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VOLUME 2

Editors: Paolo BERTOLDI, Rita WERLE

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Monitoring

Decomposing Electricity Use of Finnish Households to Appliance Categories

Virve Rouhiainen

Adato Energia Oy

Abstract

This paper presents a way to decompose the total electricity consumption in households to appliance categories by systematically combining three types of data via statistical modeling and testing. The decomposition is performed at household level in a large survey and the data is then raised on population level via post stratification. Household level decomposition allows the presentation of results on differing levels of aggregation and the choosing of appropriate concepts to describe household level phenomena with discrete variables. The approach and concepts are illustrated with examples and the results are provided and compared for 1993 and 2006. Further, comparison is made to recent results of neighboring countries and the overall picture is found to be similar. Last the approach used is discussed from cost perspective and its possible variations in monitoring and associated costs are outlined.

Introduction

This paper focuses on statistical issues in decomposing the total electricity consumption in households to consumptions by appliance categories. The need of this decomposition is taken for granted and the aim is to derive good estimates with reasonable cost. For this purpose, we have developed a procedure to combine auxiliary data with appliance specific measurements and survey information on households.

The overview of the approach is presented in Figure 1. The first point to note is that we present two types of results: those describing the situation at country level and those describing reference households. The theoretical rationale is best described by the classical example of throwing a dice. The expected value of eyes in throwing a dice is 3.5 – a number that is never realised in practice. Thus no-one is willing to use that number when betting a result of a single throw, yet when betting the sum of hundred throws number 350 is a very good guess. Because household ownership of appliances is a discrete variable, using average to describe household level phenomena will create similar interpretational problems as using expected value to describe a result of one throw of a dice. Yet when describing aggregate electricity consumption, average or expected value is a very useful concept.

Thus when one speaks of monitoring, the first issue to define is the level and purpose of monitoring. One can monitor households to provide specific advice on the electricity usage or one can monitor national development of household sector to provide information for political decision makers. One can also do both with the same dataset, but as Figure 1 shows the data is combined differently for the two purposes and so the goal will have an effect on the overall design of the project.

Comparison of our household level and national trends will also show this distinction to be of practical relevance. The trends identified at national level differ from those identified for housing segments and household types. For instance, the growth of secondary electrical heating shows in national figures but does not show in the characterization of the typical household. Had we limited our measurements to say selection criteria we used in the early measurement study of 1991, we would have failed to identify this trend of increasing heating related consumption in houses using biofuel for space heating and as our goal was to describe the national development, we would have failed to indentify an essential part of the recent development of electricity use in the household sector.

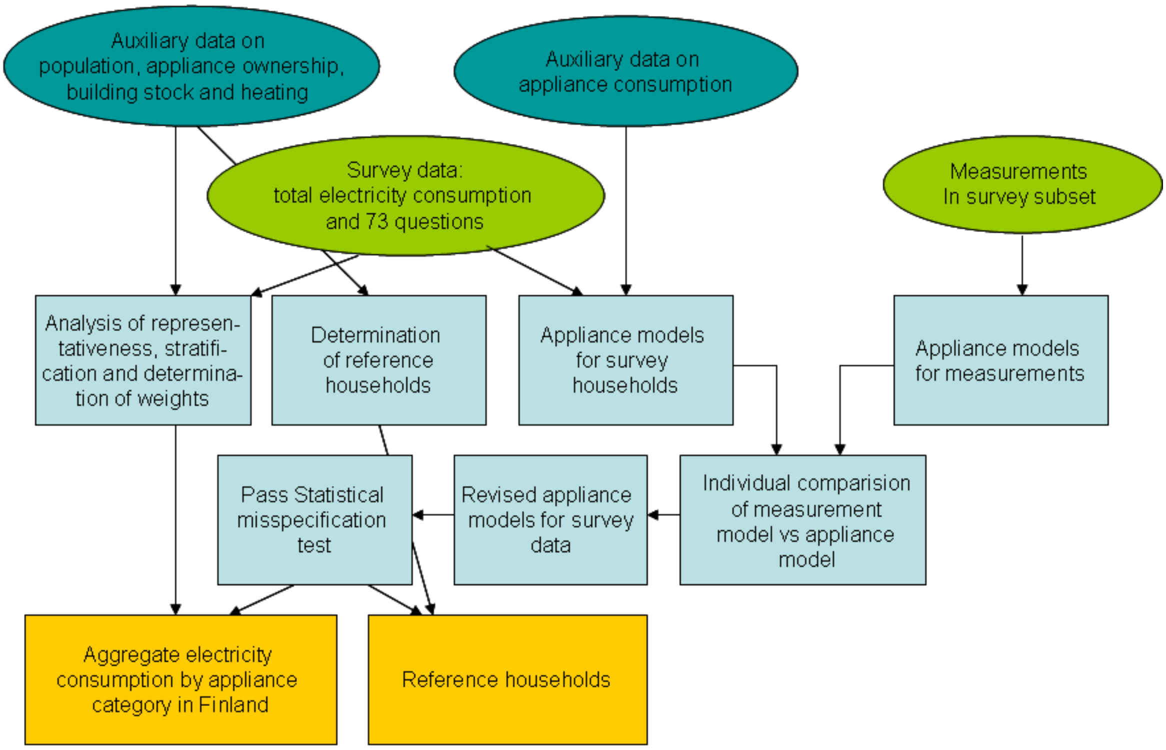

Figure 1. Overview of the Data Collection and Analysis of the Present Set of Methods

This procedure outlined in Figure 1 was first used in report Kotitalouksien sähkönkäyttö tutkimus 1993 /1/. All the elements of the approach were developed then, though the test procedure for models was less rigorous than today. The approach was developed on basis of experience gained from two early studies. By 2006 the results of this cross section study had become outdated and need for an update was pressing. The update study started in Nov 20, 2006 and was carried out by Adato Energia Oy, Finnish Energy Industries and TTS Research. The main funder was the Finnish Ministry of the Economy and Employment.

This paper is structured as follows. First, the lessons learned from the two early studies are discussed. Then the present method is outlined and the stages of analysis are illustrated with examples taken from the 2006 study. A few of the results related to testing are discussed and compared to results from other recent studies. This is done more in order to illustrate the analysis and the issues of comparison than to provide in depth comparison of results, which is not in the scope of this paper. After the combination of methods is described, the results of the cross section studies of 1993 and 2006 are compared both at national and at household level. As the concepts and basic methods used in the studies are similar, the comparisons are valid. Further, some comparison is made to recent results in neighboring countries. The last issue discussed is the alternatives of applying this procedure to reduce the costs of monitoring at national level.

Lessons Learned from Two Early Studies

The present set of methods has been developed on basis of experience gained from two early studies. The first one of these finished in 1991 was a measurement study. The second one finished in 1993 used conditional demand analysis to derive end use decomposition.

The first study /1/ was commenced in 1987 because one could not understand why household consumption of electricity was increasing in such a rapid pace. The method chosen was metering and the goal was to meter at least 50 % of the electricity consumption of each participating household. Altogether 50 households were metered. Of these 20 were apartments and 30 single family houses. The target was barely met in apartments and in single family houses the share of metered consumption was about 30 %. The electricity was not going where expected – not even in apartments.

The households for this early measurement study were selected from volunteers using defined criteria for housing type (apartment / single family house), location (rural / urban), space heating (district heat / oil fired central heating) and household size (two and four person family). In order to efficiently utilize the expensive measurement system, one decided to measure highly equipped households only. Further, geographic location was limited to reduce installing cost. In addition to these controlled selection criteria, it turned out that self-selection was present in the study. The share of houses with an air heating system was over 50 % when the share of that system in population was and still is few percentages. It is worth noting that similar phenomenon occurred in another Finnish measurement study in the early 1980's /4/. This system of heat distribution had high electricity consumption and thus households having it were more willing to participate in the study than others, because they wanted to find out the reason for the electricity consumption.

The end result of this metering study was very detailed data on a small and non-representative set of households. In the apartments average consumption was app. 40 % and in the houses app. 55 % greater than the respective averages from other sources. This data contributed to understanding of behaviour but generalizations were impossible and we could not answer the question why electricity consumption was growing, though we knew that at least in these households it was not going to cooking, washing or cold storage. The only common factor seemed to be home electronics, which was then measured in 1993 study and role of stand by consumption discovered.

Originally one had planned to complement this 1991 measurement study with a survey, but due to numerous other difficulties in the measurements that part was never realized. In 1992 a survey data was collected for Helsinki area. The sample was drawn from the customer data base of the local utility and the survey answers were complemented with total electricity consumptions. The conditional demand analysis decomposition was performed on this data set /3/. The decomposition as such worked well and the results on unit consumptions of the appliances were in line with the metering study. The effect of non-response to the representativeness of data was analyzed and systematic differences in response rates between socioeconomic groups were observed. Typically, the higher was one's consumption the more likely one was to answer.

The similarity of decomposition results of these two different approaches /3/ suggested that combination of the approaches might prove even more useful than reliance on one approach alone, especially if one was after population level results. This is because it is considerably easier to collect representative survey data than it is to collect representative measurement data. In fact, the obstacles of doing the latter are of such magnitude that a need for a generalization method like the one presented in this paper should be evident. Though it is easier to collect representative survey data than measurement data, also the representativeness of the survey needs to be analyzed and deviations caused by differing response rates need to be corrected for e.g. via post stratification.

Present Set of Methods

The experience from the two studies described above led to a development of a set of methods to combine measurements and survey. The first study with this combination of methods was finished in early 1995. Its data was collected in 1993 and comprised a survey of 2000 households and measurement data of about 100 households with app. 700 measured appliances. The 1993 numbers in the results section come from this study. This will be referenced as 1993 study and the update as 2006 study.

Figure 1 describes what kind of data is used to derive models and two types of results we present. The ellipses describe data. The first line of boxes describes analysis needed for generalization and model building and the second line of boxes describes model testing. The third line shows how these steps in the analysis are combined to derive results. Next these steps will be described in more detail.

Collection of Data

Figure 1 shows that we utilize both auxiliary data and collected data. With auxiliary data we refer to data obtained from national statistics, databases and literature. This data set is divided into data used in generalization and in the definition of household types and into data used in building the survey models. In Table 1 information under heading population represent auxiliary information.

The second type of data is collected data which in 2006 refers to a survey data of over 3000 households and measurement data over 950 appliances in 91 households. The survey data was collected via internet and mail survey and complemented with individual consumption data provided by the utility. The survey questionnaire had 73 questions some of which had several points to answers. The questions covered the ownership and characteristics of major appliances, frequency of use of the major appliances and details of the dwelling type including heating system and household size and socioeconomic back round information. The questionnaire is available in the Finnish project report /6/.

To facilitate efficient use of data and model testing the measurements were performed in the subset of collected survey. Two approaches to measurements were used. The cheap approach, where we used plug in electricity meters, turned out to be the more cost effective of the two. Households that agreed to participate were provided a measurement plan, diaries, instructions and meters. They put the meters in place and returned diaries with measurements by mail.

In total 94 metering plans were drawn. Out of the 94 households 12 returned no data. The rest returned something and the majority of them completed the measurement plan to 90 %[1]. The only compensation promised for metering was a promise of analysis of the consumption of the household in question. In the consistency tests the data checked out.

The second set of metered data consisted of 9 households and one heating system (ground to water heat pump). The electricity meters and data collection system provided by BaseN were installed at the mains. The purpose was to meter appliances like sauna and kitchen stoves for which plug metering was not possible. The original plan was to meter 30 households with the installed extra meters with 2 minute metering resolution. Though the metering system as such worked well, installing the system was more laborious (and thus costly) than expected and the data handling system was not designed for the kind of analysis we needed. Thus we only completed installations in 9 households.

Table 1 shows the distribution of the household size in the data sets of the 1993 and 2006 and that of the population. It is obvious that the data as such is not representative of the population and for representativeness the results need to be weighted. This is discussed in detail later.

Table 1. Distribution of Household Size in Finland and in Collected Data of the in 1993 and 2006.

Household Size	Population		Survey		Measurements	
	1993	2006	1993	2006	1993	2006
1	34 %	40 %	19 %	23 %	9 %	30 %
2	30 %	33 %	27 %	41 %	17 %	27 %
3	15 %	12 %	20 %	15 %	22 %	16 %
4	14 %	10 %	22 %	13 %	32 %	21 %
5 or more	8 %	6 %	6 %	7 %	20 %	5 %

Building the Models

The first stage of building the appliance models for survey data is to calculate unit consumption for all the major appliances in all of the survey households. In order to make the comparison of survey model to measurement model meaningful this is done on basis of auxiliary data. The one exception is cooking which is modeled via diary data collected from the measurement households.

The auxiliary data used was mostly laboratory appliance test results, but it could as well have been other field measurements or even technical calculations. In addition to facilitating testing this independent modeling offers a way of incorporating into analysis appliances for which one has survey data but no measurements.

The exact formulation of the survey model varied from one end use to another and reflected the questions we had asked in the survey. For cold appliances we had survey data on appliance types in

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[1] This means that the household left at most 10 % of the appliances mentioned in the measurement plan unmeasured.

the household (fridge, freezer, combination fridge-freezer etc.), number of months the appliance was used, the age of the appliance and its energy class. An appropriate specific use per month was then found in the literature for the classification described above, and used to calculate annual consumption for all cold appliances in the survey.

For dishwashers, tumble dryers, washing machines, electric sauna stoves and car heaters, we had survey data on appliance ownership, appliance age and number of uses per week. An appropriate specific consumption per use was then found in the literature for the classification appropriate for each appliance and the consumption for all appliances was calculated by multiplying the appropriate specific consumption by frequency of use.

For computers and TV's the estimates were calculated on basis of hours of use and the size and type of the appliance.

For cooking another approach was used. We used diary data to calculate the electricity consumption of cook top and oven. In the survey we had 17 cooking related statements and the household was to choose whether these described it well or poorly. From this data set in the survey three factors with factor scores were derived by factor analysis and the factor score of the households in the survey were correlated with the diary data of the same households. This modeling exercise provided improved fit with same number of variables compared to model derived in 1995.

The end uses modeled in the survey data on basis of auxiliary data include comfort floor heating, mechanical ventilation, heating system equipment (circulation pumps, heat exchangers and burners), lighting and car heating. As electric space heating was not in project scope, it and related component water boilers was not modeled in detail, though general estimates of the size of those components were derived.

After this modeling the total electricity consumption y_i of each household i in the survey was decomposed on basis of the questionnaire data to end-uses EU_j and an error term ε_i

(1) $$y_i = \sum_{j=1}^{k} EU_j + \varepsilon_i$$

The next step in the modeling was to test this decomposition.

Testing the Survey Models by Comparing to Measurement Models

The first set of tests of survey models were based on the overlapping structure of the survey and measurement datasets. This means that for each measured appliance in households we had a corresponding modeled appliance in the survey and we could compare how well the survey model compared with the measurements and if they were different why they were different. For this purpose the measurement data was modeled with help of the accompanying diaries which were kept by the households during measurements. This stage of analysis is illustrated below with examples of the comparisons.

The appliances for which survey models and measurement results matched very well were cold appliances and dish washers. For dishwashers average difference between the modeled consumption and the measured consumption was 2.7 %. The comparison of dishwashers is illustrated in Figure 2.

