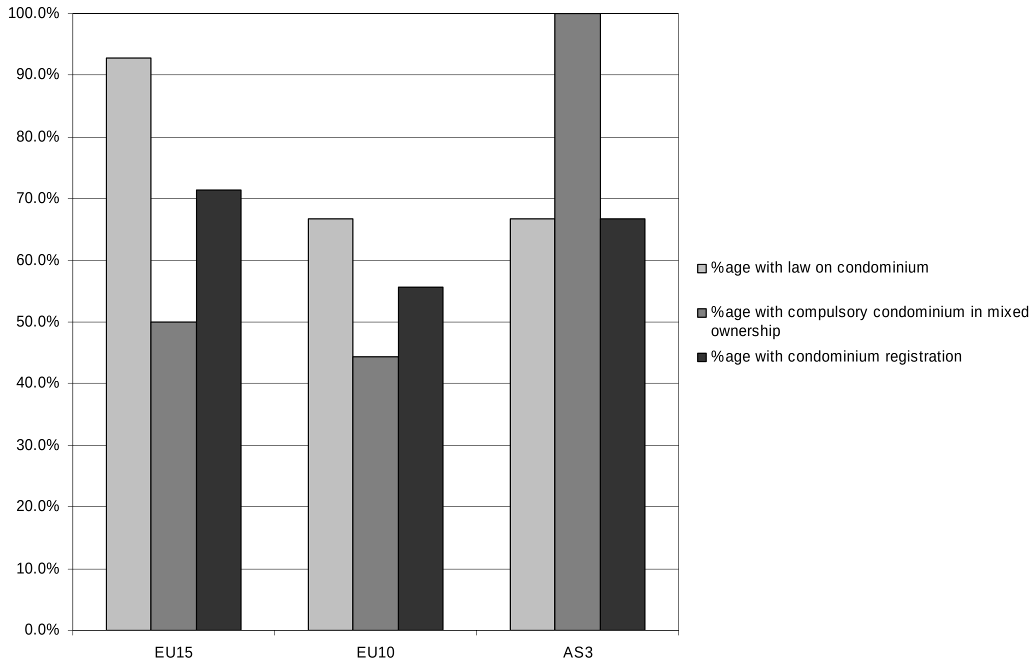

Figure 8: Prevalence of condominium law in high-rise buildings

Socially,
Marketing and energy advice appropriate to the energy use culture and tailored to the individual to ensure energy efficient systems are used effectively is an essential opportunity to be taken with any refurbishment, in particular to counter the barrier of entrenched energy use practices, such as opening windows and/or using secondary heating systems in response to the widespread problem in high-rise buildings of over- and/or under-heating.
The potentially collective nature of living in high-rise buildings should be harnessed to get residents to support each others' energy-saving behaviour, especially in lieu of the requirements for individual metering and billing.
Employing tried and tested methods of holistic stakeholder involvement with both pre-refurbishment consultation and post-refurbishment evaluation of stakeholders' views, helps strengthen communities, helps eliminate potential problems before they arise and contributes to the body of good energy efficient refurbishment experiences [2], in turn helping to improve the often negative perception of high-rise living [12].

Moving towards an integrated policy for high-rise buildings

In recognition of the cost-effective and very substantial CO_2 emissions reductions that can be achieved, especially in EU10 and AS3 countries but also in EU15 countries with the existing pattern of energy prices, it is proposed – on the basis of the mapping of the significant opportunities and barriers surrounding high-rise residential buildings – that policy makers:

- Recognise the inherent market failures and barriers to energy efficiency refurbishment that apply in the building sector as a whole, but most acutely in multi-tenanted residences, and devise and implement policies to remedy them.
- Incorporate energy efficiency improvement as a legal requirement whenever refurbishment is undertaken in high-rise buildings to maximise the cost-effectiveness of investment, in line with the spirit of the Energy Performance of Buildings Directive.
- Close gaps in building or estate level condominium legislation and collective decision-making rules to facilitate refurbishment.
- Prepare for energy market liberalisation, in particular in EU10 and AS3 countries, and ensure that individual metering and billing replaces the existing energy consumption infrastructure, in line with the spirit of the Energy End-Use Efficiency and Energy Services Directive.

- Consider implementation of framework energy efficiency delivery mechanisms – such as the UK Energy Efficiency Commitment or the Italian and French white certificate schemes – that could be used, amongst other purposes, to fund energy-efficient refurbishment activities.
- Facilitate and support the creation of new European funds to accelerate sustainable, energy efficient refurbishment – especially for EU10 and AS3 countries where it is most needed, and because no structural funds for housing or energy demand management exist as yet. Moreover, on a national level, consider:
    - Adopting Danish-style requirements for condominium dwellers to contribute a small monthly payment to a refurbishment fund;
    - Introducing fiscal incentives for refurbishment such as tax-deductions for refurbishments that improve the overall energy performance of the building or lower rates of tax on the rental income of landlords that improve the energy performance of their rental stock;
    - Developing specific additional funds and obligations for energy-efficient refurbishment in the case where high-rise residences are publicly owned.
- Link all of the above actions to the implementation of the Energy Performance of Buildings and Energy End-use Efficiency and Energy Services Directives, to exploit as well as inform the legal and institutional infrastructure being put into place to support the them.

Taking the opportunities and overcoming the barriers outlined in this paper will require work to synchronise the objectives of various government departments and other authorities involved in the delivery of sustainable housing and energy. To this end there is a need to employ consistent methodologies across government to quantify the wider benefits of energy efficiency improvement and to commission further research to identify the most innovative forms of financing.

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A Least Cost Strategy for Increasing Energy Efficiency in Residential Sub-Sector of Developing Countries

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Abstract
From the macro-economy point of view, it is essential to give a response to the question of which energy efficiency approach in the residential sub-sector should be given priority and with what timetable for implementation? The objective of this paper is to propose a long term least cost plan as a response to this question for developing countries. The Iranian residential sub-sector is selected as a sample energy flow network to verify the proposed approach. This network contains all energy consuming appliances and parts. Energy Flow Optimization Model is used to minimize the total discounted cost of the proposed energy network. With due attention to the current prices of energy, using the lowest grade evaporative coolers will be economical for the consumers in the arid regions of the country. Whereas if the energy to be priced on the basis of the imposed costs on the national economy, only using evaporative cooler in the highest energy grade will be selected. The shell insulation of the building diminishes the thermal loss. It reduces the heating and cooling demands. This will reduce the capacity of the cooling and heating equipments and required investment costs, as an interesting result of the study. The paper looks at the introduction of compact fluorescent lamps (CFLs) for lighting. If any limitation to be applied in using CFL lamps, then it is recommended to use fluorescent lamps. The proposed plan results in 27%, 54% and 10% saving in energy consumption, energy cost and investment cost, respectively.

1. Introduction

In the developing countries, rapid growth of the energy systems must be treated within a wider context. On the one hand, it must be coordinated with the growth of other sectors of the economy in a more explicit manner. On the other hand, it must be viewed within the framework of a longer term evolution of the energy system. Recent experiences in some developing countries have shown that an energy model called Energy Flow Optimization Model (EFOM) can be a useful tool for purposes of sectoral analysis and planning within the framework of the overall energy system [1]. EFOM was developed in mid-seventies for the needs of the overall energy systems analysis activities of the European Commission by SYSTEMS-EUROPE (SE). It consists of a database management system (DAMOCLES), a simulation model (SIMUL), and an optimization model involving a matrix generator "ORESTE", a linear programming code, and a report generator "ORACLE").

Because of its wider view of the energy system the EFOM methodology deals with a more aggregated representation of the energy system planning than what is classically used in this area. In fact EFOM can be used in two following modes for energy system planning:

- The Single-Sectoral (SS) mode, in which it is used to provide a quick and rough plan and define overall directions of action and policies for the energy sector.
- The Multi-Sectoral (MS) mode, in which it is used to provide boundary conditions and consistent exogenous data for the conventional energy system planning tools.

Usually these sorts of models are a mapping of the whole energy conversion chain and possible future options for energy supply and emission reduction into a network of energy flows. They use the minimization of the total discounted costs as the goal function under the restriction of maximum allowed emissions and technical conditions. EFOM has been developed for purposes of techno-economic analysis of the overall energy system, and has been applied to different European, Asian and American countries in this context. This paper is not intended to present the EFOM methodology in its detail. Only a brief introduction is provided. The interested reader is referred to consult the reference [1]. The paper will present an example application of EFOM in what was referred to as the single sectoral mode above.

Application of EFOM for sectoral analysis and planning within the overall energy system framework was used for the first time in Iran in the context of a 1-year project (2004-2005) [2]. Iran is one of the world’s biggest oil producing countries with a 9% share of the world oil deposits (90 billion barrels). In recent years, domestic energy consumption in the country has been growing rapidly and reached about 44% of the total energy production. If this trend continues, It is predicted that Iran would become an energy importing country by 2018. Approximately 75% of Iran's foreign currency earning depends on the petroleum products. It is, therefore, an important issue to secure oil export through establishing efficient energy utilization. In order to solve the problems, the government, as stated in the 3rd five-year national development plan (2000-2004), is preparing to execute the following countermeasures:

- Reduction of energy pricing subsidies to better reflect actual costs
- Public awareness activities on energy conservation and management
- Implementation of demonstration projects for energy efficiency
- Financial assistance to energy efficiency projects
- Enhancement of legal systems relevant to energy management

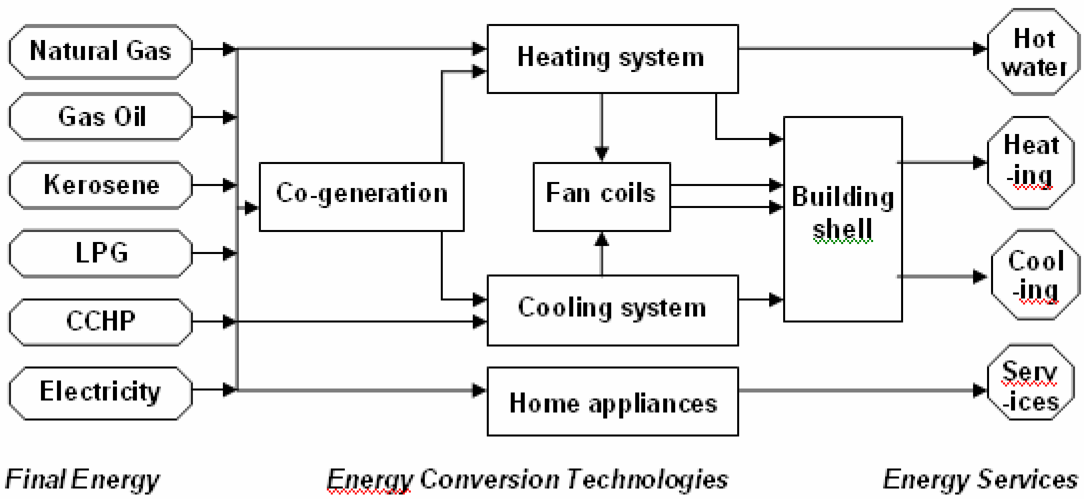

Figure 1: Residential sub-sector break down into different sub-systems

The residential sub-sector in Iran enjoys a broad potential in energy management. However it is not so easy to achieve those objectives since it demands a wide range of measures and major initial investments as well. The key question is: "Which group of approaches should be given priority and what is the timetable for their implementation?" To respond to this question, the overall energy system framework is proposed in part 2. Technical and economical specifications of the building shell have been presented in part 3 of the paper. In part 4, the paper makes a demand estimation of useful energy and energy services required in the residential sub-sector for a 25-year period. The 5th part presents the results of the proposed energy efficiency plan. Finally a conclusion is provided in the last part of the paper.

2. The overall energy system framework

A combined analysis of major final energy carriers supplied to residential sub-sector and energy conversion technologies can provide a common framework for coordination of sectoral planning activities. A methodology suitable for this purpose is based on representation of energy flow within and among the parts. Starting from final energy delivered to residential sub-sector, the path of energy flow is schematically represented as it passes through the main processes of heating, air conditioning, co-generation, shell loses and home appliances services. This is normally represented by a unidirectional network graph. Each link in the graph represents a "process" in a general sense (e.g. refrigeration, air conditioning, heating, illumination, etc.). Flow of energy through each process (i.e. each link of the graph) entails costs (investment as well as operations cost), losses, environmental effects, manpower, equipment, etc. These are all expressed as per unit of process output or process capacity as relevant. These per unit data are in fact describing parameters for each typical process. Collectively, they make up the main part of the data base needed for overall energy system analysis and planning. The "nodes" of the graph simply represent the connection among the processes, and carry no process information. Energy flowing into a node from its upstream processes leaves it through its downstream links; the net flow at each node is thus zero. To facilitate representation of the overall energy system the energy system graph is broken down into sub-graphs, each representing a so-called "sub-system".

Figure 1 shows a possible breakdown of the residential energy flow network into different parts. More details about this network can be find in reference [2] reported this study in detail. In addition to the process data, scenario oriented data are also considered in the study. These concern mainly scenarios related to the energy prices. One of the parameters in which influences the results of the energy network optimization is the efficiency of energy consuming means and equipments. Since the output of most of these equipments is usually of the type of services and can not be expressed in terms of energy units, consequently it is not possible to determine the efficiency in regular way. To develop the energy labelling standards for these equipments, the energy performance index over one unit of energy services is defined. Accordingly, the equipments in different ranks are compared with each other on the basis of this index [3, 4, 5, 6, 7, 8, 9, 10, 11].

In the lighting systems, theoretically, each Watt is equal to 680 Lumen upon which the efficiency of the lamps can be evaluated from the relationship $\eta_{lamp} = Lm/W/680$. Thus, in the lamps, the real efficiency is used instead of using the agreed concept of relative efficiency.

The time horizon of the study was chosen to be 2004-2029. The study sub-periods are (2004-2009, 2009-2014, 2014-2019, 2019-2029). It is worth mentioning that in energy modelling; logically the investment cost is measured in comparison with the output energy capacity of an equipment or process. It is less determined in terms of the capacity of input energy flow. On this basis, the capacity of annual energy consumption of the equipment has been multiplied by its energy consumption efficiency to determine the capacity of output energy. The technical and economical specification of the modelled equipments in accordance with the data of the references [3, 4, 5, 6, 7, 8, 9, 10, 11] is provided to this study.

3. Walls, floors, ceilings and windows data

The average quantities of the thermal loss in the present situation of the country's buildings are: walls 35%, floors 7.5%, ceilings 7.5% and windows 50%, respectively [2]. In order to calculate the shell investment cost, the following assumptions are considered.

The thermal loss of the walls during summer is 7% less than that of the winter [12]. In this study, the model of thermal losses has been supposed as to be the same in all seasons of a year. The calculations have been made on the basis of a model building having an area of 75 square meters, area of walls: 125 square meters, the area of windows as of 10 square meters, the area of floor and the ceiling, as 75 square meters. The cost of constructing the insulated walls has been considered 1.3 times of the non-insulated ones and the costs of insulating the already-built walls have been considered that of 40% of the cost of the non-insulated walls. The cost of making the double-glazed windows has been considered 1.5 times of those of single-glazed windows and the cost of doubling the layers of the single-glazed windows has been considered 50% of the cost of those of single-glazed windows. The cost of insulated floor and ceiling is 1.5 times of that of the type without insulation and the cost of insulating the already-built floor and ceiling is 40% of the cost of the type without insulation. The shell investment cost per energy flow capacity in the building in terms of monetary unit on ton oil equivalent in a year (TOY) is calculated from the relationship $C/Q.A * 8760 * 93{,}47 * 10^{-15}$ in which C is the actual cost in terms of monetary unit, Q is the thermal load of the shell in terms of kilo calorie per hour and A is the share of the heat transfer for the shell in terms of percentage.

4. Useful energy consumption of residential sub-sector

In this part, the exogenous variables of the heating load, cooling load and the demand of home appliances services are estimated. *Useful energy* is the energy form that is really demanded by the consumer for heat, light or mechanical motion. The amount of useful energy delivered from a given amount of final energy, that is available to the consumer, depends on the efficiency of the end-use technology. Useful energy reaches the consumer by providing some type of energy service. Energy services include, for example, thermal comfort, illumination, food refrigeration and cooking. While we generally discuss energy end-use efficiency with regard to the conversion from final to useful energy, it is actually the quantity and quality of energy services that determine whether the consumers' needs are met. For example, a relatively efficient air conditioner can reduce the electricity demand of an office building, but a well-designed building could provide the same energy service of thermal comfort with no air-conditioning at all [13].

To procure the comfortable conditions, there is a demand for each person to have a 0.708 cubic metre of fresh air in a minute with the humidity of 50% and temperature of 26 Celsius in summer and that of 18 Celsius in winter [12, 14 and 15]. This can be provided by ventilation and infiltration of outside air into the building that must be included as part of the heat load. The formula to be used is:

$$Q_{air} = 20.12 \times CMM \times (T_{out} - T_{in}) P_o / P_A \qquad (1)$$

in which, Q_{air} is the ventilation and infiltration heat load in terms of joule per second, CMM is the outside air that enters or brought in through the building in terms of cubic meters per minute, T_{out} is the outside temperature and T_{in} is the inside comfort temperature of the room in terms of Celsius, P_o is the barometer pressure of the place and P_A is the standard pressure in terms of bar. The heat load of hot water consumption is obtained from relationship (2).

$$Q_{hotwater} = 5.8 \times CMD \times (T_{needed} - T_{incoming}) \qquad (2)$$

in which, $Q_{hotwater}$ is the hot water heat load in terms of joule per second, T_{needed} is the needed water temperature and $T_{incoming}$ is the incoming water temperature of the building in terms of Celsius and CMD is the rate of needed hot water in terms of cubic meter per day. The standard average demand of hot water for each person per day is 0.075 cubic meters daily [14]. The total heat load resulting from the hot water and the air ventilation and infiltration have been calculated with regard to the existing population in different regions and climate conditions of the country [16].

In order to estimate the energy services demand for home appliances during the years of the plan, the relationship (3) is suggested:

$$D_n = \sum_{i=A}^{LastGrade} No_i . ECapa_i . AUF_i . \eta_{relativei} . (1 + IR)^n \qquad (3)$$

in which, No is the number of the energy consuming equipments being used in the base year, ECapa is the capacity of energy consuming equipments in terms of energy units in a year, AUF is the annual utilization factor in terms of percentage, $\eta_{relative}$ is the relative efficiency of the equipment as explained in part 2 in terms of percentage, IR is the annual increase rate of the number of equipments in terms of percentage, n is the year under consideration in comparison with the base year, i=A, B,...., LastGrade is the energy labelling grade of the equipment and D_n is the total demand for the service of equipments in year n in terms of energy unit. Concerning the real definition of the efficiency for lighting, this definition has been used instead of relative efficiency. Thus, the estimated lighting demand not only procures the modelling needs, but also has a physical concept by itself.

5. The proposed plan

After determining the system framework and providing the necessary technical and economic specifications and exogenous demand forecasting in previous parts of the paper, the energy flow plan in the sub-sector is optimized with the help of Energy Flow Optimization Model (EFOM). The objective of the optimization is to minimize the total cost of residential sub-sector while respecting some technical and environmental constraints including energy flow, capacity and environmental pollution bounds, exhaustible reserves and exogenously generated constraints. Interested reader may refer to the reference [1] for more details

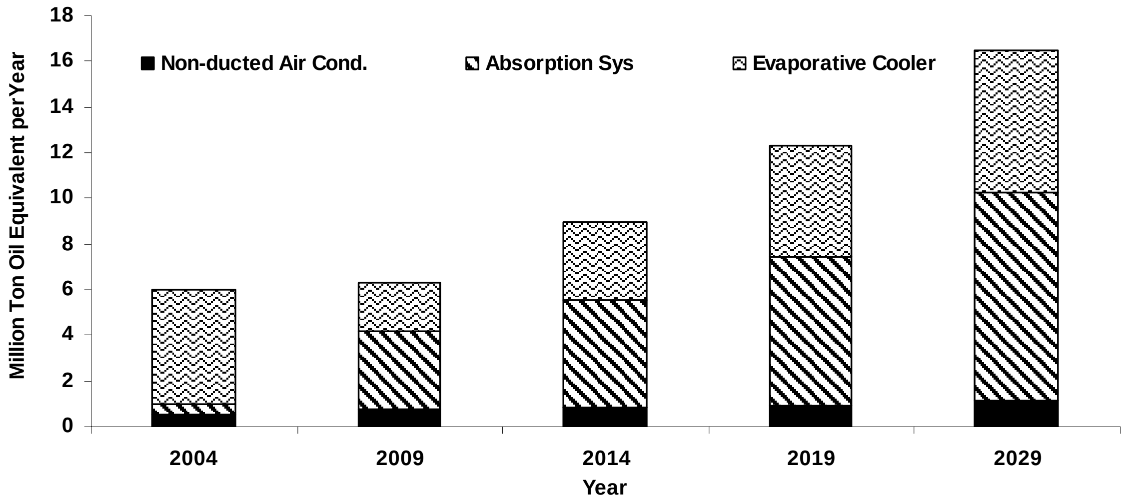

Figure 2: Required cooling system capacities during planning period in whole country

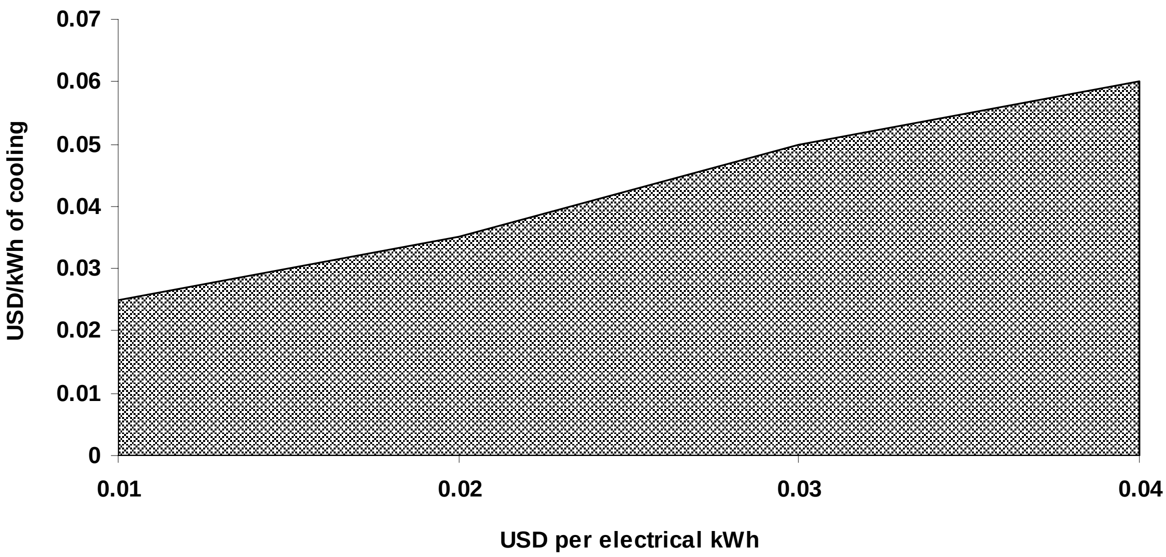

Figure 3: Economically feasible region for CCHP cooling compared with electric compression cooling systems

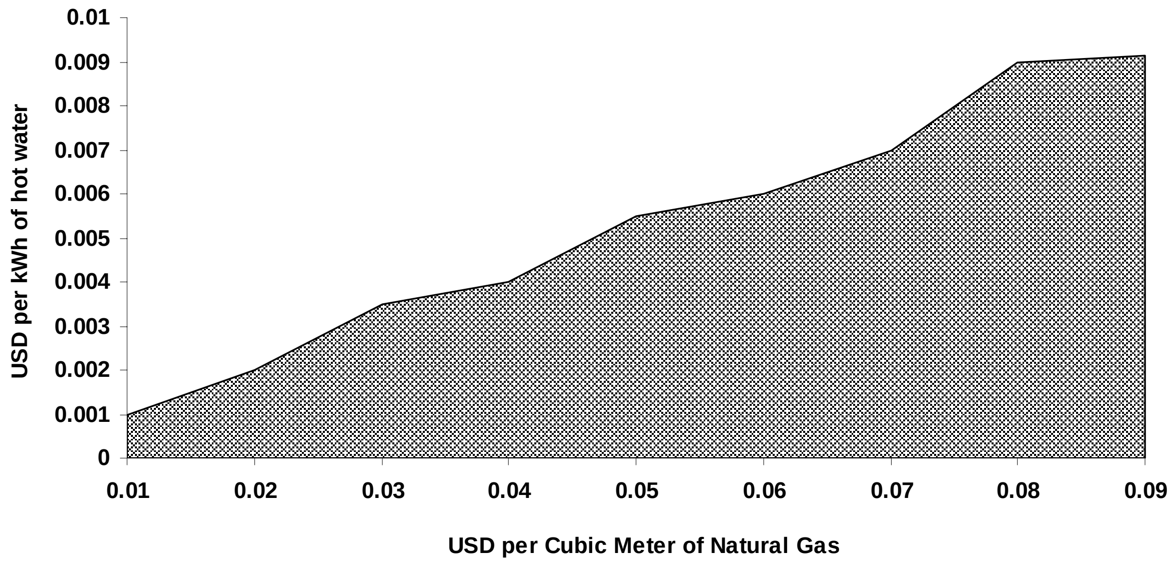

Figure 4: Economically feasible region for CHP heating compared with gas fired heating system

Continuing, the resulting plan and its impacts are reviewed for the period 2004-2029. The figures for 2004 show the present situation of the sub-sector. The least cost plan recommends using the gas-fired heating systems to supply the building heating demand in the regions where natural gas network is available. The central heating system has more chance among others.

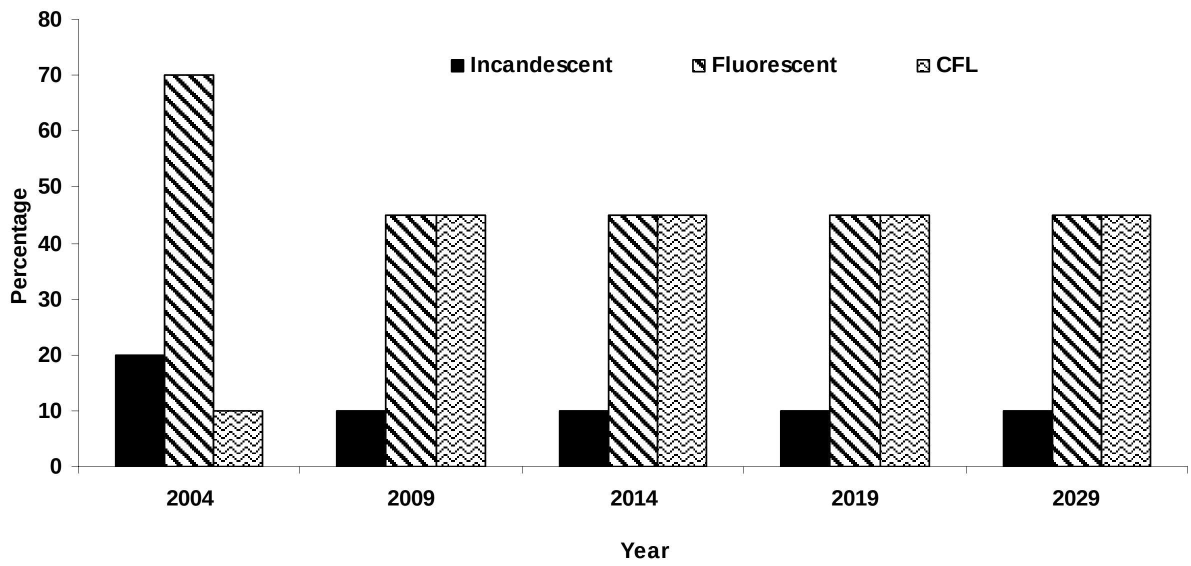

Figure 5: The shares of selected lighting systems in the proposed plan

The main reason to use central heating system is its concurrency with the absorptive cooling system that according to Figure 2, it has been broadly selected for the cooling system. In the event of the lack of using the central heating systems, then using gas instant heater and wall-mounted gas instant water heater have been selected to supply heating and hot water. For those areas where there is no gas service, the best option for heating is to use the gas oil central heating system.

Fig. 3 shows the economically feasible region of supplying cooling from the combined cooling, heating and power (CCHP) systems in comparison with other cooling alternatives in lieu of different prices of electricity. In the above sensitivity analysis, the price of natural gas has been considered as equal to USD 0.06 per cubic meter which is conservative assumption for the Iranian context. As it is observed,

for the actual selling price of the electricity in the country, i.e. USD 0.025 per kWh, the economic break even point of the CCHP cooling is USD 0.04 per kWh of cooling. When it is compared with other methods of cooling supply, it proves itself as an economic method. If we consider the current selling price of the electricity sale to the residential sub-sector, i.e. USD 0.0125 per kWh, then the economic break even point of CCHP cooling is equal to USD 0.025 per kWh of cooling. It is clear that this pricing regulates the behaviour of the consumers inconsistent with the national interest of the country. The economic region of hot water and heating of the CCHP system against the gas price is presented in Fig. 4. The economic break even point in lieu of the present price of the gas sale to the residential sub-sector, i.e. USD 0.01 per cubic meter is USD 0.001 per kWh of heating. From the national viewpoint, in which the actual supply cost of the gas is assumed as to be about USD 0.025 per cubic meter, the economic break even point for hot water and heating of the CCHP system is equal to USD 0.00215 per kWh of that of thermal. It is worth mentioning that the actual cost of the heating of these systems is estimated less than USD 0.0012 per kWh of the thermal [2].
According to the results of Fig. 5 in order to provide the residential lighting, the compact fluorescent lamps (CFLs) have been selected. If any limitation to be applied in using CFL lamps, then it is recommended to use fluorescent lamps. It goes without saying that in some applications, it is inevitable to use incandescent lamp. The sensitivity analysis shows that even reducing the cost of electricity by one third, using the CFL lamps is still of priority.

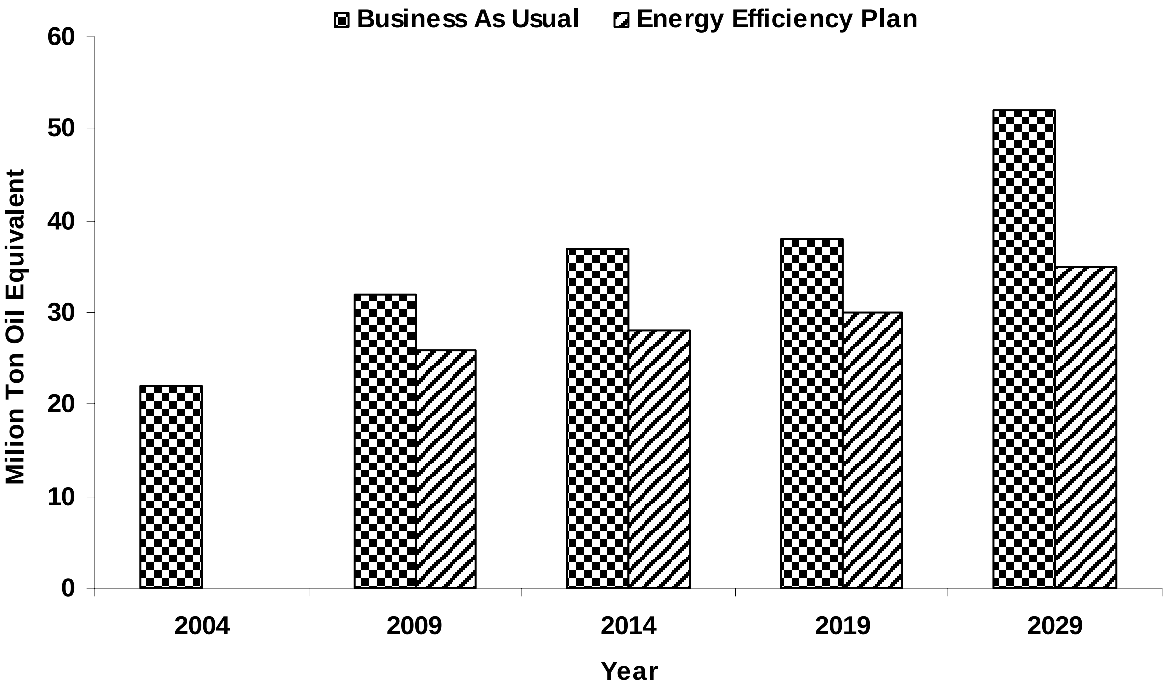

Figure 6: Total required energy for heating and cooling

The reduction in energy consumption as a result of the proposed plan is presented in Fig. 6. The main part of this reduction is related to the insulation of the buildings shell which reduces the loss by about 50%.
On the basis of the optimization results, with due attention to the current prices of energy sale, using the lowest grade evaporative coolers will be economical for the consumers in the arid regions of the country. Whereas if the energy to be priced on the basis of the imposed costs on the national economy, only using evaporative cooler in grade A will be selected.

6. Conclusions

In this study, the energy flow needed for energy services in the residential sub-sector is optimized with the help of Energy Flow Optimization Model to propose a long term energy efficiency plan. The main achievements for the Iranian context as an example of developing countries are as following:
Using gas-fired absorption system is of first priority in cooling while evaporative coolers in grades A and B are suitable in dry climate. Gas-fired system is the best option for space heating and provision

of hot water. Using the central heating is a better selection due to concurrency with gas fired absorption chillers. Gas instant heater and wall-mounted instant water heater are the following priorities. The insulation of the shell and making double-glazed windows in the existing buildings and those under construction, even by doubling its expenses are the priorities. Observing the highest grades of the energy labelling standard of equipments and using compact and non-compact fluorescent lamps for the lighting of the building have economic priority.

Acknowledgments

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Energy Saving Potential and Environmental Impacts of Televisions Using Energy-Efficient Power Supplies

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Abstract

This paper analyzes the standby power consumption of household televisions (TVs) and considers the new technologies available for switching-mode power supplies (SMPS). Semiconductor companies have introduced new, energy-efficient semiconductors, which have matured to the point of being currently available for SMPS applications. Further, these companies claim that 25% of total energy consumption is now consumed in the low power/sleep/standby modes.
This analysis estimates the annual reduction in energy consumption and the CO_2 conservation accruing from the reductions in natural gas power plant emissions that will result from the use of more energy-efficient TVs. It takes into account information about production, energy consumption, lifetime, and market share of TVs (assuming annual Brazilian sales of 20-inch TVs of 2,251,080 units in 2004 as estimated in a recent Brazilian government essay).
Results indicate that at least one television is found in 87.7% of Brazilian homes. Throughout the country, household TVs consume 7.2 to 10.9 terawatt-hours (TWh) of electricity per year, or about 10–15% of Brazil's residential electricity consumption. The overall consumption in 2002 was 72.7 TWh.
This paper uses the Energy Star and Ecolabel standby criteria for reference, since regulations for establishment of *standby* power standards have not yet been passed by the Brazilian Congress.

I. Introduction

In 2001, the Brazilian law 10.295/2001 set the principles for the "National Energy Conservation Policy and Rational Use of Energy"[1]. As long as this law is in place, all electric equipment commercialized in the country will be required to comply with Brazil's energy efficiency regulations. Energy standards are promoted around the world through well-known ecolabeling and energy efficiency programs, such as Energy Star in the USA, the Ecolabel in Europe, and the Top Runner in Japan. In Brazil, the Procel labeling program has been continuously updated and revised following the worldwide trends. However, only recently, the Brazilian Congress decided to use the labeling program to establish *standby* power standards [2]. Since the Brazilian standards had not yet been established at the time of this research, this paper uses the North American and European standards for reference purposes.
The main intent of this work is to assess the television (TV) sets available in the Brazilian market, based on the Energy Star and Ecolabel standards, which are the *standby* power criteria in the USA and Europe, shown in Table 1.
Additionally, semiconductor companies have introduced technological improvements with impacts on energy efficiency. Some new semiconductor devices have matured to the point of being currently available for switching-mode power supply (SMPS) applications, which can increase the energy efficiency of TV sets. Finally, this paper summarizes the economic and environmental impacts of cost-effective improvements in TVs, based on the reductions in energy consumption and CO_2. It takes into account information about production, energy consumption, lifetime, and market share.
In July 2005, Energy Star program celebrated the achievement of its first goal, i.e., the establishment of a 1-watt (1W) standby limit for TVs. As seen in Table 1, beginning in March 2005, advances in standby regulations in the European Community may yield even more strict limits on standby losses.
Electronic improvements, however, may necessitate changes in the standby consumption regulations. In fact, the current standby definition may become inconsistent (see table note "a") as a result of the establishment of new operating modes, such as "sleep" and "deep sleep." A worldwide agreement for household appliances operating on standby mode has been discussed on numerous occasions; a low

power mode (LOPOMO) designation, which is under discussion, is outlined on the standby power home page of Lawrence Berkeley National Laboratory [6].

Table 1: Energy-Efficiency Specifications for Qualified TVs

Product	**ENERGY STAR (USA)[4]** (standby mode[a])			**ECOLABEL(Europe) [5]**
	Phase I (effective 7/1/02)	Phase II (effective 7/1/04)	Phase III (effective 7/1/05)	Effective from 1 April 2002 until 31 March 2005.
TV	≤ 3W	≤ 1W (analog) and ≤ 3W (digital)	≤ 1W	< 1W (for passive *standby* consumption[b] and < 9W (for active *standby* consumption[c] of the televisions which have an integrated digital receiver/decoder)

[a] Standby power is defined as the power being used when the product is connected to a power source, produces neither sound nor picture, does not transmit nor receive program information and/or data (excluding data transmitted to change the unit's condition from "standby mode" to "active mode"), and is waiting to be switched to "on" (active/play mode) by a direct or indirect signal from the consumer, e.g., with the remote control [1].
[b] Passive standby – the television is connected to a power source, produces neither sound nor picture, and is waiting to be switched into an "off", "active standby," or "on" mode, on receipt of a direct or indirect signal, e.g. from the remote control [2].
[c] Active standby – the TV is connected to a power source, produces neither sound nor vision, and is exchanging/receiving data with/from an external source [2]

II. Test Criteria

The specifications that products must meet to get an energy-efficiency endorsement in different regions depend on the local electrical distribution system and other circumstances. For Energy Star labeling, only the consumption in the standby mode is considered, whereas the European Ecolabel regulations also take into account the consumption in "on mode."[1].
Energy Star specifies general criteria for voltage and total harmonic distortion (THD) lower than 3% and ambient temperature in the range of 22°C ± 4°C. The nominal voltage is a market-specific criterion; the recommended values are listed in Table 2.

Table 2: Market-Specific Criteria for Energy Star

Market:	**United States**	**Europe and Australia**	**Japan**
Voltage	115 VRMS ± 3 VRMS	230 VRMS ± 10 VRMS	100 VRMS ± 5 VRMS & 200 VRMS ± 10 VRMS
Frequency	60 Hz ± 3 Hz	50 Hz ± 3 Hz	50 Hz ± 3 Hz & 60 Hz ± 3 Hz

Ecolabel regulations use the technical standard EN 50301 [7] to measure power consumption of appliances and equipment during normal operation ("on mode"). In addition, Working Group 9 of the International Electrotechnical Commission (IEC) Technical Committee TC59 prepared the international standard IEC 62301, i.e. "Household Electrical Appliances – Measurement of Standby Power"[8].
Progressively more energy-efficient standby power devices have been offered by semiconductor manufacturers since the Energy Star, Blue Angel, and Top Runner programs released their energy efficiency specifications for power supplies used in consumer electronics products. To highlight these manufacturers' efforts, the following section discusses the energy losses in a very common topology for SMPS.

III. Reduction of standby losses in Switching-Mode Power Supply

Semiconductor manufacturers claim that 25% of total energy is consumed in low power/sleep/standby mode and around 75% of average total energy consumption is in active mode. Further, in active mode, changing semiconductor efficiency from 60% to 75% can result in 15% energy savings [13].
Consequently, much analysis is being done on the losses in standby and active mode (see example in Figure 1 for flyback topology), on driving TV sets and other audio devices [13].

1 "On mode" - the television is connected to a power source, and produces sound and vision.

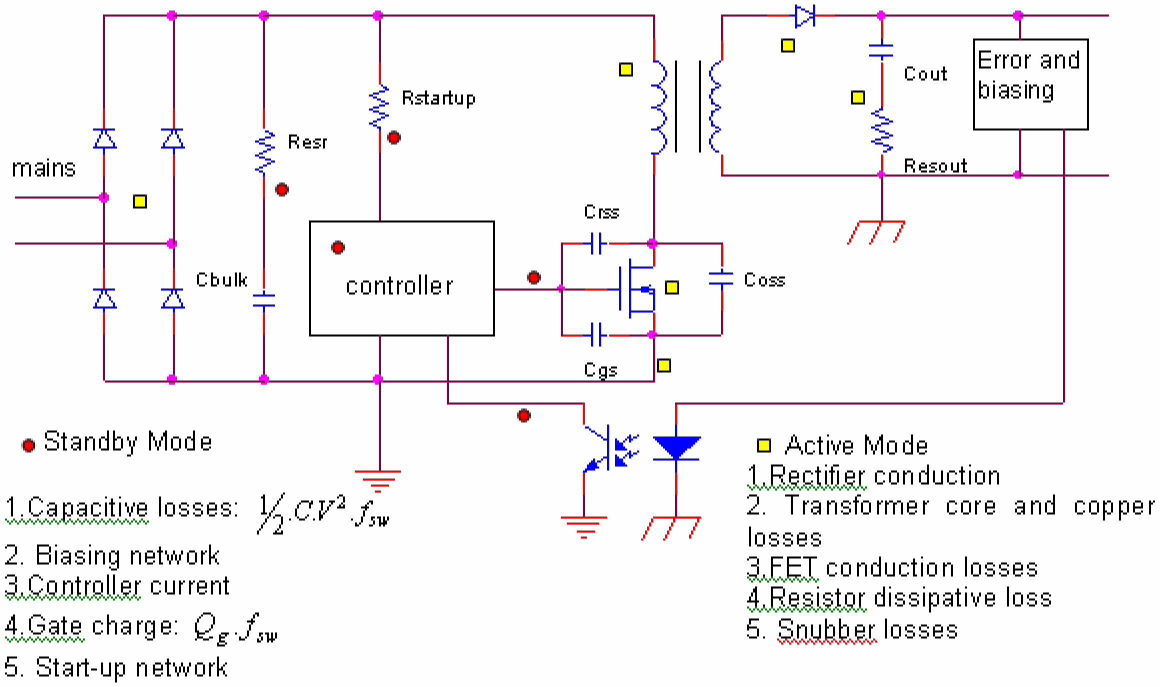

Figure 1: SMPS common topology: losses in *standby* mode

There are several key sections of the SMPS that can be optimised to minimise standby power consumption. The losses can be categorised into two types – conduction losses and switching losses [19]. Power switches based on MOSFET (Metal-oxide-semiconductor field effect transistor) technology devices have a named on-state resistance, $R_{ds(on)}$, which represents a major area of conduction loss. This loss can be minimised by selecting MOSFETs with lower $R_{ds(on)}$. Unfortunately, these devices tend to have a larger gate capacitance, which in turn increases the switching losses. However, depending on the output power rating, it is possible to select a MOSFET that strikes an appropriate balance between switching and conduction losses. Power input (P_{in})—see equation (1)—helps provide a comprehensive insight into SMPS losses with regard to both aforementioned strategies. It is deduced considering that, in a switching period, the energy drawn by the transformer during the on-time is transferred to the output during the off-time. As a result:

$$P_{in} = \frac{1}{2} \times L_p \times I_{pk}^2 \times f_{sw} \qquad (1)$$

where L_p is the transformer primary inductance, I_{pk} is the inductor peak current, and f_{sw} is the normal working switching frequency.

Two strategies, both linked to the SMPS switching frequency, have been established to reduce losses. By employing burst-mode operation (the so-called “skip-cycle” mode) or decreasing the switching frequency as much as possible, one may achieve a reduction in the switching losses in standby mode. These strategies are described below.

a) Burst-mode operation or skip-cycle mode

Especially when the requirement to provide output power is minimised, it is possible to operate the power supply in “bursts”, whereby the output power is supplied in small periodic bursts of pulse width modulated (PWM) operation, rather than in continuous mode. This minimises both conduction and switching losses. While this feature has been employed in high-end designs, it has only recently been needed in power supply designs for output power under 100 W.

In this mode, switching cycles are automatically skipped when the output power demand drops below a given level. This is usually accomplished by monitoring a feedback pin available in controllers. When the controller enters the controlled-burst operation, the power transfer depends on the width of the pulse bunches, as seen in Figure 2 for P1<P2<P3 [20].

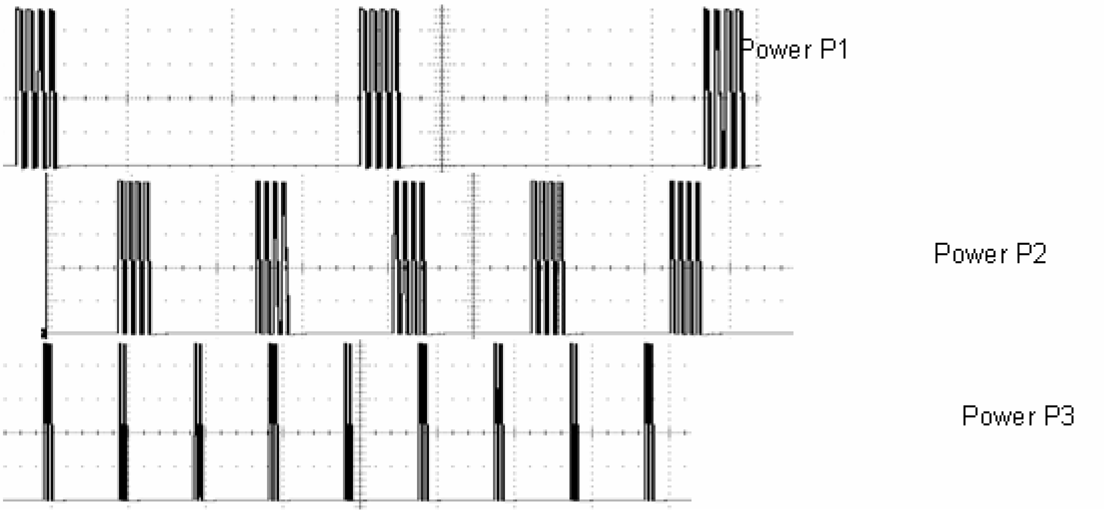

Figure 2: Output pulses at various power levels. Horizontal scale: 5us/div.

In an example where Lp=300 microhenries (μH), Ipk=600 miliamperes (mA), and fsw=65 kilohertz (kHz), a theoretical power input from (1) is Pin=4W. If skip cycle or burst mode takes place with a bunch length of 10 ms over a recurrent period of 100 milliseconds (ms), then the total power transfer is P_{in}= 0.4W.

b) Decreased switching frequency

In such a strategy, the SMPS controller automatically detects a light load condition and, as a result, decreases its oscillator frequency as well. The normal oscillation frequency is automatically resumed when the output load builds up and exceeds a defined threshold. This function allows for the minimization of power losses related to switching frequency, which represent the majority of losses in a lightly loaded flyback, without giving up the advantages of a higher switching frequency at heavy load [21]. This is accomplished by monitoring a feedback controller pin whose signal depends linearly on the peak primary current in the transformer. If the peak primary current decreases (as a result of a decrease of the power demanded by the load) and the voltage at the feedback pin falls below a fixed threshold (V_{T1}), the oscillator frequency will be set to a lower value (f_{SB}). When the peak primary current increases and the voltage at the feedback pin exceeds a second threshold (V_{T2}), the oscillator frequency is set to the normal value (f_{osc}). This operation is graphically shown in Figure 3.

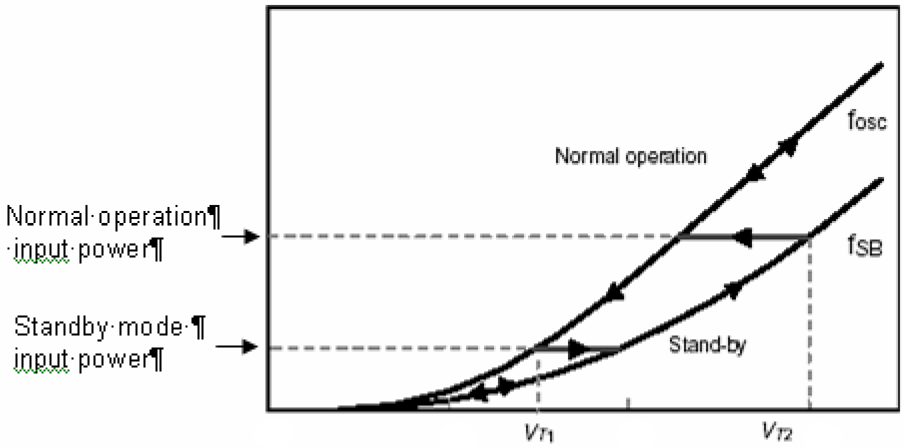

Figure 3: Standby dynamic operation.

In some SMPS controllers, the highest rate for the ratio $\frac{f_{osc}}{f_{SB}}$ has been set at 5.5 [21]. Thus, based on (1), the standby losses may be similarly reduced.

IV. Power Consumption Tests

In order to better represent the TV market, three leading Brazilian brands were purchased—all with 20-inch screens—and their energy consumption was measured according to the Energy Star criteria. Standard international testing procedures specify that the voltage and frequency shall be within ±1% of the nominal, and THD voltage shall not exceed 2% (Ecolabel) and 3% (Energy Star). Ambient temperature shall be within 22^{o}C ± 4^{o}C. So, a qualified AC Source model CI 4500iL manufactured by California Instruments provided the power, as necessary. California voltage (rms) accuracy (@25^{o}C ± 5^{o}C) is with 0.15%+0.3volts (V) and frequency accuracy is 0.01%+0.01Hz for the 45-100Hz range. The CI 4500iL model allows delivering 15Amps (45Hz-1kHz) while maintaining maximum 1% of THD voltage.
Figure 4 shows the voltage harmonic distortion in supplying a TV model HPS-2023 manufactured by CCE. A voltage distortion of 0.08% for the high THD current of 83.45% states the power performance specifications provided by California's power supply. Voltage and current waveforms with regard to these distortions are shown in Figure 5, such that supplied voltage and current are respectively 114.8V and 0.996A root-mean-square quantities, which performs with 5.85W of active power.
For true power measurements of 10W or less, the measurement instrument must have a resolution of 0.01W or less to comply with the Ecolabel regulations. True standby power measurements require the use of a true power wattmeter. In such an exercise, care should be taken to select appropriate power measurement equipment, since TV sets may draw current that is not sinusoidal, as shown in Figure 5. The high crest factor of the current may cause internal peak distortion on a common wattmeter, i.e., it may clip off the top of the current wave.
To avoid low accuracy, low resolution, and peak distortion, an oscilloscope with a current probe was used in the tests of standby operation.

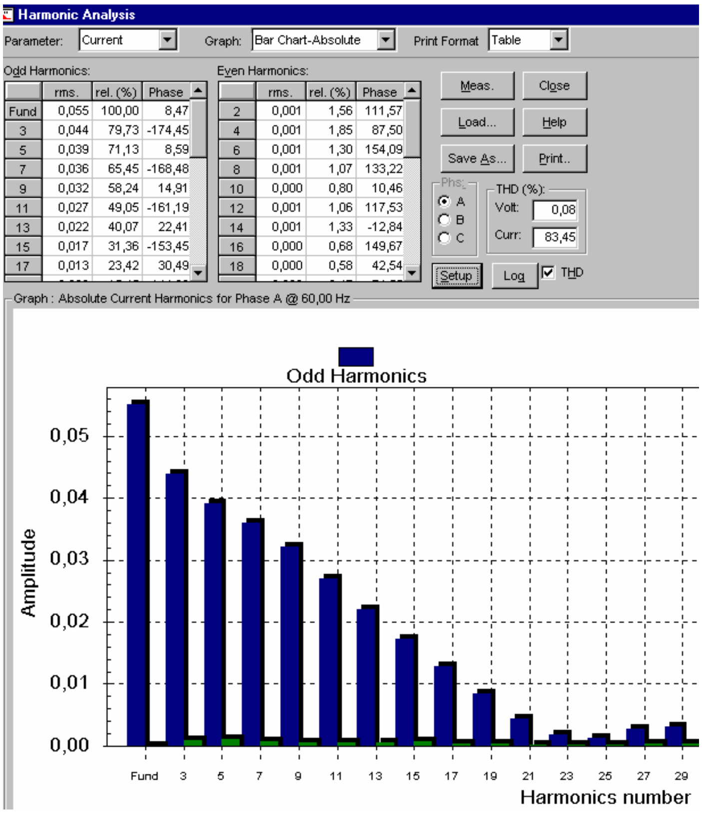

Figure 4: AC Source measurement window. Current and voltage harmonic distortion (THD) and current spectrum.

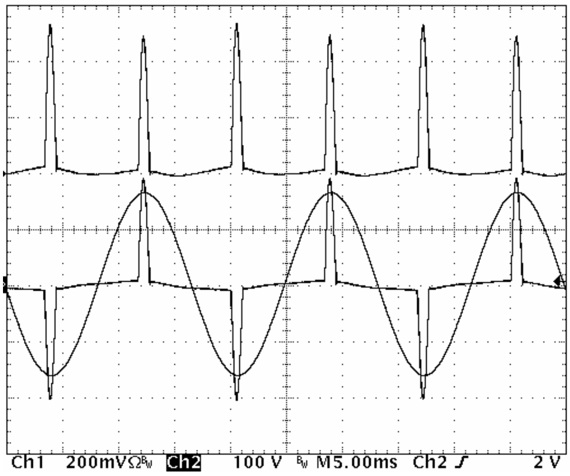

Figure 5: Top: instantaneous active power in TV. Bottom: voltage and harmonic current waveforms for CCE HPS-2023 model.

Measurement Equipment

The TDS430A Tektronix digitizing oscilloscope has the following features, which enable the measurement of energy consumption:

- 400 megahertz (MHz) maximum analog bandwidth
- 100Megasamples/second maximum digitizing rate, on each channel simultaneously
- Up to 30,000-point record length per channel
- Each channel with 8-bit resolution[2]. Nevertheless, in High Resolution Mode, up to 15 bits of digitized resolution is available. This is a nominal trait of high-performance digitizing oscilloscopes.
- Minimum voltage setting is 1mV/div.

To avoid current distortions due to a high crest factor, a TCP202 50MHz current probe containing a Hall effect device was used. The TekProbe interface allowed the TCP202 probe to be directly connected to the oscilloscope. The TCP202 probe has a maximum peak current of 50A, with a pulse width ≤ 10μs (500μAseconds). As the frequency decreases, the maximum current rating increases, limited to 15A (DC + peak AC).

V. Standby Power Consumption - Experimental Results

Estimates of the number of TVs in Brazil were taken from the CPqD Foundation's *Implementing Model of Digital TV in Brazil Project* [9], a statistical report prepared exclusively for the Telecommunications National Agency (ANATEL) in 2002. Results indicate that at least one TV is found in 87.7% of Brazilian homes. Nationally, residential TVs use 7.2–10.9TWh of electricity per year, accounting for about 10–15% of Brazil's residential electricity consumption. The overall consumption in 2002 was 72.7TWh [10]. These figures justify research into standby power consumption by residential TVs in Brazil.

Performing experimental tests on all TV screen sizes is expensive. As a result, the 20-inches screen size was chosen as the focus of this study, based on its 37% market share. Models of the three most common brands were purchased for testing; their respective features are listed in Table 3.

Although none of the brands has standby technology embedded in compliance with international standby regulations, it is evident that these models are able to meet worldwide market requirements. Furthermore, from Table 3, it is obvious the lack of technical specifications for power consumption measurement as seen by the different measurements conditions used.

Experimental evaluation of Brazilian TV sets was carried out according to the aforementioned international standby requirements. A summary of the experimental results for both rated voltages of 115 and 230V is shown in Table 4.

[2] Displayed vertically with 25 digitization levels (DLs) per division. Expressed as a voltage, a DL is equal to 1/25 of a division times the volts/division setting.

Only one model currently complies with the North American energy efficiency program. Further, there is a large discrepancy between manufacturers in the power consumption in standby and “on mode” operation in Table 3 and Table 4.

Table 3: TVs features of three major brands (according manufacturer specifications)

Brand/model	Voltage /frequency	Energy consumption in “on mode”	Standby consumption
PHILIPS /20PT3331	Universal (90 to 255)V/ 50 or 60 Hz	46W (approximated) Measurement conditions: not mentioned	**< 3W** Measurement conditions: Voltage at 220V
LG / RP 20CB20A	Universal (100 to 240)V/ 50 or 60 Hz	85W (maximum) Measurement conditions: not mentioned	10W Measurement conditions: not mentioned
CCE / HPS 2023	Universal (100 to 240)V / 50 or 60 Hz	54 W ± 10% Measurement conditions: Voltage at 120V, “color bars” signal, volume=15, brightness/contrast and color = 50%	Not mentioned

Previous work by Alan Meier (of Lawrence Berkeley National Laboratory), testing 321 TVs, has shown that the TV active power draw (“on mode”) is closely related to screen size and manufacturer, while TV standby power draw is related only to the manufacturer [11]. Despite the small number of TVs tested in this study, the results of Table 4 show the same divergent standby power measurements, as verified in Figure 6 [11].

Table 4: Standby consumption –Brazilian TV sets with 20-inch screens.

Brand/model	Standby Power [W]	
	115V	**230V**
PHILIPS /20PT3331	1,78	1,96
LG / RP 20CB20A	5,3	7,8
CCE / HPS 2023	5,85	8,1

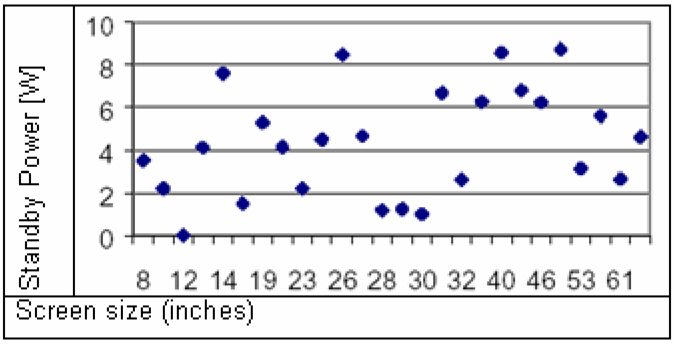

Figure 6: Average standby power consumption values by screen size [11]

Consequently, it may be inferred that standby power consumption depends basically on the SMPS provided by the TV manufacturers, while the active consumption depends mainly on the vacuum tube technology.

Despite the focus of this work on standby power, active power consumption also must be taken into account when applying for the European Ecolabel program; this is because the Ecolabel includes environmental[3] criteria, in addition to the energy-efficiency criteria considered by Energy Star.

[3] Related to the use of energy, the Ecolabel criteria aim in particular at promoting:
– the reduction of environmental damage or risks related to the use of energy (global warming, acidification, depletion of non-renewable resources) by reducing energy consumption.
Observation: There are others criteria related to the use of natural resources and related to the use of hazardous substances.

Applicants to the Ecolabel program for TVs need to consider passive standby, active standby, and “on mode” consumption. The following section discusses the additional requirements of the Ecolabel.

VI. Ecolabel Criteria for Televisions

The main environmental impact of a television results from energy consumption during its use; this includes both standby and “on” modes. The Ecolabel criteria set requirements for both passive and active standby modes (refer to Table 1), which are similar to those set by other organizations [12].
Active standby is becoming more significant as televisions use this mode for receiving electronic programme guides; this may become a standard feature in new TV sets. In addition, service providers of digital television transmissions may require an integrated receiver/decoder (IRD) to be in the active standby mode for significant periods of time [12].
Consumption in the “on mode” is becoming more important as improvements in picture quality increase electricity consumption. The Ecolabel criterion set for “on mode” energy use requires that televisions meet an energy-efficiency index (EEIon) of < 65%, which is between the proposed energy efficiencies for the A and B ratings in the energy label for televisions. [12].

A. Ecolabel “on mode” power consumption criterion

The “on mode” energy efficiency index EEIon shall be derived from the equation:

$$EEI_{on} = P_{on} \Big/ P_{on,bc} \qquad (2)$$

Where:

- P_{on} is the measured energy consumption in the “on mode”.
- $P_{on,bc}$ is the base case energy consumption of the television in the on mode. This is calculated using the following formula:

$$P_{on,bc} = 16 + 16 \cdot idd + \frac{0.75 \cdot format \cdot scrnsize + digit \cdot 0.33 + 0.38 \cdot scrnarea}{0.825} \qquad (3)$$

Where:

- digit is equal to 1 if the television has digital processing for picture scanning, and 0 if it does not have such processing.
- format is equal to 0.80 for a standard screen (4:3 aspect ratio), and 0.87 for a wide screen (16:9 aspect ratio).
- scrnsize is the screen diagonal in cm.
- scrnarea is the area of the screen in dm2, i.e., it is equal to scrnsize x scrnsize x 0.48 / 100 for a standard screen (4:3 aspect ratio), and scrnsize x scrnsize x 0.427 / 100 for a wide screen (16:9 aspect ratio).
- i_{dd} is equal to 1 if the TV has an Integrated Digital Decoder for digital broadcast signals, otherwise it is equal to 0.

In summary, the following assessment and verification must be ensured for applying to Ecolabel labeling [12]:
The applicant shall provide a test report stating that the level of power consumption in passive standby, active standby, and “on” modes has been measured using the procedures shown in EN 50301 (Methods of measurement on receivers for TV broadcast transmission). The report shall state the measured power consumption in each mode, the calculated base-case “on mode” consumption, and the calculated percentage of base-case consumption in the “on mode.”

B. Experimental results for “on mode” power consumption

“On mode” power consumption measurements and base case power consumption are shown in Table 5. Digital processing is not integrated in the evaluated three 20-inch screen TV models, so the following parameters were used as a base case:

- digit=0;
- format=0.8;
- scrnsize=48 centimeters (cm);
- scrnarea=11.06 square decimeters (dm^2);
- i_{dd}=0.

In Brazil the standard NBR5258 sets to approximately 48cm the screen size of 20 inches television, so, applying equation (3) it is found that the base case power is about Pon,bc=58.18W.

As seen, measurements of standby power (Table 4) and EEIon (Table 5) show the non-conformity of the three Brazilian televisions analyzed to Ecolabel requirements. The Philips model—EEIon=0.68 and standby power of 1.96W (230V – European specific voltage)—comes closest to complying with the Ecolabel standard. With regard to Energy Star, the Philips standby power of 1.78W (115V North American specific voltage) satisfies the required limit of 3W, which is effective starting July 2005.
Considering the TVs' overall performance, with the exception of the Philips model, this paper addresses the technological enhancements, with regard to SMPS, needed to comply with the international standards.

Table 5: Ecolabel Energy Efficiency Index

Manufacturer/ Model	"On mode" power (P_{on}) [W]		Base case power ($P_{on,bc}$) [W]	Energy Efficiency Index (EEI_{on})	
	115V (rms)[#]	230V (rms)[#]		115V (rms)[#]	230V (rms)[#]
PHILIPS/ 20PT3331	39.6	--	58.18	0.68	--
LG/ RP 20CB20A	67	72		1.15	1.23
CCE/ HPS 2023	41	43.2		0.70	0.74

[#]root mean square

VII. Environmental and Economic Analysis

This analysis estimates the annual reduction in energy consumption and CO_2 emissions from natural-gas power plants that could result from the use of more-efficient TVs in Brazil. The study is based on estimated annual sales of 20-inch screen TVs (2,251,080 units in 2004), as stated in a recent Brazilian government essay [15]. The analysis was based on the following assumptions:

• Standby time: An average time of 6.6 hour (h) in active mode was recorded for all social groups in Brazil [15]. Therefore, the televisions are assumed to stay in standby mode for 17.4h.

• Market Share: Brand (%) sales, as detailed in Table 6.

• Standby power consumption: The brand weighted-average power was calculated from experimental data rather than that stated by manufacturers, which does not provide a sufficient basis for evaluation.

Using the data from Table 6, the average power is respectively 3.45W and 4.37W, for the 115V and 230V North American and European specific voltages. A 1W mandatory standby standard would yield an average power reduction of 2.45W (115V) and 3.37 (230V) in 2005.

Table 6: Market share

Brand	Model	Standby – as stated by manufacturer in the technical manual [W]	Standby – experimental results [W]		Market Share
			115V	230V	
Toshiba	TV 2090AV	3.0	assumed to be 3.0	assumed to be 10% higher than for 115V, i.e., 3.3	23%
Philips	20PT3331	< 3.0 (220V)	1.78	1.96	21%
CCE	HPS 2023	not declared	5.85	8.1	14%
LG	RP 20CB20A	10	5.3	7.8	13%
Philco	TP-2053	< 2.5	assumed to be 2.5	assumed to be 10% higher than for 115V, i.e., 2.75	13%
Panasonic		not available	(assumed to be <1W)		10%
Mitsubishi		not available			4%
Sony		not available			2%

• An increasing rate of 15% in sales was estimated to 2005 [16].

In conclusion, assuming a mandatory 1W standby power requirement, one can estimate a power reduction of 5.32MW (115V) and 7.32MW (230V) in 2005. This reduction is due to power improvements in only 84% of Brazil's TVs, since the last three brands (Table 6) are assumed to already comply with the mandatory 1W standard.
Table 7 summarizes the results for energy savings, and power and CO_2 reductions. The estimated 17.4h standby period was used to calculate the energy savings. As a result, the nation could save 16.25 (gigagrams of CO_2) $GgCO_2$ (115V) due to avoided emissions from natural gas-fueled thermoelectric plants (assuming a coefficient of 0.48gCO_2/Wh [17]). Similar analysis may be done to the 230V grid.

Table 7: Environmental and economic saving.

Voltage [V]	Technical/Economic data				Results		
	Real power [W]	Units sold in 2004	Retail rate increasing to 2005 [%]	Time in standby [h]	Power saving [MW]	Energy saving [GWh]	CO_2 reduction [$GgCO_2$]
115	3.45	2.251.080	15%	17,4	5,32	33,85	16,25
230	4.37	2.251.080	15%	17,4	7,32	46,56	22,35

VIII. Conclusions

The recent discussion about energy-efficiency standards in Brazil's national Congress might require manufacturers, in the medium term, to improve the standby technology embedded in TV sets. It was theoretically shown that at least 84% of brands currently do not comply with energy savings. As a result, e.g., for the 115V grid, the establishment of a 1W standby standard in 2005 could save 8.53 million reais (R$) on electricity bills (for 33.85GWh in Table 7 and an electricity price of 252 R$/MWh, including the 18% of tax on the tariff of the National Agency of Electric Energy - ANEEL). More societal benefits could also result, for instance, avoiding 16.25Gg of CO_2 emissions. Similar analysis may be done for the 230V grid.
Currently, new SMPS controllers comply with the energy-efficiency labels worldwide. Nevertheless, these controllers are developed for more common topologies and for limited power—for instance, flyback converters and 150W, respectively. Therefore, more effort from researchers on studying standby power losses should be encouraged.
Finally, assuming that 50% of all 2,251,080 units sold in 2005 are connected in the 115V grid and the remainders are connected in the 230V grid, the average values from Table 7 are:

- Power savings = 6.32MW, energy savings = 40.2GWh, and avoided CO_2 emissions = 19.3 $GgCO_2$.

To serve as a reference, the estimated power savings are 30% of the total wind power capacity installed in Brazil, i.e. 20.3MW [18].

IX. Acknowledgments

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Designing Energy Efficiency Electric Motors (EEEM) by Using Reliability Indicators

C. D. Pitis

Femco Mining Motors

Abstract
Millions of swimming pool motors (SPM) are running without electricity consumption being scrutinized (EC's efficiency grading system bands starts from 1.1 kW). Swimming pool unit is attracting the owner attention only when it fails. In about 65 to 75 % of failures, motor replacement criterion is preferred, decision being based on initial investment.
Approaching an EEEM design by using higher quantities and/or quality of active materials (reducing as consequence motor losses) is a very basic method. As a result, the motor cost becomes prohibitive. Besides lifetime expectation of 3…4 years trouble free at competitive price, the end users start asking for energy efficient motors (EEEM) as an extra feature.
The target was to obtain a new SPM-EEEM design with minimum changes (alterations), but achieving also an optimum balance between costs and EEEM lifetime expectancy (MTBF equivalent) in order to ensure business sustainability. The author described one of his experiences in designing EEEM. Multidisciplinary techniques (including statistic-probabilistic methods and thermodynamics calculations) have been correlated to obtain a financially competitive product with improved technical performances.
Paper presents a case study of a low efficiency 0.75 kW SPM currently existent on the market (efficiency bellow EFF 3 Class). Input data were obtained by evaluating existent SPM population reliability based on "fault tree" method. The motor was re-designed to an EEEM – EFF 1 Class with higher life expectancy, 15…16 % energy efficiency improvement, being manufactured at a competitive price. Further energy savings were obtained by improving power factor of the motor (reducing reactive power costs). In-house and site tests results validated the design. Currently, the product is part of a patented series of SPMs.