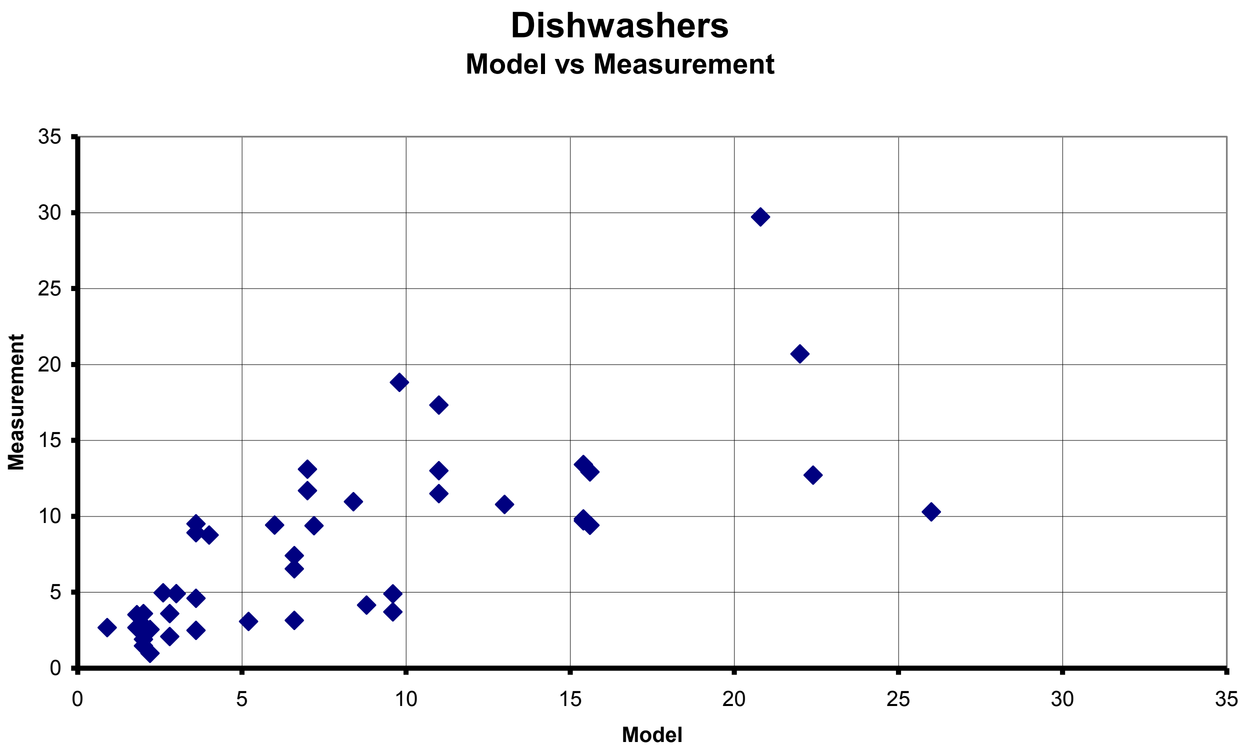

Figure 2. Weekly Electricity Consumption of Dishwasher - Survey Model Result versus Measurement in Respective Households

Washing machines were similar to dishwashers in the respect that the frequencies of use households gave in the survey matched well to diary data. However, the data gave no support to there being a difference in cycle consumption attributable to age of the appliances. The data is illustrated in Table 2.

The average per cycle consumption is 0.73 kWh. This is close to the average per cycle consumption 0.68 kWh of washing machine measured and reported in REMODE report 10 (Table 3-3) /7/. The draft report of the Swedish /8/ data does not give the average consumption of wash cycles, but estimated from the histogram (Figure 2.227) it seems to be around 0.6 kWh. It is worth noting that this difference may, instead of differences in behavior or appliance stock, be attributed to different way of calculation. In our approach we are calculating the per wash consumption by washing machine and averaging these, when the estimate for the Swedish data is calculated over all washes. If low per wash consumption also means higher number of loads for a particular washing machine, the calculated per wash average over washes is then lower than the per wash average calculated over washing machines.

Table 2. The Comparison of Auxiliary Data Used for Modeling and Measurement Data – Cycle Consumption of Washing Machines and Machine Age

Washing machines	Average use per cycle kWh	
Appliance Age in Years	Survey Model	Measurements
less than 5 (19)	0.76	0.78
5 to 10 (14)	0.80	0.69
over 10 (11)	1.00	0.71

Numbers in parenthesis refer to number of appliances.

The tests for the tumble dries and sauna stoves indicated need of adjustment. The model for sauna stoves is shown prior and after the test in Figure 3. It is worth noting that the data set is very small and thus the model is tentative. As the specification test (see Table 3) indicates that the consumption could be even smaller this revision was in order. For tumble driers the cycle consumption estimates made from the available literature turned out to be too high and they were revised downwards. The average cycle consumption for the measurements was 1.58 kWh, which is again of similar magnitude as the estimate 1.72 kWh in Table 3.3. of REMODECE report 10 /7/. For the Swedish data /8/ the cycle consumption seems to be slightly lower. The median estimated from table 2.243 is about 1.2 kWh. Similar reservation to Swedish comparison as with the case of washing machine applies.

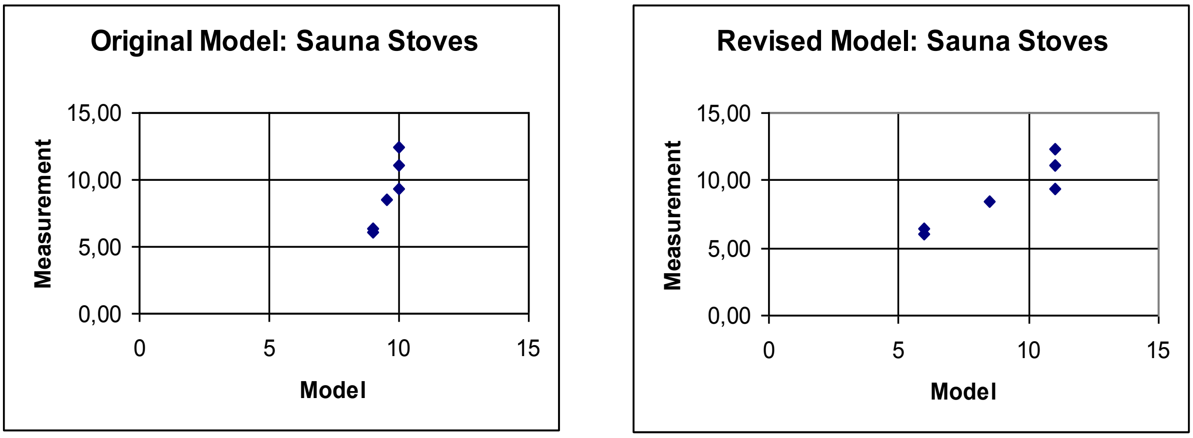

Figure 3. Comparison of the Original and Revised Survey Model and Measurement Model for Sauna Stoves

The survey model for computers was the one were most revision was needed. Even though the households were able to give good estimates for the frequency of use of their appliances, they underestimated the hours of use of the computer if they used it less than three hours a day. Heavy users on the other hand were able to give correct estimates. This indicates a need to find a better way to ask about the computer use in future studies. In addition, the technical data on power consumption needed adjusting as well. With the help of measurements we were able to improve the model considerably. Figure 4 shows the revision bath for desk tops. The first picture depicts the survey model calculated with diary hours of usage. The second shows survey model calculated with diary hours of usage and standby. The third picture shows the survey model with revised power consumption figures and the forth shows how the revised model would look with stand by if that were available in the survey. Unfortunately, this was not the case and the third figure shows the final survey model as no question on stand by usage was included in the survey.

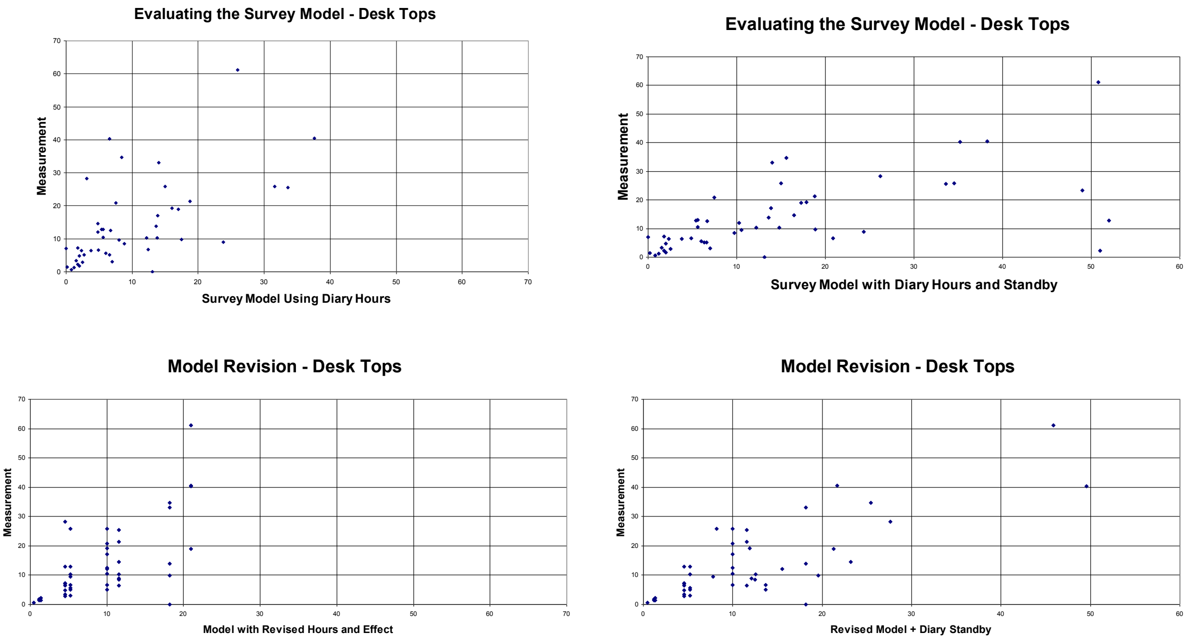

Figure 4. The Revision Path for Desk Top Model

The comparative analysis of survey and measurement data shows that for some appliances the frequency of use can be reliably estimated from survey but this is not uniformly the case. Measurements and diaries are one way to improve information, but developing survey questions remains also a viable option and may in the long run be more cost effective. Further, the analysis shows that the quality of the available auxiliary information varies. For cold appliance with long tradition of testing the model derived with auxiliary information turned out to be good, when for computers the model based on auxiliary information needed considerable revision. Further, given the correlation between family size and the frequency of use of certain appliances like washing machines, one should be very careful in applying standardized numbers in describing frequency of use. For instance, the standard number of cycles for washing machines is 220 when the average number of cycles in Finland is app. 170. In rough per person terms this would mean the 85 cycles per person which is again very close to numbers presented in the Swedish report (p. 150) /8/.

Testing the Survey Model Statistically

After checking and revising the end use models of survey data against measurement data and models, the survey model is statistically tested against misspecification. The test used is general and will thus react to number of possible problems. These include the households changing their behavior during measurements and the measurements being non representative with respect to survey. Further, on some of the appliances modeled in the survey we have no or only very limited number of observations and thus the test is helpful in determining whether the modeling is good enough or whether more data is needed.

The test used is standard for testing restrictions set for parameters in linear regression models. Basically we write the equation (1) in form of linear regression by adding the regression coefficients β_j for all the end uses i.e.

(2) $$y_i = \beta_j \sum_{j=1}^{k} EU_j + \varepsilon_i$$

If the model is correctly specified $\beta_j = 1$ for all j. To test the hypothesis of correct specification one estimates both the restricted and unrestricted model. The test statistic F is constructed from the error sum of squares is

(3) $$F = \frac{(SSE_r - SSE_f)/(p-q)}{SSE_f\ /(n-p)} \approx F((p-q),(n-p))$$

Imposing the restriction $\beta_j = 1$ for all j reduced the model fit very little. The F(1,1130)=0,033 corresponding p-value 0,86. Thus it was possible to conclude at 14 % significance level that the model was correctly specified and the $\beta_j = 1$ for all j's of the free model that according to t-test were significantly different from 1 just reflected chance. With 16 explanatory variables one would expect at 5 % level significance one falsely significant β.

Few points are in order. First, the test is performed for a subset of data for which all the major end-use components were modeled. As modeling electric space heat was out of project scope, this part of the data was not included in the test. Second, if we have very little belief in our models, it possible to require the significance level of not rejecting the correct model specification to be higher than 14 %. Then the estimated β-coefficients of the free model that are different from one can be taken as indicators of the appliance models needing improvement.

Table 3 shows the estimated coefficients of the free model and associated 95 % confidence intervals calculated separately for each of the coefficients. As one can see, number one falls outside the confidence interval for some of the coefficients. Note however, that for simultaneous testing of all coefficients performed above this is not the case and the hypothesis of correct model specification would not be rejected at 5 % significance level.

Table 3. Testing the Survey Model – Estimation Results of the Free Model and 95 % Confidence Intervals for the Regression Coefficient with Interpretation

End Use Category	Regression coefficient	Standard deviation	Lower limit	Upper limit	Indication
Lighting inside	0,794781	0,094748	0,609079	0,980484	r
Electric sauna stove	0,736033	0,05872	0,620944	0,851123	rr
Cooking	0,287061	0,151175	-0,00924	0,583359	?
Computer paraphelia	1,642043	4,618906	-7,41085	10,69493	?
Floor heating other	2,149323	0,643678	0,887737	3,410908	ok
Lighting outside	0,980146	0,424299	0,148536	1,811756	ok
Dishwasher	1,258665	0,251401	0,765928	1,751402	ok
Television paraphelia	1,130675	0,186216	0,765699	1,495651	ok
Mechanical ventilation	0,735105	0,166685	0,408409	1,0618	ok
Washing machine & tumble dryer	1,283387	0,163543	0,962848	1,603925	ok
Heating system	1,129621	0,156542	0,822805	1,436438	ok
Cold appliances	1,131526	0,097614	0,940206	1,322847	ok
Floor heating vestibule	3,237204	0,904242	1,464923	5,009486	i
Car heating	2,118212	0,256091	1,616284	2,62014	ii
Computer	1,507797	0,187153	1,140984	1,87461	ii
Television	1,41131	0,184489	1,049718	1,772902	i
Floor heating washing room	1,769992	0,142768	1,490173	2,049812	ii

r / rr - model estimates are too high with respect to confidence interval (r 95 %, rr 99 %)
i / ii - model estimates are too low with respect to confidence interval (i 95 %, ii 99 %)
ok - model estimates fall within 95 % confidence interval
? - estimated coefficient for the model may be zero, model success questionable

In Table 3 it is interesting to note that the appliance groups for which the free model indicated a β-coefficient significantly different from one were those appliance groups for which we had constructed the model with little auxiliary or measurement data (e.g. floor heating) or for which we knew that something was missing (e.g. computer stand by). Further, though our model for cooking worked for the measurements, it does not seem to work so well outside the measurement data. So had we required a significance level higher than 14 % or had we had more resources for modeling or data collection this test would have helped us to determine where to direct our efforts.

Generalization to Reach Population Level Results

As stated earlier, surveys suffer from bias induced by differing response rates of population groups. The way to correct for this is post stratification, which means that one analyses the representativeness of the data with respect to population (number of persons in households, age structure, type of dwelling, geographical location, socioeconomic position), systematic difference in the variables of interest (type of heating, electricity consumption level, ownership of appliances) and identifies systematic differences in response rates.

From the analysis it was obvious that households with electric space heating had 1.6 times higher response rate than households without electric heating. Thus high electricity consumption increased the likelihood of answering and electric heating became one of the factors in creation of strata. This required that housing type also became a stratification factor. Table 1 showed that the survey data was not representative with respect to household size. Thus household size also became a factor in stratification. The comparison of age distribution of the survey to that of the population showed that we had too few elderly, so within 1 and 2 person households the households of the elderly became a stratum as well. In other respects the data distributions corresponded well enough to those of the population.

To derive the population level numbers we found out the number of households in population in each stratum from official statistics and calculated the average of consumption all the modeled appliances in the survey by stratum. If a household did not have an appliance, the consumption of that appliance was zero. Technically this corresponds to the ownership correction in table 3-6 of REMODECE report

10 /7/. Then for each stratum the average was multiplied by the size of the stratum and the totals were added together.

If the households within the stratum are representative of that stratum, this method will give an unbiased estimate of the variable to be estimated. Because the total electricity consumption of the household sector is a known number, we were able to compare the sample estimate of the total to the population total. The weighted (or bias corrected) sample estimate was 17.7 TWh, when the temperature corrected population total was 18.7 TWh for 2006. The size of the temperature correction for 2006 is about 0.5 TWh. Further, the difference of using households of which Finland had 2.45 million in 2006 instead of dwellings 2.7 million created a difference of app. 0.2 TWh, thus corrected sample figure was about 18.4 TWh. We found this to be close enough given the other uncertainties around the figures. It is worth noting that had we generalized the data without correcting for representativeness our estimate for total use of electricity in household sector would have been 24 TWh instead of the above mentioned rough 18 TWh.