1. Setting the Problem

1.1. Short presentation of application
Standard SPMs are TEFC IP55, IP41 types, fitted together with water pump in an approximate 900 x 600 x 600 mm cubicle enclosure (CE) glass enforced by resin impregnation. The application passed homologation tests performed long time ago by South African Standards Authority. The tests have been performed on dedicated stands, at continuous running regime, with normal (clean) water.

However, on site, the application recorded a relative high failure rate. As a result of unexpected specific working conditions characterizing the application, upon investigations it was confirmed that the motors are the "weak point" of the application.

- The motors are not matching the load requirements (not always running continuously): numerous stop/startings at very short interval are occurring.
- The water is not clean but contaminated with foreign substances as: atmospheric dust and sand, muddy, mulch, etc.

Rotor and stator electric losses represent about 2/3 of the total losses. Critical states are the overload and re-starting conditions when these losses are higher. During a **motor re-start attempt** after overload tripping while the motor starts, the starting losses are 150 to 220% higher than continuous motor running losses. If the overload sensor keeps tripping the motor temperature will rise beyond its standard conditions. This situation (with many re-starts in row) is very detrimental to the motor life expectancy. Subsequently accelerated ageing effects on winding insulation and bearings are occurring.

The condensation is appearing in specific climatic conditions, (when motor stops) due to unusual high temperature gradients into the motor. This condensation is very detrimental to the bearings and

lubricants, especially. For specific SPM types, the end user has chosen to drill draining holes at the bottom of the motor enclosure (the motor enclosure becoming not IP55 anymore). This measure is proving the fact that motors may run better in a close contact with environment.
Nevertheless, because of high failure rate of SPMs, trying to prevent unplanned stoppages and warranties, the end user preferred to oversize the motors. Subsequently, SPMs are running at lower performances than their rated values with much higher losses (125%…135 %) on active and reactive power.

1.2. Loading an oversized motor and efficiencies.

Oversized SPMs frequently are occurring in this specific application as a consequence of various allowances accumulated during the process of design, procurement, commissioning and imposed by reliability (warranty) conditions. These allowances are motivated by various reasons mainly related to SPM lifetime and guarantee period. As a result the SPMs are loaded in a range of 50%…70%, running at lower efficiencies and power factor. Table 1 shows a typical example of a 1.1 kW SPM efficiencies when running at various loads.

Table 1: Efficiency and power factor variations of a standard 1.1 kW SPM (hot) @ different loads

No	Shaft power [Watts]	Input [Watts]	Efficiency [%]	Power factor (p.f.)	Combined: Efficiency x p.f.
1	1350	1980	68.2	0.97	
2	1100	1570	70.0	0.95	100 %
3	850	1180	67.4	0.90	91.2 %
4	580	860	59.0	0.76	67.4 %
5	290	580	50.0	0.54	40.6 %

Table source: Femco 150100069/QPS 20

At 50 % load the motor will run 16 % under rated efficiency and 20 % under rated power factor with corresponding increases in electricity bill (combined efficiency x power factor reduction are 32.6 %, if 100 % has being considered rated values). **The annually energy losses are reaching 1570 kWh/motor.** Selecting the correct size motor for an application can increase motor efficiency.

2. Reliability Analysis of SPM by Using Fault Tree Methods

2.1. Fault tree method

Since reliability is the reciprocal of failure, and failure is a random event, probabilistic measures are most appropriate. The laws of probability theory shall apply. A simplistic example is to consider a motor having 6 (six) identical components with equal Mean Time Between Failures, MTBF = 3 years. The failure rate function of MTBF is estimated as:

$$\lambda = 1 / MTBF \quad (1)$$

Then we would expect 6 x (1/3) = 2-device failure per year, which means SPM, will fail every 6 months!
Fault tree analysis is a method of combining various component failure rate, first proposed by HA Watson to analyze the Minuteman Launch Control System **[1], [2].** This method models a system failure of interest called Top Event (TE) i.e. SPM failure. The fault tree breaks down TE into lower-level events (LLE).

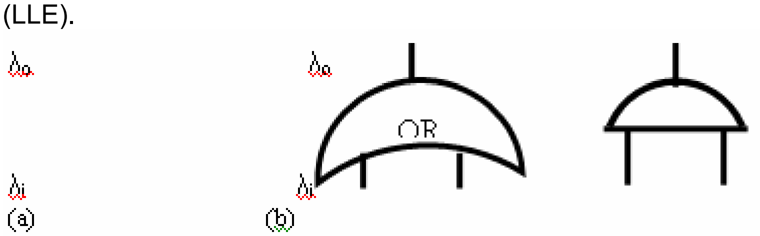


Figure 1: Gate “OR” and gate “AND” description

Logic gates show the relationship between LLE and TE. Mathematical model is based on Boolean algebra. The “OR” gate showed in figure 1 (a) express the idea that any of several component failures can cause output event, here, TE = SPM failure. The output event failure rate λ_o function of LLE failure rates λ_i is:

$\lambda_o = \Sigma \quad \lambda_i$ [1/hours] **(2)**

The gate "AND" showed in figure 1 (b) express the idea that both (or all) components must fail in order to produce the output event. The output event failure rate λ_o function of LLE failure rates λ_i is:

$\lambda_o = \Pi\ \lambda i$ [1/hours] units **(3)**

2.2. Fault tree of a SPM

Regarded as a product with unique (simple) function (no reparability feature), SPM design as EEEM is based on reliability concepts as" the aptitude of a product to fulfill correctly the specified functions in a given period of time and in prescribed running conditions". The failure rates estimation from processed statistical data on MTBF is shown in Table 2. SPMs have been considered running in average 12 hours per day, 365 days per year.

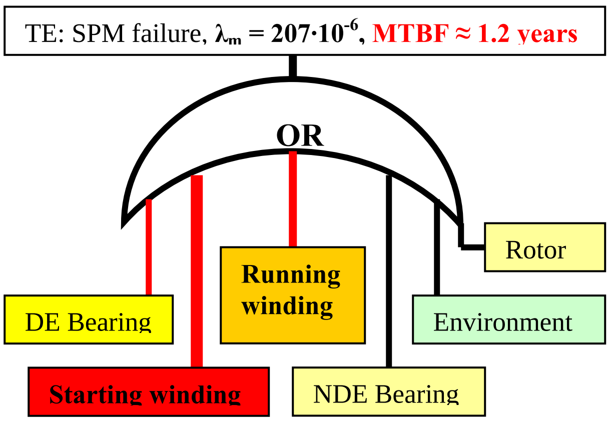


Figure 2: Basic fault tree designed for a SPM.

Basic fault tree of an SPM is presented in figure 2. TE failure rate is expressed in 10^{-6} [1/hour]. LLE are the bearings, windings and rotor failures, and environmental conditions, too. Any of them can produce TE = SPM failure.

2.2. SPM evaluation based on fault tree method

SPM fault tree is the basic point in evaluation of a standard SPM behavior from reliability point of view. According to table 2:

- SPM failure is occurring beyond warranty period (ensuring "business sustainability"!).
- Declared "weak points" of the motor are the windings and drive bearing, with environment having a substantial contribution.

Table 2: Basic failure rates used in estimation of failure probability for standard 0.75 kW, SPM.

SPM Component	MTBF [hours]	$\lambda_i \times 10^{-6}$ [1/hour]	Lifetime expectancy
Starting winding	23490	42.5	**5.3 years**
Running Winding	24360	41.0	**5.6 years**
Drive bearing	26100	38.31	**6 years**
Rotor	30960	32.3	7.3 years
Environment	30450	32.8	7 years
Non-drive bearing	48550	20.6	11 years
Total for SPM		**207.51**	1.2 years

Table source: Femco 150100069/QPS 20

The failures of the "weak points" were found to be mostly due to thermal stresses: overheating, poor heat transfer non co-ordination of heat transfer and cooling.

As shown in figure 3, the SPM is an IP 55 type of enclosure & IC41 **[3].** Because of the external fan position, nondrive endshield (with its bearing) is the most effective in the cooling process and its weight in heat radiation is in a range of 10%…15 % of the total heat evacuation. The casing and ribs are partially cooled by air fillets going along. However, there is an obvious cooling gradient along the casing due to air slight and progressive separation from the casing profile.

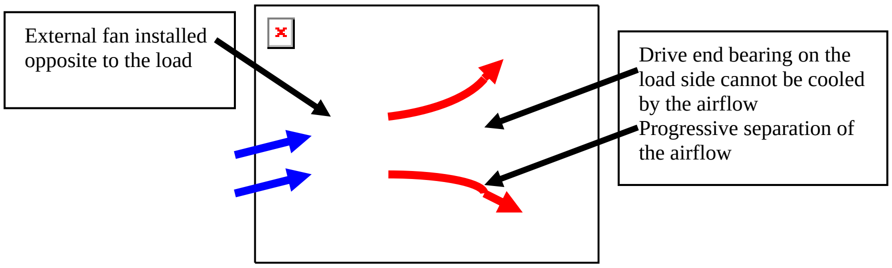


Figure 3: Standard SPM (IP 55, TEFC) with pump. source: Femco 150100069/QPS 20

In a TEFC motor, the active materials do not take a direct cooling from airflow generated by the external fan placed on non-drive end side of the motor. The heat dissipation is based on:

- Stator winding heat transfer by conductivity to the casing and ribs
- Casing and ribs heat transfer by conductivity and radiation (being taking away by the air flow)
- Rotor heat transfer by radiation to the winding and by conductivity to the bearings

Due to specific working conditions the rotor may influence negatively the behavior of the motor components.

3. Directions of the Heat Flux Transferred from the Rotor

Paths of the heat radiated by the rotor in a TEFC motor are shown in figure 4. Rotor fanning effect does not influence consistently heat dissipation. The heat flux is transmitted along 2 (two) directions.

AXIAL direction: Overheat produced into the rotor is conducted along the shaft producing bearing journal expansion, reducing bearing clearance inducing eventually bearing failure. Rotor life span can be drastically reduced because of **bearing collapsing and rotor rubbed** on the stator. A classic example is known as “bow rotor” when, as a result of a local thermal vector, the active material is emerging out from the rotor

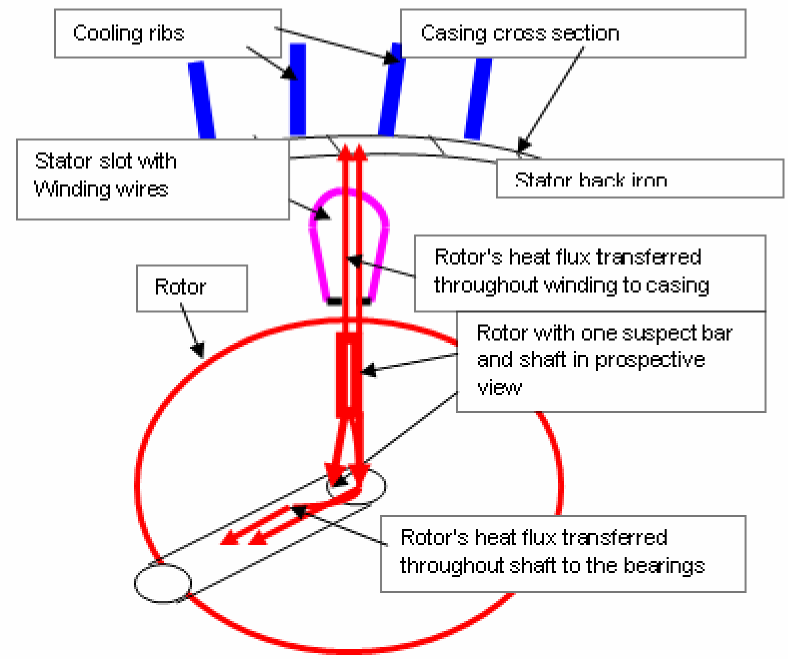
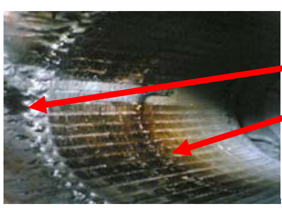


Figure 4: Rotor' heat flux paths toward bearings and winding source: [4]

RADIAL direction: Rotor' heat flux radiated on radial direction is increasing stator temperature gradient. Hidden voids in aluminium cast material produce so called "hot spots" seen as a "circle of fire" effect on the stator winding as shown in figure 5.The same route is applying for the heat generated by the rotor during the overload, starts and re-starting. Thermal stress is ageing winding insulation and bearings.



Winding being unevenly thermally stressed produced interturns shortcircuit.
The hot spot of a thermal local vector situated on the rotor overheat the stator winding as "circle of fire".

Figure 5: Winding affected by rotor' heat radiation
Photo source: Femco 150100069/QPS 20

4. Investigating SPM Weak Points"

4.1. Analyzing drive end-bearing failure

In a TEFC, B5, IP55 motor, the drive end bearing is situated in a worst position. Besides generating heat by itself from the load to be taken, bearing is receiving extra heat from adjacent components.

- Heat received from the winding overhangs by radiation
- Heat received from the rotor via shaft by conduction
- Heat received from the sealing arrangement (friction of rotating shaft against the seals lips) via shaft

As shown in figure 3, the drive end bearing does not take a direct cooling from the airflow generated by the external fan placed on non-drive end side of the motor. During load working time the heat dissipation of the bearing is function of the drive end shield material conductibility and end shield radiating area against motor enclosure and against pump. Any extra heat transferred by thermal conductivity via drive end shield it takes a time delay due to thermal inertia (confirmed by measurements to be in a region of 10…15 minutes).

It is well known that fractional motors perform high slip rotor features. Electric losses on the rotor (and heat generation, too) are direct proportional to rotor slip. The critical situation (as over-heat generation) intervenes at re-start and overload conditions.
During motor re-start in the first 10 to 15 minutes running conditions, the bearing will be overheated (and possible collapsed) as a result of an additional thermal shock at motor re-start (superimposed on the existent "hot" condition). This thermal shock is occurring in relative short time "Δt" and may be considered as "**quasi-adiabatic**" **[5]** as demonstrated in the following thermo-dynamic heat transfer calculations.

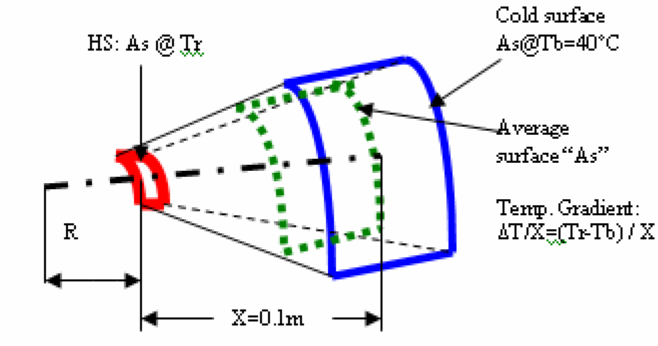


Figure 6: Basic graph of the rotor' overheat flux transferred by conductivity via shaft.
Figure source: **[5]**

Consider a drive end bearing temperature rise Trise = 30°C @ ambient of To = 35°C. It result the bearing is running at Tb = 65°C. After re-start, the rotor of mass Mr = 0.5 kg and average specific heat c = 2.2 cal/kg °C records a temperature Tr =150°C (minimum δT = 55°C/start) as "thermal shock".
According to figure 6, heat developed into the rotor HS, is transferred via shaft area As = 78.5 10exp(-6) m² by conduction to the "cold area" (drive bearing). Steel mean thermal conductivity is K = 14.4 cal/m sec °C and average distance between the rotor bars and bearing is X = 0.1 m. Time duration **Δt** of the heat to be transferred from the rotor to the bearing via shaft is estimated according to equation 4 **[6]:**

$$\mathbf{Mr \times c \times \delta T = K \times As \times [(Tr - Tb)/X] \times \Delta t} \qquad \mathbf{(4)}$$

It needs **Δt = 153** seconds for the thermal shock heat flux generated by the rotor to reach the bearing inner ring. The bearing inner ring (diameter Do = 30 mm) dilatation due thermal shock is estimated according to equation (5):

$$\mathbf{D = Do\,[\,1 + \alpha\,\Delta T]} \qquad \mathbf{(5)}$$

For ΔT = 85°C and α = 15.7·10 exp. (-6) it results an increase of 36 microns of the bearing inner race diameter, while the maximum radial clearance for this type of bearing is only 25 microns. As a result of inner ring dilatation beyond internal clearance allowance, the bearing will overheat in a "snow ball" effect reducing its clearance until collapse.

4.3. Thermal shocks in the windings during re-start and overload conditions.

Consider the motor run in "HOT" thermal stabilized conditions. Extra heat generated during transients overload or re-start conditions will be superimposed onto existent thermal equilibrium. Rotor heat radiation will stress thermally the windings as shown in figure 4. During these transient situations a new thermal equilibrium has to established as a result of:

- Starting currents circulating into the winding
- High currents circulation in rotor bars and short-circuit rings

Consider copper thermal conductivity K = 91.8 cal/m sec °, slot cross section As = $1 \cdot 10^{-4}$ m^2 and temperature difference between rotor Tr = 150°C and winding Tw = 120°C, (Tr – Tw = 30°C). The heat transmission to a distance of X =0.1 m will occur in a "***quasi adiabatic***" thermal process with **Δt** = 10 to 15 seconds obviously overheating the windings insulation system. Time duration of thermal stress applied to windings will depend by the cooling thermal constant (heat has to be transferred outside of the motor casing and radiated in the airflow stream). Windings will be overheated unevenly, until overload protection sensor will trip.

5. New Swimming Pool Motor

5.1. Essentials of application engineering

As demonstrated, standard SPMs do not comply with five essentials of application engineering.

i. Matching the driven machine conditions.
ii. Matching the power supply conditions.
iii. Matching the environmental conditions.
iv. Matching the reliability conditions.
v. Matching the business sustainability conditions.

5.2. The targets of the new design

The new design targets were to transform existent low efficiency SPM in an EEEM without alteration of main components.

- Stator and rotor geometrical sizes.
- Rotor and stator slots profiles
- Quantity and quality of the laminations raw material
- Quantity of aluminium used for the rotor electric circuit
- Quantity of the copper used for the windings

These targets are imposed by the above five essentials of application engineering with special references to specific conditions of the mass production technological process and business sustainability.

5.3. Basic steps in increasing SPM reliability and efficiency.

Has been demonstrated that SPM failure rate is function of thermal ageing effect. That means the process of heat transfer and evacuation has to be addressed before any changing of SPM electromagnetic design.

First step is to re-direct the cooling flow directly to the declared “weak points” (winding, bearings and rotor) in dispersing the transient overheat and “thermal shock” effects. As a result, the components ageing effect will be suppressed.

Second step in efficiency improvement is obtained by direct cooling of active materials with consequence of reducing motor temperature rise. This will reduce stator and rotor copper losses RI^2 in proportion.

Third step is obtaining by reducing friction (existent in double seal’ arrangement) and windage losses.

Fourth step is obtaining by minimizing the increase of specific losses [W/kg] of the laminations by improving technological process (degassing, annealing, and punching). Specific losses of the lamination packs were reduced with 25 %. Reduction of the core losses enabled an increased magnetic loading, reducing electrical loading in proportion and subsequently RI^2 Joule losses.

6. Patent description [7]

New SPM (shown in figure 7), EEEM type denominated as “Evolution” (Ev) was designed and manufactured according to conditions presented above. The motor stator core (including the winding) is hold in position by two “spider brackets” **(SB)**. The long screws holding the brackets have different length, according to different core lengths enabling motor power adjustment in a range of 0.6…. 1.5 kW for the same laminations profiles.

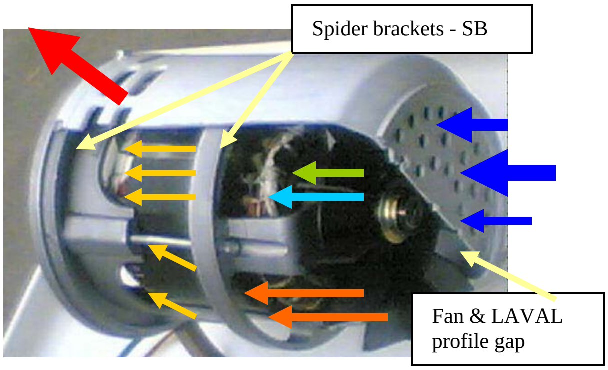


Figure 7: Cross-section of new SPM, EEEM (180° rotated) Photo source: [7]

Legend of the arrows indicating air-flow
Blue = inlet air
Sky blue = air in the winding overhang
Lime = air into the airgap
Orange = envelope of air between back iron and casing
Gold = cooling air for drive bearing
Red = Outlet air

By construction and tolerances, SB play a major role in motor functionality by ensuring:

- Mechanical alignment on radial and axial directions between stator and the rotor;
- Space for winding overhangs;
- Air flow guidance (with reduced turbulence and aerodynamic resistance);
- Suitable fitting for casing

A special profiled fan (low windage losses) is attached to the shaft, outside of nondrive spider bracket, but inside the motor enclosure. Air is entering axially into motor enclosure. Throughout an aerodynamic profiled gap between fan's fins and the casing (LAVAL profile) the fan creates a suitable airflow inside the motor enclosure, the air being accelerated without turbulence towards:

- Nondrive bearing;
- Windings overhangs;
- Motor air gap (plus windings and rotor);
- Back of the stator core (air envelope in the space between casing and stator core)
- Drive end bearing.

At the end, all stream flows are re-united on drive end side. Outlet air apertures are available at the bottom of the motor.

7. Testing Activities & Results.

7.1. Basic comparison between standard and new Evolution ("Ev") SPM designs.

Table 3 shows a comparison between standard and "Ev" series of 0.75 kW, 2 poles, SPMs.

Table 3: Performances comparison of SPMs

SPM Items	Standard	New "Ev"
Rated output power [kW](ii)	0.75	0.75
Rated speed [r/m]	2787	2898
Rated current [A]	4.96	4.2
Current in main winding [A]	4.64	3.93
Current in auxiliary winding [A]	2.16	1.83
Power factor	0.910	0.952
Input power [kW]	1.095	0.925
Rated efficiency [%]	68.5	81.1
Stator copper losses [kW](iii)	0.126	0.095
Rotor losses [kW](iii)	0.070	0.031
Iron losses [kW](i)	0.100	0.039
Friction and windage [kW](iv)	0.049	0.010
Total losses [kW]	0.345	0.175
Temperature rises [°C](v)		
Main winding [°C]	77.2	40
Auxiliary winding [°C]	75.6	45
Drive end bearing [°C]	55	30
Non drive bearing [°C]	30	10
Rotor [°C]	150	93

Table source: Femco 150100069/QPS 20 & [7]

Motors performances were assessed on dynamometer, real conditions as shown in figure 8.

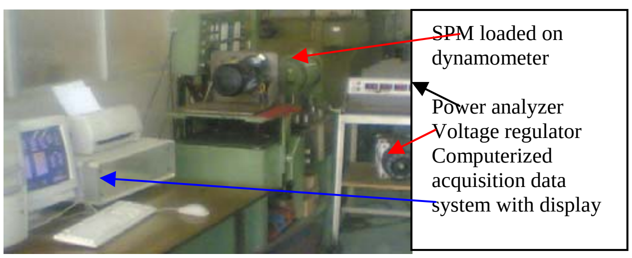


Figure 8: Dynamometer tests on SPM
Source: FEMCO test bay

7.2. How were obtained such performances?

i. By changing the balance between magnetic loading and electrical loading in electromagnetic design (increasing magnetic loading as a result of improving lamination specific losses [Watts/kg]).
ii. Unchanging geometrical dimensions of electromagnetic design but reducing electrical loading.
iii. Reducing thermal level of the active materials and subsequently RI^2 losses due to reduced electric loading and due to direct cooling of the windings and rotor.
iv. Reducing friction and windage as a result of a new cooling principle and heat coordination.
v. Reducing temperature rises (thermal stress) of the motor components slowing ageing effect and minimizing the failure rates of these components.

The results of energy efficiency improvement validated by site validation activity are shown in figure 9.

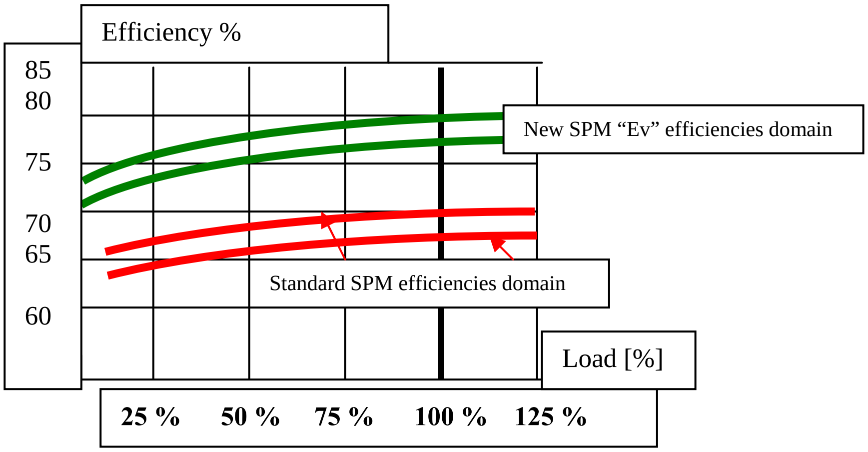


Figure 9. SPM, EEEM efficiency domains improvement compared to standard
Figure source: Femco 150100069/QPS 20 & [7]

7.3. Matching five essentials of application

The motor new design is matching the load conditions: impeller performances are matching motor performances, the motor running at its rated values **(essential one).**
Reducing electrical loading of electromagnetic design enabled a better motor behavior in different conditions of the power supply **(essential two).**
The design structure complies with environmental conditions required by application **(essential three).**
Ageing effect was suppressed by reducing thermal stresses. According to very conservative estimations of components failure rate presented in table 4, it results that SPM "Ev" predicted lifetime is 2.7 times bigger than standard motors (**essential four).** Estimations have been done according to Montsinger and Dakin formulas using Svante Arrhenius chemical rate equation **[8].** Additional endurance tests performed on stands simulating accelerated ageing conditions confirmed the results.

Table 4. Failure rate estimation of new "Ev", SPM.

Component of new "Ev" type	**MTBF [hours]**	**λ_i x 10^{-6} [1/hour]**	**Lifetime expectancy**
Starting winding	86000	11.6	20 years
Running Winding	96000	10.4	22 years
Drive bearing	77500	12.9	12 years
Rotor	75500	13.2	7.3 years
Non-drive bearing	91500	10.9	13 years
Environment	55600	17.9	11 years
Total for SPM		**76.9**	**3.1 years**

Table source: [7]

Regarding essential five, minor changes of technological process occurred with reduced expenses (production costs have been consistently reduced).

- Tooling maintenance interval was shortened.
- Lamination processing was improved.
- Winding specifications were simplified.
- Casing, cooling system (fan cowl) and rotor costs were considerably reduced.
- Labour reduction in winding and assembly process
- Assembly processes become simpler.

8. Conclusions

It was demonstrated that a multidisciplinary approach has to be considered when designing motors. This exercise proves that statistical probabilistic methods might revolutionize the physical shape of any product.

Proposed method ensures minimum changes and costs of EEEM manufacturing process. Energy efficiency concept was accomplished by:

- **Reducing of daily power consumption in a region of 2 (two) kWh per SPM, or 8400 kWh per year.**
- Reducing ownership costs, indirect costs related to pool water damages and logistics, by increasing product life expectancy and reducing failure rates.
- Reducing SPMs manufacturing costs.

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A Tale of Two Topics: Evaluation and Incentives in Utility Regulatory Award Mechanisms For Energy Efficiency Programs And Measuring Indirect Non-Energy Benefits --A Poster Session

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Abstract and Introduction

This poster session addresses two very different and distinct topics related to energy efficiency program evaluation:[1]

- The issue of the use of well-designed financial incentives to encourage implementation of effective energy efficiency programs by utilities is examined. In this section, the poster reviews four different designs of award mechanisms that have been used in the US, and discusses advantages and disadvantages of each. Then, the apparent performance of each award mechanism is examined based on the findings from an extensive review and verification performed on the activities, outcomes, and rewards for four award periods and four utilities in California. Information on award mechanisms from other states, and proposals for modifications to generate improved performance are also presented.
- The complexities of deriving estimates of the indirect non-energy effects from energy efficiency measures and programs – and feasible approaches – are presented. In this section, we provide background and methods for estimating non-energy benefits (NEBs) in a credible and defensible manner. The pros and cons of alternative measurement approaches, and issues related to bias, implementation ease, and applicability to different program types are presented. Results applying these advanced measurement approaches to several US programs – both residential and commercial – are provided for illustration and discussion.

The poster presents charts, graphs, and results to compare the performance and impacts of alternative methods of addressing both these two topics.

Lessons in Incentivizing Energy Efficiency: Review of US Energy Efficiency Award Mechanisms for Utilities

Introduction

The authors conducted a review of alternate versions of award mechanisms that have been proposed and/or used to incentivizing utilities for energy efficiency programs and investments around the nation. The work tracked changes in mechanisms over time, examined the impacts of these modifications on activities and outcomes, and compared the results to provide "lessons learned" in the design and implementation of incentives. Advantages and disadvantages of the various award mechanisms were assessed from two perspectives – from the perspectives of

- providing a performance incentive and
- verifying achievement.

There are pros and cons in the ability of the award mechanism to encourage effective progress in the delivery of energy efficiency services and programs by the utilities (first perspective). Secondly, there are advantages and disadvantages in terms of how readily and unambiguously the activities can be verified (second perspective). Types of award mechanisms reviewed by the authors included:

- expenditure-based,
- accomplishment-based,
- milestone-based, and
- retention-based.

The authors found some of these mechanisms to be more straightforward and effective than others. Results showed that the award mechanisms varied in their suitability for various program types and

[1] Combining these two separate topics into one poster session was requested by EEDAL. As such, each discussion is truncated. For more information on either topic contact www.serainc.com.

their abilities to reflect progress in different types of program goals; however, some common themes were identified. The authors examined the strengths and weaknesses of different award mechanisms and developed recommendations on specifications.
Overall, the question is how metrics can best be designed to carry forward the original intent related to comprehensive, effective, and efficient service delivery of programs; lead to well and directly carried out program and service activities delivering this service; and support reflection of those efforts and intentions through reasonable documentation. The results have implications for states and regulatory agencies looking to refine their energy efficiency incentives and design the "next generation" of mechanisms to incorporate "best practices" from national experience.

Background on the Project
The Annual Earnings Assessment Proceeding (AEAP) provides the basis for California Public Utilities Commission (CPUC) review of the level of success achieved by the four California IOUs (independent owned utilities) in implementing a variety of energy efficiency (EE) programs. The AEAP reviewed was a consolidation of the IOUs' AEAP applications filed in 2000, 2001, 2002 and 2003 for shareholder incentive earnings for Program Years (PY) 1999-2001 and for PY 2002 accomplishments. The AEAP review process is the mechanism that determines how the CPUC distributes IOU shareholder earnings to each of the four utilities (Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), and Southern California Gas (SCG) based on their activities and accomplishments. The review process included an assessment of the achievement of energy efficiency program related milestone goals by the IOUs.

Skumatz Economic Research Associates (SERA) [2] was hired to conduct an independent third-party assessment of energy efficiency program-related milestone goals and to identify the shareholder earnings claims that could be validated and thus, should be paid to the utilities. Three sets of PY assessments conducted as part of this project:

- PY 1999-2000, which was based on cost reimbursement for program delivery, but also provided an additional incentive based on superior or acceptable achievement of program-related milestones;
- PY 2001, which provided incentive awards partially based on achievement of energy savings targets, and partially based on market transformation and program implementation targets as in the previous years;
- PY 2002, which included no shareholder earnings. Instead, reimbursement of a portion of program costs was at risk if reasonable efforts toward meeting program accomplishment goals were not made.

The steps that were conducted for this work included:

- Reviewed the utilities' AEAP filings and developed requests for documents to establish milestone goals, award values, and verification requirements;
- Developed a milestone claims inventory and checked both that the claims were consistent with Commission-approved milestones and that individual claims summed to totals claimed by the utilities;
- Selected a sample of milestones for detailed review and analysis;
- Submitted claims verification requests to the individual utilities related to the selected milestone claims; and
- Assessed milestone award claims to identify which portions of award claims could be supported based on a review of the documents submitted, and which portions of dollar award claims may possibly be at risk.

Across the years for which milestone incentives were available, utilities pursued a variety of different milestone types, each with a unique set of measurement metrics and award mechanisms. In order to facilitate the milestone verification process, the SERA team categorized milestones into four major groups:

[2] The project team for this assignment included Skumatz Economic Research Associates (SERA) and its subcontractors Summit Blue Consulting (SBC), blueConsulting Company, and GEP (Global Energy Partners). SERA reviewed claims from three utilities and Summit Blue reviewed one. Thanks to Leah Fuchs (SERA), Ingrid King (SERA), and Stuart Schare (SBC) for suggestions helpful to the development of this paper. The client assignment consisted of a review of documentation and support for award claims. Additional work to examine and compare a variety of award mechanisms was not was part of the client assignment, but was undertaken and funded independently by the authors.

- **Energy Savings milestones,** related to the achievement of specific savings targets for kW, kWh, and therms (for PY01 only, including possible bonus awards).
- **Progress Indicator-based milestones,** related to indicating market progress toward transformation of the market (used in PY02)
- **Expenditure-based milestones,** based on the utilities spending most or all of the approved program budgets (e.g., Aggressive Implementation or Performance Adders)
- **Miscellaneous milestones,** which include all those classified as Administrative, Base, Activity, or Market Effects milestones. Some were similar to Progress indicators, but were less directly “market progress” related.

The list of award types starts with the indicators most directly related to some of the end-goals or desired outcomes of programs; however, they are harder to measure and validate. Expenditure and miscellaneous mechanisms are easier to measure and validate, but reflect indicators less directly linked to outcomes and more geared to activities. Energy savings milestones perhaps most directly reflect one of the key outcome indicators associated with the programs. Progress indicator milestones explicitly recognize outcomes broader than energy savings, including market transformation changes related to supply chain effects and market progress. For the California project, across all the utilities and years, the SERA team checked 30% of the utilities’ milestone award claims worth 50% of the total claimed dollars for the period, providing a wide sample of award types, program types, and dollar awards at risk. The work took many months, and the records requested filled several dozen full-sized storage boxes.

Pros and Cons of Award Mechanisms
Inspired by the project work, the authors then reviewed mechanisms from the project and other states, and undertook work to analyze the strengths and weaknesses of alternative award mechanisms. Advantages and disadvantages of the various award mechanisms are assessed from two perspectives – from the perspectives of:

- providing a performance incentive and
- verifying achievement.