Determination of Reference Households

To determine how to define the reference households we first look how the Finnish households fall into categories with respect to household size and type of dwelling. This data for 2006 is shown in Table 4.

Table 4. Finnish Households in 2006 Cross Tabulated with Respect to Type of Housing and Household Size.

Number of inhabitants	**Houses**	**Row houses**	**Flats**	**Other**	**Total**
1	8 %	6 %	**25 %**	1 %	40 %
2	**15 %**	**5 %**	13 %	1 %	33 %
3	7 %	**2 %**	**3 %**	0 %	12 %
4	**7 %**	1 %	2 %	0 %	10 %
5 or more	4 %	0 %	1 %	0 %	6 %
Total	41 %	14 %	43 %	2 %	100 %

For 2006 data we defined 8 household types and those are marked with bold font in Table 4. For 1993 data four types were defined. The types defined for 2006 are listed below and the ones defined already in 1993 are shown in bold font and marked with x. One of the reference households of 1993 – four persons living in a 90 m^2 row house – was changed to be three persons in a row house.

1. **One person living in a typically equipped flat (x)**
2. One person living in a highly equipped flat
3. Two persons living in a typically equipped row house
4. Two persons living in a relatively highly equipped house
5. **Three persons living in a typically equipped flat (x)**
6. Three persons living in a fairly highly equipped row house
7. **Four persons living in a typically equipped house (x)**
8. Four persons living in a highly equipped house

As these reference households are mostly used to provide information to household on typical electricity use, the groups are defined so that all household types are more or less covered. For instance, one person household living in a house can compare its consumption to that of two persons living in a house. If our purpose is to inform households of the relative size of their consumption the use of simple averages is not enough as there are clear systematic differences between family types and thus the fair comparison is to similar family type. For instance 4000 kWh is small consumption for a four person household living in a house and large consumption for one person living in a flat.

The appliance ownerships and consumptions for the typical households are defined on basis of median figures. For ownership this means that if over 50 % of the household type in questions owns this appliance then the typical reference household has it. For instance in 1993 the prevalence of tumble dryers in 4 person households was less than 50 % so it was not included in the appliance stock of the typical household. Today the prevalence is greater than 50 % so tumble dryer is included. The rationale for this definition is that real households own whole appliances. After this the typical consumption of the appliance for the household category in question is determined on basis of median consumption. The reason for this is for skew distributions that median is better suited for comparison as 50 % of the observations are below and 50 % of them are above median.

In this paper we only present results for reference households 1 and 7, as this is enough to demonstrate the concepts and show trends. However, the usefulness of percentiles in comparison is worth point out. As the list shows in addition to typical household we have defined two highly equipped households. For instance, the consumption of home-electronics in reference household 8 is 1800 kWh compared to 750 kWh of a reference household 7. The detailed description of these results is available in the project report /6/.

It is also possible to ask the question what is the right comparison from the energy efficiency point of view. We could as well set the comparison lower that to mid point of distribution and talk instead of typical consumption of target consumption and define this to be, say the first quartile.

Results

Results at Country Level

Table 5 shows the household electricity consumption in Finland by appliance category in 1993 and 2006 at national level. The consumption by cold appliances has decreased both in share and absolute level. It is interesting to note that the saving potential estimated in 2002 for period 2000-2005 has been realized /5/. The other component showing reduction in absolute level is cooking. Here the explanation is more the change in behavior than in technology though increased use of microwave ovens also contributes to the development. In total the consumption of home electronics PC's, television and related appliances has clearly increased. In 1993 these appliances were reported as one group, but the role of PC's was then minor. Thus the major contributor to the increase is PC's. The share of lighting is unchanged, but given its share the increase in absolute value is considerable. This observation is even more important when we remember that considerable technical saving potential within lighting exists. The other element with considerable growth is other consumption.

Table 5. Household electricity consumption in Finland by appliance category in 1993 and 2006

Appliance category	**1993 GWh**		**2006 GWh**	
Cold appliances	2 215	30 %	1 461	13 %
Cooking	796	11 %	653	6 %
Dish washing	125	2 %	261	2 %
Washing and drying laundry	316	4 %	391	4 %
Television and related appliances	537	7 %	834	8 %
PC's and related appliances			407	4 %
Electric sauna stoves	606	8 %	852	8 %
Heating and ventilation equipment (1)	483	6 %	621	6 %
Electric floor heating (2)	0	0 %	206	2 %
Car heating (3)	226	3 %	218	2 %
Lighting (inside)	1 541	21 %	2 427	22 %
Lighting (outside)			89	1 %
Other equipment (4)	623	8 %	2 572	23 %
Total	**7 468**		**10 992**	

1) mechanical ventilation, circulation pumps, heat exchangers
2) excluding electrically heated houses
3) excluding flats and row houses
4) due to definition used contains electric space heating type of components

First leads to the enigma of other consumption can be found in looking the development in housing segments. Table 6 shows the development in three housing segments. In flats and row houses the increase in consumption is due to increased number of units and per unit the consumption remains about the same or has even decreased. In single family house, the main contributor is the increase in unit consumption.

Table 6. Development of electricity consumption by housing type

Housing segment	**Year**	**Number**	**Average consumption per household kWh**	**Total consumption in the segment GWh**
Single family houses	1993	887 700	5 300	4 705
	2006	996 263	7 550	7 522
	Change %	**12 %**	**42 %**	**60 %**
Row houses	1993	280 783	3 800	1 067
	2006	340 979	3 525	1 202
	Change %	**21 %**	**- 7 %**	**13 %**
Flats	1993	890 116	1 950	1 736
	2006	1 065 423	2 109	2 247
	Change %	**20 %**	**8 %**	**29 %**

Table 7 shows how the electricity consumption is divided by appliance category in the three housing segments. The share of group miscellaneous in single family houses is almost triple of its share in flats and row houses. When taking closer look one finds heating related consumption in this category. Finland has about 260 000 households using wood or other biofuel as source of space heating. Very often electricity is used as the back up or complementary space heating energy. We also noticed that air to air heat pumps are installed to houses with oil and even district heating. This suggests that the definition we use in Finnish energy statistics needs to be updated to reflect present practises of energy use[2].

Table 7. Electricity consumption by housing type and appliance category

Housing Type **Appliance Category**	**Single family houses**		**Row houses**		**Flats**	
Interior lighting	1 738	23 %	219	17 %	469	21 %
Cold appliances	785	10 %	186	15 %	490	22 %
Sauna stoves	613	8 %	148	12 %	91	4 %
Heating and ventilation system	515	7 %	54	4 %	52	2 %
Audiovisual appliances	434	6 %	117	9 %	283	13 %
Cooking	309	4 %	98	8 %	245	11 %
Washing machines and dries	229	3 %	52	4 %	110	5 %
Car heating	191	2 %	24	2 %		
Computer sites	182	2 %	57	5 %	168	7 %
Dishwasher	171	2 %	36	3 %	54	2 %
Floor heating	278	4 %	96	8 %	83	4 %
Outdoor lighting	73	1 %	12	1 %		
Miscellaneous	2 201	29 %	156	12 %	202	9 %
Household Electricity	7 720		1 255		2 247	
Space heating and water boilers		5 435		865		150
Residential Electricity		13 155		2 120		2 397

[2] Both Norwegian and Swedish statistics distinguish between households using only electricity for space heating and those using electricity and other energy source like biofuel.

Heating Related Consumption in Sweden

Growth of heating related consumption is one of the results of a large metering study of Swedish households. Though the approach to analysis is slightly different and the Swedish results are not presented at population level but as average by household type, rough quantitative comparison is worth doing and is presented in Table 8.

Swedish figures are taken from Figure 2-32 /8/. The first column gives the average total consumption for electricity in houses with non-electric heating system. For Finland this is the estimated population average. For Sweden the higher of the numbers refers to four person households and the lower is an average of the two types of two person households.

The second column gives an average of what the Swedish report calls specific consumption, which is used to make the consumptions in houses and flats comparable. We estimated this figure for the Finnish households.

The numbers are rough but the message is clear. This heating related consumption in houses without electric heating is now approximately 45 % of the total in Finland and over 50 % of the total in Sweden. The higher level of this consumption in Sweden confirms to expectation, because e.g. heat pumps are more common in Sweden than in Finland. The size of this component, at least in Finland, was a surprise.

Table 8. Comparison of Heating Related Electricity Consumption in Houses without Electric Space Heating

Houses Without Electric Space Heating	Average total electricity kWh/a	Average specific electricity kWh/a	Average heating related electricity kWh/a
Sweden	7600 – 8400	3100 – 4100	4300 - 4500
Finland	7700	4200	3500

Results at Household Level

Figure 5 and 6 depict trends at household level. The definition of these reference households was described earlier in a separate chapter and similar definition has been used for both the 1993 and 2006 study.

The purpose of this description is to provide information to households of the relative size of their consumption. Providing just one average is not enough, as clear systematic differences between types of families exist. For instance 4000 kWh is small consumption for a 4 person household living in a house and large consumption for one person living in a flat. Thus the fair comparison is to similar family type. A more detailed breakdown of the components is available in the Finnish project report /6/.

The important thing to note is the difference of trends in household types compared to those observed at national level. The figures show for instance the following:

1. The general trend for cold appliances was decreasing from 1993 to 2006. However, in one person households in flats the trend in consumption was increasing, because ownership of freezers was still increasing. In 1993 the typical one person household owned one refrigerator. In 2006 the typical cold appliance was a fridge-freezer.

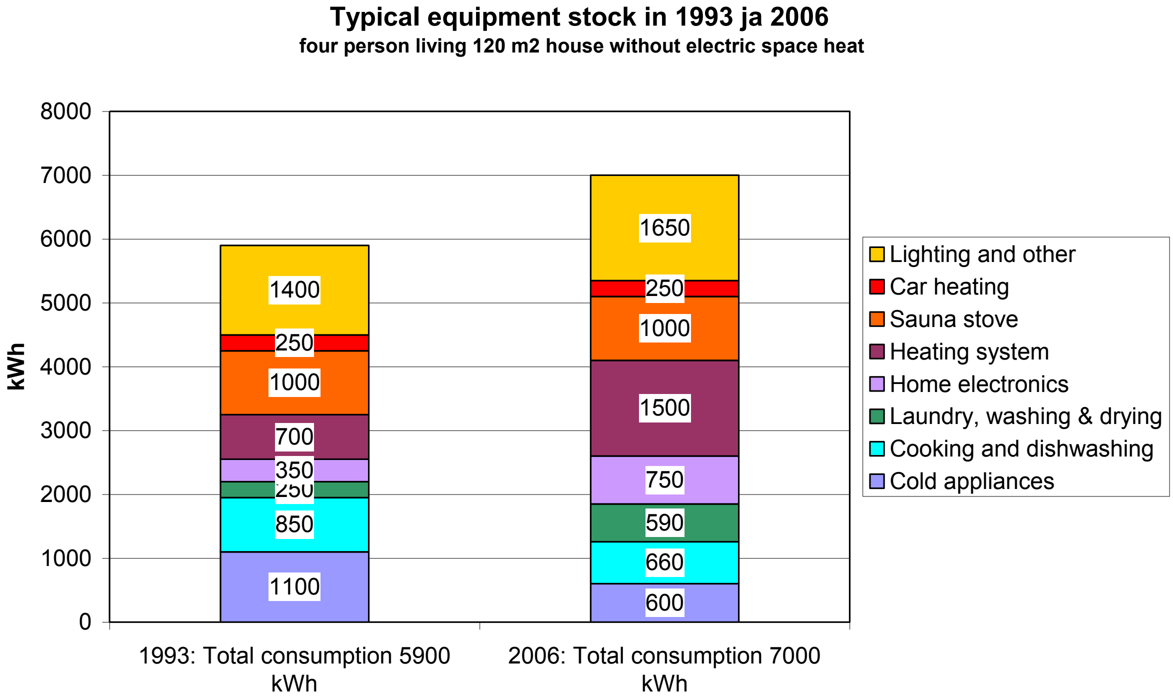

Figure 5. Typical four person household in 1993 and 2006.

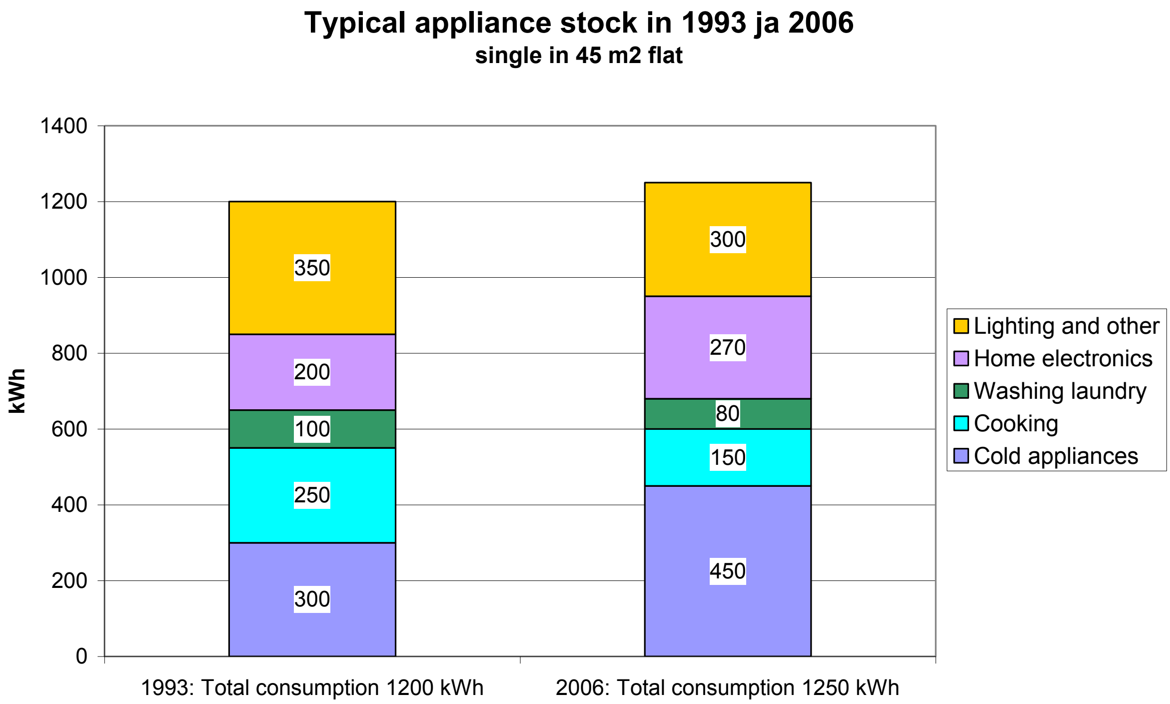

Figure 6. Typical one person household in 1993 and 2006

2. The general trend for heating system & ventilation showed an unchanged share from 1993 to 2006. Yet the share of the heating system & ventilation in a typical four person household in a house increased from 12 % to 21 %. The change is due to the share of mechanical ventilation increasing in share over 50 %. This example illustrates the fact that large changes that affect only part of the population do not show in general trends.

3. The general trend of consumption increase for single family houses was app. 40 % when for the example it is 20 %. The first number includes the increasing heating related components, which are relevant at country level. The second number describes best the development in households where these developments are not relevant.

Characterization of household groups can be useful in number of ways. Segmentation can help to direct campaigns to appropriate target groups. The burden of planned policies can be evaluated by household type.

Comparison Results of Finland, Norway and Denmark

Table 9 is compiled from results of REMODECE and Finnish 2006 study. The average consumption of the appliances is calculated conditional on appliance ownership.