There are pros and cons in the ability of the award mechanism to encourage effective progress in the delivery of energy efficiency services and programs by the utilities (first perspective). Secondly, there are advantages and disadvantages in terms of how readily and unambiguously the activities can be verified (second perspective). Overall, the question is whether the metrics carry forward the original intent related to comprehensive, effective, and efficient service delivery of programs; whether it leads to well and directly carried out program and service activities delivering this service; and whether those efforts and intentions can be well reflected and demonstrated with reasonable documentation.
Each award mechanism has advantages and disadvantages; none is perfect. Those mechanisms directly requiring delivery of energy savings may be harder to demonstrate and verify. Those addressing “activities” may be easy to verify but may suffer from difficulties in that activities may not be effective at capturing energy savings. Further, the ease of verification is affected directly by the quality and comprehensiveness of records maintained and analyses conducted by the utilities. Incentives need to address the cost of this data collection, or the utilities may find it is not worth pursuing particular activities or goals if the cost of recordkeeping is too high. Although utilities may wish to be reimbursed on the basis of activities (reflected through costs incurred), a balance may need to be achieved between demonstrating efforts and effects. Advantages and disadvantages of each award mechanism are summarized in the tables to be presented in the Poster session.

Summary And Recommendations
The authors examined the strengths and weaknesses of the different award mechanisms from the perspectives of encouraging good performance and the ability to verify performance. The review included an analysis of achievements under a variety of award mechanism designs used in California over a period of years. Based on this analysis, verification issues could be addressed from both a conceptual side and a practical side, and detailed results presented at the Poster session. As discussed, the ability to verify is affected by several factors: the specificity of the intended goal or achievement, the utility’s assessment of the cost to implement and maintain an appropriate tracking methodology and the quality of tracking mechanism they implement as a result; and the work involved in the actual verification. As a result, the utility’s incentives for pursuing particular goals are affected by the incentive or award, balance by the cost to achieve and monitor. Therefore, incentives need to be designed to take all these issues into account. Overall, the results of the review indicate that each

type of award mechanism was more suited to meeting different types of program goals. However, common themes related to what works included:

- For savings based awards: verification of saving levels is difficult; therefore, clear, approved, or commonly accepted savings and lifetimes for buildings and measures need to be agreed upon at the beginning of a program
- For progress / accomplishment based awards: the relevant indicators can be derived from program theory and logic; however, best efforts being utilized toward an end was not an easily independently verified award mechanism.
- For expenditure based awards: the acceptance of committed funds in a program year led to verification difficulties and left questions related to the degree of follow-through in completing committed projects.
- For miscellaneous milestone based awards: again, they can be derived from program theory/logic and clear dollar amounts for attaining well defined and easily documented activity or other milestones proved highly effective; however, electronic databases as a verification requirement left room for uncertainty.

In constructing award mechanisms, outcomes are very important; however it is also important to acknowledge that efforts are what incur costs. Given this, and the fact that there are inherent risks that even good-faith efforts will not always result in the expected levels of outcomes, the best basic concept may be expenditure-based awards requiring that either energy savings or progress milestones[3] be established and achieved in order to be eligible for the award. For example, such an award might be structured as follows:

- If 2 GWh of savings are achieved (or 5,000 meters installed), the utility receives an award of an additional 30 percent on the first $1 million in expenditures, and an additional 5 percent on the remaining expenditures.
- If 3 GWh of savings are achieved (or 10,000 meters installed), the utility receives an award of an additional 40 percent on the first $1 million, 25 percent on the second $1 million, and 5 percent on the remaining expenditures.

This general type of structure may constitute a candidate for the next generation of awards by providing an incentive for greater achievement by having the award increase with greater accomplishments. It may also encourage efficiency by having the magnitude of the incentive decrease with each increment of financing required to achieve the specified result.

Finally, in addition to assessing the structure of award mechanisms, the review also led the researchers to provide suggestions about the actors that should be involved in designing mechanisms. There may be issues that arise from the involvement of the utilities in the initial establishment of the mechanisms and details of the awards (i.e. energy savings per CFL, and threshold levels). It may be that these should either be written purely by the government agency responsible, or by the agency in conjunction with an independent contractor that has no conflict of interest with any potential recipient of the awards – with review and consent by the utilities. Review by the utilities can provide valuable input on: whether the ultimate metrics are cost-effective, potential monitoring costs or monitoring (M&V) options, adequacy of incentives, risks related to timeliness of awards, and other factors.

The authors are continuing to review award mechanisms from other states to identify strategies that provide the most effective balance of incentives and verifiability for awards for good performance in delivering effective energy efficiency services. This work helps provide a basis for consistent and effective design of award mechanisms in the future.

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Non-Energy Benefits: Measurement and Applications in Energy Efficiency Evaluation

Measurement of NEBs

NEBs are becoming more recognized as relevant omitted program effects in evaluation. NEBs include a variety of program impacts– positive and negative – that are beyond energy savings and result from the program.[4] Starting with work in the mid-1990s, the literature began to sort these benefits into three "perspectives" (See Reference [6]):

- Utility / Agency NEBs: Net benefits accruing to the utilities or program-sponsoring agency, including fewer billing-related calls and other follow-ups, lower bad debt from unpaid bills, lower T&D losses, and other benefits, which result in lower revenue requirements for the agency, and are appropriately valued at the agency's marginal cost and discount rates.
- Societal NEBs: Net benefits beyond those accruing to the utilities / agencies or directly to participants, including economic multipliers or job creation benefits, reduced environmental impacts from emissions, and other benefits valued at societal costs and discount rates.
- Participant NEBs: Positive and negative impacts that are realized and recognized by program participants. For residential buildings these translate to greater comfort, lower noise, and a variety of other benefits for residents. For commercial applications, they may include comfort, fewer tenant complaints, better ability to sell or lease the property, productivity, fewer lost days at work, and many others. These effects are measured using valuation methods appropriate to the residents or owners.

Many of the net effects in the first two categories can usually be measured using programmatic, utility, and secondary data.[5] However, measuring the effects realized by the third category – participants – is more complex. The benefits to participants derive from several main "drivers" – specifically "net" impacts from:

- Payment and collection-related effects,
- Education and knowledge of energy use, building, and equipment,
- Changes in Building stock / building value,
- Health-related changes,
- Direct and indirect changes from equipment service (including comfort, O&M, services, etc.)
- Changes in other utility bills (e.g. water bills, etc.), and
- Other changes.

Well-researched measurement work on NEBs, based on detailed literature research were pioneered in the late 1990s, and followed up with detailed research over the last ten years.[6] Granted, NEBs are, almost by definition, Hard to Measure (HTM); however, not measuring the effects means that decisions about programs are likely to be suboptimal because they ignore the effects. Running scenario analysis around ranges or order of magnitude values would be preferable to excluding the impacts altogether. Thus, approximate estimate provide value; the improving sophistication of measurement methods implies that these approximations are getting better and better.

To provide credible estimates of the participant NEBs actually attributable to the program, the results must be "net" and represent only the effects due to the program or measure – above and beyond what would have occurred without the program. The authors have addressed these concerns in important ways, presented in the Poster. The authors have also researched, tested, and applied a number of measurement methods for estimating NEBs. These include:

- Willingness to pay (WTP) / Willingness to accept (WTA) / contingent valuation (CV),
- Comparative and scaling approaches,
- Direct measurement and regression approaches,
- Discrete choice, ranking, and logit methods,

[4] The literature historically calls these effects "non-energy benefits" even though they may be negative in the "net". There have been several suggestions to call them non-energy effects or non-energy impacts (See Reference [3]), using the traditional term better respects the literature, and there is nothing lost by calling them net-NEBs or NEBs, and the literature remains more robust.

[5] A model for estimating all three categories of NEBs has been developed ("NEB-It ©SERA) and results from programs using this model will be demonstrated at the poster session.

[6] Measurement methods have been discussed in detail in previous papers including in References [5] and [7]. Choice models have also been applied in several projects, including projects in this paper, with strong results. Results for this paper were gathered via phone, in-person, fax, and web approaches.

- Other revealed and stated preference approaches, and
- Other approaches.

Each method has advantages and disadvantages, and an assessment of the advantages, disadvantages, and illustrative outcomes are presented as part of the poster session.

The authors have conducted detailed work on NEBs for scores of residential, commercial, and other programs (low income, renewables, real-time pricing, commissioning, etc.). The findings have demonstrated that the total of NEBs from the three perspectives can easily exceed the value of the direct energy savings from the program. Although NEBs from the utility point of view tend to be small, extensive work by the authors on the societal benefits and the participant benefits show estimated NEBs to range from 25% to 400% of the value of program savings, depending on the program design, measures included, region of the country, and other variables. NEBs are a significant and measurable omitted program effect.

Application / Uses of NEBs

Typical process evaluations examine program design, delivery, and progress in an array of program progress indicators. They gather scalable responses on program awareness, understanding, strengths, weaknesses, barriers, and provide feedback on decision-making factors and a variety of other program feedback. While typical process evaluations can provide input to many “researchable questions”, the answers relate mostly to “more” vs. “less” of an effect – and fall critically short of providing quantitative information that would help inform their importance or identify which, if any, next steps are warranted (and cost-effective).

The work in non-energy benefits (NEBs) has progressed to the point where it can fill this gap and go beyond typical marketing, targeting, and benefit-cost applications. A well-designed analysis of NEBs provides key *quantitative* information on program strengths, weaknesses, and decision-making factors that are not typically outcomes of process evaluations. State of the art practices in NEBs measure net NEBs in the sense that they:

- measure both positive and negative NEBs,
- net of the impacts that would have been realized from the choice of new standard efficieny equipment, and
- measure the impacts above and beyond what would have been experienced without the program (net of free riders).

Measured well, the positive impacts provide dollar values of the value of the program’s benefits. More importantly, the negative impacts provide dollar estimates of cost of remaining “barriers” participants and non-participants associate with the equipment that are not addressed by the program. Recent research by the authors illustrates the point, providing quantitative estimates of the dollar value of remaining maintenance, labor, and other barriers for several programs. These estimates provide dollar estimates of the unaddressed barriers, and thus provide estimates of the investment that might be needed to address those barriers. Program planners can then make intelligent decisions whether to address the barriers, given the investment requirements indicated. This is far more practical and valuable than standard process evaluation feedback that notes a barrier score has fallen from, hypothetically, 3.3 to 3.2 on a 5 point scale. Finally, NEB analysis can show the degree to which program information is getting to key program actors – and the degree to which the understanding of measure features is leading to underinvestment in efficiency.

Drilling Down in NEBs: Applications and Implications

Analysis of NEBs has wide applications beyond the simple “valuation” of the NEBs. Examining the perceptions of NEBs that are positive and negative, and those that are most valuable, provide information important to program evaluation, decision-making, marketing, and other applications.

- **Marketing and Targeting**: Highly valued NEBs are likely easier to “sell” than energy efficiency, and more importantly, they are likely to appeal to owners or decision-makers. Tailoring the program message to the high scoring NEBs for the audience of interest is potentially more fruitful than continuing to push energy efficiency on efficiency or bill savings grounds. Furthermore, the research on NEBs identifies those participants that gain the highest NEBs, which can provide information for targeting the program.
- **Benefit-Cost**: The NEB values provide information for the benefit/cost analysis and payback computations from participant point of view, and may be useful as inputs for scenario analysis around regulatory tests as well. Some states are looking into scenario analysis around program benefit costs analysis.

- **Barriers Analysis**: Negative benefits are indications of program barriers that remain – either perceived or real (or both) depending on which actors report the negative NEB. If non-participants or vendors report a negative NEB but the participants do not, then the program may benefit by providing greater education or data on that factor. The program would likely obtain more applicants, and the vendors may be able to make a stronger case for the energy efficient equipment. If, however, the barrier represents a real cost – if participants or others (A&E, contractors) notice the problem as well – the NEB results provide an estimate of the cost of the rebate, refund, warranty buy-down or other interventions that may help participants become indifferent to the barrier – and spur participation and adoption of new measures. Tracking these negative values over time provides useful information feedback to let program staff check whether the program is decreasing these barriers over time.[7] The dollar value provides information on the level of investment that may be needed to overcome the barrier.
- **"Disconnects"**: The authors believe a robust evaluation of the NEBs gathers information from multiple actors involved in the program, as well as non-participants. These results allow an examination of differences in positive and negative perceptions about NEBs as well as differences in associated values. Using this approach, our work has been able to identify situations in which architects / engineers / contractors assign more "negatives" to NEBs than do owners – leading to underinvestment in energy efficiency. The implication is that bids and construction may be including less energy efficiency than owners might be willing to "buy". Additional education, incentives, or other program interventions targeted at those with more skepticism may aid the program; feedback on the owner perspective may also help.

The work shows that "hard to measure" NEBs can be measured in all three perspectives – utility, societal, and participant. The authors have applied this work to more than 50 residential, low income, commercial / industrial, and specialty programs. Examples of these applications are presented in the Poster session.

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[7] This feedback is potentially more useful than tracking barrier "scores", which provide less information on the importance of the barrier before or after.

Energy+ Pumps – Technology Procurement for Very Energy Efficient Circulation Pumps

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Abstract

Circulators in single or double family homes and flats cause about 2–3 % of the overall electricity consumption of the EU. A new technology of pumps with electronically commutated (EC) motor pumps is available now; it is one possible way to achieve a reduction in circulator annual electricity use by 60 % or more.

If these new very energy-efficient pump technologies became the new technology standard for circulators, they would save about 1 % of current EU electricity consumption, that is 25 TWh/year, and reduce CO_2 emissions by 10 million tons per year.

This paper gives an overview about the potentials, describes the technical background of the new technology and presents a new “Intelligent Energy - Europe” project that addresses these potentials.

The project’s objective is a market transformation towards new very energy-efficient pump technologies – Energy+ pumps – for circulators in heating systems, both stand alone and integrated in boilers. The most important market barrier is a high initial price due to low production numbers. Therefore, only few manufacturers have so far introduced the new pump technology to the market for single or double family homes and flats; among these, the two most important ones on the European market have recently launched it.

The short-term objective of the project is, therefore, to bring more products to the market from all major manufacturers, to contribute to their market success, and to reduce their prices through mass production. A conservative estimate is that the buyers aggregated by the project might purchase 10,000 Energy+ pumps during the project; this would save 2.5 million kWh per year. If at the end of the project, a market share of 5 % has been achieved, it will mean annual savings of 100 GWh/year from the products sold in that year alone.

In order to achieve its short-term objective, the project will adapt and apply the technology procurement methodology as it was very successfully tested in the European Energy+ project on energy-efficient cold appliances.

Large buyers, mainly (social) housing companies will be aggregated, to activate the pump and boiler manufacturers. Sales and training materials, and sizing spreadsheet software for installation contractors will be developed and applied. A competition both for energy-efficient products and marketing campaigns will be organised and the information on the Energy+ pumps will be disseminated widely through website, newsletter, media, and fairs.

Introduction

In the EU-15, the electricity consumption by circulators for heating purposes in households amounted to about 41 TWh per year in 1998 [1]. This is caused by 87 Million circulators, most of them with a power input below 250 W. But private households often do not even know that they have a circulator in their heating system, much less do they know that the circulator is responsible for 5 to 10 % of their electricity bill. As long as their rooms get warm, they don’t care about this and trust their installer that he or she installed a good system. The consumer does not know the electricity costs he or she has to spend for running the circulator and if he/she knew, he/she also might not care because the absolute amount of money of about, say, 60 Euros per year is not so high that the consumer would try to spend much effort to minimise this.

But for society the energy used by circulators is equal to between 2 and 3 % of the overall electricity consumption and causes CO_2 emissions of more than 20 million tons per year, so efforts to minimise this would be worthwhile both for economic and for climate-change mitigation reasons.

Potentials

A typical circulator used in European heating systems has a power input of 80 to 100 W. Several studies show that this is far oversized (e.g. [2], [3]). Installation contractors tend to install a big pump so as to receive no complaints from their customers; the contractors do not have to pay the electricity bill. Normally, a smaller pump would be sufficient in a heating system. An additional issue is the hydraulic balance: A correct hydraulic balance secures the same heat supply to all radiators. If the heat supply is uneven, a stronger pump will be necessary to compensate this. So, if the hydraulic balance were correct in a heating system, which is not the case under normal circumstances, even a smaller pump could be installed. For the above mentioned example, a circulator with 35 W will be sufficient [2].

For a number years, a new technology of pumps with electronically commutated (EC) motor pumps has been available. By this high-efficiency circulator, a reduction in circulator annual electricity use by 60 % or more is achievable. Fig. 1 shows a comparison of the possible savings compared to a typical situation.

By which technical measures has it become feasible to increase circulator energy efficiency? First, the motor efficiency of "conventional" asynchronous motors of the size used in small-scale circulators is around 50 %, whereas for EC motors, e.g., permanent magnet motors, this is around 60-80 %. In case the high-efficiency motor is, as the second measure, combined with an improved impeller design enabled by the high revolving speeds of the high-efficiency motor, the hydraulic efficiency can also be raised from on average 35 % to 60 %. Combining these two measures achieves a total circulator efficiency of approximately 40 %, compared to an average efficiency of 5 % to 24 % for circulators with asynchronous motors.

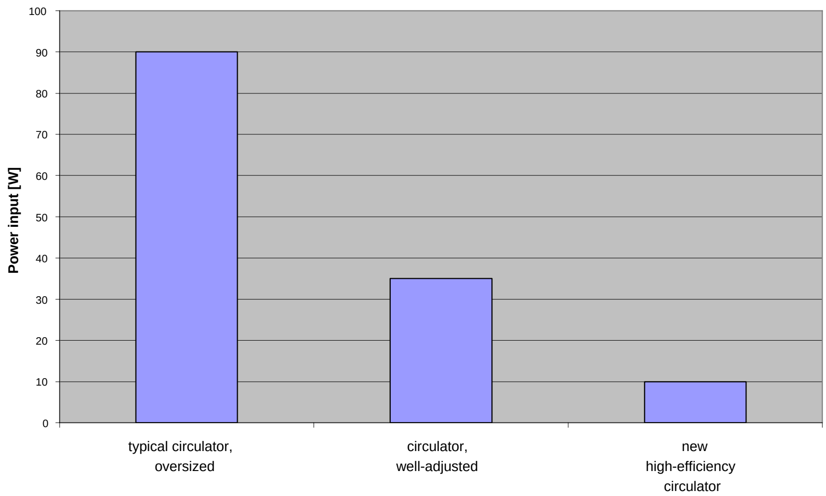

Figure 1: Comparison of the input power of different circulators. Source: [2]

This new high-efficiency circulator, that was first developed by the Swiss manufacturer Biral in 2000 and brought to the market soon afterwards (see Fig. 2), would save about 1 % of current EU electricity consumption, that is 25 TWh/year, and reduce CO_2 emissions by at least 10 million tons per year. For the first few years, this new pump was not very successful on the market. It was caught in a vicious cycle of high initial prices and low production numbers. Therefore, Biral remained for a number of years the only manufacturer to have introduced the new pump technology to the market for single or double family homes and flats. Only in the autumn of 2005, the two European pump market leaders, Grundfos and Wilo, entered the market with a similar pump. With an end-consumer price of about 300 Euros, the price is still high but much more affordable now.

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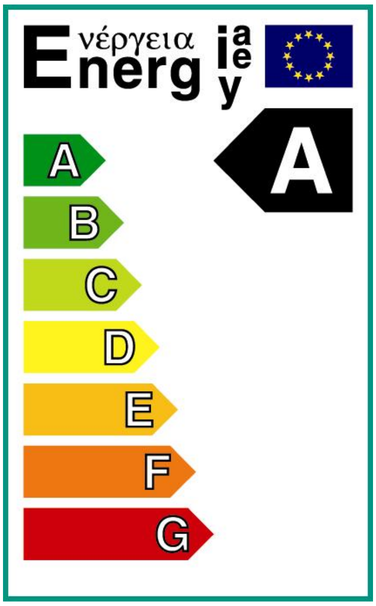
Figure 2: Swiss manufacturer Biral’s EC motor circulator for single family homes, and Grundfos´and Wilo’s actual product

The Europump label

Synchronised to the launching of the high-efficiency pumps in the market, Europump, the “European Association of Pump Manufacturers”, proposed a pump energy label similar to the European energy label for appliances. This label may act as a marketing instrument for the installation contractors and promotes the high-efficiency pumps, because only these pumps can achieve the A-label. But this label is voluntary and only new pumps are labeled. In addition it only covers stand-alone circulators, built-in circulators are excluded.



A	< 0,40	high efficiency drive
B	0,4 < EEI < 0,6	variable speed drive
C	0,6 < EEI < 0,8	unregulated
D	0,8 < EEI < 1,0	unregulated
E	1,0 < EEI < 1,2	
F	1,2 < EEI < 1,4	
G	1,4 < EEI	

Figure 3: The Europump Label Source: [4]
EEI = Energy Efficiency Index, calculated according to measurement standards and formulas described in [4]

The Energy+ Pumps project

Though the conditions for the introduction of the new technology in the market are given now, there exist a lot of barriers. Current market barriers include a high initial price (300 Euros) due to low production numbers, low customer interest caused by the fact that not the final customer but installation contractors or even boiler manufacturers are usually choosing the pump, and vendors selling to the final customer on product price only.
This is a notable difference to the market for medium-sized circulators (200 to 400 Watts of input power, for office and other larger buildings), for which major manufacturers (Grundfos, Wilo, Biral; KSB may follow) all have a range of EC motor pumps on the market. The reason is that this is a

market of institutional buyers that specify the pumps themselves and are used to economic calculations, hence easier to convince than the single homeowner.

Objectives of the project
This project will therefore mainly target the market for the small-scale circulators, to foster the market entry and uptake of these.
The **short-term objective** of the project is, therefore, to bring even more products to the market (at the end of the project we expect at least 10 pumps for space heating and sanitary hot water by at least 3 manufacturers, and at least 10 condensing or low energy boilers with the new pump built in), to support their rapid break-through in the market and thereby to reduce their prices through mass production. According to one manufacturer, an annual production volume of 30,000 to 40,000 pumps would be needed to start mass production and bring down prices.
We expect that the project will contribute to bringing small-scale Energy+ circulators to the market for single or double homes and flats from all major manufacturers, and to reducing the price premium over conventional electronically controlled circulators for that market to less than 50 % or 60 Euros. A conservative estimate is that the buyers aggregated by the project might purchase 10.000 Energy+ pumps during the project; this would save 2.5 million kWh per year. If at the end of the project, a market share of 5 % has been achieved, it will mean annual savings of 100 GWh/year from the products sold in that year alone.

How to achieve the goals?
This will be achieved through the **methods of technology procurement** that have been successfully tested in the European Energy+ project for energy-efficient refrigerators and freezers, co-funded by the SAVE programme (cf. [5] and [6]).
The project will, therefore, bring together institutional buyers such as housing companies, intermediate buyers such as boiler manufacturers, installation contractors and their associations, and pump manufacturers to build mutual trust:

- confidence for the pump manufacturers in the existence of a market demand large enough to start mass production,
- confidence for installers and boiler manufacturers that it will be feasible and easy to convince final buyers of the benefits of the new pumps,
- and buyer awareness of the benefits of the new technology and confidence that a supply at appropriate prices will be feasible.

The methodology of technology procurement therefore implies an active co-operation with the following target groups.

- On the demand side of circulators: particularly large institutional buyers to sign procurement declarations, but potentially all building owners as purchasers of the new kind of pumps, or boilers that have these pumps built in;
- On the supply side of circulators: pump and boiler manufacturers, as well as installation contractors and their associations;
- For support of the dissemination of information: further national, regional, and local energy agencies than those already in the consortium, environmental and consumer NGOs, energy companies, associations of building owners and market participants, and other organisations interested in the subject.

Potential large institutional buyers will be approached and invited to sign a procurement declaration. This will either concern an indicative number of pumps, e.g., for replacement, or of boilers that have the new pumps integrated. Final customers buying such pumps in larger quantities could be big housing companies. Apart from bigger multifamily buildings where the bigger pumps are needed, they may also have blocks of smaller multifamily or even row houses, or they may have heating systems by apartment (with wall-mounted boilers). In the bigger multifamily houses, such small pumps could be used in sanitary hot water circulation systems. Although the small circulators are at the focus of this project, the procurement declarations could also include medium-sized circulators (200 to 400 Watts of input power, for office and other larger buildings) used in bigger apartment blocks, in order to achieve synergies.

The **pump manufacturers** will be invited to develop and launch to the market pumps fulfilling the criteria developed by the project, and to present them to the Energy+ team for inclusion in lists of qualifying products. They are also expected to actively market their products once they are on the market.

Boiler manufacturers will be contacted, too. They are in an intermediate position as buyers of the pumps, but manufacturers of products that are sold to the final customers. Hence, they must see a potential market for boilers with the efficient pumps integrated, in order to become buyers for the pumps. The project will build their trust in such an initial market.

Finally, further energy agencies, environmental and consumer NGOs, energy companies, associations, and other organisations interested in the subject will be invited to support the project with publicity. Governments and energy companies might also support the market uptake of the new pumps with financial incentive programmes. This will **indirectly** target the whole market of **all building owners** in order to achieve a wider market break-through for the new energy-efficient circulators.

To further support this process and increase sales volumes, **installation contractors** must be integrated in the project. They too must be convinced that there is a market for the new pumps and that it is worth the effort to actively sell them to their customers. For this purpose, they must receive easy-to-use materials to convince their customers and be trained about selling the efficient pumps based on life-cycle costs. In order to achieve synergies, this will cover both the small and medium-sized circulators.

The project will actively co-operate with professional training agencies, institutes and organisations, associations of installation contractors, and pump and boiler manufacturers to organise the training seminars.

None of the primary market agents (buyers, manufacturers, installers) are Members of the Consortium. The reason is that the Co-ordinators of a technology procurement at European and national level must be **independent** from those directly involved in the target market.

All of these market agents will furthermore be **actively involved in the project from the beginning**. Their interest in the project and its objectives will be stimulated during the first work package with direct information and interviews. They will then be invited to sign procurement declarations, support declarations, or to file products to the lists. The participants and products will be featured on the website and the other publicity organised by the project. As has been described above, the different target groups – manufacturers, supporters, associations of installers – will also be actively involved in the dissemination of project results.

The project will also enable a field-test of the appropriateness of the method for classification of circulators proposed by the European manufacturer organisation Europump. The consortium will also actively seek to co-operate with Member State governments and energy suppliers about potential financial incentive programmes and awareness campaigns. E.g., the new pumps could be targets for energy efficiency programmes in the framework of the Italian White Certificate system, or the obligations for Flemish grid companies, or the Energy Efficiency Commitment in the UK.

Furthermore, in the context of the EU Directive on the overall energy performance of buildings, reducing the electricity consumption for the circulator will make it easier to achieve the primary energy performance targets for new and refurbished buildings. A close link is also intended to other planned EU projects on related subjects.

The **ultimate long-term objective** is to transform the market so that the new technology will become the standard technology, at prices close to those of today's pumps. This seems feasible, since the new technology enables smaller pumps and hence requires less material, and the extra costs of the electronic controls are constantly decreasing.

The project consortium

Many members of the consortium for this project (7 out of 10) have been partners to the recent Energy+ projects on household cooling appliances ([5], [6]).

Figure 4: The Energy+ logo

The consortium was rounded off with SEVEn to represent the Czech Republic, Escan to represent Spain, and DENA to organise the award and share with the Co-ordinator the national work in Germany.

All in all, the team consists of:

- seven national energy agencies, who have a lot of experience in working with market actors on the dissemination of energy-efficient technology, and of which four were already partners to the Energy+ cold appliances project; one of the agencies (ADEME) co-operates with the subcontractor SOWATT, which was assisting the agencies leading the last Energy+ project;
- two research institutions that were partners in the Energy+ cold appliances project and have worked on applied energy efficiency research for at least 10 years;
- and a company that has a lot of experiences in energy efficiency markets as well.
- Furthermore, the Swiss company ARENA will co-operate with this project as an external partner, acting as the national procurement Co-ordinator for Switzerland.

The team also represents all regions of the EU-25, and 9 countries with a total of around 120 million households.

The following table presents an overview of the roles of the partners in the project.

Table 1: Partners of the Energy+ project

Partner	**Role in the project**
Wuppertal Institute	Project Co-ordinator; shares national procurement co-ordination for Germany with DENA
A.E.A	national procurement Co-ordinator for Austria
eERG	national procurement Co-ordinator for Italy
VITO	national procurement Co-ordinator for Belgium
CRES	national procurement Co-ordinator for Greece
Escan	National procurement Co-ordinator for Spain
SEVEn	national procurement Co-ordinator for the Czech Republic
MOTIVA	National procurement Co-ordinator for Finland
DENA	shares national procurement co-ordination for Germany with the Wuppertal Institute
ADEME	National procurement Co-ordinator for France
SOWATT	*Subcontractor of ADEME*
ARENA	External national procurement Co-ordinator for Switzerland

Work Programme

The first project phase will be a market and feasibility study (work package 2), for which 8 months are planned. The market and feasibility study needs to fine-tune the methodology of co-operative procurement to be used during the project and to define the energy+ product criteria. With interviews and market research, the market structure and the barriers for the market introduction and diffusion of the new circulator technology will be analysed. Furthermore, the willingness of the market players to co-operate in the technology procurement will be assessed. Based on this research, the methodology developed in the Energy+ project on cold appliances will be refined and adapted to the pump market.

After these preparations, the second project phase will implement the technology procurement for 28 months until the end of the project. This phase includes the work packages 3 (implementation of the technology procurement with buyers, manufacturers, and installation contractors as well as supporters, development of lists of qualifying products, interested buyers, and supporters eager to promote the products, and development and application of sales and training materials and a training course for installers), 4 (award, given to the most energy-efficient products and the best promotion campaigns; also including an independent test of products, likely to include the award winners), and 5 (dissemination through website with product and participant database, newsletters, brochure, and a wide media coverage organised by the partners as well as the supporters).

During the last 6 months of the project and in parallel to the second phase, an evaluation of the project and its impacts will be carried out (work package 6). It will provide the basis for the final report.

Overarching these three phases are the work packages 1 (project management) and 7 (common dissemination activities upon request of the European Commission).

The following flow chart provides an overview of the structure of the Energy+ pumps project and the interaction of its work packages.

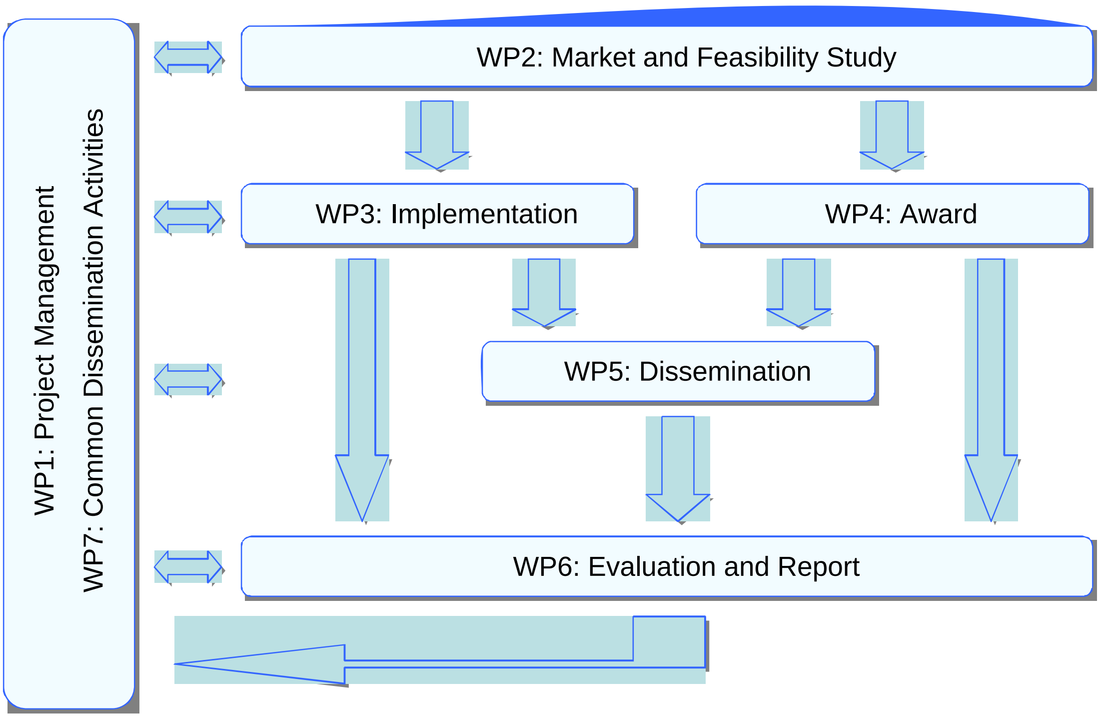


Figure 5: Flowchart of the energy+ project

Conclusions

Since the Energy+ Pumps project has only begun in January of 2006 and is at the time of the EEDAL conference at the stage of the feasibility study, it is to early to draw conclusions on the success of the project. We therefore wish to give some indications on why we expect it will not fail.
There are only two critical steps where the project could fail: if either no manufacturers would list their products, or no institutional buyers would declare their interest in purchasing the new, energy-efficient pumps and boilers.
However, based on the experiences with the Energy+ project on cold appliances and on preparatory talks with market players for circulators, we are confident that the technology and market procurement approach of the Energy+ project will also work for the circulators.
For cold appliances, the Energy+ project started with two products from one manufacturer on the first list and ended with almost 900 models from 21 manufacturers. This is unlikely for circulators since there is only a handful of manufacturers and a smaller range of product types, but leads us to the expectation that there will be interest from manufacturers for this project too. This is shown by letters of support from three manufacturers and the fact that two major manufacturers have recently launched small EC motor circulators.
On the buyer side, the Energy+ project for cold appliances attracted around 20 institutional buyers owning more than 1 million dwellings, and dozens of retailers with more than 15,000 retail outlets across Europe. Installation contractors and boiler manufacturers are playing a similar intermediary role for the circulator pumps, as are the retailers for the cold appliances. We will, therefore, involve these two types of market actors from the very beginning.
The success of Energy+ among housing companies also shows that it will be feasible to overcome the problem of split incentives between landlords and tenants. This will certainly be easier in a market with a surplus of apartments for rent, and/or a building certification in place, where the energy costs are important for the ability to rent out apartments.

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Energy Consumption and Efficiency Potentials of Lifts

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Abstract

Lifts can account for a significant proportion of energy consumption in buildings. In a research project that was concluded in 2005, the energy consumption of 33 lifts from a variety of manufacturers was measured. The most important finding concerned the surprisingly high stand-by consumption, which accounted for between 25 and 80 percent of the total consumption. Average efficiency rates were favourably high at around 60 percent. One notable finding was that modern hydraulic lifts can be just as efficient as traction lifts thanks to the use of counterweights or energy storage. Overall efficiency shall be achieved by reducing stand-by consumption and using energy-efficiency concepts and criteria for architects, designers, planners and customers.