The first column shows the confidence interval for all the REMODECE data. It is calculated from numbers of table 4-1. Provided that one has drawn a probabilistic sample from the population, the true population expected value or, in this case the average consumption of the appliance type in question in the investigated countries, will lie within the confidence interval with a given probability. Customarily this probability is chosen to be either 95 % or 99 %. The appliance consumptions for Denmark and Norway are taken from table 3-5 /7/. In the table the country averages that fall within the confidence interval are underlined. Those that fall below the confidence interval are in cursive and those above the interval are bolded[3].

It is easy to see that the averages for Finland for the most part fall below the REMODECE average and they never exceed the upper limit of the confidence interval. With respect to cold appliances this result may be real as the numbers for Norway and Denmark also fall below the REMODECE average. However, the rest of the appliances are such that the household size in the datasets is likely to explain much of the difference.

For instance, the Finnish number for washing machines is clearly below the average, yet we know that the average cycle consumption for Finland is in fact slightly higher than the one for the REMODECE figure. As the number of washes is greatly influenced by the family size, the main reason for this difference is likely to be the difference in family size which for Finland is representative of the population and as noted in the report which is not the case for the REMODECE figure as “the share of families in the measurements is in some cases 50 % compared to country average of 30 %”. Thus only indicative comparisons are possible.

This said it is worth noting that despite these reservations with respect to comparability, the numbers in broad terms are similar.

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[3] To do this by the book one should calculate the confidence intervals for all the averages and see whether the confidence intervals overlap. As performing this analysis on basis of available data would have required number of unrealistic assumptions, simplified approach was deemed sufficient for the purpose of this paper.

Table 9. Comparison of Appliance Consumptions in Finland, Norway and Denmark

Country Appliance	Confidence Interval REMODECE	Denmark kWh/a	Norway kWh/a	Finland kWh/a
Refrigerator	365 - 403	*287*	*307*	*223*
Fridge freezer	431 - 471	*379*	*374*	*402*
Freezer	506 - 580	*496*	**631**	*368*
Washing	175 - 193	184	**207**	*124*
Clothes dryer	262 - 432	-	267	284
Dishwasher	218 – 250	-	206	*186*
Desktop PC	254 – 298	**303**	*97*	*191*
Laptop PC	49 – 63	61	87	*33*
Router for Internet	46 – 70	**102**	51	-
TV CRT	116 – 132	109	**172**	118
TV LCD	169 – 203	174	**223**	
TV Plasma	326 – 474	427	325	240[1)]
DVD	19 – 27	25	21	19
Hi-Fi	42 – 50	**51**	**103**	-
Set top box	65 – 85	83	84	72
Air conditioner	50 – 694	-	1179	-
Oven/cooker	211 – 391	-	287	318
Microwave	25 – 41	-	30	33
Water kettle	54 - 86	-	24	-
Lamps	-	908	1013	990

1) Numbers for LCD and Plasma TV's are combined for Finland. About 20 % of the appliance in this group are plasma TV's and 80 % are LCD's.

Efficient Data Collection and Analysis as a Way to Reduce the Monitoring Costs

The approach presented in this paper to decompose the electricity consumption of household sector into end use components has been developed on basis of lessons learned. The most important insight is that the alternative of trying to measure a representative sample of all appliances of all appliance categories and generalize those datasets is in practise very difficult and costly. On the other hand, as our and the Swedish results show, representativeness is of utmost importance in correct identification of relevant trends.

Our solution is to derive a tested model for a representative survey by combining data from literature and measurements and to generalize from that. Collecting representative survey is considerably cheaper than collecting a representative sample of appliance measurements and this is the basic rationale for our method. The cost of collecting survey of couple thousand households is typically around 25 000 € or 10 to 20 € per household. Depending on the measurement technique used and the scope of measurements the cost of measuring one household ranges from 100 to 2500 €. The all inclusive cost of the Finnish 2006 study was app. 200 000 €. If one uses expensive measurement technique, this amount of money will barely cover measurement costs for 100 households.

When establishing a monitoring system one needs to decide the frequency of updates and the required accuracy. It is worth noting that our technique can be used in varying combinations. For instance, to establish a biannual monitoring one can collect and model a survey every other year and complement the survey with a measurement study every four or six years. Table 9 shows the estimated costs of these simplified alternatives in rough numbers. The monitoring round with a survey only is estimated to cost 50 000 € and the combination of the survey and measurements is estimated to have the same cost as our latest study. In reality the monitoring cost is likely to decrease in later rounds. To fully utilize the advantages of the presented combination of methods one should also look into the possibility and cost of obtaining auxiliary data like laboratory measurements or of conducting a separate measurement campaign on the appliances which the statistical test procedure indicates as candidates needing revision.

It is worth noting that the discussion above centers on issues relevant on collecting and analyzing data to monitor and provide information on the development of end uses at country level. Developing monitoring and feedback systems to individual households is another question and is not addressed in detail in this paper, though the method described allows presentation of results by type of household.

Table 10. Cost of Biannual Monitoring Using Different Combinations of the Approach

Monitoring alternative	Cost over 12 year cycle	Cost per monitoring
Biannual survey and measurement	1 200 000 €	200 000 €
Biannual survey and measurements in every four years	750 000 €	125 000 €
Biannual survey and measurements in every six years	600 000 €	100 000 €

Conclusions

This paper presents the approach developed to provide two kinds of results on household electricity consumption. The first is the decomposition of total electricity use of the household sector into end uses or appliance categories. The second is the description of reference household. The target group for these results is individual households needing information on their electricity consumption. For both purposes, same data is used, but it is combined differently to take into account the discrete nature of the appliance ownership. At household level percentiles (median, quartile) are preferred over mean. In addition to theoretical considerations this, choice of a statistic also allows defining lower target consumptions for reference households.

The approach has been developed on basis of lessons learned in two early studies. The most important insight is that the alternative of trying to measure a representative sample of all appliances and generalize from those is in practise very difficult and costly. On the other hand, as our results show, representativeness is of utmost importance in correct identification of relevant trends. Had we used the criteria of an early measurement study we would missed the growth of secondary electric heating. This trend is also identified in Swedish study using representative data to be published shortly.

Our solution to the problems encountered is to derive a tested model for decomposing electricity consumption of a representative enough survey at household level by combining data from literature and measurements and to generalize that via post stratification. As collecting representative survey is considerably cheaper than collecting representative sample of appliance measurements, our method offers an affordable way to establish a regular monitoring of electricity end use consumptions in household sector. The ability to vary the data collection between periods offers another way to reduce costs. Further, the test procedure outlined can be used to find out on what more data is needed. In our case it points to the direction of heating and ventilation related items. Additional information on lighting is also likely to be useful.

Given that this is second time this method is applied to Finnish households we are able to show trends both at national and household level. For instance, the consumption of cold appliances has decreased both in share and absolute level and the size of realized potential corresponds to that estimated in 2002. Efforts to increase the energy of efficiency of cold appliances have been successful and the decision to implement energy labelling scheme on home electronics is likely to produce positive results. This appliance group has grown both in share and absolute value.

The comparison of our results to recent results in our neighboring countries shows the estimates and identified trends to be similar in broad terms.

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Characterization of the Household Electricity Consumption in the EU, Potential Energy Savings and Specific Policy Recommendations

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Abstract

Although significant improvements in energy efficiency have been achieved in home appliances and lighting, the electricity consumption in the average EU-27 household has been increasing by about 2% per year during the past 10 years. Some reasons for such increase are associated with an increased degree of basic comfort and level of amenities (particularly in the new EU member countries) and also with the widespread utilization of relatively new types of loads whose penetration and use has experienced a very significant growth in recent years.

With the objective of contributing to an increased understanding of the energy consumption in the EU-27 households for the different types of equipment including the consumers' behaviour and comfort levels, and to identify demand trends, a large energy monitoring campaign, co-funded by the IEE programme, was carried out in 12 countries, accompanied by a lifestyle consumer survey. The acronym of the project was REMODECE (Residential Monitoring to Decrease Energy use and Carbon Emissions in Europe). The research focused mainly on new electronic loads such as: entertainment, information and communication technologies, stand-by consumption, lighting, as well as air conditioning in the southern countries. In Central and Eastern Europe, because of lack of reliable data, white appliances have also been targeted. From the measurements carried out it can be concluded that electronic loads, including standby, are a key contributor to the power demand. In basically all types of loads there is wide range of performance levels, including new emerging technologies, in the models available in the market. Available technology, associated with responsible consumer behaviour, can reduce wasteful consumption. The technical potential electricity savings that exist in the residential sector in Europe, and that can already be implemented by existing means, like the use of BAT efficient appliances or the elimination/mitigation of standby consumption, can reach up to 50% savings. An overview assessment of National legislation, fiscal and supportive instruments has been carried out, and the main problems identified. Specific policy recommendations to promote market transformation and behavioural changes in the equipment selection and operation have been identified.

Context

Although significant improvements in energy efficiency have been achieved in home appliances and lighting, the electricity consumption in the average EU-27 household has been increasing by about 2% per year during the past 10 years, despite the numerous energy efficiency policies and programmes at EU and national level [1], [2].

Some of the reasons for such increase in the residential sector electricity consumption are associated with a higher degree of basic comfort and level of amenities (particularly in the new EU member countries) and also with the widespread utilization of relatively new types of loads whose penetration and use has experienced a very significant growth in recent years. The main important factors for such increase are:

- An increased degree of basic comfort and level of amenities due to an increase of the living standards (particularly in the new EU member countries).
- Increased penetration of traditional appliances (e.g. dishwashers, tumble driers, air conditioners and personal computers) which still did not achieve the saturation level.

- Increased use of the equipments: more hours of TV watching, more hours of use of personal computers (widespread use of internet, tele-working), more washing and use of hot water.
- Increased number of lamps per home.
- Introduction and widespread utilization of relatively new types of loads whose penetration and use has experienced a very significant growth in recent years, mainly consumer electronics and information and communication technologies (ICT) equipment, in particular: personal computers, printers/fax/multipurpose machines, set top boxes, DVD players and recorders, broadband equipment, cordless telephones, game consoles/play stations, large-screen home theatres/DVDs, HVAC auxiliary equipment, air conditioners, chargers (phones, power tools), home security systems, garage door openers, etc., many with stand by losses. A wide variety of small appliances (bread makers, coffee makers) with electronic controls is also entering the market in an increasing scale. Households are becoming more and more dependent on electronic/electric devices and gadgets, with ubiquitous microcontrollers/digital controls being embedded into most apparatus, to improve the performance and the quality of the provided services. Unfortunately in many cases little or no attention is given to the energy consumption, particularly in the standby modes.
- Increased number of double or triple appliances, mainly TVs and refrigerators-freezers, as well as computers.
- Increased size of some appliances like refrigerators and TV screens.
- More single family houses and larger houses and apartments. This results in more lighting, heating and cooling. Population is getting older, spend more time at home, and therefore demand higher indoor temperatures and all day heating in winter and cooling in summer.

Next picture shows the situation in terms of final electricity consumption in the participating countries for the previous years, in the household sector. As it can be seen, on average the electricity consumption has been increasing by about 2% per year in the household sectors [3].

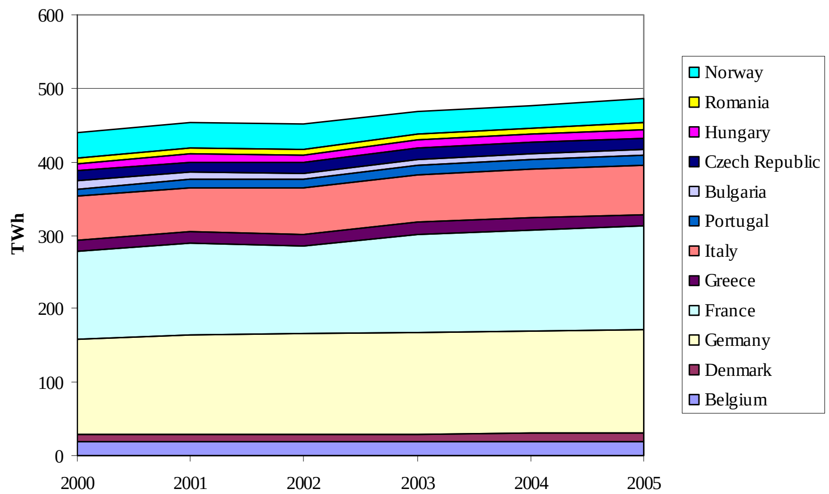

Figure 1: Final electricity consumption in the residential sector

Despite the large electricity consumption increase and the consequent impact in CO_2 emissions, there is little reliable knowledge at European level where the electricity is used. The aim of the REMODECE project was to contribute to an increased understanding of current and impending electricity use by European households resulting from different types of equipment, consumers' lifestyles, and comfort levels. The project evaluated how much electricity could be saved by the use of the most energy efficient appliances, by adopting a suitable behaviour and by the reduction of standby consumption.

The REMODECE project was about a large-scale monitoring campaign and a consumer survey carried out in 12 countries such as: Belgium, Bulgarian, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Portugal, Romania and Norway. At least 100 households have been audited per country and 500 detailed questionnaires have been collected in each country. The measurement campaign was performed in about 1300 households and the survey involved the collection of 6000 questionnaires. About 11500 single appliances were analyzed.

Major findings of the project

1. The average electricity consumption per household per year was estimated to be 2700kWh, excluding electric space and water heating. Electronic loads (PC & accessories and television and peripherals) which have been growing at a very fast rate are now a key contributor to the electricity consumption representing 22% of the total electricity consumption. In basically all types of loads there is wide range of performance levels, in the models available in the households.
2. By changing to the Best Available Technology and Best Practice, the households can reduce their electricity consumption by about 1300 kWh, representing 48% of their total consumption. The aggregated savings for the participating EU-12 countries are roughly estimated to about 165 TWh. The estimated reduction of electricity consumption is translated into 72 million ton of avoided CO_2 emissions per year. At European EU-27 level the savings potential would amount to around 268 TWh.
3. Standby consumption represents a significant share of the total household consumption, being responsible for about 9,4 % of the total household consumption, mostly concentrated in electronic equipment (PC & accessories and television and peripherals). The standby consumption may be even slightly higher if all the appliances having standby consumption within the household had been monitored.
4. The way forward to save electricity is: the adoption of compact fluorescent light bulbs and Light Emitted Diodes (LEDs), the change to A+ and A++ appliances, reduced standby power requirements, use of the washing machines at full load with as cold water as possible, drying clothes by natural means whenever possible, selection of LCD TVs instead of plasma or CRT TVs, selection of energy-star labeled office equipment, switching-off electronic appliances (PC & accessories and television and peripherals) when not in use, in summer use night ventilation for free-cooling, use of solar water heaters, etc.
5. To take advantage of the identified energy-saving opportunities, some product minimum efficiency standards need to be introduced and others have to be tightened, coupled with suitable policy incentives. Current regulations and fuel subsidies, for example, often favour consumption over efficiency. But many possible actions are not taken, because energy users lack information or do not value efficiency enough to change their buying habits. Regulation changes, information campaigns, with clear and simple messages targeting households, together with financial incentives can stimulate energy efficiency in the residential sector.

Methodology

The detailed characterization of residential electricity use and credible estimates of the huge potential energy savings are important results of this two and a half year long research project, carried out in 12 different countries: Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Norway, Portugal and Romania, with the objective of contributing to an increased understanding of current and impending electricity use by European households resulting from different types of equipment including, consumers' lifestyles and comfort levels. A large-scale monitoring campaign in 12 countries and a consumer survey have been carried out: 100 households have been audited per country and 500 detailed questionnaires have been collected in each country. The collected data is accessible from the project Database which is online from the project web-site [www.isr.uc.pt/~remodece].

Besides the field collected data with the REMODECE monitoring campaigns and survey questionnaires, energy consumption data from previous campaigns has been collected and was considered for analysis whenever useful. All the collected data is stored in the developed European Residential Electricity Consumption Database, available at the project web-site: http://www.isr.uc.pt/~remodece/database/login.htm.

The decision about what data to collect was very important for a cost-effective and reliable characterization. Based on the already existing databases, enough data was collected to update the existing information. To estimate the disaggregation of electricity consumption by each major end use, the following methodology was selected:

1. Analysis of already existing studies, surveys, metering campaigns, databases, statistics, manufacturer's information, market information, etc., on energy consumption in the residential sector, focusing end-use equipment and operating modes.

2. Conducting household surveys (500 questionnaires per country of the study). The questionnaires have been accompanied by expert interviews whenever possible, and user behavior has also been addressed.

3. Conducting detailed audits in 100 households per country, focusing on demand load profiles in real situations. These households have also participated in the survey.

4. Conducting spot measurements for a series of appliances/ end-uses, especially to determine consumption in the standby and off modes of operation, because the available data is still relatively poor in this area.

The measurement campaign was performed in about 1300 households and the survey involved the collection of 6000 questionnaires, addressing both quantitative and qualitative data. The starting point of the methodology was to elaborate a detailed list of all the main end-uses to be analyzed, in Eastern European Countries and in the old EU Countries, as well as the definition of the main modes of operation to consider for the monitoring of the different appliances. The list of loads investigated was divided according to their main function: domestic computers and peripherals, new domestic entertainment, other standby loads and other loads, including lighting and air conditioning. About 11500 single appliances were analyzed. The time interval for the measurements was 10 minutes, and the monitoring period for the campaign was two weeks, which enabled the extrapolation to determine the yearly consumption. In France air conditioning was monitored over a longer period 3 months. In other Southern Europe Counties, because of the lack of monitoring equipment, a two week period was used.

The standby definition in the REMODECE was based on the standard IEC62301: "House electrical appliances – Measurement of standby power", published in June 2005, and its European on going transcription EN 62301". According to this international standard, the definitions for standby mode and standby power are as follows:

The *standby mode* is 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.
The standby power is the average power in standby mode.
The standby mode is usually a non operational mode when compared to the intended use of the appliance's primary function. The measurement of energy consumption and performance of appliances during other operating modes or intended use are generally specified in the relevant product standards and are not intended to be covered by this standard.

Survey results

The survey was based on the collection of at least 500 questionnaires per country, of which 100 households have been monitored, addressing both quantitative and qualitative data, as the objective was to collect data on the type of appliances and lighting people have at home, and also to understand their behavior concerning the electricity use in their houses and their choices when buying new equipments.

In order to avoid a biased sample and to increase the rate of response, a mix of techniques such as: face to face interviews, telephone interviews, internet (web-based platform), direct email contacts (emailing lists) and mail, has been used to collect the questionnaires in the several countries.

The average electricity consumption per month and household per country is presented in Figure 2

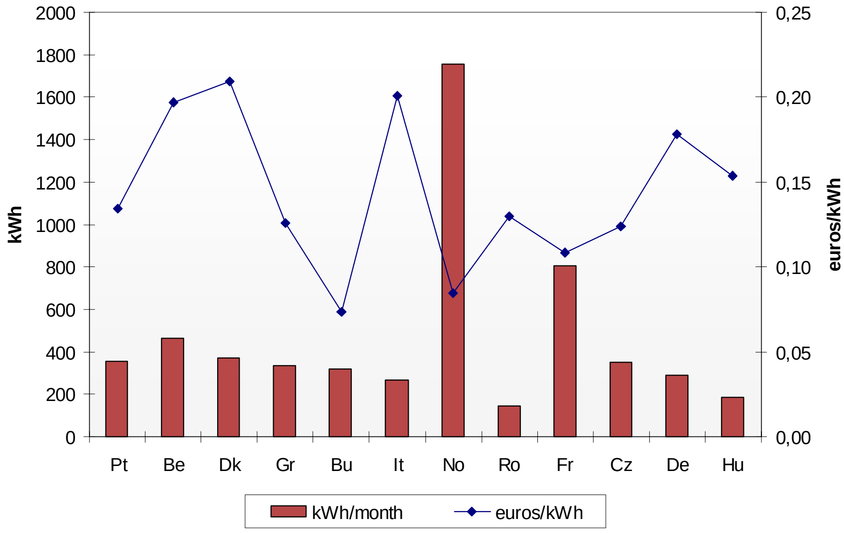

Figure 2: Average monthly electricity consumption per household per month [4]

As expected Norway has by far the highest average electricity consumption per household followed by France. Both Norway and France have high penetration of electric space and water heating due to the low electricity rates.

The ownership rate for electrical appliances in the EU-12 is presented in Figure 3. The average ownership rates are weighted by the number of household in each country and corrected for ownership in each country. It is important to note that these are conservative figures, and in some cases the penetration rates are most likely to be higher.

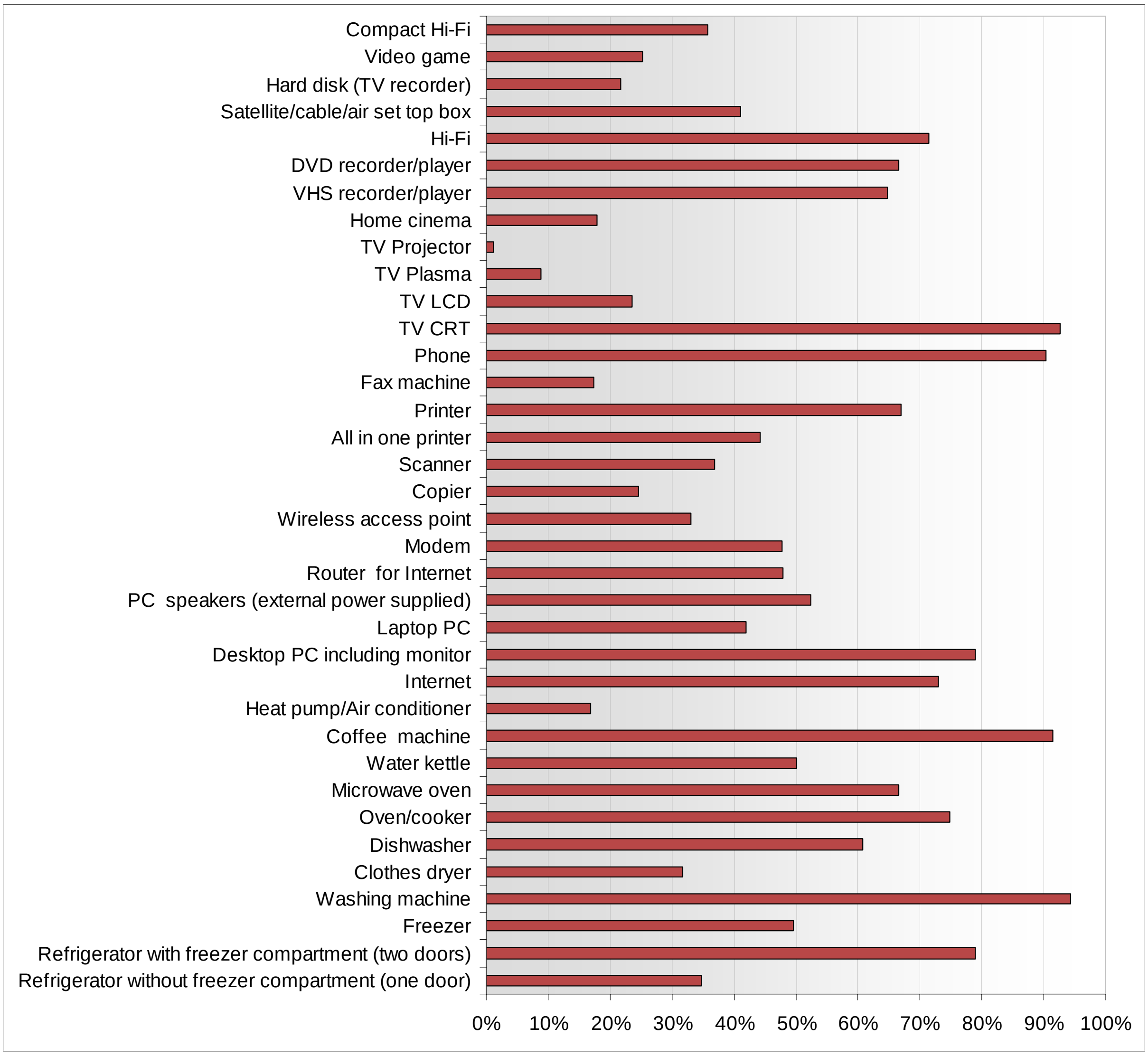

Figure 3: Estimated average ownership rate by the main end-use by 2007, [4].

The number of households with double or triple refrigerators has been increasing in recent years. The number of households with more than one refrigerator in Belgium, Norway, France and Germany is quite high, representing about 71%, 60%, 28% and 32% respectively. One reason for this high share is because people keep the old refrigerator running in the garage to cool beer and other drinks instead of disposing it in a proper manner by calling the local waste management facility and ask about disposal of “white goods”. There is a very high Internet penetration rate, and Norway, Denmark and Belgium are the countries with the highest penetration rates, in the order of 90%. The ownership rate for desktops, laptops, monitors and printers is generally quite high.

Regarding the operating state in which the office equipment is kept while it is not being used, the vast majority of respondents mentioned they do turn off the equipments. Only few percent of households admit they keep their computers on the stand-by mode and on the on-mode, when it is not being used. Households do not behave so well with fax machines, modems and routers/hubs, because they fear to loose the pre-definitions and have to reprogram them if they turn them off.

Because of increasing global temperatures and increasing standards of living, air conditioning is increasing fast. The ownership rate of air conditioning is about 17%. Air conditioning is mainly used in the southern countries to cool part of the house, being Greece the country with the highest penetration rate followed by Italy. Surprisingly, Norway is the third country in the ranking.

The average age structure of white appliances is quite similar for all the countries, except for Denmark, where a significant percentage of equipment is under 5 years. One reason for the high percentage of recent appliances within the Danish households is the intensive Danish energy-saving policies, where several energy efficiency incentive programs are available that help households to change their old inefficient appliances by new more efficient ones.

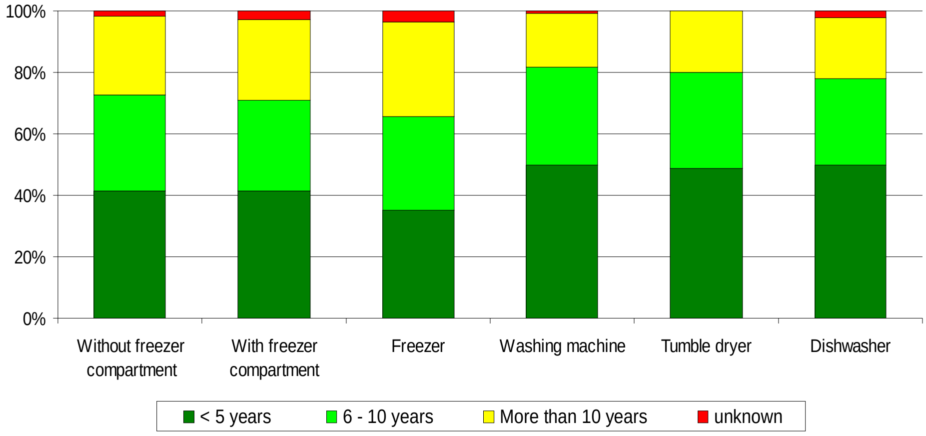

Figure 4a: Vintage of white appliances.

Regarding the efficiency class of white appliances, it should be noted that most countries have a big percentage of unknown labeled equipment. The average value for the EU-12 ranges from 43% for dishwashers to 55,6% for freezers.

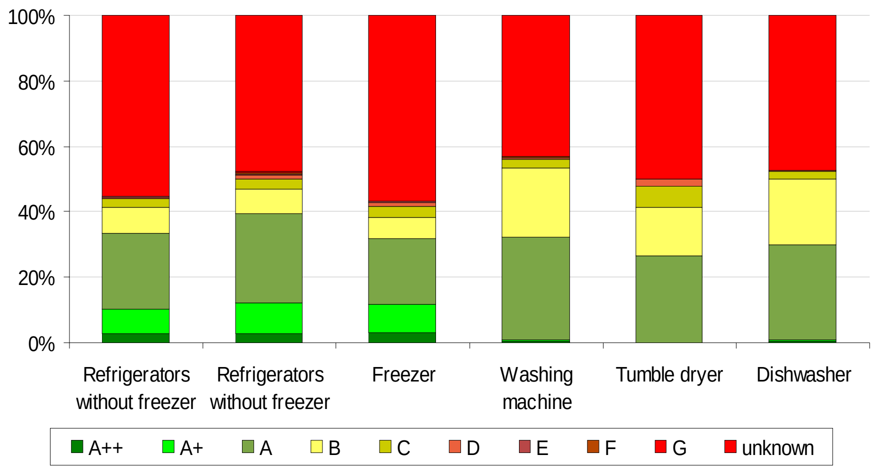

Figure 4b: Share of efficiency classes.

The share of A++ and A+ appliances is still very low, representing around 10% of the cooling appliances in EU-12, and less than 1% of the washing machine and dishwashing, and being insignificant for tumble dryers.

The most important criteria for buying a new domestic appliance is the price, followed by the electricity consumption, and by the ease of use. The design/style and external dimensions are mentioned as the less important. The main criterion for saving electricity is to obtain economical savings, followed by security of supply and greenhouse effect. War risk due to electricity crisis is the less important concern for households.

Monitoring campaigns

On average 5-10 meters have been used to monitor major appliances or end-uses per household (cold appliances, washing machines, consumer electronics, …). In the case of lighting, at least the 10 light sources have been monitored per household including the lamps with highest burning hours. At the time of installation of end-use recording equipment additional information has been collected, such as:

1. information about every end-use recorded - this was especially important when several appliances went in as a sum and only one end-use recording meter was used for recording of the load for the cluster. This was the case of PCs and monitors.
2. information from the appliance label has been collected for several appliances but was not used because the information is not unique among the partners. One exception was for lamp bulbs, for which the number of lamps and wattage was available, and this information was used to find wattage of different types of lamps for the countries whenever needed.
3. size of the family, type of home and area, would have enabled to divide the residential customers into different strata. However due to economic constraints most of the partners did not want to do stratification. However this information is collected for most countries, and stored along with the time series data - ready for stratification. Stratification is only performed for Norway, and in this way Bias for family size etc is corrected in Norway.
4. spot metering on small appliances not included in the end-use recording including standby consumption measurement.

For the analysis of the huge amount of collected end-use data, the Useload software tool (Developed by Sintef) was employed. This powerful software analysis tool has been further developed adapting to needs in the REMODECE Project. Several features have been added, Useload has both been used for the data analysis and calculation of the potential electricity savings that can be implemented by existing means through replacing the old inefficient appliances (Present State) by the best available technology present in the market (BAT) and changing to best practice use of application (BP) including reduced standby consumption.

The measurements were cleaned for data errors, first manually by each partner and then automatically by the software. Some data had less resolution regarding number precision, since decimals were missing. The lowest power specified in these situations was 1 Wh/10 minutes, or 6 Watts. As much consumption in standby mode is less than 6 Watts, this would clearly be a problem to figure out what the stand by consumption was. Therefore, a consumption of 1 Wh/10 minutes (accumulated energy) was distributed over the preceding minutes if the consumption was reported to be 0 (zero). The result of this adjustment yields an unaltered energy demand as expected, but a more exact estimate of standby consumption. The results from the updated standby analysis is presented in this paper.

The consumption of two weeks of measurements was multiplied with a factor to account for the number of utilization days in the year to obtain the yearly consumption. This factor equals the number of weeks in the year minus two weeks for vacation etc. Refrigerators, freezers and water heaters are assumed to be in use the whole year, while air conditioning is defined to have a utilization period of 3 months per year. The resultant value is called yearly consumption per appliance [kWh/appliance/year]. This value per appliance is multiplied with the appliance ownership to obtain the average yearly consumption per household [kWh/household/year]. Finally the yearly consumption per household is multiplied with the number of households in the country in order to obtain the national and multinational consumption per appliance [GWh/appliance]. This is the Present State (PS) of residential electricity consumption. The Present State is country specific, is based on data from the monitoring campaigns, and is also based on previous campaigns, for some appliances. Besides the PS, also the BAT and/or BP need to be established for the calculation of the potential national energy efficiency savings. The power (Watt) used by the best technology (BAT) of the appliance was found from scanning and analyzing the collected measurements, manufacturer specifications, information from databases like Top Ten[1] and results from the Eco-design[2] studies. The BAT (Watt) per appliance is the same for all countries. The aggregate saving potential through BAT/BP depends on the country specific hours of utilization and ownership level per appliance. The annual energy demand of BAT appliances are found by multiplying the BAT power (Watt) with the load factor (utilization hours) of the country. In this way the load pattern of each country is applied. In addition the BAT calculations assume that the standby consumption is reduced to a minimum (0,5 W).