Current situation, objectives

The electricity consumption of lifts is dealt with in the new SIA standard 380/4 ("Electricity in buildings") [1], and is also an integral part of the declaration of overall energy consumption by building systems (energy certificate for buildings). A research project that was concluded at the end of 2005 [2] set out to extend the somewhat limited knowledge about the electricity consumption of lifts by carrying out measurements. The broad-based project team was supported by the lift industry in that Schindler Aufzüge AG provided technical assistance while seven other manufacturers provided the necessary local support for the measurements.

Project partners

- Swiss Agency for Energy Efficiency (S.A.F.E.), project management
- Swiss Federal Office of Energy, SwissEnergy programme
- Swiss Society of Engineers and Architects (SIA)
- City of Zurich civil engineering office, and energy-efficiency fund of the City of Zurich electricity works (ewz)
- Office for Environmental Protection and Energy (AUE), Basel-Stadt
- Schindler Aufzüge AG
- Other companies affiliated to the Association of Swiss Lift Manufacturers (VSA)
- S.A.L.T. (Swiss Alpine Laboratories for Testing of Energy Efficiency], Chur), implementation of measurements

The main objectives of the project were to determine the level and structure of electricity consumption by lifts in Switzerland and to identify efficiency measures and ways of implementing them in various situations. For measurement purposes, typical lift systems in use in Switzerland were classified by type, size, building type and lift properties (Table 1, Figure 1).

Table 1:No. of measured lifts by year of manufacture and building category

Year of manufacture	**Prior to 1980**	**1980 - 1997**	**After 1998**	**total**
Residential buildings	1	1	12	14
Hospitals/clinics	-	2	1	3
Shops	-	-	1	1
Office blocks	1	2	5	8
Car parks	1	-	3	4
Industrial buildings	-	1	2	3

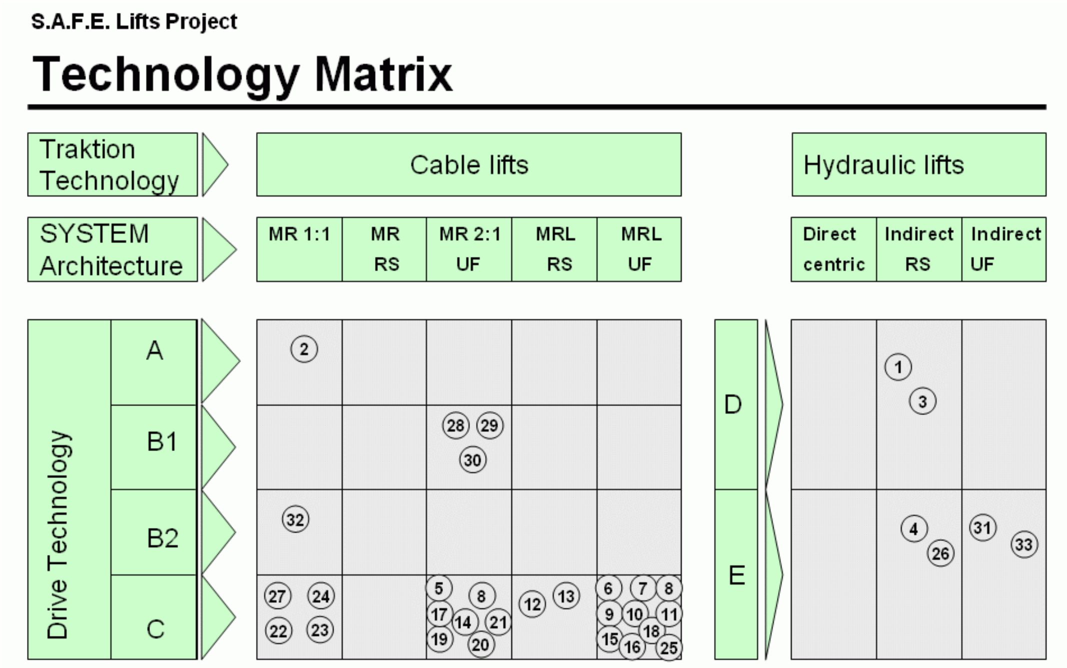


Figure 1: Measured lifts (technology matrix). Circled figure = project no. of lifts

Key to technology matrix:

Traction lifts:

A		Worm gearing with AC motor for fine adjustment (2 speeds)
B1		Gearing with AC motor, voltage control
B2		Gearing motor, with frequency converter
C		Gearless drive, permanent-magnet motor with frequency converter
MR 1:1	=	Lift with machine room, cabin suspension 1:1 (direct, centrical)
MR / RS	=	Lift with machine room, direct eccentrical suspension (“backpack”)
MR 2:1 / UF	=	Lift with machine room, suspension via rollers beneath cabin / 2:1 indirect suspension (lower block)
MRL / RS	=	Lift without machine room, with eccentrical suspension
MRL / UF	=	Lift without machine room, suspension via rollers beneath cabin

Hydraulic lifts:

D/E		Hydraulic valve control
Direct centrical	=	Central hydraulic hoist beneath cabin
Indirect RS	=	Hydraulic hoist beside cabin, suspension indirect via roller on hoist
Indirect UF	=	Hydraulic hoist beside cabin suspension, indirect via roller on hoist, suspension 2:1 via rollers beneath cabin

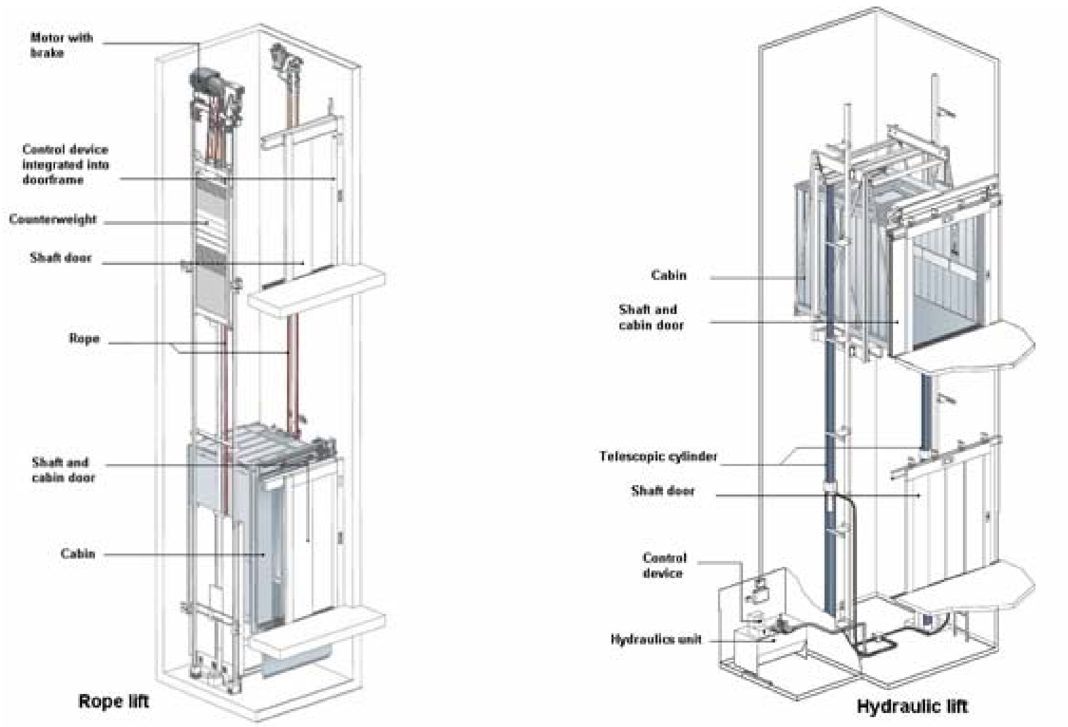


Figure 2: Diagram showing construction of modern lifts. Source: Schindler Aufzüge AG

Measurements

To measure the energy consumption while in operation, each lift was put through a single travel cycle (ascent and descent) while empty, and its stand-by consumption was measured. In this way the minimum and maximum loads were recorded. Due to the extremely wide range of loads, the demands placed on the measuring equipment were very high: it was necessary to work with mobile recording devices that were easy to install, covered a range from a few watts in stand-by mode up to 30 kW three-phase, including negative feed for recuperation, and guaranteed a high degree of accuracy. On top of this, the relevant safety requirements also had to be met. The readings per travel cycle were recorded three times per second in order to ensure that peak levels due to acceleration were included in the measurements.

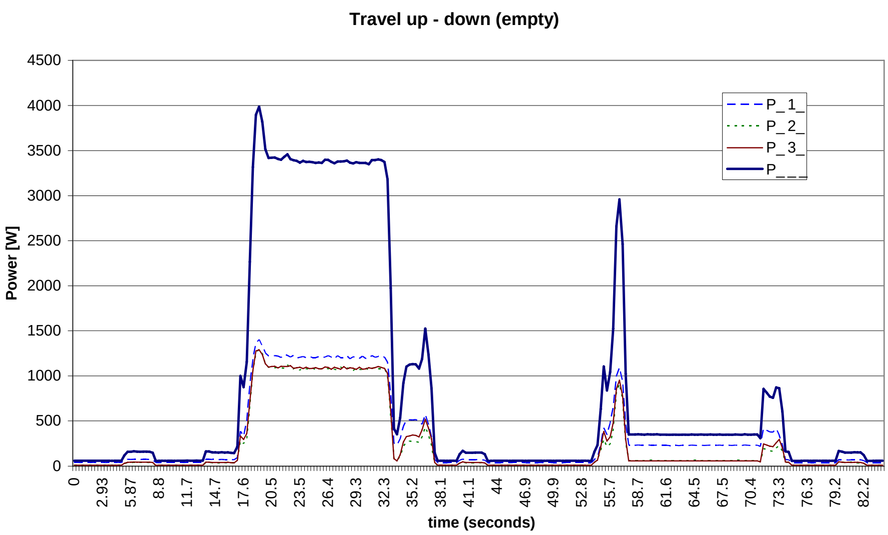


Figure 3: Readings for travel cycles of a traction lift (when empty) with counterweight.
P (strong) = total load, P_1/2/3 (thin/dotted) = 3 phases.

The graph in Fig. 3 depicts the typical readings for travel cycles of a traction lift (when empty) with counterweight. The segments before and after the almost constant hoist segments show highs and lows (due to acceleration and braking), and minor loads due to door operation are also visible.
In order to determine the energy consumption for standard usage (representing typical use) from the highs and lows recorded during ascents and descents over the full hoist height, the calculation method defined for SIA standard 380/4 [1] was applied. This method describes load factors and the proportion of corresponding travel cycles by drive technology, as well as a hoist height factor, so that the energy required for moving the lift can be calculated using the maximum hoist height, motor output and travel speed, as well as the number of travel cycles; stand-by consumption can be calculated on the basis of the corresponding power consumption and 8,760 hours of operation.

Stand-by and travel-cycle energy consumption

The number of travel cycles is the decisive factor for determining the energy consumption of a lift in motion. For all lifts in the study (with the exception of 5 brand-new ones), this figure was obtained by evaluating the travel cycle meter, and was used for calculating the energy consumption (Fig. 4). The figures thus obtained were used in the calculation for standard usage by type of building in accordance with SIA standard 380/4: 60,000 for residential buildings, 200,000 for office buildings. The results can vary enormously, even for the same types of buildings.

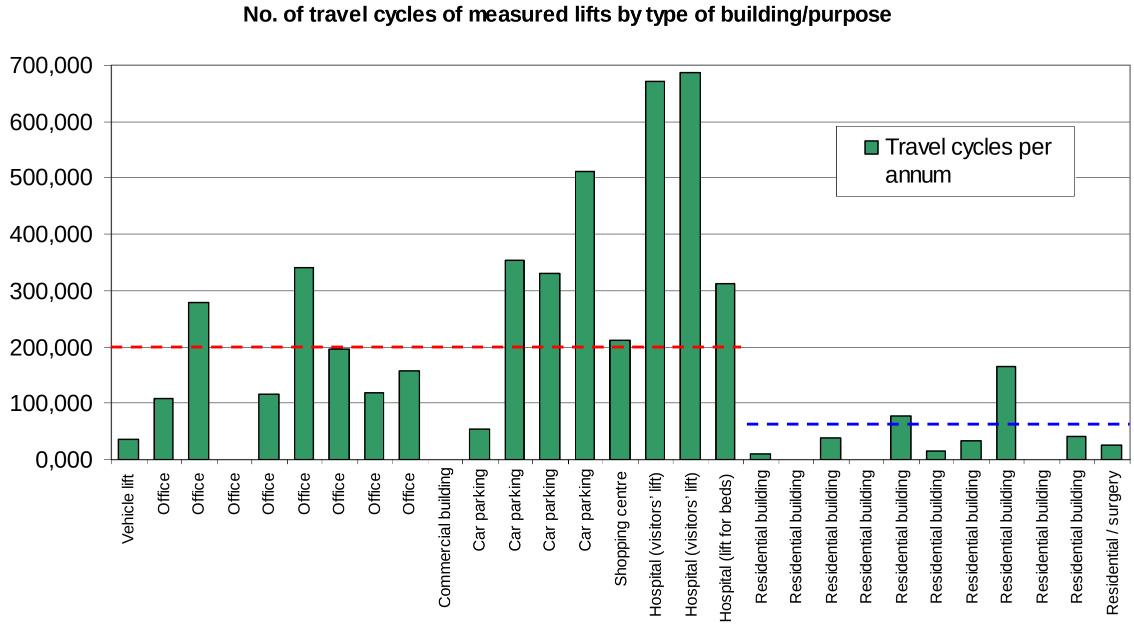


Figure 4: Travel cycles of measured lifts by type of building

To compare stand-by and travel-cycle consumption (Figs. 5 and 6), the annual travel-cycle energy consumption ($E_{F,a}$) was calculated as follows, in accordance with the method defined in SIA standard 380/4:

$$\boxed{E_{F,a} = \frac{Z_F * k1 * k2 * h_{\max} * P_m}{v * 3600}}$$

$E_{F,a}$ Energy requirements for moving cabin (travel cycles) in kWh per annum
Z_F Number of travel cycles per annum
k1 Average load factor (technology factor):
rope traction 0.35 (with recuperation 0.21), hydraulic w/o counterweight 0.3
k2 Hoist height factor, average/maximum hoist height = 1 if 2-storey, otherwise 0.5
h_{max} Maximum hoist height, between lowest and highest stop, in metres
P_m Motor output (as a rule, nominal output as per rating plate), in kilowatts
v Speed in metres per second.
Formula “1/(speed * 3600)” indicates the travel time in hours (simplified!)

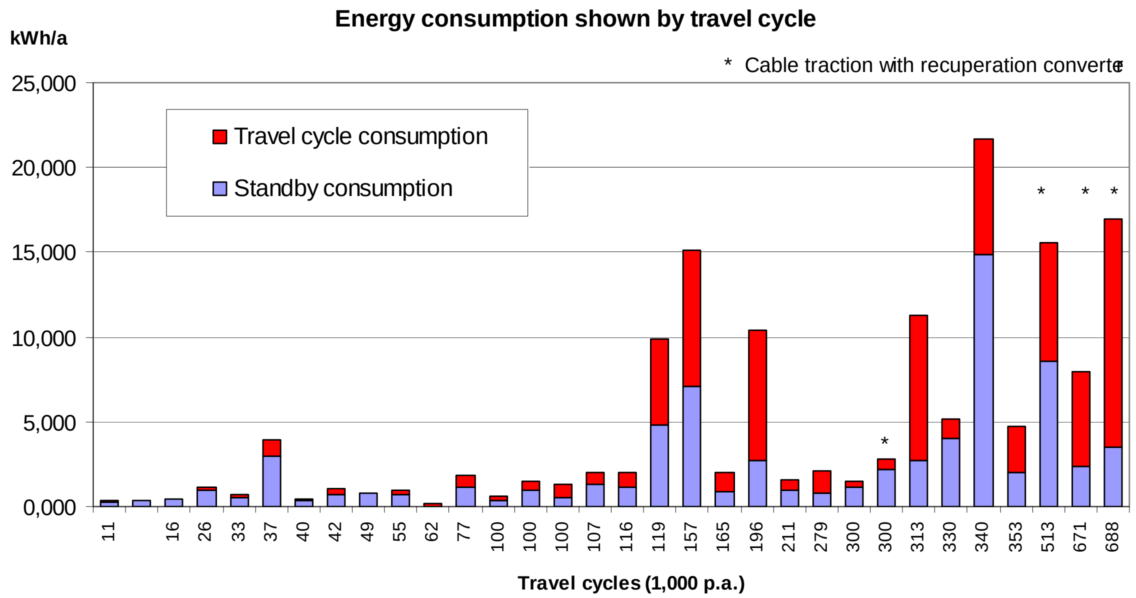


Figure 5: Stand-by and travel-cycle energy consumption of lifts by number of travel cycles; travel-cycle consumption calculated using the above formula. Lower travel-cycle consumption despite a higher number of travel cycles may be attributable to nominal load, motor output and hoist height. No basic conclusions can be made.

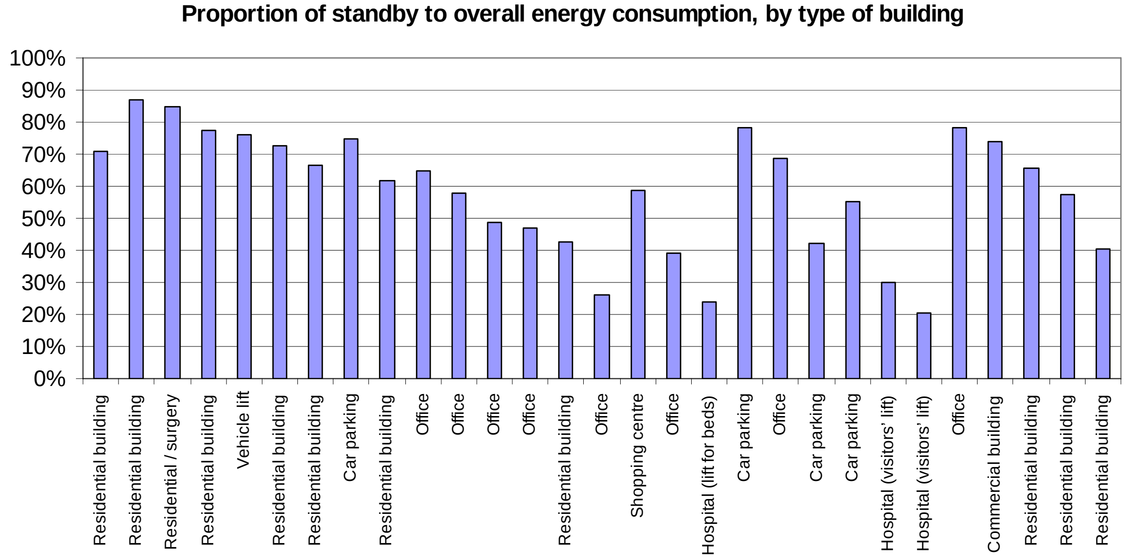


Figure 6: Proportion of stand-by to overall energy consumption, by type of building, sequence as in fig. 5, except 3 lifts where not applicable. Figures below 30% indicate systems with very high numbers of travel cycles.

Efficiency of lift drives

By using the method for calculating drive energy consumption per travel cycle as defined in SIA 380/4 [1, 3] it was possible to measure the efficiency of the drives of the lifts included in the study on the basis of fundamental physical data (hoist height, cabin weight, speed). For this purpose, the “load cycle” data with maximum motor output were used. In the case of traction lifts, this concerns the descent when empty (due to the counterweight); in the case of hydraulic lifts without counterweight or air accumulator, this concerns the ascent with nominal load. The figures thus obtained indicate an uncertainty factor, since the exact cabin weights were not known. The calculated average degree of efficiency was 60 percent, which was in line with expectations. The efficiency rates for hydraulic lifts with counterweight were similar to those for traction lifts. Measurements concerning lifts with recuperation (which require significantly higher investments) were of particular interest. Degree of recuperation refers to the ratio of recuperated energy during ascent divided by the required energy during ascent and descent. For the 5 lifts with recuperation, the readings varied from a disappointing 9 percent up to a satisfactory 47 percent. Here too, careful optimisation appears to be essential in order to utilise the technical potential.

Projection and composition of consumption

The analysis of the electricity consumption per travel cycle and year for typical traction lifts resulting from the measurement campaign (Table 2) allows for a comparison of energy requirements. But as the measurements indicated, significant variations may occur in some systems for a variety of reasons.

Table 2: Energy consumption of typical traction lifts (type C as per Fig. 1)

Type of building/purpose	**Capacity**	**Speed**	**No. of stops**	**Wh per cycle**	**No. of travel cycles p.a.**	**kWh p.a., including stand-by**	**% in stand-by mode**
Small apartment building:	630 kg	1 m/s	6	4	40,000	950	83%
Office block/medium-sized apartment block:	1,000 kg	1.5 m/s	8	13	200,000	4,350	40%
Hospital, large office block:	2,000 kg	2 m/s	12	19	700,000	17,700	25%

The projection in Table 3 shows that 58 percent of the energy consumption of lifts is attributable to stand-by mode. This figure would be even higher if similar systems that are not covered by the Lifts Ordinance (e.g. inclined haulage, stairlifts – which have relatively low utilisation frequencies) were included in the projection.

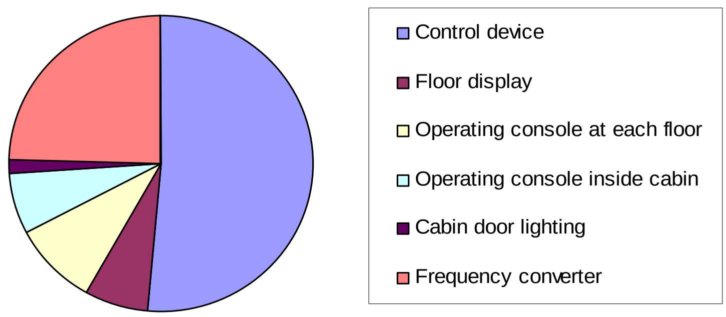
Table 3: Projection of energy consumption of lifts in Switzerland (type of building/purpose shares estimated). The total of 280 GWh p.a. is equivalent to 0.5 percent of the country's electricity consumption.

Type of building/purpose	**No. of lifts**	**%**	**Typical lift**						**Projection as per SIA 380/4**					
			Storeys	**Hoist height**	**Travel cycles p.a.**	**Speed**	**Capacity**		**Energy**			**% of total energy**		
							Motor	Stand-by	Stand-by	In motion	Total	Stand-by	In motion	Total
				m		m/s	kW	W	GWh	GWh	GWh			
Residential dwellings	97,500	65	6	14	40,000	1	6	90	77	16	93	28	6	34
Hospitals	1,500	1	12	30.8	700,000	2	25	500	7	19	26	2	7	9
Clinics	13,500	9	8	19.6	300,000	1.6	10	200	24	24	48	8	9	17
Shops	6,000	4	3	5.6	200,000	1.6	20	150	8	4	12	3	1	4
Offices	18,000	12	8	19.6	200,000	1.5	21	200	31	48	79	11	17	28
Car parks	6,000	4	4	8.4	60,000	1.6	18	100	5	2	7	2	1	3
Industrial buildings (goods lifts)	7,500	5	4	8.4	40,000	0.8	30	150	10	4	14	4	1	5
Total	150,000	100							162	117	279	58	42	100

Measures to reduce stand-by consumption

Stand-by consumption incorporates a broad variety of components. From the point of view of energy efficiency there are two major factors that can cause unnecessarily high stand-by consumption: permanently running cabin lights and door locking devices, which require constant power. With the present-day status of technology, the stand-by consumption of a lift in an apartment block ranges from 40 to around 100 watts, but in view of the negative factors referred to above, this figure may also be considerably higher.

Composition of standby consumption



Composition of standby consumption

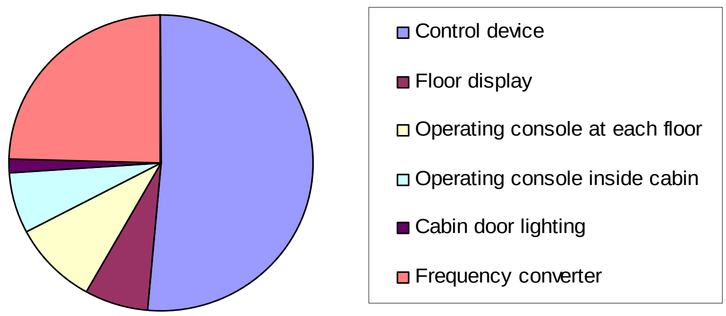


Figure 7: Shares of the different components to stand-by consumption – example with switch-off of cabin lighting facility. Source: U. Lindegger

Potential ways in which stand-by consumption can be reduced include:

- Switching off the frequency converter control device and other control functions when the lift is not in motion. During off-peak periods, a stand-by mode requiring a lower power supply would be feasible, e.g. similar to the sleep mode used in electronic devices, would be feasible. Under certain circumstances this would lead to slightly longer waiting (wake-up) times.
- Use of more efficient power supply units (switched units, toroidal transformers)
- Use of efficient display options (e.g. LEDs)

Despite the use of automatic switching devices, lighting in lifts still contributes to overall energy consumption to a substantial degree if inefficient solutions such as halogen filament lamps are used. In this context, lift suppliers could take efficiency into account as a criterion in addition to design.

Developments in the area of drive technology

Hydraulics versus rope traction

Our measurements and studies have shown that hydraulic lifts, which up to now have been generally regarded as inefficient compared to traction lifts, are no less efficient if the newest technologies are used. Any progress is slow here because the investment costs are slightly higher, but the advantages to be gained thanks to lower requirements concerning motor capacity on the other side can help in reduceing costs. A variety of advanced technologies are available on the market or are currently under investigation:

- Closed instead of open loop control of valves
- Counterweight (possible with “hydraulic indirect”)
- Energy storage (instead of counterweight)

Recuperation converters

A perfect lift drive would feed exactly the same amount of energy back into the grid during ascent as it requires for its descent (min./max. load travel cycle). In this case, the ratio of recuperated energy to required energy would be 1:1. However, real lifts also require energy for accelerating, braking, stopping, overcoming friction and for motor losses, and if at all this energy can hardly be recuperated. Thus the degree of recuperation (ratio between recuperated energy fed back during minimum load travel divided by the energy required during complete ascent and descent cycle) is unlikely to exceed 50 percent, and in the case of smaller lifts the limit is closer to 30 percent (see “Efficiency of lift drives” section). In terms of both energy efficiency and economic viability it therefore primarily makes sense to use recuperation converters in large lifts with a high degree of utilisation.

Optimisation of counterweight

According to data provided by the lift industry, the average occupancy rate of lifts is only 20 percent of the nominal load, whereas the figure for counterweights is 40 to 50 percent. Optimisation in terms of smaller loads would result in a more favourable balance with corresponding savings in energy required for travel cycles.

New technologies

Matrix converters do not have an intermediate DC circuit and thus have the potential for reducing losses. However, there are still a few technical problems associated with their use in lifts, and in the next few years we will find out whether it will be possible to develop a suitable solution. Linear motors would in fact be suitable as lift drives in view of the advantage of fewer moving parts and more precise positioning, but a number of obstacles still have to be overcome, including strong lateral force (friction!) and the technical complexity associated with the greater length of such motors.

Energy-conscious planning and dimensioning

Lift systems are going to be installed in buildings to an increasing extent, including in those with a low number of storeys. As more and more lifts are put into use, additional attention should be paid to their energy efficiency. In order to find suitable solutions from the point of view of economic viability and energy efficiency, it is important to incorporate the following aspects during the planning stage:

For planning purposes, the required transport capacity should be specified on the basis of the following criteria:

- Type of building (residential, office, etc.)
- Occupancy of building (no. of people per floor)
- Location of lifts (thoroughfares, location of rooms, storage areas, etc.)
- Utilisation patterns

The number and size of lifts should be determined on the basis of anticipated demand for transport capacity. The following general rules apply with respect to the specified cabin size:

- In residential buildings with maximum 5 storeys, normally 1 lift is required with a capacity of 630 kilograms and interior cabin dimensions of 1.1 x 1.4 metres (in order to accommodate wheelchairs).
- In apartment blocks with more than 7 storeys, at least 1 lift is required with a capacity of 1,000 kilograms and cabin dimensions of 1.1 x 2.1 metres (to allow for transport of furniture, stretchers, etc.). For higher capacities it is important to consider whether to install a bigger and faster lift or a second one.
- For all other buildings, detailed analyses of transport demand and patterns have to be carried out.

Accelerating and braking cause a substantial share of the travel-cycle energy consumption, increasing with lift speed (cf. "Recuperation converters" above). The choice of lift speed should therefore be made on the basis of the following rules while taking energy consumption and travel time into account:

Travel time for entire hoist height:

• For residential buildings	25 to 35 seconds
• For office blocks, hotels and hospitals	20 to 32 seconds

These criteria result in the following typical theoretical speeds:

• Residential building, 4 storeys, hoist height 9 metres	0.26 to 0.36 metres per second
• Office block, 10 storeys, hoist height 27 metres	0.84 to 1.35 metres per second

Since time for acceleration and braking also has to be taken into account, slightly higher speeds are required in practice. Thus for residential buildings with up to 6 storeys, the standard minimum speed of 0.63 metres per second is sufficient. With respect to transport capacity, the possibility should be considered that, under certain circumstances, choosing a slightly faster lift could eliminate the need for a second one. In office blocks, speeds of over 1 metre per second are only truly required in buildings with more than 8 storeys.

Choice of an energy-efficient lift system

The following construction properties have an influence on the energy efficiency of lifts:

- System architecture: Suspension (centrical, eccentrical, etc.). Centrical suspension and low-friction guide elements reduce (friction) losses.
- Drive: Adjustable speed motors accelerate with lower losses than is the case with pole changing motors that have been widely used in the past. By comparison with conventional worm gear mechanisms, drive losses can be reduced by using gearless or planet gear drives. A travel cycle with slower acceleration is more efficient but takes slightly longer.
- Control mechanism: Control mechanisms with collective operation save travel energy versus taxi operation (i.e. without stops in between). Adjustments can be made according to time of day. And of course, attention has to be paid to stand-by consumption!

Conclusions

There are high saving potentials in lift systems. Two major paths lead to higher overall efficiency: Lowering stand-by consumption, that should be addressed by the lift industry and demanded by the buyers' side . On the other hand, in an integral planning process of architect, planner, orderer and lift supplier the system should be optimized regarding design and technology to satisfy comfort, cost and energy requirements.

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The Best Choice: Comparison of Alternatives for Residential Water Heating in Brazil

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Abstract

In Brazil, the typical residential appliance used for bath water heating is the electric shower. The equipment is cheap (models can cost less than US 10.00), easy to install but mean a significant electricity load in the house, and a problem to the utility: in residential areas, the peak load can be doubled in a few minutes if all residents decide to go to bath at the same time. For larger residences, an interesting alternative is to use an electric heater with storage tank.

In some locations, gas is available and the resident can decide what the best alternative is: electric shower or a gas heater, with our without water storage. Although the gas heater is expensive in Brazil, it represents reduced costs during its lifetime. A new source is expanding its penetration in Brazil: natural gas. In cities as Rio de Janeiro and Sao Paulo, natural gas pipelines are replacing old manufactured gases, and offering a cleaner alternative – but slightly more expensive too.

The residential consumer in those areas now has four alternatives: electric showers, solar heating, LPG or natural gas. The paper will compare the costs and benefits of different technologies, considering financial indicators. The operational costs will be considered, and possibly the best alternative will depend on family size and habits.

As additional results, the paper can demonstrate to utilities companies how they can approach consumers, showing what specificities should be highlighted in order to avoid the migration to another energy source or attract the consumer.

The paper will consider a specific location where the three sources live together, as in Rio de Janeiro.

The water heating market in Brazil

There are few statistics of installed equipments for residential water heating in Brazil. According to Sociedade do Sol [1], 36 million residences use electric showers for water heating. IBGE [2] presents the evolution of total equipments sold, from 2001 to 2003.

Table 1: Number of water heaters sold in Brazil, units per year

Year	Electric showers	Gas heaters
2001	13,456,772	332,740
2002	13,546,392	29,999
2003	23,172,749	31,081

Source: IBGE – Industrial Survey

The numbers show the penetration of electric showers, due to several reasons:

1. Cost. A standard electric shower costs nearly US$ 18.00, but are cheaper models costing less than US$ 10.00.
2. Electric showers are easy to install, requiring only an electrical connection to work (besides water piping).
3. Electric showers can be replaced and repaired. The component to fail is the resistance that can be replaced at low cost (less than US$ 5.00 per unit).
4. Lack of regulatory restrictions. Although some equipments have power greater than 5 kilowatts, the utility cannot avoid their installation in residences.

Electric showers are cheap only from consumer standpoint. According to Ferreira [3], in 2001 each additional kilowatt costs US$ 663.00 – more than 100 times the cost for a single shower with 3 kW. Equipments with storage tanks and stand-by resistances can have total power of more than 9 kilowatt, corresponding then to almost US$ 6,000 in investments for generation, transmission and distribution.

The utilization of gas for water heating until the eighties was limited to specific locations such as Sao Paulo and Rio de Janeiro, where manufactured gas[1] pipelines are available since the nineteenth century. The expansion of oil exploitation brought together natural gas, offered in new places in the last ten years. Consumers in other places now can decide what the best choice is.
Considering that, from a technical and safety standpoint all alternatives are similar; the financial comparison of these available alternatives becomes the main issue. If considering only acquisition costs, electric showers would remain incomparable; but a deeper evaluation brings new questions to be answered.
The evaluation will consider a typical residence in the State of Rio de Janeiro, where all technologies are well known and a network of suppliers and installers is available.

Considered costs

Energy

For the present evaluation, the following unitary energy costs[2] will be considered. All include taxes and other charges to residential consumers, according to Brazilian legislation valid in April 2006.

1. Electricity: US$ 0.278 / kWh.
2. Natural gas: US$ 1.399 / cubic meter.
3. LPG: US$ 2.646 / kilogram.

Purchase of appliances

The appliance costs are estimated based upon a survey with local suppliers[3], and are shown bellow.

1. Electric shower: US$ 20.00
2. Gas heater (both natural gas and LPG): US$ 195.00
3. Solar heater: US$ 340.00

Installation

Installation costs were estimated according to Lorenzetti [4], and are presented bellow:

1. Electric shower: US$ 9.00
2. Gas and solar heaters: US$ 68.00

Operation

For estimating operation costs, the following parameters were considered:

1. Family with 4 people, each one taking 2 baths / day.
2. Average duration: 8 minutes per bath.
3. Hot water flow: 3 litres/minute (electric shower), 2 litres/minute (gas and solar heaters mix hot with cold water).