Structural effects like change of load patterns due to possible change of behaviour, as well as market transformation effects (autonomous savings), were not integrated in the calculations. It may take several decades to replace inefficient equipment with more efficient equipment. Old equipment may also be replaced with larger sized equipment, thus using more energy.

Figure 5 shows the distribution of yearly electricity consumption for a typical (average) European household. Refrigeration, including refrigerators and freezers, is the group of appliances requiring the largest part of the total household electricity consumption, with a share of 28%. Lighting is the second largest electricity end-user with a share of 18%. Other appliances such as vacuum cleaners, radios and chargers, represent about 3% of the total household electricity consumption. Standby consumption which represents about 9,4% of the total consumption is embedded in all end-uses, but is mostly concentrated in office equipment (includes Internet plus communications) and entertainment appliances.

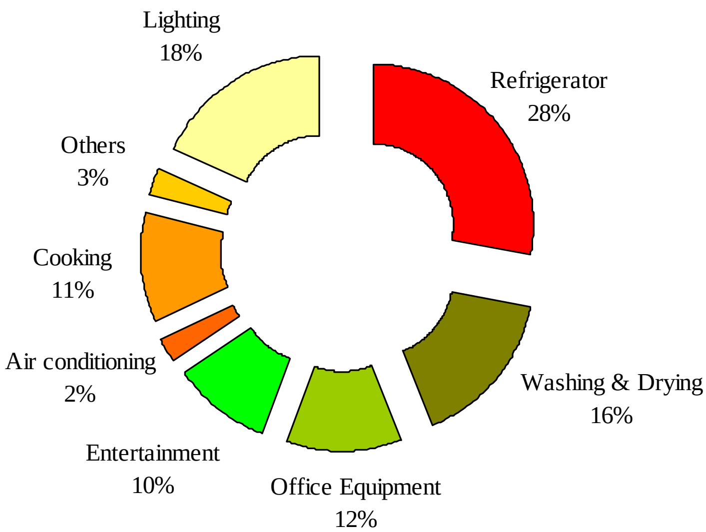

Figure 5: Electricity consumption breakdown in the residential sector in the EU-12, excluding electric space heating and electric water heating [4].

Energy demand per appliance type

Figure 6 a), b) and c) show estimates of yearly energy consumption for all the audited equipments: average, minimum and maximum consumption values per appliance are presented as well as the total number of equipments monitored, at the top of each bar. The values presented are not corrected for ownership levels.

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[1] Top-Ten is a consumer-oriented online search tool, which presents the best appliances in various categories of products. The key criteria are energy efficiency, impact on the environment, health and quality (www.topten.info).

[2] Ecodesign aims the integration of environmental aspects to into product design with the aim of improving the environmental performance of the energy-using product throughout its life cycle (http://ec.europa.eu/enterprise/eco_design).

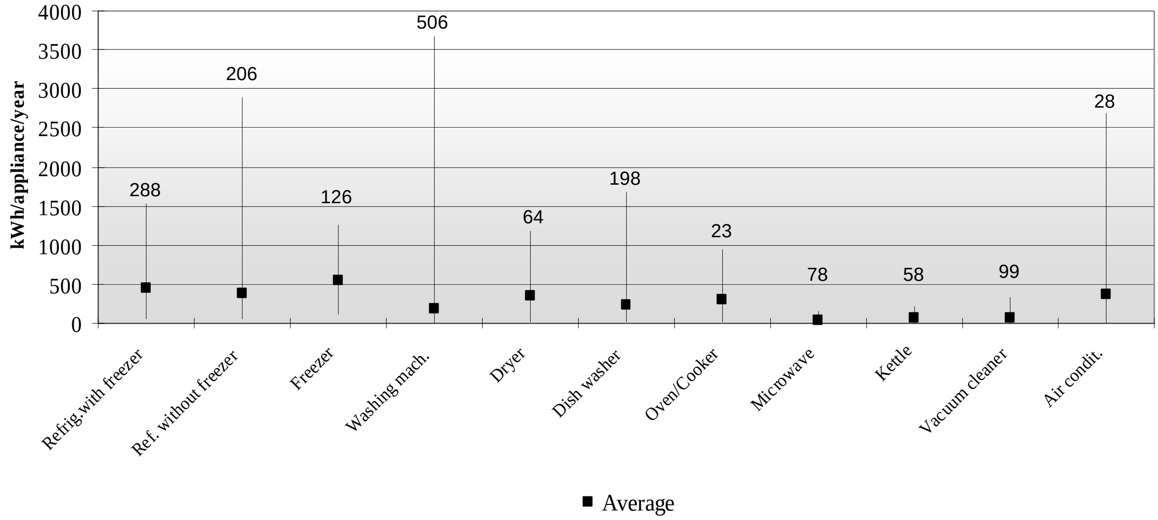

Figure 6a): Annual electricity consumption range for several appliances [REMODECE campaign].

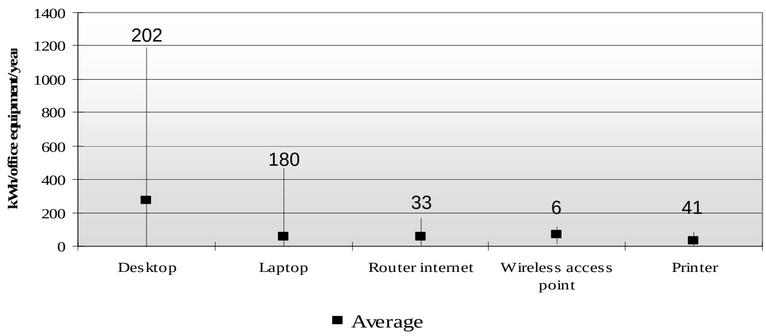

Figure 6b): Annual electricity consumption range for office equipment [REMODECE campaign].

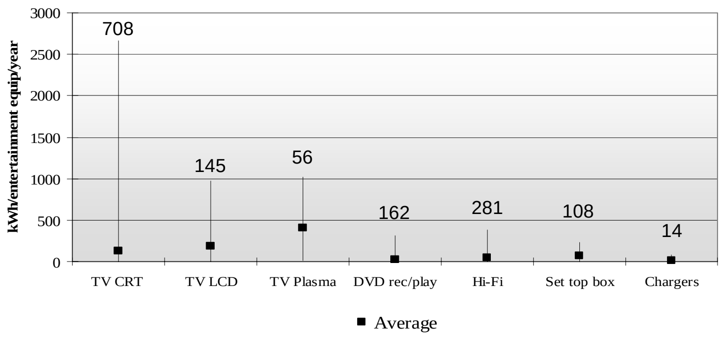

Figure 6c): Annual electricity consumption range for entertainment equipment [REMODECE campaign].

Most of the differences between the minimum and maximum values can be explained by different usage pattern and by the different technologies. For appliances that are automatically operated, it is difficult to find a reasonable explanation for the large variations apart from some differences due to different sizes and technologies. In some cases it may be that the appliance has not been normally used in the measurement periods and/or that the estimated minimum values for the yearly consumption is only the standby consumption. Old appliances (e.g. refrigerators and freezers) can have a much poorer performance than “Up-to date” appliances.

Energy Demand during day

The load curves for a typical European-12 household for a typical week day of the year, based on the results from the monitoring campaigns, is presented in Figures 7 and 8.

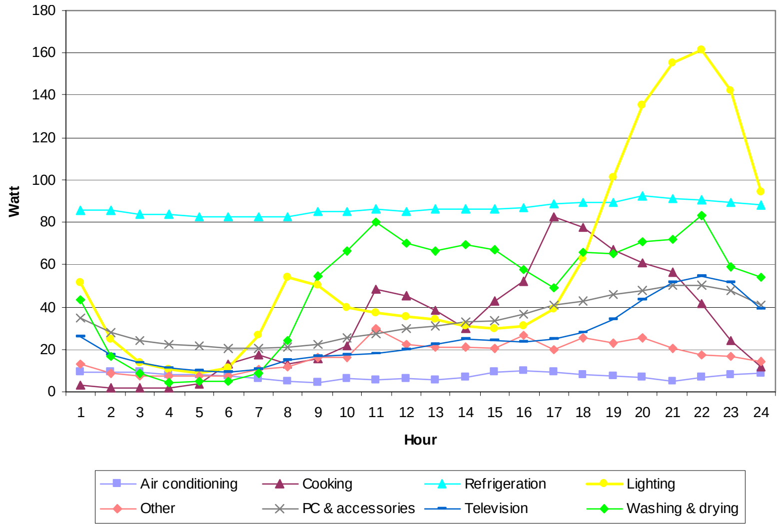

Figure 7: Electricity consumption in group of appliances for a typical household on a typical day of the year.

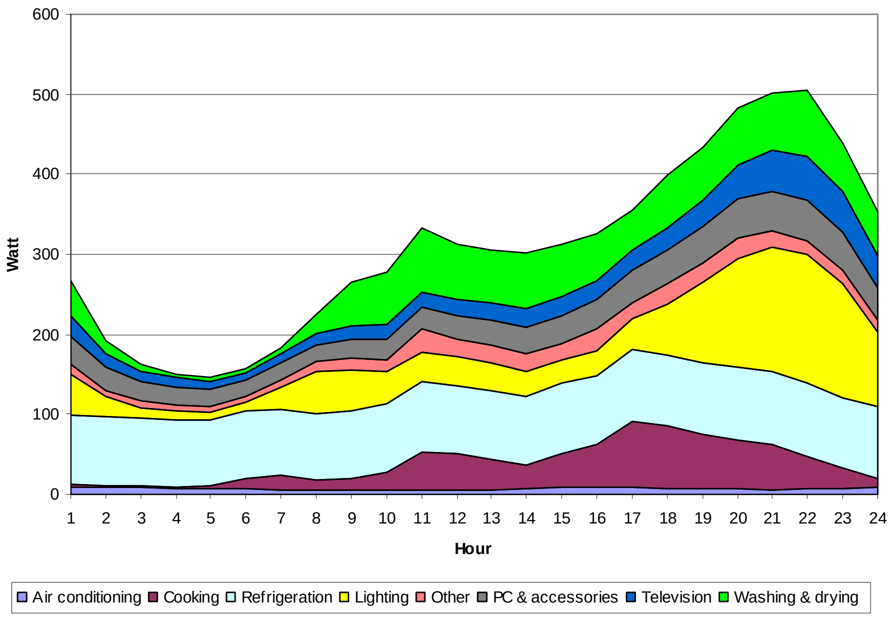

Figure 8: Electricity consumption for the average day for a typical household in Europe.

Washing and drying are mainly used during the day, with peaks at 11:00 and 22:00 hours. Night time consumption is low although it is recommended to load shifting these loads if cheap night tariff is available. The refrigeration consumption is relatively flat although it is possible to see a greater variation of the consumption demand during the day, due to more use of these appliances and more door openings. Concerning electronic equipment, (PC & accessories and television and peripherals), these loads are mainly used during afternoons when people are back home from work, but in the case of PC & accessories, it is noticeable that many of these loads are being used 24 hours per day (an increasing amount of people work at home and others don't turn the equipment off), and in the case of TVs and peripherals, some activity due to stand by mode is visible during night. Lighting is clearly more used during afternoon hours, after 17:00 hours and the peak is around 10:00 hours. Some lights are on during nights, mostly outdoor lights and people tend to shut off lights in unoccupied rooms. The total average number of lamps per household is 27. On average there are 4 compact fluorescent lamps per household. Incandescent and halogen are the most widely used lamps, and there is a large potential for the application of CFLs in the households, for the replacement of incandescent lamps, which represent 50% of the total lamps installed.

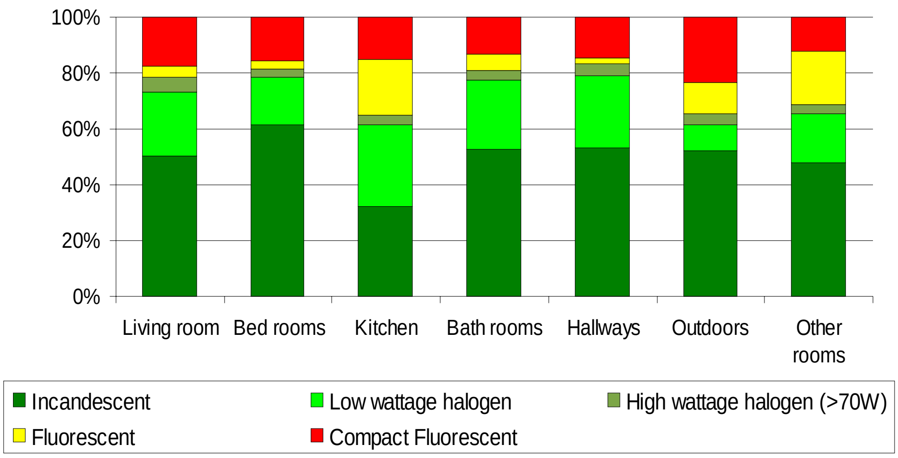

Figure 9: Disaggregation of the type of lighting per type of room.

Energy demand when appliances are in standby mode

The standby electricity consumption for the appliances measured under the REMODECE project is presented in Table 1. The shown values are based on metered demand as well as on spot measurements of the low power modes for different types of electronic equipment in the households.

Many appliances with standby energy demand were not part of the metering campaign of REMODECE. These appliances are for example:

1. Electrical toothbrush, shavers and other toilet requisites.
2. Electrical tools with chargers: Drill, saw, screwdrivers and other tools.
3. Electronics as DAB radios, Amplifiers, Musical instruments etc.
4. Some kitchen equipment.
5. Garden equipment with chargers.
6. Home security systems.
7. Garage door openers.

Some of the new electronic appliances have a relatively high share of standby consumption. In such appliances standby may be the electricity required[3] to keep information (such as storing TV stations in set top boxes, etc.) in the appliance memory. On average the standby electricity consumption per household and per year is about 250 kWh, which is about 9,4% of the total annual electricity consumption per household. Standby power is roughly estimated to be about 41 W per household, representing about half of the electronic loads consumption.

In terms of behaviour, households seem to behave pretty well concerning turning off the computers and monitors. On opposite they let fax machines, modems and routers/hubs, on stand by mode because they fear to loose the pre-definitions and have to reprogrammed them if they turn them off. Roughly 40% of the households do not turn off the television with the on-off button, keeping it on standby mode.

[3] Can be avoided by using ”non-volatile” electronic components storing information even if the power supply is disconnected.

Table 1: Standby energy consumption – results from the measurement campaign.

APPLIANCE	MEASURED YEARLY STANDBY CONSUMPTION	SHARE OF TOTAL YEARLY CONSUMPTION	STANDBY POWER PER APPLICATION
Unit	***kWh/household***	***Percent***	***Watt/application***
Chargers	5,8	68,0 %	0,74
Refrigerator without freezer	1,2	0,9 %	1,85
Refrigerator with freezer	3,0	0,8 %	2,20
Freezer	0,9	0,3 %	1,60
Washing machine	1,8	1,0 %	0,27
Clothes dryer	0,6	0,6 %	0,25
Dishwasher	1,2	0,9 %	0,28
Desktop PC including monitor	20,6	9,4 %	4,50
Laptop PC	3,1	13,2 %	1,18
Router for Internet	9,7	34,6 %	4,61
Wireless access point	21,1	89,1 %	8,60
Printer	20,5	93,4 %	3,88
Scanner	*17,8*		*6,30*
All in one printer	*14,9*		*4,40*
Fax machine	*5,3*		*4,00*
TV CRT	12,2	10,7 %	2,09
TV LCD	1,5	3,7 %	1,09
TV Plasma	0,4	1,2 %	1,86
TV projector	*3,2*		*37,5*
Home cinema	*3,7*		*2,70*
VHS recorder player	*24,3*		*4,90*
DVD recorder/player	9,9	66,1 %	1,95
Hi-Fi	18,2	55,9 %	3,75
Compact HI-FI	*7,7*		*2,80*
Satellite/cable/air set top box	16,2	52,4 %	7,11
Hard disc (TV recorder)	*3,5*		*2,10*
Video game	*2,9*		*1,50*
Air conditioner	0,8	1,6 %	3,18
Oven/cooker	5,2	2,3 %	0,96
Microwave oven	4,5	20,9 %	0,88
Water kettle	0,1	0,2 %	0,02
Vacuum cleaner	0,5	0,7 %	0,06
Lamps (22.5 units)	10,4	2,1 %	3,13
Total	252,7	9,4%	122,24

In table 1, text in normal case are from a revised analysis where metered data with low resolution (no decimals reported) were formatted so that low power demand could be correctly handled in the analysis. The revised analysis was carried out after the REMODECE project was finished in January 2009.

Rows shown in *italics* are from the original metering campaign of Remodece [4]. Data for these appliances are based on spot measurements of standby consumption.

Examples of standby consumption

Figure 10 and 11 show typical daily load diagrams for a set top box and for a desktop PC with monitor, both for “ON” mode, and also when the appliance is in Standby mode. As it can be seen in Figure 10, a TV set top box has a quite high power demand during night hours. This shows that most people do not switch the set top box into standby mode when they do not watch TV. The standby consumption is about 50% of the ON consumption (the device is interpreted to be in standby when the consumption is less than 90% of the peak registered power and less than 20 Watt)

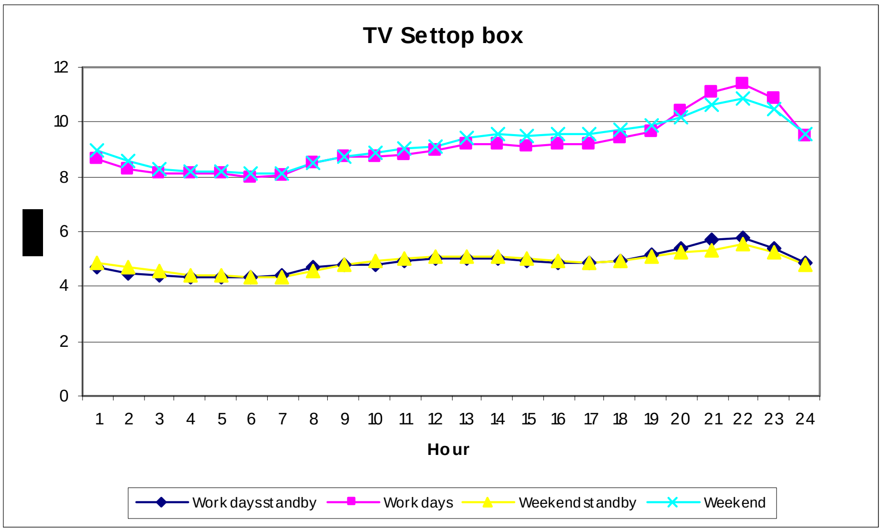

Figure 10: Electricity consumption for a TV Set top box, showing standby consumption

The graph of a desktop PC with monitor shows that the consumption differs a lot between afternoon hours when most people are expected to use the PC, and night hours. The standby consumption remains stable during the 24 hours per day. This shows that PCs are switched off into standby mode either automatically (Energy Star or other regimes) or manually. The demand in standby mode is less than 5 Watts. Some users leaves their PCs in on mode all day and night, this can be interpreted from the demand during morning hours, since the standby demand is less than the demand in ON mode.

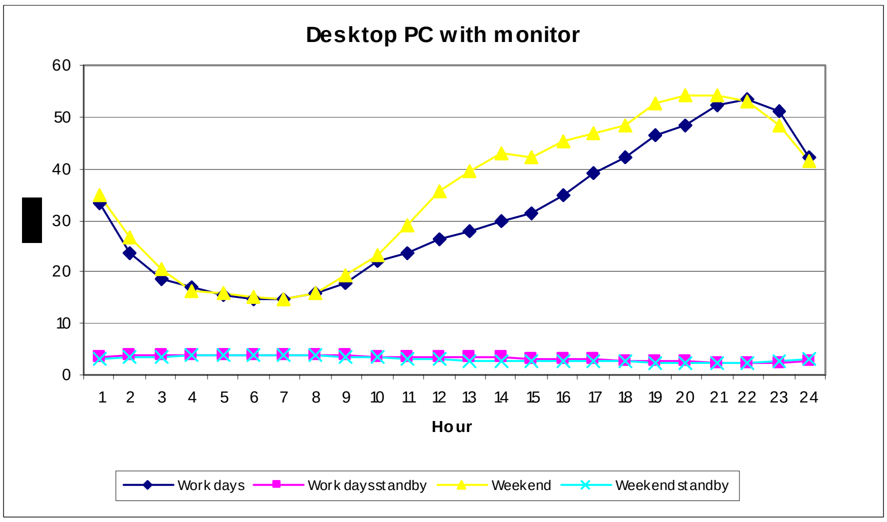

Figure 11: Electricity consumption for a desktop PC including monitor showing standby consumption

Potential electricity savings

As it was already mentioned, the technical potential electricity savings was estimated based on the replacement of the existing installed inefficient technologies with the Best Available Technology (BAT). Hence, the BAT is a combination of Best Available Technology and Best Practice or most economical use of the appliances. This combination is referred as BAT only, even if in same cases most of the savings are allocated to Best Practice. The BAT per appliance is the same for all countries, but the aggregate values will depend on ownership level, and on the use pattern (load factor) of the individual countries. The Present Sate is country specific based on data from the monitoring campaigns and on previous campaigns.

The baseline to consider is stock replacement and not the market replacement. The total savings (technical potential) by replacing installed inefficient technologies by BAT/BP in the market are therefore estimated. Structural effects are not integrated in the calculations. The lifetime of the equipment or penetration time of BAT was neither taken into account. Equipment with short lifetimes, e.g. desktops and laptops, will be replaced soon but other appliances like electric cooker/oven may have a long lifetime and it may take several decades to replace today´s equipment with the Best Available Technology.

The annual electricity savings in a typical European household, by switching to the BAT per type of appliance is presented in Figure 12.

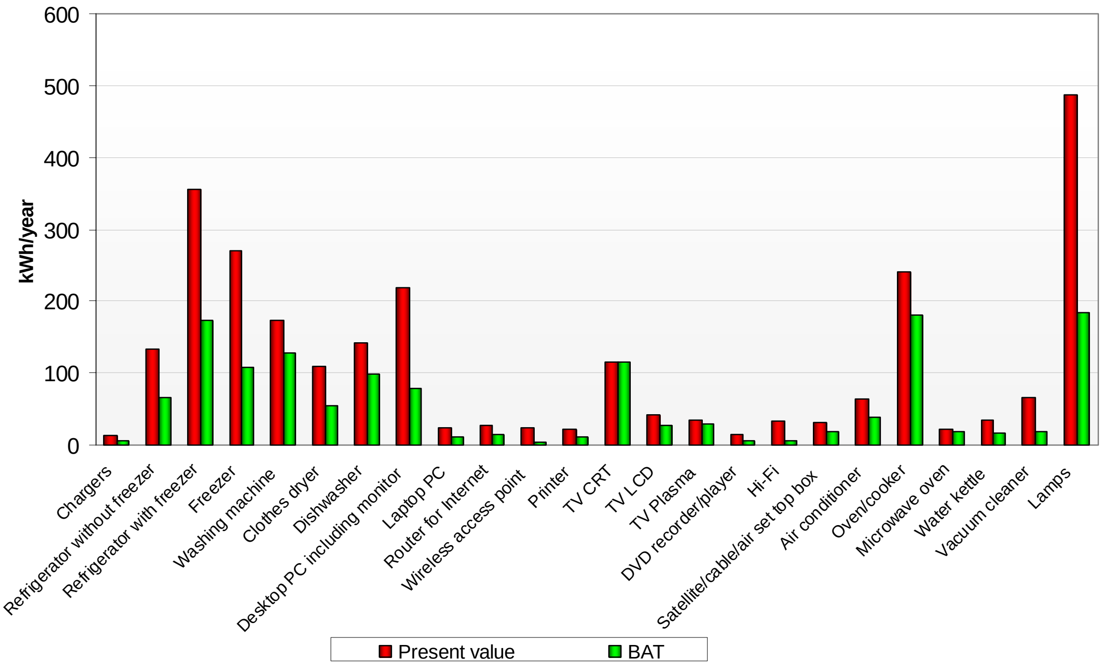

Figure 12: Annual electricity savings in a typical European household by switching to BAT.

The savings from switching from present state to best available technology were estimated to be about 1300 kWh/year/household. The aggregated annual electricity savings by using best available technology in European households for the EU-12 countries of the study were found to be 165 TWh per year, representing about 48% savings potential.

These electricity potential savings will translate in 72[4] million ton CO^2 emission savings per year by switching from present technology (PV) to best available technology (BAT). At European level (EU-27), the electricity savings would translate into 268 TWh that is 116 million ton CO^2 emission savings.

[4] For calculation of the saved CO2 emissions, a factor of 435 ton CO2/GWh is used as a common value for Europe except Norway. The factor is calculated as the European average CO2 emissions of electricity production under average generator efficiency using the average mix of fuel

For assessing the quality of the estimated values for the different appliances, the number of measurements per appliance and confidence intervals was calculated with standard statistical methods. Generally a high number of measurements give a more significant and accurate estimate than just a few measurements. A small confidence interval indicates a significant estimate, which is due to a low standard deviation in the energy consumption. In general, within each appliance, there are a lot of models with different yearly consumption (e.g. energy efficiency classes). Also, the use of some appliances is varying a lot among different consumers. A high confidence interval indicates a large uncertainty, probably associated with the fact that there are too few measurements for this appliance type. The result of this analysis is that the estimates of refrigeration and washing appliances, PCs, CRT and LCD TVs are trustworthy, while they are uncertain for for PC peripherals and plasma TVs.

Historical perspective of appliance consumption: Focus on the French monitoring campaigns

Audiovisual and computer site: assessment of the impact of introduction of new technologies in households

The REMODECE monitoring campaign helped to understand the very important changes that occurred in French households in the last ten years and more specifically with the evolution of electronic equipment (entertainment and office equipment) within households. Two main aspects deserve to be mentioned:

1- The deep change in audiovisual sector due to the introduction of new technologies, which however did not improve the service provided;

2- The emergence of home computing which constitutes a real break as it grants access to new services and of course new technologies.

From the point of view of the common consumer these changes are mainly a source of satisfaction. A lot of changes occurred during the last ten years: living standards have increased, lifestyle has evolved, and people got new habits and needs, and are keen on new products.

But from the energy expert side one can only be worried. Indeed in order to give a rough estimate, the average electrical household consumption (except the thermal uses) is about 1000 kWh per year and per person which means around 2500 to 3000 kWh per year and per household. The electrical consumption of the audiovisual site has increased during the last ten years by 78 % (from 307 to 546 kWh/year). If this trend goes on until 2050 the consumption of the audiovisual site could reach 6150 kWh/year.

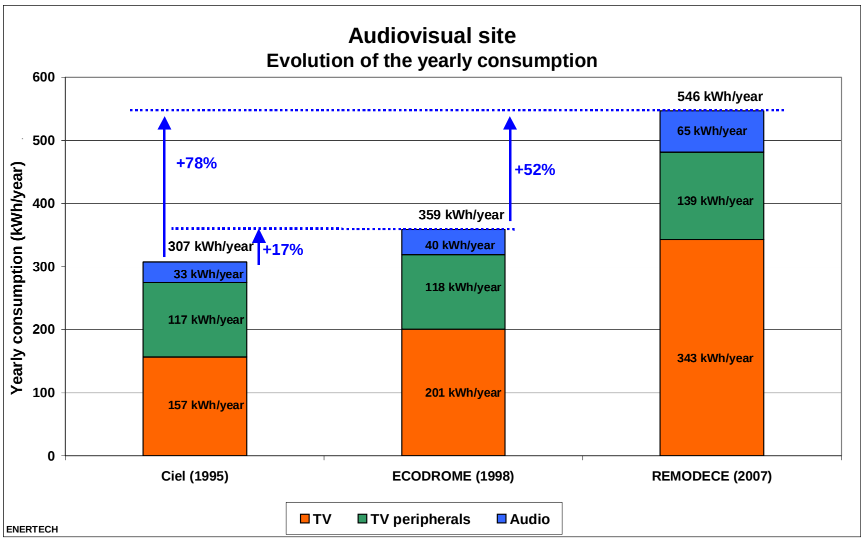

Figure 13 - Evolution of the yearly consumption of the audiovisual site in the last 12 years

Furthermore home computing adds now 396 kWh per year and per household to the electricity bill.

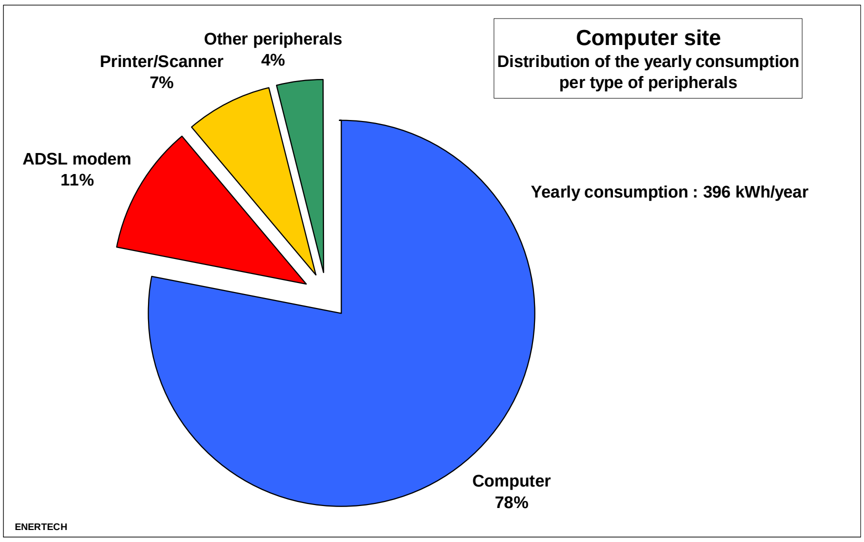

Figure 14 - Distribution of the yearly consumption of the computer site per type of peripherals

Therefore, these two relatively new uses add 635 kWh/year to the electricity bill of all French households that are equipped with these loads. We can wonder if this increase of consumption is really necessary. Indeed as far as audiovisual is concerned the introduction of flat screen does not improve significantly the quality of the image. But the 2006 football world cup facilitated the launch of a new product not optimised from an energy point of view. It has created a trend that for sure has been profitable at a business level but what about the environmental consequences? Moreover the manufacturers have gone on increasing the size of the screen and in the meantime the consumption of the product. There is still no real concern about the energy consumption of audiovisual products as it is the case for example for cold appliances.