The following table presents additional assumptions, for each technology.

Table 2: Operational data of different water heaters

Specification	Electric Shower	Gas heater (natural gas)	Gas heater (LPG)	Solar heater
Electric power	4400 W			3000 W
Consumption (per hour of utilization)	4.4 kWh	0.72 m3	0.70 kg	3.0 kWh
Utilization (hours/month)		32		
Consumption (per month)	140.8 kWh	23.0 m3	22.4 kg	96.0 kWh
Monthly cost (US$)	39.14	32.18	59.27	26.69

Sources: Electric shower and solar heater [4].
Gas heaters (150 litres model) [5].

[1] Manufactured gas was initially obtained from coal.
[2] For all purposes, a reference Exchange rate of 1US$ = 2.2 R$ (Brazilian currency) is considered.
[3] For electric shower and gas heater, prices were obtained in www.bondfaro.com.br. For solar heater, the source was www.shopping.clickgratis.com.br.

Maintenance costs and useful life

For considered technologies, the following maintenance costs and useful life are considered.

Table 3: Maintenance costs of the 4 alternative technologies during their life-time and the length of useful life

Item	Electric Shower	Gas heater (natural gas)	Gas heater (LPG)	Solar heater
Maintenance actions	Replace resistance	Cleaning and adjusting		
Maintenance costs (US$/yr)	5.00	35.00		
Useful life (yr)	4	10		

Cash flow analysis

Correspondent cash flows were created to each technology, considering all costs and:

1. Tariff readjustments of 8.0%/year, applicable to electricity, natural gas and LPG.
2. Inflation of 5% / year, applicable to appliance, installation and maintenance costs.
3. Discount rate of 15.75%, equivalent to basic interest rate in Brazil (April 2006).
4. Period of evaluation equal to 10 years.

The calculations are given below in tables 4-7, with a summary of the results and the total costs of using different technologies in table 8.

Table 4: Electric shower cash flow analysis.

Year	*Appliance cost*	*Installation cost*	*Operation cost*	*Maintenance cost*	*Total cost (nominal)*	*Total cost (discounted)*
0	20.00	9.00	469.68	5.00	503.68	503.68
1			507.25	5.25	512.50	442.77
2			547.83	5.51	553.35	413.01
3			591.66	5.79	597.45	385.25
4	24.31	10.94	638.99	6.08	680.32	378.99
5			690.11	6.38	696.50	335.21
6			745.32	6.70	752.02	312.68
7			804.95	7.04	811.98	291.68
8	29.55	13.30	869.34	7.39	919.58	285.38
9			938.89	7.76	946.65	253.80
10			1,014.00	8.14	1,022.15	236.76
Total	**73.86**	**33.24**	**7,818.05**	**71.03**	**7,996.18**	**3,839.20**

Table 5: Gas heater (natural gas) cash flow analysis.

Year	Appliance cost	Installation cost	Operation cost	Maintenance cost	Total cost (nominal)	Total cost (discounted)
0	195.00	68.00	386.16	35.00	684.16	684.16
1			417.05	36.75	453.80	392.05
2			450.42	38.59	489.00	364.98
3			486.45	40.52	526.97	339.80
4			525.37	42.54	567.91	316.37
5			567.40	44.67	612.07	294.57
6			612.79	46.90	659.69	274.29
7			661.81	49.25	711.06	255.42
8			714.76	51.71	766.47	237.86
9			771.94	54.30	826.23	221.52
10	317.63	110.76	833.69	57.01	1,319.10	305.54
Total	**512.63**	**178.76**	**6,427.82**	**497.24**	**7,616.46**	**3,686.57**

Table 6: Gas heater (LPG) cash flow analysis.

Year	Appliance cost	Installation cost	Operation cost	Maintenance cost	Total cost (nominal)	Total cost (discounted)
0	195.00	68.00	711.24	35.00	1,009.24	1,009.24
1			768.14	36.75	804.89	695.37
2			829.59	38.59	868.18	647.99
3			895.96	40.52	936.47	603.86
4			967.63	42.54	1,010.18	562.75
5			1,045.04	44.67	1,089.71	524.45
6			1,128.65	46.90	1,175.55	488.78
7			1,218.94	49.25	1,268.19	455.55
8			1,316.46	51.71	1,368.17	424.59
9			1,421.77	54.30	1,476.07	395.75
10	317.63	110.76	1,535.51	57.01	2,020.92	468.10
Total	**512.63**	**178.76**	**11,838.94**	**497.24**	**13,027.57**	**6,276.43**

Table 7: Solar heater cash flow analysis.

Year	Appliance cost	Installation cost	Operation cost	Maintenance cost	Total cost (nominal)	Total cost (discounted)
0	340.00	68.00	315.48	35.00	758.48	758.48
1			340.72	36.75	377.47	326.11
2			367.98	38.59	406.56	303.45
3			397.41	40.52	437.93	282.39
4			429.21	42.54	471.75	262.80
5			463.54	44.67	508.21	244.59
6			500.63	46.90	547.53	227.66
7			540.68	49.25	589.93	211.91
8			583.93	51.71	635.64	197.26
9			630.65	54.30	684.94	183.64
10	553.82	110.76	681.10	57.01	1,402.70	324.90
Total	**893.82**	**178.76**	**5,251.32**	**497.24**	**6,821.14**	**3,323.19**

Table 8: Summary

Technology	Appliance cost	Installation cost	Operation cost	Maintenance cost	Total cost (nominal)	Total cost (discounted)
Electric shower	73.86	33.24	7,818.05	71.03	7,996.18	**3,839.20**
Gas heater (natural gas)	512.63	178.76	6,427.82	497.24	7,616.46	**3,686.57**
Gas heater (LPG)	512.63	178.76	11,838.94	497.24	13,027.57	**6,276.43**
Solar heater	893.82	178.76	5,251.32	497.24	6,821.14	**3,323.19**

The results for discounted cash flow show that the solar heater is the best choice, from a financial perspective. It's necessary to reinforce that results are obtained for a 10 years period, and the difference for electric shower results are not so relevant (close to 15%). Another constraint is that solar heating can be used specially for houses; when a building is considered, even with the possibility of using a roof area for installing solar collectors, the installation costs are increased and the numbers would change significantly.

Conclusions

Several technologies can be used for residential water heating in Brazil. The calculations presented in this paper show that a solar heating system is the best alternative, when technically possible and for a 10 years period of analysis.

Utilities and other stakeholders could consider the assumptions presented here to stimulate the market to adopt more efficient technologies. The use of natural gas for heating results in competitive costs, but to demonstrate them is necessary. If the client is inclined to consider only short-term costs, the utilization of electric showers will remain dominant.

Energy planners should take these results as reference, in order to create mechanisms to avoid the utilization of electric showers in Brazil. If a small amount migrates from grid and generation expansion to reduce initial costs for natural gas heaters, for example, consumers would be stimulated to adopt this technology, reducing peak demand significantly and postponing investments only for meeting the needs of residential water heating.

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Barriers and Drivers to Energy Efficiency – A New Taxonomical Approach

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Abstract
This paper develops a new systematic classification and explanation of barriers and drivers to energy efficiency. Using an 'actor oriented approach', the paper tries to identify (i) the drivers and barriers that affect the success or failure of energy efficiency investments and (ii) the institutions that are responsible for the emergence of these barriers and drivers. This taxonomy aims to synthesise ideas from three broad perspectives, viz., micro (project), meso (organization), and macro (state, market, civil society). The paper develops a systematic framework by looking at the issues from the perspective of different actors.[1] This not only aids the understanding of barriers and drivers; it also provides scope for appropriate policy interventions. This focus will help policy-makers evaluate to what extent future interventions may be warranted and how one can judge the success of particular interventions.

Introduction

Economic development has traditionally been linked to energy adequacy. Countries pursuing economic growth are expected to resort to increasing levels of energy use. Achieving these levels of energy production and utilisation through present technologies is not only difficult and expensive, but also environmentally unsustainable. Various studies indicate that increased energy efficiency can bridge the gap between growing demand and reduced energy supply without adversely affecting the quality of service (Golove and Eto 1996; S. Reddy 2003) However, as the past experience has shown, this may not happen, unless the issues that hinder the penetration of efficient technologies are addressed (A.K.N. Reddy 1991; Hollander and Schneider 1996; Sorrell 2000). There is a gap between the theoretical opportunities for cost-effective[2] energy efficiency investments and the levels that can be achieved practically. The origins of the gap seem to lie in the set of barriers which may be divided into categories such as financial, legal, organizational, or informational. These barriers prevent investments in energy efficient technologies. It is also certain that there are drivers that help increase investments. The barriers hinder the penetration of energy efficient technologies, even though these technologies have been shown to be economically cost-effective. If policies to encourage investments in improved energy efficiency are to be successful, understanding the nature of these barriers and drivers is essential. These policies must succeed in the context of liberalising energy markets, falling energy prices, and increasing the development of a broad-based energy service industry.

Lighting is an important household energy service. This is because lighting usually involves the use of commercial energy and often not many alternatives exist. Nearly 0.3 billion people in India — more than the world's population in Edison's time — still have no access to electricity. The majority of people who lack direct access are mostly from rural areas. Even those households which us electric lighting, the level of illumination are far lower than with modern electric lighting. The result is a substantial amount of primary energy use with little service received in return. The aim of the present paper is thus to examine the nature of barriers and drivers for efficient electric lighting. It also analyses the circumstances in which they arise, their relative importance in different contexts, and the manner in which different actors intervene to overcome these barriers. The paper reviews current perspectives on barriers and drivers, classifies them according to their influencing patterns, and

1 The actors include: the consumer/investors, utilities, government agencies (ministries, state agencies, parliamentary commissions, and intergovernmental commissions), financial institutions, regulatory bodies, local authorities, research and development organisations, equipment manufacturers, market institutions, energy consultants, NGOs, energy service companies, the International organizations (e.g., Intergovernmental Panel on Climate Change), etc.

2 Economic cost-effectiveness depends on both: where the actor-concern boundary is placed (the individual or the society as whole), the time perspective (static or long term dynamics included) and the system regarded (ceteris paribus – all other things equal - all things concerned are changed). Here, the perspective is individual-static-ceteris paribus.

provides supporting evidence for their prevalence. Finally, the paper tries to evaluate the effectiveness of different institutions for improving energy efficiency. The debate on barriers and drivers is contentious and is characterised by disagreement over basic theoretical and conceptual principles. Hence, the primary objective of this work is to develop a new systematic theoretical framework.

The energy efficiency debate

There has been a long running debate over the issue of energy efficiency (EE) between energy economists and energy analysts. One issue concerns the rebound effect. Although definitions vary, this effect describes the following linkage: the efficient use of energy leads to an increase in the use of energy. This may partly offset the savings in energy use achieved by the EE improvement. The rebound effect is rooted in neoclassical economic theory. The extent of the rebound effect depends on the price elasticity of demand. Therefore, the assumption of rational decision making is the precondition for an explanation of this effect.

Henry Saunders (1992), argues that 'energy efficiency gains can increase energy consumption by two means: by making energy appear effectively cheaper than other inputs; and by increasing economic growth, which pulls up energy use.' The debate grew more intense in the 1990s, spurred by global warming concerns. The argument for EE, however, is independent of environmental concerns. The market failure that distorts energy use is under pricing of energy by regulators and deregulation is preferable to EE into which utilities were forced to reduce energy prices. There are also other market failures, such as split incentives (landlord-tenant), etc (Reddy, 1991). The reality is that while EE is technologically feasible, it will require a significant change in our collective approach to making it work. What this means is that, while technologies are already available, the problem lies in their application. Another aspect to which contributions to the EE debate can be associated is what one describe as a matter of *governmental intervention*. Gunn (1997) who investigated the paradigms of EE stated that it is important to recognize that the primary debate is over the optimal level of governmental intervention in energy markets rather than over the optimal level of EE. There are many forms of government intervention such as Subsidies and taxes; Special purpose loans; Facilitation (information systems; well-structured markets; approved suppliers); Guarantees for specific risks, or offering insurance; and Arranging objective non-partisan product information (e.g energy labelling)

The justification and degree of governmental intervention is a matter of debate in the international literature. Barriers which are attributed to market failures make governmental intervention necessary and justifiable and a large body of international literature relates barriers to market failures. However, others claim that only few market failures can be defined as such. Haugland, Bergesen, and Roland (2000) argue that most barriers merely reflect 'unaccounted (transaction) costs or simply result from the consumer's liberty to choose freely his/her convenience and service levels and willingness to accept a higher energy bill for their personal taste or lifestyle.' Therefore, governmental intervention might be questionable.

A large body of international literature puts effort in an empirical approach to this question with different objects of investigations and findings (Helm 2002, Sloman and Sutcliffe 2000, Vine *et al* 2003, Banerjee and Solomon 2003) Governmental stimulation of the implementation of new technology by promoting associated research and development was found to be counterproductive. Although it leads to technological progress it may hinder corporate investments in new technology . Firms may favour to wait for the next generation of technological developments. In the case of a restructuring electricity market pro-interventionists ask whether the market alone is able to overcome EE barriers. It is argued that governmental support in promoting EE and load management can be advantageous. Further, an evaluation of US energy labelling programs led Banerjee and Solomon (2003) to conclude that, 'government support is the most critical factor for the success of a labelling program.' Altogether, the challenge of reconciling government and free market contributions with regard to the energy market and EE remains.

With regard to EE potential, a distinction has to be made between: (i) the *economc* potential: achievable by removing market failures; ii) the *technological* potential: achievable by the additional removal of 'non-market market barriers[3]'; and (iii) the *hypothetical* potential: achievable through the additional elimination of market failures[4] in fuel and electricity markets (Jaffe-Stavins (1994) . This framework is summarised in Figure 1.

[3] Technical barrier is the one where the new technology might be found wanting or become rapidly outdated.

[4] Market failure is a distinct notion for such problems that can not be solved (in full) by use of market instruments, such as public goods, externalities, etc. Such failures cannot be eliminated though there are some "Pareto-sanctioned" measures that redeem

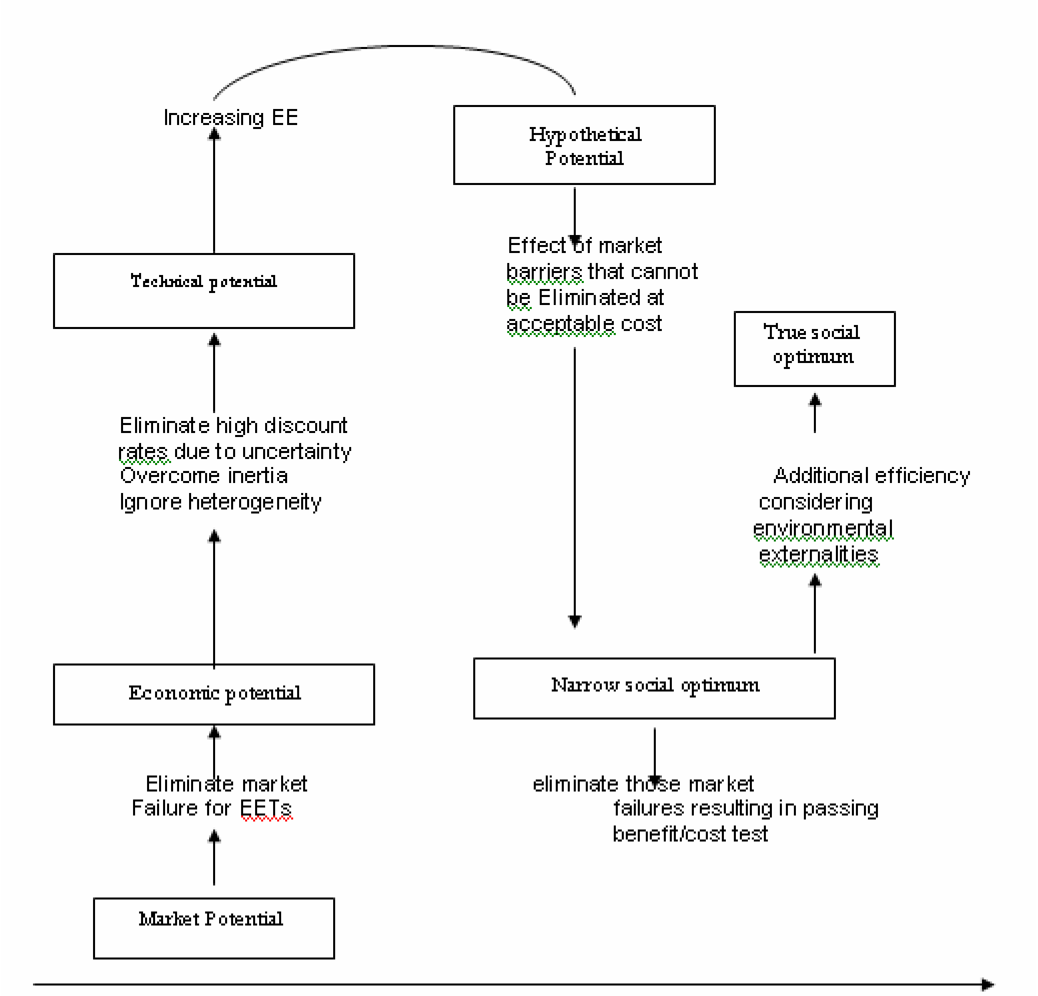

Figure 1: Characterization of energy efficiency potential

On the right hand side of Figure 1, various potentials for EE are represented. The market potential is the efficiency improvement that can be expected to be realized for a projected year under a given set of conditions (e.g., energy prices, consumer preferences and energy policies). The market potential reflects barriers and market imperfections that keep efficiency potential from being fully realized.

The economic potential is the energy saving that would result if during each year of the period in question, all replacements, retrofits and new investments were shifted to the most energy-efficient technologies that are still cost-effective at given energy market prices. The economic potential implies a well-functioning market, with competition between investments in energy supply and demand. It also assumes that the barriers to such competition have been corrected by energy policies. It is assumed that as a result of such policies, all users have easy access to reliable information about the cost-effectiveness and technical performance of existing and emerging options for energy efficiency.

The technical potential represents achievable energy savings under theoretical considerations of thermodynamics, where final energy consumption is kept constant, and energy losses can be minimized through process substitution, heat and material re-use, and avoiding heat loss. This can be considered as hypothetical potential and represents achievable energy savings that result from implementing the most energy-efficient technology available at a given time, regardless of cost considerations and reinvestment cycle.

On the right hand side we examine the social optimality. The narrow social optimum in the market for energy efficient technologies represents the rate of energy efficiency uptake that would be observed if all barriers that were deemed to be irrational on a cost-effective basis were eliminated, i.e., if people adopted all measures that could leave them economically better off given the current pricing

them. The market failure here means "market imperfections" where market pricing, ownership etc. can be applied successfully (at least in part).

environment. In this situation, one has to get energy prices right implying that narrow social optimum should include cost effective removal of market failures for energy. The true social optimum would include additional efficiency diffusion that would likely to be seen by considering environmental externalities.

Actors in the field of energy efficiency

There is a growing recognition that the usual investment decisions such as payback period, rate of return on investment, net present value, etc, do not account adequately for actual business behaviour. Technical solutions above are not likely to succeed unless there is an interface between various actors in the field of EE. In conventional energy programmes, there are only two main participants, that is, the suppliers and the consumers. In the EE system, there are many actors such as equipment manufacturer, financial institutions, NGOs, etc, who play important roles. If the EE programmes are to be widely accepted, all these parties should work together. Each actor has relations to other actors. The actor experiences constraints and stimuli; has abilities and weaknesses; and holds rights, responsibilities and obligations. All these lead to series of decisions. All the actors, and their decisions, describe the whole socio-technical structure and the processes that occur.
While discussing the drivers and barriers, it is important to consider the role of actors such as the national government, regional and local authorities, supranational bodies such as international development agencies, the United Nations and its specialised bodies, the World Bank Group, international and national professional and trade bodies, etc. One could try to indicate which 'actor' has the power to create/reduce/remove certain barriers and on which actors the particular barrier has an influence. One could also try to indicate whether the barrier can be modified in the short term (eg through a subsidy), in the medium term (eg through new legislation), or only in the long term (eg through improving general education), or probably never (eg in the case of cultural/religious barriers). One could also look at the mechanisms as means to overcome the usual constraints and pave the way for smooth functioning of programmes. This, in turn, encourages the removal of barriers and positively affects investments. Such an 'actor-oriented' approach would give clearer insights into barrier analysis. Through such an approach we can find out the role of actors. For example, if any barrier is named, we can see who created it, and who, therefore, is (in principle) able to remove it. The actors can be divided into the three sub-groups – micro, meso and macro.

Figure 2 illustrates actors in the field of EE in general, from 'macro' and 'micro' perspectives

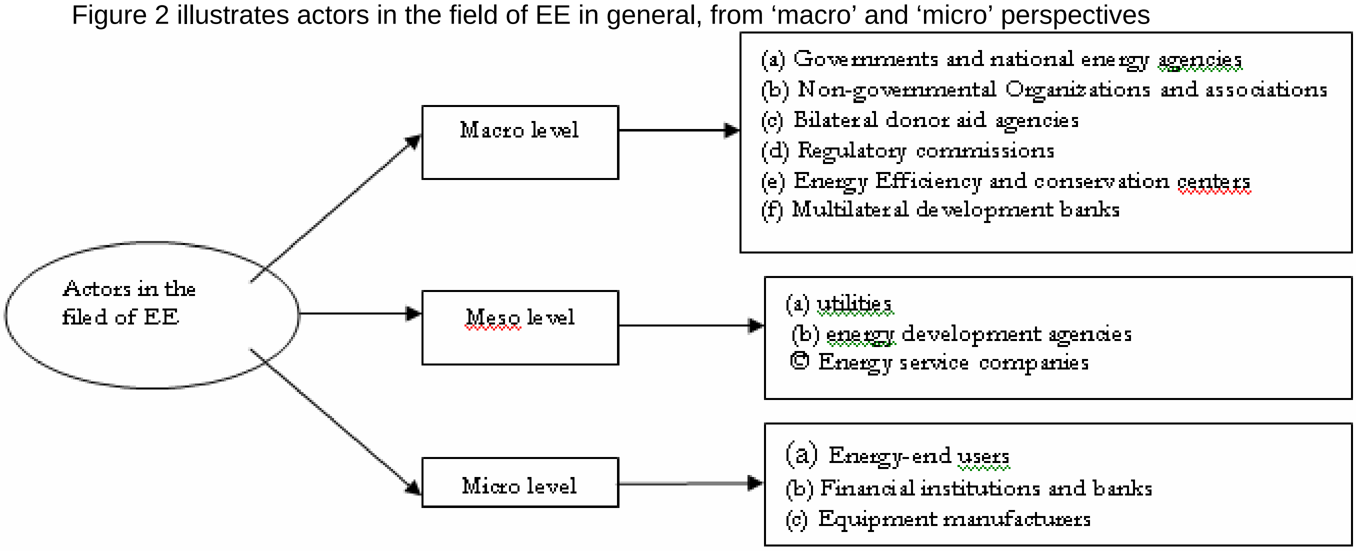

Figure 2: Actors in energy efficiency

At the *micro level*: To design better programmes, they are the persons/consumers to address (information, training, support by specialists, etc).
At the *meso level:* Organisations such as utilities, energy development agencies, service companies, etc. Through new incentives, organizational reform, and other changes, barriers can be reduced or removed.

At the *macro level:* Relate to the 'higher-level' institutions (state/market/civil society) that determine the setting under which the lower levels have to operate.

The actions needed to address barriers are different for each. Through this approach, we not only need to look at the barriers themselves, but also at the institutions/situations that create the barriers. Each actor would then have two roles: (i) to carry out a project at his own level, the actor has to work within existing 'external constraints' given by 'higher-level' institutions, and (ii) establish conditions (either barriers or drivers) for other actors at a 'lower level'.
Each actor in the field of EE has a specific function, but even without being an active performer, everybody can be positively influenced by EE thanks to its character of positive externality. Everybody has a responsibility: governments, industries, business associations, donors, and international institutions; they all should recognize their respective roles. The EE process can be completed only by cooperation, by a common achievement. If the government wants to promote EE, it needs to see how the whole system can be modified which can lead to more EE-directed decisions. Table 1 demonstrates main functions of the actors in the field of EE. Each of them has a specific role(s) in the process of the implementation of EE. They are mutually connected:

Table 1: Functions of the actors in energy efficiency lighting systems

Actors	Functions
Governments	• Establish legal and institutional frameworks; • Integrate EE in decision-making in all sectors, • Support administrative efforts to enhance EE;
EE agencies	• Collect and propagate information about activities, experiences, programs and projects; • Develop and implement EE programmes; • Put programmes together to ensure a larger market response.
Business and industry enterprises	• Disseminate the achieved results; • Appeal to members to apply EE; • Negotiate with involved partners in terms of achieving EE targets, eg with government, foreign organizations, etc.
Energy Supply agencies (Utilities)	• Improve energy services – supply, transmission and distribution; • Propagate EE lighting technologies; • Provide incentives to those who use EETs and disincentives to those who do not .
Equipment manufacturers	• Provide a whole range of lighting devices to the consumers; • Cooperate on developing and later promoting EE lighting technologies; • Make consumers understand they should not consider only purchasing but life-cycle costs.
Financial Institutions	• Help to finance EE programmes; • Disseminate information about EETs; • Cooperate with other agencies to implement common programmes;
Non-governmental organizations	• Publicise good examples; • Network to make use of the latest experiences in research both in technology and applications.
International organizations	• Develop supporting instruments for monitoring and evaluation; • Support mutual interest by adapting routines and instruments; • Serve as a forum to disseminate results; • Act as a clearing-house to establish collaborative actions.

Source: based on OECD, 1999

Barriers to energy efficiency

Micro barriers
These can be referred to as the obstacles that are unique to a particular project. Here the barriers could be in terms of project design. A poorly designed project can make insufficient use of synergies

or drivers, or take too little account of barriers. The person to address is the project designer (information, training, support by specialists, etc). Examples include:

A lighting programme, which only focuses on upgrading the lighting unit, is likely to be less profitable than the one which, at the same time, upgrades leakage in distribution systems, creates incentives for energy savings, such as metering in households, and gradually raises lighting prices to recover costs.

A medium size or large project, consisting of households from a group of villages or a town, is usually more profitable than dispersed and one-off small projects due to lower transaction costs and economies of scale.

A project that consults the representatives of benefited target groups (e.g., consumers, equipment manufacturers, financial institutions) is usually more feasible than the one that is imposed from above.

By changing the features of a project – for example, by modifying incentives for energy savings, replacing the technology, increasing the project size, or creating legitimacy through consultation – the financial viability and feasibility could be improved. Also, changes in project design can reduce the internal barriers to profitability and feasibility.

Meso barriers

These relate to the organizations affiliated with the project. These barriers can be common to a wide variety of projects and can be tackled with efficient organizational design, human resource, as well as time management. Examples include:

The implementing agency may be understaffed, bureaucratic, or lack proper incentives for promoting energy efficient lighting systems;

The project target groups (eg rural households) may be small, inexperienced and undercapitalised;

The consumers may lack experience in a particular lighting technology

The implementation authority may be unaware about the details of a geographic area where the project has to be implemented;

The government authorities may put forth rules and procedures that can raise the cost of the project and/or reduce the feasibility of implementation.

Macro barriers

The macro barriers can be divided into three categories: state, market, and civil society related. Since these barriers are not project or organization-specific, they cannot be altered by changing project or organizational design. For project sponsors and financiers, macro barriers are externally driven and are difficult to influence (unless they have the power of influencing policies, market, or culture). In some cases, projects include policy components, which can affect macro variables (eg electricity tariffs, laws about who will keep financial savings from energy efficiency projects, subsidies, etc). It is usually easier for project sponsors and investors to change the project characteristics than it is to influence government policies such as electricity tariffs and subsidies. Therefore, many projects do not even attempt to change macro variables and instead focus on overcoming or neutralizing the adverse effects of macro barriers through increased financial subsidies – or, more rarely, through innovative project and organizational design. The benefits of tackling macro barriers are usually much greater than focusing merely on micro and meso level barriers, and the sustainability of results over time is much greater as well.

Barriers relating to the state are those that can be traced to the behaviour (action or inaction) of governments or state-run organizations (e.g public utilities). Barriers relating to the market are those that can be traced to the behaviour of individuals, private firms and financial institutions, which reflect the prevailing market structure. And finally, barriers relating to civil society can be traced to the behaviour of NGOs, academic institutions and other civil society organizations (CSOs). While the distinction between state, market and civil society barriers is useful as a means of classification, in practice, there are linkages between them. For example, markets react to policy changes and vice versa; policy is affected by the lobbying of firms; and NGOs and other civil society organizations operate within a political and economic context. Efforts to remove or reduce macro barriers need to pay attention to these relationships in order to be effective.

The barriers can be further classified into internal (barriers due to flaws in the project or the organization) and external (policy, market, and civil society barriers). Internal barriers are easier to overcome, because they require only changes in the project or the organizations involved in the project whereas external barriers require policy changes, measures to affect the workings of markets, or measures to influence civil society or the culture of a country. In designing a complete model, there are numerous variables that could potentially be relevant: there are variables in the three categories of project, organization, and policy design, and there are variables in the causal pathway (the categories of drivers and barriers).

Removing, reducing, and avoiding the barriers

It is important to explore the relationship between the independent variables (the stimuli mechanisms) and the linking variables (the drivers and barriers). This relationship can be described as a process of stimulating the drivers and overcoming the barriers to private investment. Overcoming the barriers would reduce the overall financing need for energy efficiency and promote sustainable development. It is important to recognize that the process of 'overcoming' barriers is not a single process, but, in fact, three separate processes.

Type 1: *Removing* a barrier (or risk) means getting rid of a barrier altogether, so that all present and future projects no longer face that barrier. For example, if a government repeals a law that obstructs energy efficiency, the change of legislation will affect all present and future projects. Unless the law is reintroduced later, the barrier is removed altogether. In terms of policy objectives, this is the most desirable form of overcoming barriers.

Type 2: *Reducing* a barrier (or risk) means that the barrier remains in place, but that its deterrent effect is diminished. For example, if a government increases electricity tariffs but not sufficiently to cover long-run marginal costs, the barrier of distorted electricity pricing is reduced but not removed.

Type 3: *Avoiding* a barrier (or risk) means that the barrier can be overcome or avoided during a particular programme, while remaining in place for others.

While Type 1 and Type 2 are actions addressed primarily to the actor who has created the barrier, Type 3, is addressed primarily to the actor who wants to 'work around' the barrier (a different person/institution).

Of all the approaches to overcome barriers, *removing* obstacles (Type 1) may be the most expensive and difficult. Yet, it is probably the most cost-effective, because in this way, barriers disappear for all projects in an economy – present as well as future. In practice, however, the most common approach seems to be the least effective, namely, the avoiding of barriers (Type 3). It seems that many agencies promoting energy efficiency merely 'lift' projects over the same hurdles time and again. From a public policy perspective, this is not a desirable approach, as it represents a waste of public funds.

A case in point is the Global Environment Facility (GEF). The *Operational Strategy* of GEF states that the removal of barriers to energy efficiency and renewable energy are central to the mission of the organization (GEF 1996, 33). The GEF supports projects (and 'programmes') that tackle institutional and structural shortcomings, and in this way modify the barriers and drivers. Two of the ten operational programmes at GEF are specifically aimed at removing barriers to energy efficiency (Operational Programme # 5[5]) and renewable energy (Operational Programme # 6) (GEF, 1996). However, the incremental cost principle, based on which GEF distributes its funds, contradicts this objective because it usually results merely in 'lifting' the projects over barriers, rather than reducing or removing the barriers that create the incremental cost problem in the first place. As a result, the barriers remain in place, 'waiting' to obstruct the next project.

To illustrate this important point, consider an energy efficiency lighting programme, which addresses two main barriers: high initial cost of efficient light bulbs and lack of consumer awareness. Given enough financial resources and successful project implementation, both barriers can be overcome. This, however, does not guarantee that those barriers will permanently disappear. It may happen that the consumers, who got used to highly subsidized prices, make it difficult for the manufacturer to sell the bulbs at commercial prices once the project is over. This is because the consumers tend to forget the benefits of efficient light bulbs after a while, or because they are simply unwilling to accept increased prices. In order to prevent this, incentives must be given to the project developers to ensure the durability of the barrier removal measures so that the impact stretches beyond the

[5] The United Nations Framework Convention on Climate Change (UNFCCC) seeks to stabilize atmospheric greenhouse gas concentrations at levels that would prevent dangerous anthropogenic interference with global climate. The Operational Strategy of the GEF puts initial emphasis, among others, on the removal of barriers to energy conservation and energy efficiency.

individual programme. The sustainability of barrier removal should be one of the main criteria by which development agencies allocate funding to programmes. This should be made mandatory in all the business plans submitted as part of applications for energy efficiency funding.

While barrier removal (Type 1) is quite rare, many projects achieve barrier reduction (Type 2). It can be hypothesized that all successful energy efficiency projects contribute to the reduction of costs or other barriers, thus accelerating the process of commercialisation. Types 1 and 2 refer to possible actions by an authority, which is responsible for the barrier/driver, or has the power to modify it. The primary target for barrier removal and reduction should be the government, but other institutions may also be able to influence the process in direct and indirect ways. For example, rather than lobbying a reluctant government, it may in some cases be more effective to work with private sector or civil society organizations, if they have an influence reducing or removing barriers.

Type 3 refers to the ways in which the implementing agency and the programme manager can 'get round' the problem. Although this is usually the least cost option in the short term, avoiding a barrier is a short cut that should not be taken, as it does not improve the process of commercializing energy efficiency. Programme developers and financiers are likely to choose the cheapest and easiest method of overcoming the barriers – which is usually to avoid them, leaving the task of reducing and removing barriers for other agencies. However, even for private programme developers and financiers, this makes only short-term sense, as they would themselves benefit from barrier removal in the long term.

In the light of this analysis, one can arrive at two approaches to overcome the barriers to private investment. The first one has the primary objective of removing, or at least reducing barriers, which can be referred to as a targeted barrier removal effort. The second approach has the primary objective of maximizing the project's profit. Examples for targeted barrier removal efforts include:

Policy initiatives to remove direct and indirect subsidies for fossil fuels;

Initiatives to provide energy efficiency information (eg through mass media, Internet) to create awareness;

Initiatives to train programme developers, financiers and government officials, and to provide them with the means and incentives to change the structure of barriers and drivers.

If successfully implemented, these activities are likely to yield high economic and environmental benefits per unit of consumer expenditure on energy.

Analysis of drivers

Along with the barriers one should understand the motivation and forces that lead consumers to adopt energy-efficient measures. Information directed towards understanding consumer's decision-making behaviour and preferences as well as the behaviour of other stakeholders would give a better understanding of the drivers that push energy efficiency measures. A few examples of drivers are given below:

Awareness: It is clear from the above discussion that there are a wide variety of players that can contribute to barrier removal measures, who can also stimulate the drivers and thereby help the penetration of energy efficient technologies. A case in point is the strong competition between technology manufacturers that results in aggressive advertising campaigns. The advertising campaign in this example is the measure (stimulant), and the high level of awareness of energy efficient technologies, thus created, is the driver.

Decrease in technology price levels: A high level of awareness is usually not sufficient to attract private investment and guarantee market success. The general understanding of market mechanisms dictates that price of a technology is an important factor in its speedy penetration. Hence, one can assume that educational/promotional activities are important, even though, there should be other considerations as well. Along with advertisement campaigns, the competition should lead to a decrease in the cost of the technology. Such reductions in prices can safely be assumed to lead to an increase in the sales of the technology.

Increase in energy prices: Cost savings in energy bills through reduced use of energy is one of the reasons for the decision to buy energy efficient equipment. A look at the electricity prices in developing countries over the past few years indicates that nominal electricity prices increased manifold during the 1990s. In real terms, the price increase may be less but is still significant to affect purchasing and investment decisions. Increased energy prices place a higher burden on consumers. If there is a continuous and predictable increase in its price, consumers are more likely to be motivated to adopt energy efficient equipment to conserve electricity and heat.

Technology appeal: While analysing drivers, one factor that may be of worth considering is the 'smartness' of the technology. If the energy-efficient equipment gives an impression that it looks 'modern', 'appealing', and 'fashionable', there is a higher probability of consumers purchasing the technology. These non-economic motivations, in general, dominate the decisions primarily of high-income groups, for whom, technological appeal is a major driving factor.

Non-energy benefits: Non-energy benefits are important drivers of energy efficiency. They accrue at the national level, e.g. via improved competitiveness, energy security, job creation, From a consumer perspective, it is often the non-energy benefits that motivate decisions to adopt energy efficient measures. The benefits to the consumer through these measures include (i) improved indoor environment, comfort, health, safety, and productivity; (ii) reduced noise; (iii) labour and time savings; (iv) improved process control; (v) increased reliability, amenity or convenience; and (vi) direct and indirect economic benefits from downsizing or elimination of equipment.

Environmental Regulations: Environmental regulations, if properly designed, can serve as a driver for investments in energy efficiency. In the absence of environmental regulations, the societal costs of electricity generation in the form of air emissions, water use and other environmental impacts are not borne by the energy producer or by the consumer. Consequently, these actors do not see the true societal costs of their production and consumption decisions. Environmental regulations can force producers and consumers to internalize these environmental costs into the price of their energy goods and services in the form of increased environmental compliance costs. These increased environmental costs can send a price signal for increased investments in energy efficiency by making efficiency investments comparatively more attractive financially. Not all environmental regulations are created equally, however. If an environmental regulation simply mandates that an industry install a particular pollution control device, then the industry's response will be to seek ways to minimize its cost of compliance with the pollution control requirement and the price signal for efficiency investments will be muted. Once the pollution control device is installed, there will be little incentive to improve the efficiency of the overall production process. If, on the other hand, the environmental regulation uses market mechanisms to reward industry for reducing emissions through, for example, tradable permits, then the industry would have the incentive to improve the efficiency of and continuously improve its manufacturing process and potentially turn the environmental regulations into a source of profitability. A more efficient manufacturing process would naturally follow.

Conclusions

This paper attempts to study the barriers and drivers that influence investments in energy efficiency using an actor-oriented approach. It starts with the development of a new taxonomy of barriers/drivers classifying them in terms of profitability and feasibility of private investments in energy efficiency. The barriers are classified into three broad categories, viz., micro, meso and macro. In practice, these barriers are of the following types: perceptual-behavioural, financial-economic, institutional-structural and market oriented. Such classification is expected to help devise the response measures to remove, reduce, or avoid the barriers. The paper is also aimed at understanding which drivers contribute to the successful diffusion of energy efficiency measures. This would facilitate development of appropriate support mechanisms at financial, policy, institutional, regulation, and information levels.

Further, using this taxonomy, the paper develops a theoretical framework which proposes a methodology to analyze the causal relationship between barriers/drivers and the appropriate response measures. This work brings out clearly the need for a different set of response measures, depending on which group a barrier belongs to. At the policy level, some barriers can hardly be influenced by an energy efficiency project team, and whoever encounters them has to accept them. But if the 'project' is of a wider scope, let us say, a programme of institutional development financed by international donors, that programme may be able to modify some of the barriers. Hence, it is important to try to assess which barriers are more or less 'unchangeable', and which may be worth tackling by such programmes. This would greatly help both the multilateral and government agencies in devising their strategies in terms of support to future barrier removal programs. This analysis has profound implications for barrier taxonomy, which, in turn, helps design energy efficiency projects. The paper underlines the significance of the identification and classification of real barriers, which is a precondition for the successful diffusion of energy efficient technologies.

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Load Demand Pricing - Case Studies in Residential Buildings

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Abstract

Since the liberalisation of the Swedish electricity market in 1996, the competition between utilities has increased, and the generation capacity has gradually been adjusted to suit the demand. Consequently, the earlier excessive electricity production capacity has been reduced. However, if the gap between the generation capacity and demand will be too narrow, this may result in notable power shortages in the electricity market. In order to achieve lower load demand, to avoid load peaks and to reduce electricity cost, a Swedish electrical utility - Skånska Energi Nät AB (SENAB), is planning to include a load demand component in its electricity tariff to make customers more aware of their energy consumption pattern and (possible) load demand problems. This study investigates the impact of the new tariff from the viewpoint of the utility as well as its customers, compared to the existing tariff. The project was carried out by the Efficient Energy Use in Buildings Research Group at the Department of Energy Sciences, Lund University.

The results of the investigation show that if a load demand component were to be introduced into SENAB's network tariff, primarily customers with a 16-ampere fuse would incur higher network charges whereas customers with a higher fuse level would incur lower charges. With the existing network tariff, customers with high fuse levels pay relatively high standing charges in relation to their exploitation of the grid and as such they are subsidising customers with lower fuse levels. The study also shows that it is important that the new load demand pricing strategy (tariff) is communicated to customers in a comprehensive manner, so that they understand it and furthermore realise that they can save money by changing their energy consumption patterns without lowering their standard of living or comfort.

Introduction

Sweden has a relatively high electricity consumption per-capita, about 17 000 kWh per inhabitant annually, more than twice as high as the European Union average. In the year 2005, Sweden was in fourth place in the world, in terms of electricity consumption, after Norway, Iceland and Canada. The high electricity consumption in Sweden is due to electricity-intensive industries and the high demand for space heating caused by the cold climate. Over the past thirty years, the electricity consumption in Sweden has increased at the rate of almost 3 % annually [1].

The Swedish electricity market was reformed in 1996 and then again in 1999 for household users. As a result of the electricity market reforms, consumers may now choose their electricity supplier and all trading must be competitive. However, the grid operator can not be chosen by the consumer, and is still regulated. A corporation that pursues network operations may not pursue trading in or generation of electricity. Therefore, there must be a clear distinction between generation of and trading in electricity and network operations.

Electricity consumption varies between different hours of the day, between days of the week and between seasons of the year. The highest power demand occurs only during a few hours when the outdoor temperature drops. In recent years, the power demand has reached new peak levels but due to predominantly economic and political reasons the load reserves have dwindled. The reliability of supply criteria that determined the required peak load generation capacity before the market reform was abandoned in conjunction with the liberalisation. The problem of load capacity has become more and more obvious during the last years. According to the law (in force until March 2008) the Swedish national grid operator is obliged to ensure reliability of electricity supply by purchasing reserve capacity.

One possible solution to the load problem may be the introduction of a new pricing strategy with a load demand component, which means that consumers pay for load demand instead of electricity consumption only. In this way, the customers would be more aware of their energy consumption pattern and may be incited to lower the load demand, which could help the utility to avoid high load peaks.

The objective of this study was to investigate how such a tariff would affect one of the Swedish electricity utilities and its more than 16 000 electricity customers.

Electricity price at user level

The total electricity price charged to the Swedish customers consists today typically of three parts: electricity fee, network fee and taxes.

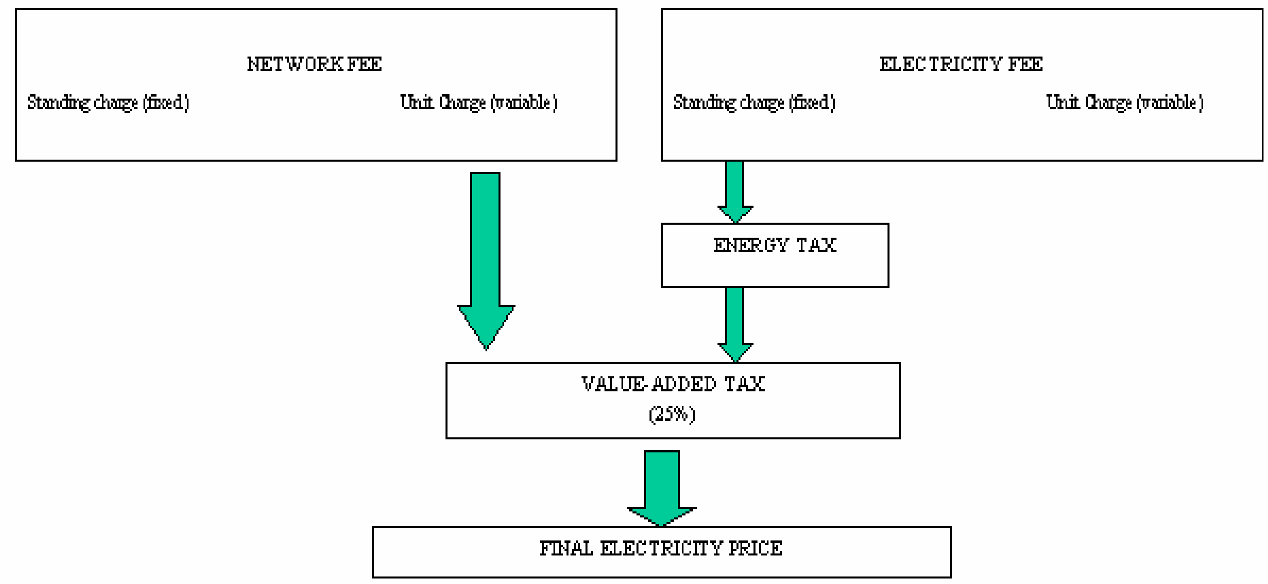

Figure 1: Residential electricity price structure [4].

The only part of the electricity bill that the customers themselves are able to influence is the electricity fee. All customers have the opportunity to switch their electricity supplier or renegotiate their existing contract, and, in this way, get a lower price.
The second part of the total electricity price, the network fee, is paid to the network owner in the area. The network owner provides the physical transmission of electricity from the generation plants to the end-user. Customers cannot choose their network provider so the network fee must be reasonable and non-discriminatory. Network tariffs are supervised and published by the Swedish Energy Agency.
The third part of the electricity charge is taxes. In Sweden, like in all the other Nordic countries, the consumption of electricity is taxed. Swedish customers have to pay two different types of taxes, an energy tax and a value added tax (VAT). The energy tax for domestic customers depends on the region. Industries pay no taxes at all at user level. The VAT is applied to the total price of electricity, including the energy tax.
About 40 % of the total electricity price to a domestic customer is the price of electrical energy, 20 % is the share of the network tariff and taxes account for 40 % [2].
Residential electricity customers can often receive two bills: one from the electricity supplier and another one from the electricity grid company in the area. Both bills divide the fees into variable (depending on the amount of electricity used) and standing subscription fees (see Figure 1). The variable fee on the network bill is the charge for transmission and network services. The fixed part is based on the main fuse used in the household and includes also governmental charges (as green certificates etc) [3].

Previous experience from load demand tariffs

The main purpose of implementing a load demand component into electricity pricing is to draw the customer's attention to load demand (kW) rather than energy demand (kWh). In this way, customers will hopefully become more conscious of their energy consumption pattern and possible load demand problems.
As of January 1st 2001, Sollentuna Energi became the first Swedish energy utility to have incorporated a load component into their grid tariff. Their experience is therefore of great interest when other utilities are investigating the possibility of implementing load based electricity pricing strategies.

Sollentuna Energi's load charge depends on the customer's average load value of three daily 1-hour load peaks during one month. This means that through achieving more even electricity use pattern, customers can lower their network bill. The utility introduced the new tariff in a broad campaign explaining "load demand" terms and giving many advices about different ways to lower load demand in residential buildings, with and without electrical heating.

Sollentuna Energi's new tariff showed that customers living in flats with a 16 ampere fuse level had paid, with the old tariff, a lower grid fee than other customers. Some customers in flats had a surprisingly high load demand and relatively large electricity use. Generally speaking, customers living in flats with a 16 ampere fuse level incurred small increase in their grid fee while customers with higher fuse levels (25 – 63 ampere) got a significant price reduction [5]. According to the evaluation made by the utility itself it was possible to lower load demand about 5 % thanks to this new load based tariff.

The experience from Sollentuna Energi also shows the importance of customers' understanding the difference between "power/load" and "energy" terms. In a study made on 1020 of Sollentuna Energi's customers in October 2002 [6], 78 % preferred the old tariff (where customers only paid for their electricity consumption) to the new one. Some argued that it was bothersome to have one more thing to think about concerning the electricity bills. Others argued that the new tariff created higher and unfair electricity costs.

Case study - Skånska Energi Nät AB

Skånska Energi AB (SEAB) is an electric utility that operates in the southern-most county of Sweden, Scania, supplying electricity to about 17 000 customers. The vast majority of these customers, about 75%, are residential customers, but there are also schools, agricultural properties and industrial companies in the customer base [7]. SEAB is divided into a retail company - Skånska Energi Marknad AB (SEMAB) and a grid company which owns the grid in the area - Skånska Energi Nät AB (SENAB).

SENAB is buying electricity from the high voltage grid owner within this area - E.On. The contract states the highest hourly load demand, so called subscribed load, which was at the time of this investigation 78 MW. If this level is exceeded, the utility pays fine per each kW, depending on the terms of the contract with E.On. Over the past 5 years, the subscribed load capacity has been exceeded twice (by 2 MW) - once on the morning of January 21st, 2004 and once on New Years Eve, 2001. The morning peak on January 21st, 2004 cost the company about half a million SEK (54 000 EUR). In order to avoid penalty charges from the supplier and to reduce load demand, and in the long term decrease the subscribed load level, SENAB is interested in incorporating a load component into the grid tariff. In 1998, SEAB invested in an advanced remote metering/billing system, CustCom. This system, which is based on 1-hour measurements for all customers, makes it possible for the utility to introduce such a tariff.

A specialised Internet module makes it possible for SEAB's customers to enter a website and to monitor their electricity use statistics (in kWh/h) whenever they wish, which may help them to verify their network bill and to give more attention to their electricity use and load peaks.

Load demand tariff simulations

With a view to analyse how a grid tariff with a load demand charge could affect the utility and its customers, a new pricing strategy (tariff) was constructed and price simulations, with varying load tariff component values, were carried out [9].

The simulations were conducted as cost comparisons between the cost that the customers would have with the new load demand tariff and the cost that they have currently, with the existing tariff.

The structure of the load demand tariff can be seen in Equation (1).

$$\Phi = P_{av}\, a + s \qquad (1)$$

P_{av} [kW] denotes the average value of the customer's three highest hourly load peaks from three separate days during each month. **a** [SEK/kW] is a constant load price that takes two different values - one from April to October and another from November to March. **s** [SEK] is the fuse level fee of the network tariff (standing charge). Taxes and governmental fees are excluded from the analysed pricing.

The structure of the existing tariff can be seen in Equation (2).

$$\Phi = 0{,}149\, E + S \qquad (2)$$

E [kWh] is the electricity consumption during one month. 0,149 [SEK/kWh] is the energy unit price of the network and **S** [SEK] is the standing charge of the network tariff. Taxes and governmental fees are not included.

The price simulations were run for all of SENAB's customers with fuse levels between 16A and 200A. Customers were divided into groups depending on their fuse level. Customers with a 16-ampere fuse were separated into tree subgroups: customers living in flats 16L, electric heated houses 16V and houses with other heat source 16A.

In all four simulations, the condition that SENAB's total revenue would be close to zero, seen over the whole year, was applied. Component **a** was adjusted in order to achieve this.

In order to get a distinct difference between low and high demand periods, the component **a** in the load demand tariff was almost doubled during the high demand period November - March, compared to the low demand period April - October.

Simulation results

In the first price simulation the following premises were given: (1 SEK = 0.11 EUR)

s = **S**/2

a = 73 SEK/kW November-March

a = 35.5 SEK/kW April-October.

Figure 2 shows the difference in SENAB's income (load demand tariff – existing tariff) for each fuse group. Figure 3 shows the average cost increase for customers in each fuse group, when using the new load tariff compared to the existing tariff.

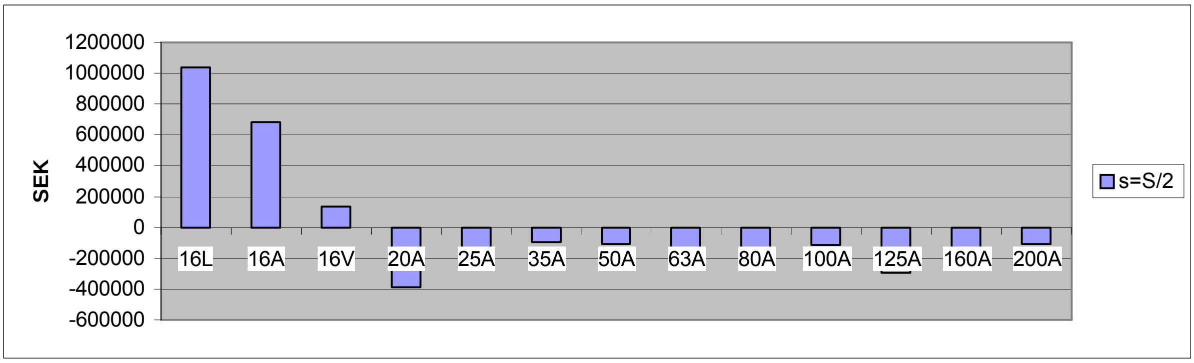

Figure 2: Difference in SENAB's income for each fuse level group (load tariff – existing tariff).
a = 73 SEK/kW November-March, a = 35.5 SEK/kW April-October, s = S/2.

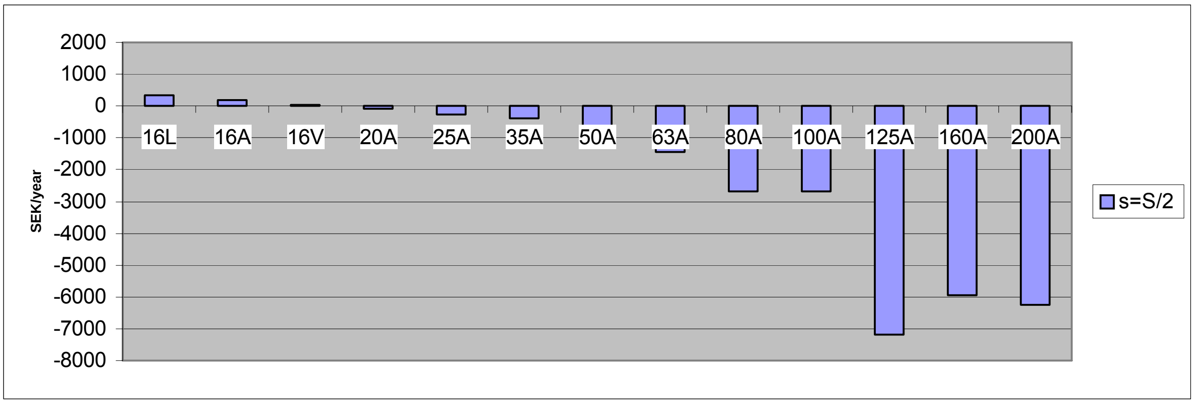

Figure 3: The average cost increase for customers in each fuse group with the new load tariff compared to the existing tariff.
a = 73 SEK/kW November-March, a = 35.5 SEK/kW April-October, s = S/2. (1 SEK = 0.11 EUR)

Negative values in Figure 3 imply that the average customer would be charged less with the new load tariff. The results show that customers with low fuse levels would generally be charged more, whereas customers with higher fuse levels would be charged less.

The second price simulation was preformed for **s** = **S**/3, **a** = 80 SEK/kW November-March, and **a** = 39.5 SEK/kW April-October. The findings from the second simulation were similar to that of the first one. 16L, 16A and 16V customers would incur higher charges with the load tariff, whereas the other groups would be charged less (see Figure 4 and 5).

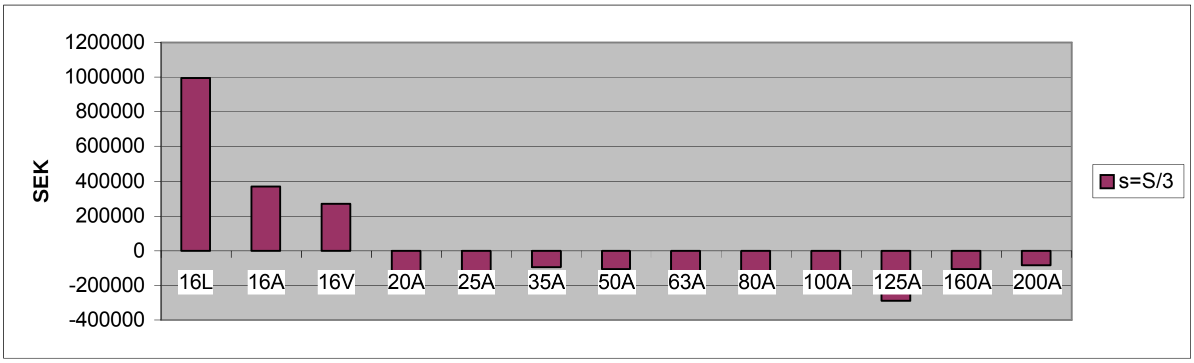

Figure 4: Difference in SENAB's income for each fuse level group (load tariff – existing tariff).
a = 80 SEK/kW November-March, a = 39,5 SEK/kW April-October, s = S/3. (1 SEK = 0.11 EUR)

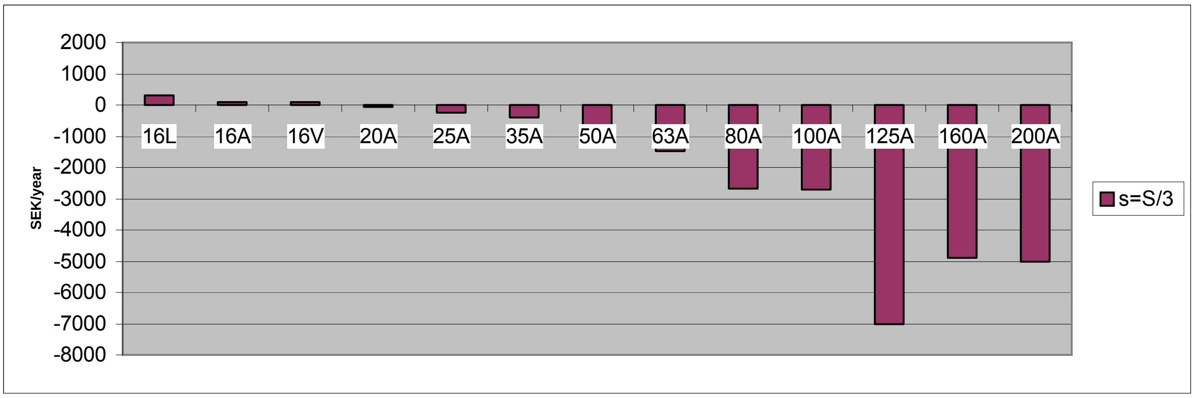

Figure 5: The average cost increase for customers in each fuse group with the new load tariff compared to the existing tariff.
a = 80 SEK/kW November-March, a = 39,5 SEK/kW April-October, s = S/3. (1 SEK = 0.11 EUR)

In order to compare how a tariff based only on a load demand component would turn out, **s** was set to zero (**s** = 0) in the third simulation. **a** = 95 SEK/kW November-March, **a** = 46.6 SEK/kW April-October. In this case, 16A customers would be charged less with the load tariff and 20A-group would be charged more, thus achieving the opposite result to the previous two cases. The other fuse groups however were still following the trend achieved in the first two simulations (higher charges for 16L and 16V and lower charges for the others groups). The results can be seen in Figure 6 and 7.

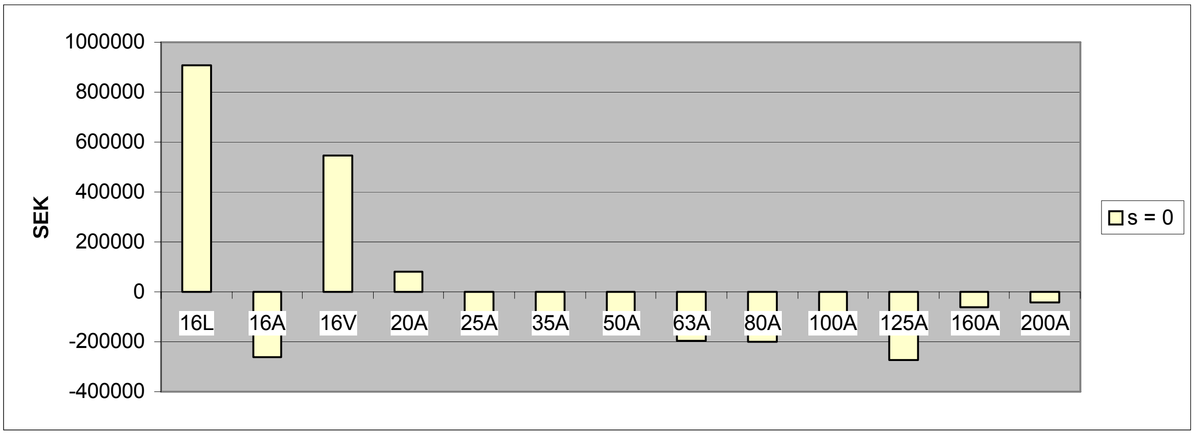

Figure 6: Difference in SENAB's income for each fuse level group (load tariff – existing tariff).
a = 95 SEK/kW November-March, a = 46,6 SEK/kW April-October, s = 0. (1 SEK = 0.11 EUR)

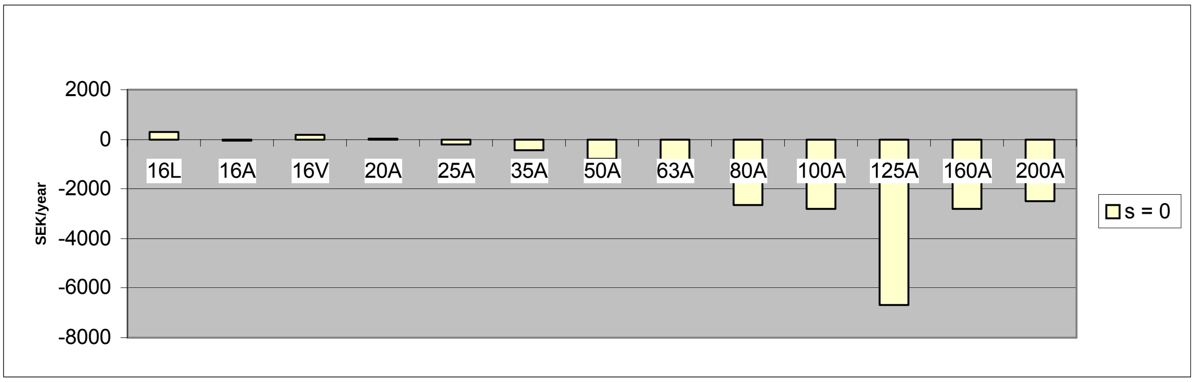

Figure 7: The average cost increase for customers in each fuse group with the new load tariff compared to the existing tariff.
a = 95 SEK/kW November-March, a = 46.6 SEK/kW April-October, s = 0. (1 SEK = 0.11 EUR)

In the fourth and final simulation, the aim was for SENAB's total revenue change, for each fuse level group, to be as close to zero as possible. In this case, **s** was the component that was adjusted. **a** was given the value of 70 SEK/kW from November to March and 35 SEK/kW during April-October. Table 1 shows the existing fuse fee and predicted fee for the new load tariff, if the goal was the one mentioned above. Customers with higher fuse levels would in general incur a higher fuse fee compared to customers with low fuse level. This means that with the existing tariff, customers with a higher fuse level pay a relatively high standing charge in relation to their load demand. It is worth noting that 125A customers would get a higher standing charge with the load tariff. This confirms the conclusion that with the existing tariff, higher fuse level customers are subsidising customers with lower fuse levels.

Table 1: Comparison between existing tariff's and load tariff's fuse fee

Fuse level (Ampere)	Existing tariff's fuse fee SEK/year (without VAT)	Load tariff's fuse fee SEK/year (without VAT)	Ratio: load tariff / existing tariff (%)
16L	696	50	7,2 %
16A	1462	606	41,5 %
16V	1800	966	53,7 %
20A	2238	1333	59,6 %
25A	2792	1820	65,2 %
35A	3861	2500	64,8 %
50A	5438	3804	70 %
63A	6758	5162	76,4 %
80A	8568	7415	86,5 %
100A	10700	8567	80,1 %
125A	13344	14570	109,2%
160A	17072	15670	91,8 %
200A	21007	18000	85,7 %

Conclusions and recommendations

Conclusions from this study and recommendations that can be relevant for energy utilities when planning load based pricing, have been gathered under some selected headings:

Existing tariff with load component
The main purpose of including load demand components into the network tariff is to achieve a lower load demand and avoid load peaks. The analysis has shown that:

- Load based tariff adjusts pricing between fuse groups,
- Totally, load based tariff together with remote meter reading is profitable for utilities,
- The difference between "energy" and "power" must be explained in a comprehensive manner,

- To reach tariff's goals, it is very important that customers understand the structure of load tariff and its aim,
- Customers have to understand that they can save money by changing their energy consumption patterns without the deterioration of comfort or standard of living,
- According to the utility's own evaluation, it was possible to lower load demand about 5 % thanks to the new load based tariff.

Tariff simulations

The results of this study show that:

- If a load demand component were to be introduced into SENAB's network tariff, primarily customers with a 16-ampere fuse would incur higher network charges compared to customers with higher fuse levels, who would be charged less.
- With the existing network tariff, based on electricity use, customers with high fuse levels pay today relatively high standing charges in relation to their exploitation of the grid.
- Several households would lower their fuse level (and the costs),
- It is not clear what would the introduction of load based tariff mean for total load demand level within the simulated area.

Some important issues when introducing load based tariff

Electricity pricing should reflect real marginal costs of electricity production and the utilities' costs. Load based price could achieve higher price elasticity and thus limit the needs for expensive peak load production. Many utilities have already invested in modern Automatic Meter Reading systems (AMR) which facilitate implementation of load based tariffs. Customers are in such a case both an exposed target and a vital potential - in many situations they really want to "help" society, and even "their" utility, to avoid problems and shortages. Therefore, promotion of a new tariff with load based price signal requires a solid and carefully prepared information campaign. It is of great importance for the result that the purpose of such a tariff is clearly introduced to the customers from the very beginning. The difference between "load demand" and "energy use" is not easy to understand and keep after for the majority of customers. They need help to gain a better insight into how their electricity costs will depend on their habits and usage of appliances and installations at home.

Load tariff structure

Load demand tariff should, as any tariff, be simple end easy to understand. The structure and price levels are of decisive importance when trying to influence and change the patterns of energy use. The tariff can always be adjusted afterwards but a comprehensive knowledge about consequences for both customers and utility will help to avoid unnecessary sources of irritation and complaints.

Construction of a new tariff should start with an analysis of load characteristics for a grid company in question - load curves for different customer groups, load factors and superposition factors as well as load aggregation on selected levels in the grid should be investigated.

It is also essential to update the customer register regarding heating system, load guards etc. The new tariff should be tested on some limited groups of customers.

A conceivable solution for a utility, when implementing a new load demand tariff, could also be to offer its customers installation of diverse electronic devices (displays, load guards, soft heating systems) helping them to "keep an eye" on load demand. Together with the new tariff, these investments should be paid back in a relatively short time, helping at the same time to lower load demand in the grid- a win-win solution for both partners.

Customer feed-back

Several investigations and studies have indicated that a continuous feed-back to energy customers is of great significance while different energy related measures and changes are in progress. Possibility to compare the results "before" and "after" or "own" with "others" can intensify and establish more long lasting behavioural changes. Introduction of load demand tariff should therefore be supported by continuous customer focused information. Market segmentation could give a hint how different customer groups should be reached and influenced, depending on their energy related behaviour, lifestyle, information sources and frame of reference.

Extra values
Introduction of load demand tariff needs, or is made possible by, a remote meter system (AMR) with hourly readings. This means that this new tariff should be seen as a part of a development of products and services connected to the AMR system. A number of applications can for example improve customer service and save needs of administration. Extra value-added services related to billing, energy statistics, monitoring, energy guidance, grid optimisation etc, can create new possibilities and values for the company and its customers.

Acknowledgements
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Innovative Thermal Energy Storage Systems for Residential Use

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Abstract

Innovative thermal energy storage (TES) systems are beneficial for residential use, especially in HVAC applications. Thermal Energy from solar collectors or waste heat from industrial processes are examples for energy sources, which can not be utilized effectively without TES. A huge potential of energy sources substituting fossil fuels can only be exploited by the integration of TES systems. They enable a greater and more efficient use of fluctuating energy sources by matching the energy supply with the demand. This finally leads to a substantial energy conservation and reduction of CO_2 emissions.

The growing peak demand of today's energy consumption, essentially caused by air conditioning, leads more often to black-outs all over the world. Such a problem - the shifting of a peak demand for only a few hours or minutes - can be solved by TES. In this context TES can be the best solution not only from the technical point of view, but also for economical reasons.

Different technologies can be used to store thermal energy. Advantages and disadvantages of these technologies have to be taken into account in order to find the most suitable application for each TES system. Demonstration projects are the best way to present the possibilities and proof the reliability of innovative TES systems. Two examples carried out by the Bavarian Center for Applied Energy Research are described in this paper.

Introduction

There is a huge potential for the application of energy storage systems. The fact that energy storage systems are not as widely used as they could, is due to several reasons, in particular because some of these systems are not yet economically competitive with the combustion of fossil fuels and their long term reliability is not yet proven. There are still some regulatory and market barriers which have to be overcome. Therefore, further attempts are being made to resolve these issues.

The IEA Implementing Agreement on Energy Conservation through Energy Storage (http://www.iea-eces.org) was established in 1978 with the objective to facilitate international cooperation on research, development and demonstration (RD&D) of new, innovative energy storage technologies. Initially, attention was primarily focused on energy storage technologies improving the energy efficiency of energy supply.

Over the last few years, the emphasis of the co-operative RD&D efforts has shifted towards storage technologies that improve the manageability of energy systems or facilitate the integration of renewable energy sources. In the future more application oriented topics like thermal energy storage for cooling and industrial processes or mobile thermal storage systems for the utilization of waste heat will be discussed. And since many storage systems are already developed products and have entered the market or are close to it, the topic of market deployment will become more important within the ECES.

The Bavarian Center for Applied Energy Research, ZAE Bayern, is active in different TES technologies. In this paper two examples of demonstration projects of innovative thermal energy storage systems, which were performed by the ZAE Bayern within the framework of the IEA ECES, are presented.

The first project developed a combination of a water and a borehole storage. The advantage of such a system is the minimization of heat losses from the water tank to the surrounding boreholes. The second project is an open Sorption storage using Zeolite for heating and air conditioning of a building in Munich. Both projects are the first of their kind world wide.

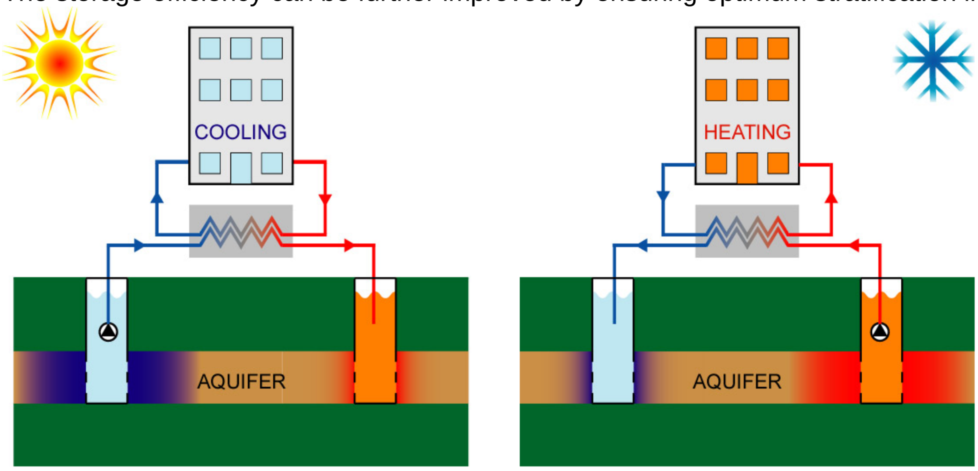
Thermal Energy Storage Technologies

Thermal energy can be stored in different ways given by the thermodynamics of the storage process. If a storage medium is heated up or cooled down the storage is called sensible. If a phase change of the medium is included in the temperature change, the thermal energy storage - TES - is called latent.

These latent thermal storages can provide higher storage capacities and a constant discharging temperature. One example is ice storage for cooling. If the thermal energy input during the charging is initializing a reversible chemical reaction, the storage can achieve even higher capacities and is able to deliver thermal energy at different discharging temperatures. The most developed reaction for thermal energy storage is the adsorption of water vapour on micro porous materials.

Sensible TES

The use of hot water tanks is one of the best known thermal energy storage technologies. The hot water tank serves the purpose of energy saving when e.g. applied to a solar tap water system and an energy supply system with cogeneration. The major aim of an electrically heated hot water tank in a tap water system is to shave the peak in electricity demand and consequently improve the efficiency of electricity supply. A state-of-the-art research project as part of the energy storage programme has resulted in the conclusion that the water tank storage technology has become mature and reliable. The storage efficiency can be further improved by ensuring optimum stratification in the tank.



Summer: cooling of office buildings/industrial processes **Winter:** heating of office buildings/industrial processes

Figure 1: Aquifer thermal energy storage system [1]

The most frequently used storage technology which makes use of the underground is Aquifer Thermal Energy Storage. This technology uses a natural underground layer as a storage medium for the temporary storage of heat or cold (see figure 1). The transfer of thermal energy is realized by extracting groundwater from the layer and by re-injecting it at the modified temperature level at a separate location nearby.

Most applications are about the storage of winter cold to be used for the cooling of large office buildings and industrial processes. It can easily be explained that aquifer cold storage is gaining more and more interest: Savings on electricity bills for chillers are approx. 75 %, and in many cases, the payback time for additional investments is shorter than five years. A major condition for the application of this technology is the availability of a suitable geologic formation.

Other technologies for underground thermal energy storage are borehole storage, cavern storage and pit storage. Which of these technologies is selected, strongly depends on the local geologic conditions.

With borehole storage, vertical heat exchangers are inserted into the underground, which ensure the transfer of thermal energy towards and from the ground (clay, sand, rock, etc.). Many projects are about the storage of solar heat in summer for space heating of houses or offices. Ground heat exchangers are also frequently used in combination with heat pumps, where the ground heat exchanger extracts low-temperature heat from the soil.

With cavern storage and pit storage, large underground water reservoirs are created in the subsoil to serve as thermal energy storage systems. These storage technologies are technically feasible, but the actual application is still limited because of the high level of investment.

Latent TES and Chemical Reactions for TES

Sensible heat energy storage has the advantage of being relatively cheap but the energy density is low and there is a variable discharging temperature. To overcome those disadvantages phase change materials (PCM's) could be used for thermal energy storage. The change of phase could be a solid/liquid or a liquid/gas process. Melting processes have energy densities in the order of 100 kWh/m^3, e.g. ice, compared to 25 kWh/m^3 for sensible heat storage.

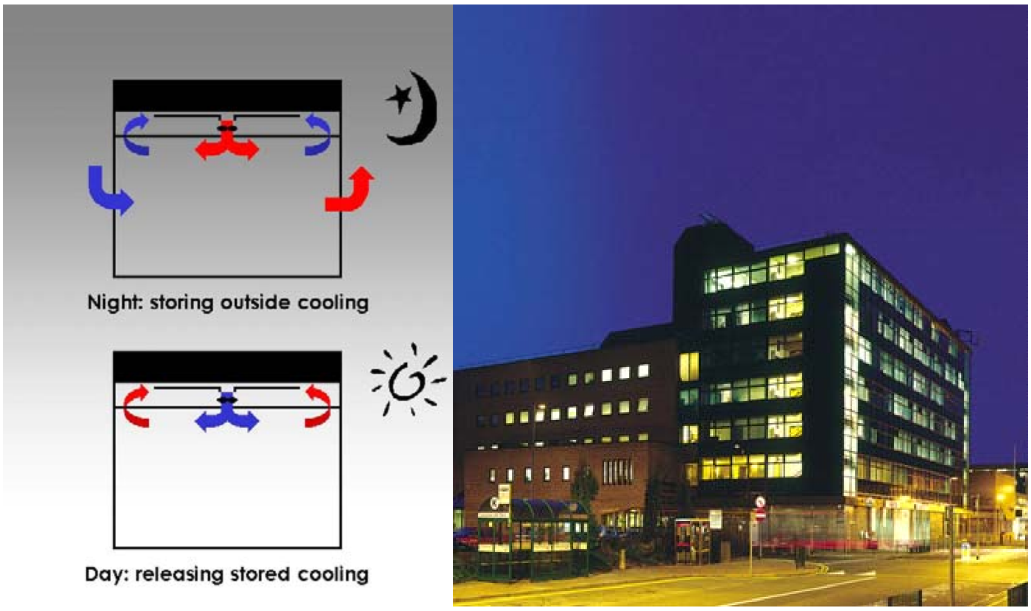


Figure 2: PCM storage system for utilization of night cold [2]

The incorporation of micro-encapsulated PCM materials such as paraffin wax into the gypsum walls or plaster increases considerably the thermal mass and capacity of lightweight buildings. By night the PCM in the microcapsules cools and solidifies. During the day the cool walls, reducing the daily temperature swing by several degrees, and thereby avoiding the need for electric chillers or, at a minimum, reducing the cooling requirements. Another application of active cooling systems is macro-encapsulated salts that melt at an appropriate temperature. The PCM is stored in a building's air vent duct and the cold air is delivered via large-area ceiling and floor a/v systems. In figure 2 such a system, called CoolDeck, in an office building in Stevenage in the UK is shown [3].
Higher energy densities can be reached by the utilization of chemical reactions for thermal energy storage. Energy densities in the order of 300 kWh/m^3 are possible. Thermochemical reactions like adsorption (the adhesion of a substance to the surface of another solid or liquid) of water vapor to Silicagel or Zeolites (micro-porous crystalline alumo-silicates) can be used to generate heat and cold as well as to regulate humidity. Of special importance in hot, humid climates or confined spaces where humidity levels are high, these open sorption systems use lithium chloride to cool water and Zeolites to absorb ambient humidity.

Examples of TES Applications

Sensible TES for Solar Applications
The solar system in Attenkirchen, a village near Munich / Germany, is an example for a sensible TES. The system includes a solar collector array, a seasonal TES, two compression heat pumps and a distribution network to deliver the heat to the buildings [4].
If higher solar fractions, above 30 %, shall be reached for solar assisted heating systems, seasonal storage of thermal energy is unavoidable in European climate. For the storage of large amounts of thermal energy in the temperature range from 0 – 90 ° C underground TES systems are for technical and economical reasons the best solution. Two categories can be distinguished:

- The storage medium water is stored in non pressurized volume like rock caverns or concrete containers.
- The storage medium is the ground, earth or rock, itself. Boreholes are necessary to charge and discharge the ground.

The storage capacity is determined by the difference between the highest and the lowest operation temperature in both cases.
The storage medium can be used as heat transport medium at the same time in the case of water storages. This leads to an easy heat distribution and high thermal power of the storage, which is important for the utilization of solar energy. Furthermore water has a comparable high specific heat, is inexpensive and ecologically safe. The high cost for the concrete container is a disadvantage of such a system.

Borehole storages have an additional heat transfer between the storage medium ground and the heat transport fluid. Additionally a slow velocity of the ground water is important. This type of sensible TES is only applicable under certain boundary conditions and needs in most cases a water storage for power buffering. Advantages of borehole storages are the low cost of construction and the possibility to enlarge the system easily.

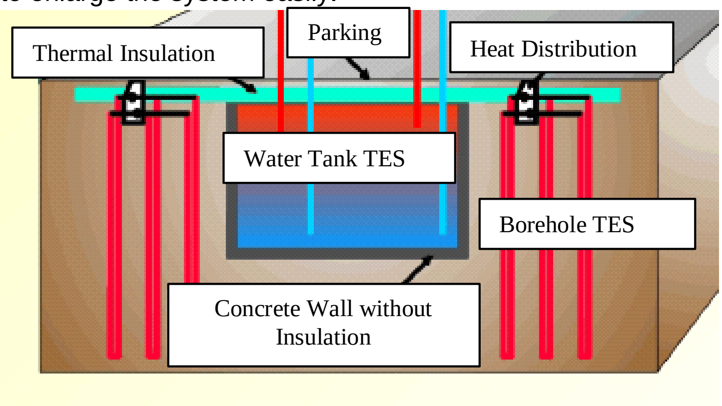


Figure 3: Hybrid TES system including water tank and boreholes

In the project Attenkirchen a combination of a water and a borehole storage were developed (see figure 3). A central cylindrical water container is surrounded by a number of boreholes. The central water tank is used as a buffer and short term storage, while the borehole ring represents the long term TES. There is no thermal insulation of the water tank, except the upper surface. The thermal losses of the water storage can be collected by the surrounding borehole storages. This system combines the operational advantages of a water storage with the economical advantages of a borehole storage. This hybrid system allows the matching of a growing demand by simply adding more boreholes.
At the end of the charging period, in late summer, the temperature within the water storage rises, which leads to a decrease in the possible solar thermal input. The maximum temperature is crucial for the reachable storage capacity. The highest temperature for non pressurized seasonal TES is about 95 ° C.


Figure 4: Construction of the hybrid TES system in Attenkirchen

Figure 4 shows the construction of the hybrid storage system in Attenkirchen. It takes about 3 years for the system to reach steady operation conditions. In the summer of 2003 and 2004 mainly the water tank was charged in order to have enough energy for the winter heating. The heating load was small in the first winter. Due to the partial completion of the residential buildings in the area, the boreholes were not used in the beginning. Ground temperatures of about 45 ° C were measure at the end of the charging phase. During the heating period this temperature was dropped to 9 ° C [5].

Chemical Reactions for TES: Sorption Storage Systems for Heating and Air Conditioning

An example for TES by chemical reactions is the open sorption storage using Zeolite as storage medium. Figure 5 shows the schematically the charging and discharging process. In an open sorption system an air stream transports heat and water vapour in and out of a packed bed of Zeolite pellets.

Temperature and humidity of the air stream were influenced by the sorption process. The input and output of heat and water vapour is shown in figure 5 [6].

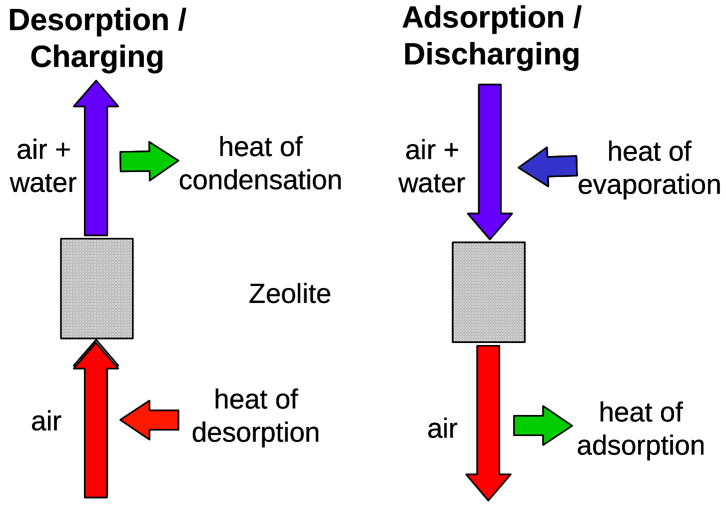


Figure 5: Open adsorption storage system

During desorption, which is the charging process, the air is heated up by the heat of desorption. This heat is loosing the bound water in the microporous Zeolite and evaporates it. The cool air saturated with water vapor is leaving the packed bed. During adsorption, the discharging process, the air is transporting water vapor into the packed bed, where it will be adsorbed. The haet of adsorption is released and heats up the air. The air leaves the packed bed hot and very dry.
For heating applications the heat of adsorption during adsorption and in some cases the heat of condensation during desorption can be utilized. Heat for evaporation during adsorption has to be available at a low temperature level. For air conditioning, which is based on the dehumidification of the air ("desiccant cooling"), cooling can be delivered only during adsorption.
Thermal energy can be stored by sperating the desorption and adsorption step. Desorpbed Zeolite stays charged until the adsorption process starts.
An open sorption storage was built up in Munich Germany by the ZAE Bayern. It is used for the heating of a school building by utilizing thermal energy at 130 ° C from the district heating net for charging and the condensate of the return line for evaporation during adsorption (see figure 5). Air conditioning is provided during Adsorption / discharging by the humidification of the dried air. Before the cooling of the air by humidification the dried air is precooled by humidification of the exhaust air.

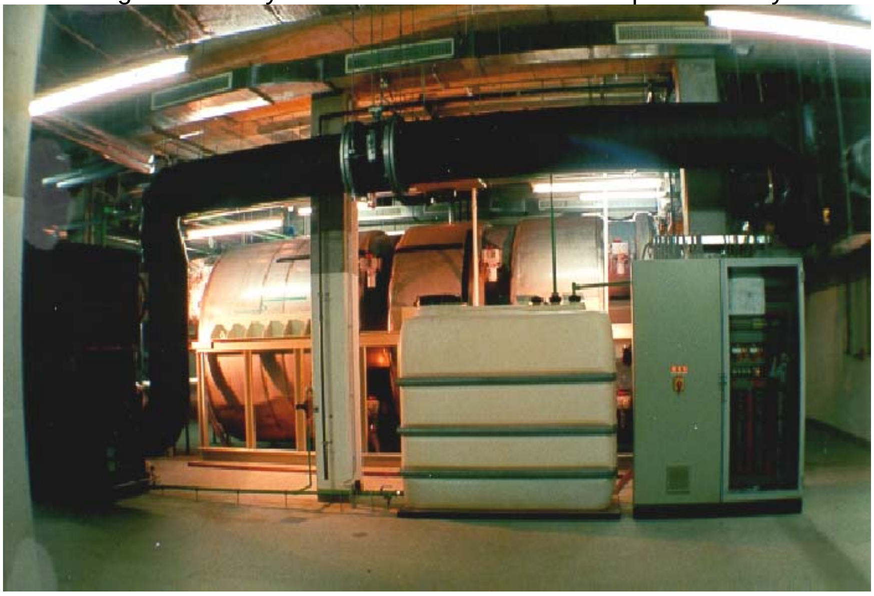


Figure 6: Open sorption storage system

The sorption storage in Munich provides peak shaving fort he district heat. Figure 6 shows the storage modules in the background. Charging takes place during night or in times of low demand. During the day and in peak hours the school building is heated by the stored energy. 700 kg of Zeolite can match

the heating demand of one day at -16 ° C outside temperature. In the summer time a jazz club, which is located in the cellar close to the sorption storage, is air conditioned by the system. In this application district heat is converted into cooling energy.
In the heating mode 92 % of the stored thermal energy could be delivered to the building. The capacity of the sorption storage reaches 124 kWh/m³, which is about 3 times the capacity of a hot water storage, at a charging temperature of 130 ° C If higher charging temperatures up to 300 ° C are available, the capacity could reach 250 kWh/m³ [7].
About 85 % of the stored heat could be converted into cooling energy for air conditioning by the system. This result was accomplished at a charging temperature of 80 ° C. The capacity of the sorption storage for this application was still high at about 100 kWh/m³ . At higher charging temperatures the ratio of usable cooling energy to charged district heat would decrease, while the storage capacity would increase.
If such a TES can be economically interesting, depends on the price for heat and cold delivered by the system. This depends strongly on the number of charging and discharging cycles per time, which was clearly increased by the double application – heating and air conditioning. 150 cycles for heating and 100 cycles for air conditioning were assumed for the sorption storage application in Munich. This leads to a pay back time for the system of about 6 to 7 years. Therefore this technology can compete with conventional systems in the near future [8].

Conclusions and Outlook

The innovative TES systems in HVAC applications described above proofed that they can store thermal energy efficiently and that they are not too far from conventional system concerning their economics. Especially the use of sorption storage system allows beside the high storage capacity a transformation from heat to cold and dehumidification [8].
Within the IEA ECES the topic of TES for cooling was emphasized over the last years. A new Annex “Sustainable Cooling with Thermal Energy Storage” was formed last year (http://www.iea-eces.org/annexes/annexes_ongoing.html). Within IEA ECES previous Annexes 7, 8, 10, 13 and 14 have looked at various aspects of cooling with TES alternatives. The results of these Annexes have lead to an increase in awareness followed by initiation of TES activities. There is a need for the new annex to provide new combinations of TES for different energy systems in different climates and spread implementation of TES systems.
Another interesting field of application for innovative TES could be domestic appliances. Here short term storage could avoid very efficiently power peaks in the future. For example the use of PCM storages in cooling appliances or the application of sorption storages for drying processes look very promising. Certainly this should be a field of future R&D activities.

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The Evolution of CLASP: A Status Report on a UN Sustainable Development Partnership Devoted to Energy Efficiency Standards and Labels

Christine Egan, Stephen Wiel

CLASP

Abstract

CLASP (Collaborative Labeling and Appliance Standards Program) was formed in 1999 as a partnership devoted to advancing the extent and quality of energy efficiency standards and labels (S&L) in developing countries. Since then it has evolved into a globally oriented, globally governed non-profit corporation. In 2001, in preparation for the Johannesburg World Summit on Sustainable Development, CLASP registered with the UN Commission on Sustainable Development as a Sustainable Development Partnership. Recently, CLASP has provided major assistance to S&L programs in China and India; played a key role in the development of a UNDP-GEF global initiative in regional S&L; partnered with APEC in creating a website for global information on S&L; incorporated as a 501(c)(3) non-profit organization; formalized collaborative relationships with sponsoring partners, country partners, implementing partners, and affiliates; and created the S&L Energy Trust Fund. This paper reports on the recent and continuing evolution of CLASP.

Background

CLASP maintains that an energy-efficiency S&L program for appliances is the most efficient and cost-effective greenhouse gas mitigation practice. Once implemented, this practice effectively results in the reduction of greenhouse gas emissions while promoting economic growth and the development objectives that accompany that growth.

A total of 34 percent of global energy consumption results from human activities in buildings. Energy consumption in buildings accounts for: (1) about 25 to 30 percent of all energy-related CO_2 emissions; (2) 19 to 22 percent of all anthropogenic CO_2 emissions; and (3) 10 to 12 percent of mankind's net contribution to climate change from all greenhouse gases. Furthermore, while energy use in buildings is growing by just under 1 percent per year on average worldwide, in many developing countries this growth rate is considerably higher—reaching nearly 9 percent in the commercial sectors of many Pacific and Asian nations.

Building energy consumption involves the use of appliances, equipment, and lighting. Energy use in buildings can be cost-effectively reduced by 15 to 25 percent over the next decade or two by the accelerated adoption of more energy-efficient appliances, equipment, and lighting. Achieving this goal would enhance economic development (especially in developing countries), reduce consumer energy bills, and similarly reduce CO_2 and local pollutant emissions. By promoting energy efficiency standards and labels (S&L) for appliances, equipment, and lighting products, the Collaborative Labeling and Appliance Standards Program (CLASP) is working toward this goal.

There are seven core stages in the S&L process including: 1) Considering a program; 2) Developing a testing capability; 3) Designing and implementing a labeling program; 4) Analyzing and setting standards; 5) Designing and implementing a communication campaign; 6) Ensuring program integrity; and 7) Evaluating the program. These are described in detail in the CLASP S&L Guidebook [1], each being a separate chapter. By the end of 2005, there were 62 countries engaged in this process that implemented at least one energy-efficiency standard or label.

CLASP History

Since 1999, the Collaborative Labeling and Appliance Standards Program (CLASP) has been helping energy efficiency standards and labels (S&L) policymakers and practitioners foster socio-economic development, alleviate poverty, improve the environment, and stimulate global trade. It is an outgrowth of an initiative begun in 1996 at Lawrence Berkeley National Laboratory to help developing countries pursue energy-efficient S&L policies. Shortly afterward, the US Agency for International

Development embraced the effort and funded Berkeley Lab, the Alliance to Save Energy, and the International Institute for Energy Conservation to pursue this initiative. They formed CLASP.

For the five years 2000 through 2004, CLASP, operating as a partnership of its three founders with increasing collaboration with additional partners and with $9.4 million from 12 different donors, provided assistance for the development and implementation. CLASP has conducted work in Argentina, Bahrain, Brazil, Colombia, Chile, China, the Dominican Republic, Ecuador, Egypt, Ghana, India, Mexico, Nepal, Poland, South Africa, Sri Lanka, Thailand, Tunisia, and Uruguay. It has supported regional S&L projects in 30 additional countries.

CLASP registered as a Sustainable Development Partnership with the UN Commission on Sustainable Development (CSD) in 2002. Since registering with CSD, CLASP has partnered with three other CSD Sustainable Development Partnerships – Efficient Energy for Sustainable Development (EESD), Renewable Energy and Energy Efficiency Partnership (REEEP), and Promoting and Energy-efficient Public Sector (PEPS). CLASP has also partnered with Asia-Pacific Economic Cooperation (APEC) by co-sponsoring the joint APEC-CLASP Energy Standards Information System (ESIS) website, a database with information on over 1700 standards.

In 2005, CLASP completed its originally intended transformation into an independent global organization open to all willing and able participants. It is now governed by 12 directors from 8 countries in four continents. Upon its incorporation, CLASP established a formal collaboration of Sponsoring Partners who fund CLASP activities, Country Partners who are the recipients of CLASP services, Implementing Partners who provide CLASP services, and interested stakeholders as Affiliates.

Highlights of CLASP's Accomplishments to Date

Overall Impacts

CLASP measures its success in terms of saved energy and reduced tonnes of carbon dioxide emitted. Saving energy reduces energy intensity. CLASP has assisted with the implementation of 21 new minimum energy performance standards, energy efficiency endorsement labels, and energy information labels that will save 90 terawatt hours (TWh) of electricity and 86 megatonnes of CO2 (MtCO2) annually by 2014– avoiding 140 new large 1000-megawatt power plants. Most of this savings is contributing to reducing energy intensity in China.

China

CLASP, with Lawrence Berkeley National Laboratory (LBNL) as its primary Implementing Partner, has helped China implement a robust energy-efficiency standards and labeling program (S&L) that includes minimum standards, voluntary energy labeling, and a residential energy consumption survey. China's S&L program has transformed several product markets, improved the nation's economic efficiency, and accelerated the pace of China's GHG mitigation

CLASP has assisted China in implementing S&L programs in the sector of the most rapid energy consumption growth in China's economy. China has now implemented 11 minimum energy performance standards (MEPS) for 9 products and endorsement labels for 11 products, including refrigerators, air conditioners, televisions, printers, computers, monitors, fax machines, copiers, DVD/VCD players, external power supplies, gas water heaters, and set-top boxes (under development). These measures are estimated to save 85 TWh annually by their 10th year of implementation. By 2020, China's S&L program is estimated to save 11% of its residential energy use, reduce CO_2 emissions by 34 million tons of carbon annually, and avoid the need for $20 billion investment in power plant construction.

As China's capacity for S&L implementation has grown, the nature of CLASP's support has shifted from technical training and capacity building for the domestic program to assistance in extending market transformation effects internationally through harmonization of efficiency specifications. Most notably, in 2005, China, Australia, and the US adopted a harmonized set of efficiency specifications for external power supplies, based on a single testing standard. Current efforts support both the application of China's S&L programs into new market transformation programs—such as government procurement—domestically as well as the expansion of China's outreach internationally in additional harmonization efforts.

The essence of CLASP's work in China is technology transfer, transferring to China the last 20 years of experience and toolkits that have been developed around the world to support S&L programs. The success relies heavily on cooperation with a wide range of organizations and groups and training of our Chinese counterparts. LBNL has provided 196 person-weeks of training for 90 officials from five agencies, split roughly evenly between training at LBNL and training inside China.

S&L has become a prominent element in China's increasing emphasis on more sustainable energy development and its recently announced energy intensity goals.

Regional S&L Projects

In order to help foster the alignment or harmonization of S&L among nations, CLASP has been providing technical support to seven regional activities with this objective involving 42 nations. CLASP has taken an active role in S&L programs within the Asia-Pacific Economic Cooperation (APEC), the South Asia Regional Initiative for Energy Cooperation and Development (SARI), the Asia and South East Asia Network (ASEAN), and the North American Energy Working Group (NAEWG), and is helping UNDP-GEF develop several regional S&L projects. These efforts address the adoption of the same test procedures, mutual recognition of test results, common comparative energy label content, harmonized endorsement energy labels, and harmonized minimum energy performance standards (MEPS).

Besides participating in numerous seminars, workshops, meetings, and teleconferences, and providing technical information on S&L, CLASP has participated in the following major ways:

- APEC [21 Pacific-rim countries] – In 2004, APEC partnered with CLASP to expand its web-based Energy Standards Information System (ESIS) beyond the APEC economies. The joint ESIS-CLASP database has information on over 1700 standards. Visit <www.apec-esis.org> and <www.clasponline.org>. CLASP has been participating in all of the activities of APEC's Expert Group on Energy Efficiency and Conservation (EGEE&C) since 2002.
- ASEAN [Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam] – ASEAN engaged CLASP to help conduct an appraisal of the ASEAN ballast market, conduct comparative "round-robin" testing for magnetic ballasts in six ASEAN countries, and develop a common testing procedure for magnetic ballasts – all in pursuit of an endorsement label for energy efficient products that would be available for voluntary use by any ASEAN member country starting with magnetic ballasts. CLASP has been working with ASEAN's Energy Efficiency and Conservation Sub-sector Network (EE&C-SSN) and it's ASEAN Centre for Energy (ACE) since 2001.
- SARI [Bangladesh, Bhutan, India, Maldives, Nepal, Sri Lanka, Afghanistan, Pakistan] – USAID's South Asia Regional Initiative for Energy Cooperation and Development (SARI/Energy) program, among other energy efficiency programs, engaged CLASP in efforts to harmonize standards developed by each country in the region in order to isolate the region from low quality and inefficient appliances and improve the energy efficiency of manufactured appliances in the region. Focusing first on harmonizing refrigerator standards, CLASP prepared white papers on testing facilities and protocols, and led workshops in Sri Lanka with key regional technical expects to discuss the regional implications of the refrigerator standards already developed by India & Sri Lanka. This historic meeting led to the formation of an informal regional technical group to pursue future regional standards.
- NAEWG [Canada, Mexico, United States] – The 3-country North American Energy Working Group's (NAEWG's) Energy Efficiency Expert Group has relied solely on CLASP to provide technical support since its formation in 2001. In 2002, CLASP assembled detailed comparisons of the three countries' test procedures, to identify areas for potential harmonization, showing that of the 46 energy-using products for which at least one of the three countries had energy efficiency regulations, three products had nearly identical test procedures in the three countries and ten other products had different test procedures but near-term potential for harmonization. Since then, CLASP has met regularly with the Expert Group conducting several other activities, all related to S&L. Recently NAEWG has become the energy arm of the broader trilateral Security and Prosperity Partnership of North America (SPP).
- UNDP-GEF – In 2002, CLASP began working with UNDP-GEF to develop a series of regional projects to foster regional collaboration in S&L. In 2004 UNDP-GEF brought an S&L international expert to its staff full-time in order to further develop and coordinate this effort. As of the spring of 2006, UNDP-GEF's regional S&L initiative has projects just getting underway in Central America (Costa Rica, El Salvador, Nicaragua, Panama), in the Andean region of South America (Bolivia, Colombia, Ecuador, Peru, Venezuela), and in Southern Europe (Bulgaria, Croatia, Romania, Turkey), with more such projects under development. Besides playing a key role in the development of the initiative, CLASP is providing several international experts to each of the three projects. For example, to the Southern Europe project CLASP is providing: 1) a policy, legal & institutional expert; 2) a market studies expert;

3) a stakeholder assessment and awareness raising expert; and 4) a verification & enforcement capacities expert.

S&L Tools

CLASP has developed four tools for policy makers and practitioners of S&L to facilitate their development and implementation of their S&L programs:

- CLASP maintains and keeps current a website making available comprehensive information about all aspects of S&L and its proponents.
- In 2005, CLASP published a second edition of Energy-Efficiency Labels and Standards: A Guidebook for Appliances, Equipment, and Lighting, designed to help train the many thousands of people worldwide needed to advance the quantity and quality of S&L practice.
- In 2005 CLASP developed a survey instrument to help practitioners of S&L collect the home and business energy use necessary to design effective S&L programs.
- CLASP has developed, applied, and is continuously improving PAMS (Policy Analysis Modeling System), a policy calculator that simplifies and decreases the cost of analysis to set MEPS levels and calculate potential savings/benefit to the economy.

CLASP Today

CLASP promotes the world's best practices in energy efficiency S&L for residential, commercial and industrial equipment and lighting. Four features allow CLASP to assist governments in saving energy and reducing greenhouse gas emissions more cost-effectively and reliably than any other organization in the world:

1. CLASP is the only organization in the world devoted solely to addressing the world's most effective policy for fostering economic development and reducing greenhouse gas emissions – energy efficiency standards and labels.
2. CLASP is one of only two UN-sanctioned Sustainable Development Partnerships devoted solely to energy efficiency.
3. CLASP embraces all organizations and individuals who have the ability and interest to foster CLASP's mission.
4. CLASP assigns the world's most qualified individual to each task independent of nationality or affiliation.

CLASP’s Future

CLASP recently announced the establishment of a Standards and Labeling (S&L) Trust Fund. CLASP hopes the fund will accelerate the adoption of S&L globally as well as enhance the efficacy of the standards and labels that are adopted for the betterment of the planet. In the countries to which funds are applied, the fund will:

- Reduce national utility bills and thus enhance socio-economic development, improve economic efficiency and alleviate poverty;
- Reduce global greenhouse gas emissions as well as local pollutants;
- Stimulate global trade and enhance local competitiveness; and
- Expand the delivery of S&L technical assistance based upon international best practice.

CLASP has successfully attracted funding for big projects in what are generally considered to be key countries including: China, India, and Brazil. With the Trust Fund, CLASP can also bridge gaps in the basic S&L infrastructure, develop new country relationships, and contribute vital support to small nations. There are many steps involved in building S&L infrastructure that sometimes don't fit the standard criteria used by sponsors—work is not country-specific, it has no measurable energy or carbon savings, its payoff is too far in the future (sometimes over-one-year is too long). Yet this work often provides the critical foundation upon which quality S&L programs are built.

CLASP has secured a central place in the S&L world and, in that position must balance varied and numerous opportunities. CLASP seeks to secure $1,000,000 in 2006 to allow it and its partners to pursue short-term and foundational investments that otherwise would be foregone. These funds would be applied to projects that satisfy the following strict criteria:

- Would result in substantial long-term impact in advancing S&L;
- Would enable or stimulate major effort by others in the long-term;
- Would establish key collaborations; and
- Would be a lost opportunity without CLASP funding.

Trust Fund projects will deliver the world's best practices provided by the most highly competent project teams assembled from among the world's most accomplished S&L experts. Sponsors will serve as Trustees, receive reports on the use of the funds and its impact, and participate in annual meetings conducted in order to focus on lessons learned and refine the Trust Fund's annual program strategy. Trust fund sponsors will receive special recognition in CLASP's outreach materials.

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Abstract
This book contains the Proceedings of the 4th International Conference on Energy Efficiency in Domestic Appliances and Lighting, London (UK), 21-23 June 2006. The EEDAL'06 conference has been very successful in attracting an international audience, representing a wide variety of stakeholders involved in policy implementation and development, research and programme implementation, manufacturing and promotion of energy efficient residential appliances and lighting. The international community of stakeholders dealing with residential appliances and lighting gathered to discuss the progress achieved in technologies and policies, and the strategies to be implemented to further this progress.
EEDAL'06 has provided a unique forum to discuss and debate the latest developments in energy and environmental impact of residential appliances and installed equipment, and lighting. The presentations were made by the leading experts coming from all continents. The presentations covered policies and programmes adopted and planned in several geographical areas and countries, as well as the technical and commercial advances in the dissemination and penetration of energy efficient residential appliances and lighting.

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