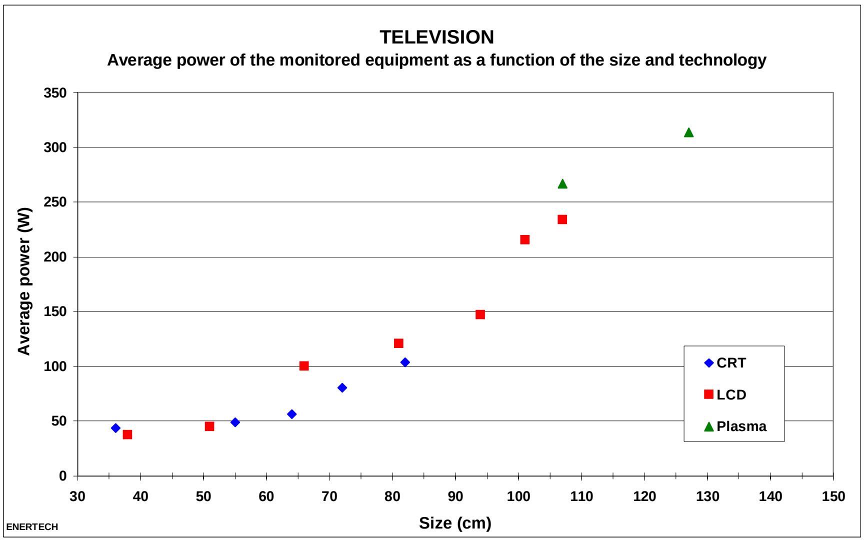

Figure 15 - Average power of the monitored televisions as a function of the size and the technology

On the other hand, the emergence of home computing brings a real additional service but one can deplore the way it has been developed. Indeed there is no energy optimisation concern. Computers are wasting a lot of energy. Their consumption is high while it can be drastically reduced (see the case of certain laptops). Furthermore the power management features are not systematically activated resulting in needless overconsumption, the size of the screen gets larger every year. It is now impossible to find a 15" screen in France, which is however sufficient for most of home computer applications. Because of the wider use of electronic appliances standby consumption is increasing a lot. It seems therefore necessary to introduce very tight energy efficiency criteria in the design of new products.

Cold and washing appliances: an update of previous monitoring campaigns

In parallel to the REMODECE project France has monitored the cold and washing appliances in 100 households, in order to update the data gathered ten years ago in previous monitoring campaigns (Ecodrôme, Ciel). The major results are:

1- Globally the consumption of the cold appliances (including all appliances within a household) has decreased by 40% since 1995 and by 16% since 1999.

2- The average consumption of the refrigerators is around 253kWh/year, corresponding to a reduction of about 32% compared to 1995 and of 10% to 1999. But on the other hand the average volume of the appliances has increased from 193 to 286 litres (about 48% larger).

3- The average consumption of fridge freezers is now equal to 460 kWh/year which represents a decrease of 36% since 1995 and of 18% compared to 1999. But during the last twelve years the volume of the fridge and freezer compartments have increased respectively by 13 and 24%. We have also noticed the disappearance of the standby power which was very common in 1995 on this type of appliance.

4- The average consumption of freezers is now 556 kWh/year which means 10% less than in 1995 but 10% more than in 1999. There is no real improvement of consumption for this type of appliance. However we have noticed an improvement of the energy class of the most recent appliances but at the same time the average volume has increased by 32%.

5- The American fridge freezers are still not so common. Their consumption has significantly decreased, about 52% since 1995 (from 1640 to 796 kWh/year).

6- The electricity consumption of washing machines has decreased by 28%. The average consumption of the cycles decreased from 875 to 648 Wh (-26%). The number of warm cycles is relatively stable (4,95 cycles/week monitored in 1995 and 4,64 cycles in the REMODECE campaign). We have noticed the emergence of standby power on these appliances, which is fortunately negligible.

7- Concerning dishwashers the present situation is not so positive: the consumption has been reduced by only 3% since 1995. However the consumption per hot cycle has decreased by 23% which indicates that the technical performances of the equipment have been improved. However, the number of cycles increased from 3,1 to 4,1 cycles per week (+32%).

Rebound effect

It can be concluded that the technology of the monitored appliances has improved during the last ten years resulting in a great enhancement of their performances. The electricity consumption of the refrigeration appliances, which had been the first target of energy labelling campaigns, has really decreased between 1995 and 1999 (period that comes just before the first legal obligation on consumption of electrical appliances). This demonstrates the positive impact of the European Commission regulations.

However this technical improvement is only partially reflected in the consumption. An in-depth analysis shows that both volume of the cold appliances and number of cycles of the dishwashers have increased a lot. The only “good surprise” is the case of the washing machines: the users have not changed their way of using it and the technical features have been improved.

Generally, the benefit achieved with the reduction of the electrical consumption have been partially lost due to behaviour changes or choice of larger equipments, which consume more electricity. This phenomenon is close to the so-called “rebound effect” which states that from the savings generated by the improvement of the efficiency, users reinvest the benefits in more services, increasing their electricity bills, leading to a reduction or even to a cancellation of the achieved energy savings.

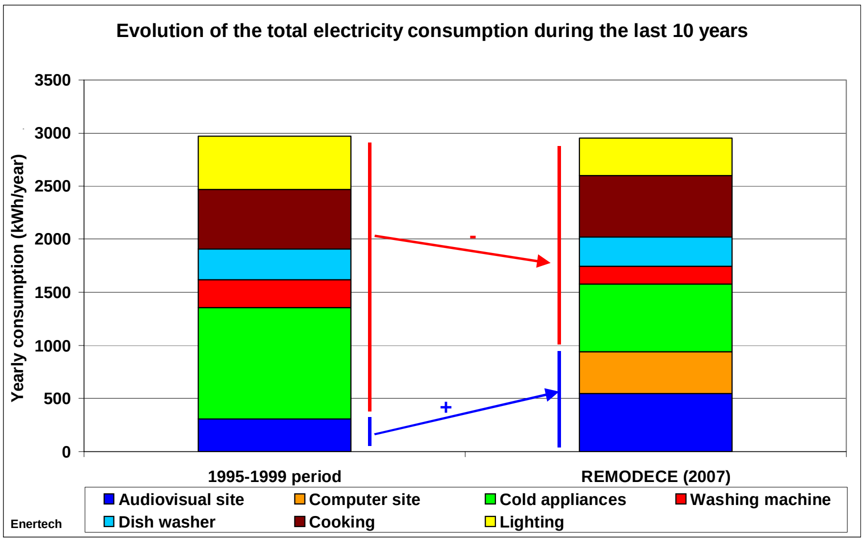

Figure 16 - Evolution of the total electricity consumption of an average household during the last ten years

It is probably one of the first times that the “rebound effect” is monitored. All the savings gained in the last ten years in the sector of cold appliances, lighting and washing are balanced by the increase of consumption of the audiovisual site and the emergence of the computer site!
It is of course necessary to consolidate these results. If this conclusion is confirmed it would be necessary to direct the consumers’ information campaigns toward more “energy sobriety”. What we have monitored during this campaign is commonly called “improvement of the service” but it is in fact only wastage which is no longer sustainable when the energy price takes off and the supplies rarefy.

We fear that the demand side management for electricity may result in the frustration of its goal. And it is necessary to boost efficiently this sector which has not been really dynamic for ten years.

Part of the domestic electrical appliances in the total energy consumption of a building for tomorrow

If we set the demand side management against the present great imperatives (prescribed in France by the “Grenelle de l’Environnement”), it is interesting to analyse the structure of the energy needs of a passive house.

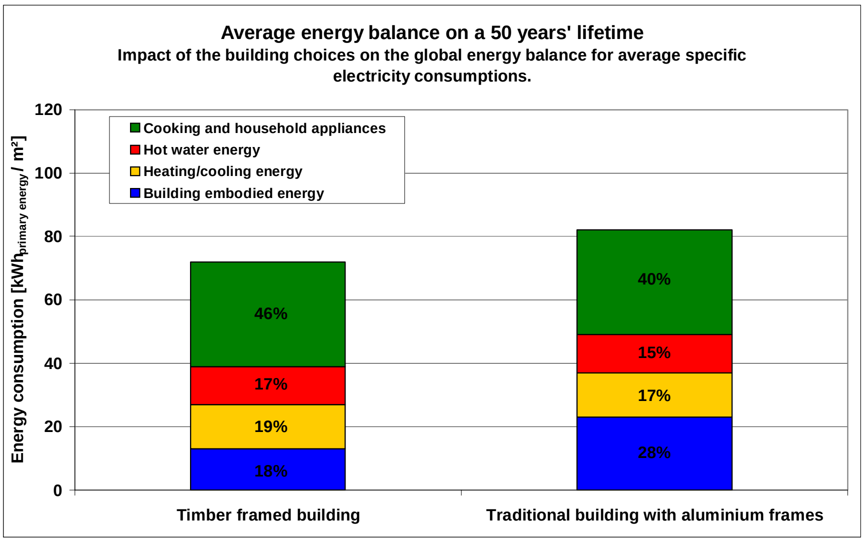

Figure 17 - Part of household appliances in the total energy consumption (primary energy) of an average household

As it can be seen in Figure 17 in a passive house heating is no longer the main end use of energy : only 11% of the annualised energy consumption (grey energy is amortised on fifty years on this graph). The most important uses are hot water and more household appliances which represent, in primary energy, 4 to 5 times more than heating consumption.

The imperatives have moved. The construction of “buildings for tomorrow” (positive energy buildings) requires substantial and stiff demand side management programs for all the uses involved.

It is mandatory to restart vigorously research work on demand side management but at the same time it is also necessary to restart the European regulatory process which is the only one to have proven its efficiency and which has been inactive for several years.

Finally it is urgent that industry leaders develop more sober and less unnecessary solutions. Authorities should also raise public awareness regarding energy sobriety.

Conclusions

According to the REMODECE project, the average electricity consumption per household per year was estimated to be 2700kWh, excluding electric space and water heating. From the measurements carried out, besides conventional uses (e.g. White appliances and lighting) with a large share of the electricity consumption, it can be concluded that IT and entertainment loads, which have been growing at a very fast rate, are now a key contributor to the electricity consumption representing 22% of the total electricity consumption. In basically all types of loads monitored there is wide range of performance levels, in the models available in the households.

By changing to the Best Available Technology and Best Practice, the households can reduce their electricity consumption by about 1300kWh, representing 48% of their total consumption. The aggregated savings for the participating EU-12 countries are roughly estimated to about 165TWh. The estimated reduction of electricity consumption is translated into 72 million ton of avoided CO_2 emissions per year. At European EU-27 level the savings potential would amount to around 268TWh. Standby consumption represents a significant share of the total household consumption, being responsible for about 9,4 % of the total household consumption, mostly concentrated in entertainment and office equipment. The standby consumption may be even slightly higher if all the appliances having standby consumption within the household had been monitored.

This study increased the level of knowledge about electricity use in the European Union. However, it is also necessary to perform more measurements, especially of energy efficient equipment, more recent electronic appliances, and different types of lamps to get more knowledge about the use of – and energy consumption in such appliances. Such measurements will permit to obtain better estimates of the potential savings by replacing old inefficient equipment as well as to design suitable strategies to tap those savings.

The most important steps and tips to save electricity identified, through the proper selection and operation of equipment are the following:

1. Phasing out indoor and outdoor incandescent lamps with CFLs and LEDs. Initial cost of the bulbs is higher but investments will be recovered from the electricity that they will pay for themselves several times over, as CFLs and LEDs last much longer. Actually it is very important to promote use of new LEDs lamps displacing the growing share of inefficient halogen spot lamps. In the near future. LED can be used instead of the high amount of small reflector halogen lamps which are very rapidly penetrating into the kitchen, bathroom, stairway etc. (often a low quality of lighting with glare problems. At a later stage during the next decade, LEDs have the potential to become the dominant lighting technology, because of the superior overall performance (efficiency, lifetime, environmental impact).

2. selection of the most efficient appliances namely the change to A+ and A++ appliances.

3. behaviour changes also play a key role in decrease electricity use. For example in the case of washing machine possible improvements can be achieved namely through the use of washing cycles at full load, washing with the coldest water as possible, as well as drying clothes by natural means whenever possible.

4. selection of efficient entertainment equipment (e.g. LCD TVs instead of plasma or CRT TVs) as well as energy-star labelled office equipment with reduced standby power requirements. Because standby represents about half of the consumption of electronic appliances, behaviour changes like switching-off electronic appliances (TV, DVD, Hi-Fi, Computer, monitor, printer, etc.) when not in use are critical to cut wasteful consumption.

5. since air conditioning is growing fast in Southern Europe, the selection of the most efficient equipment (COP>4) needs to be ensured through minimum efficiency standards. Again behaviour changes can strongly mitigate not only the consumption, but in some conditions even the need of air conditioning. A good example is the use of night ventilation for free-cooling in the summer.

6. Promotion of the use of renewable energies (e.g. sun and wind for drying clothes, solar water heating, biomass for fireplaces).

The comparison of the French monitoring data over the past 10 years and the ones from the REMODECE project points out very clearly that it is not sufficient to impose constraints on cold appliances, as already foreseen in the Eco-Design Directive. Computers and peripherals should be sold with activated power management. It is also necessary to influence user behavior on appliance selection. The size of TV screens and the volume of cold appliances, if not mitigated by consumer education can lead to a rebound effect.

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Energy demand for white goods, what influences? – Answer from in-depth metering of electricity demand in 400 Swedish households

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Keywords

Electricity use in households, end-use metering, demand analysis, appliances, behaviour

Abstract

This paper reports some of the findings from in-depth metering of the domestic electricity consumption in 390 Swedish households. The data have been logged in 10 minute intervals for nearly all electricity demanding equipment. 20 households were measured over a year and the rest over a month. 200 were one family houses and 190 apartments. The measurements were terminated summer 2008 and evaluation is still going on. The relation between measurements and enquiries are explored.
[To be revised.]

Introduction

Over the past 30 years, the domestic use of electricity in Sweden has increased from 9.2 TWh (1970) to 19.5 TWh (2006) [1]. Although the largest increase occurred during the 70's and 80's, there has been a steady growth up until now. This increase is usually explained by an increase of the number of households in combination with the total number and use of appliances in the homes. However, other trends points towards a decreasing use, due to factors like the improved energy efficiency of white goods. Thus, to get a detailed understanding of this development is not a trivial task, and requires a combination of different methods.

The paper presents some results from the project "End-use metering in 400 Swedish Households" where time-resolved measurements on an apparatus level yields detailed load curves from 10 minutes up to a yearly basis. Methodology and early results have been reported previously in [2], but in this paper further analyses are presented. However, the measurements started in September 2005 and finished during the summer 2008, and since all data are still being processed, definitive results have to be awaited later on.

Apart from measurements, several research institutions was invited to carry out studies based on the data produced, mostly from a social science and interdisciplinary perspective. The results will be presented in separate papers or at other arenas. But in short, these behavioral studies have given deeper insights when trying to explain user patterns and attitudes towards the domestic end-use. This combination of measurements and behavioral studies is quite unique for these types of projects.

Finally, a main goal with this paper is to present some results from the measurement study and to demonstrate the different analyses that are possible to perform. Both raw and processed data will be made public available in order to stimulate further research and studies based on data.

The results in this paper are divided into the following parts:

- Overall results – all appliances for houses and apartments, respectively
- Results for different types of households
- White goods. Analysis of the correlation to the socio-economic factors of the households
- Label vs field: analyses of dishwashers and cold appliances

Methodology

The methodology has been presented in some detail in [2], but we repeat the most important features here.

Selection of households

The selection process has been done in cooperation with the statistics agency in Sweden, "Statistics Sweden", where households representing different types of families in combination with the type of house or apartment in terms of age and location (big town, small town, countryside), have been chosen.

However, the geographic spread was limited to be within the region of Lake Mälaren, since it offers the desired variety of households within a practical size of area. But in order to check for factors due to geographical location, especially regarding lighting since this probably can vary as a function of latitude and season of the year, a few households were chosen from the far north (town Kiruna) and south (town Malmö).

Measurements

The number of loads in a typical Swedish home may be substantial; in all it can easily be over 60 loads. Thus, to measure them all was a difficult task and required a combination of *direct* and *indirect* measurements. It was performed in the following way, based on the concept used in the EURECO-study [3]:

- As much as possible was measured in the switchboard by means of special wattmeters – the total consumption, stove and oven, freezer, fridge etc.

- The other appliances (TV, PC, etc) were measured by serial meters placed between the socket outlet and the appliance.
- Light sources were measured in an indirect way: light sensors measured when the lamps were on and off; together with information of the nominal power it was then possible to *calculate* the energy consumption (energy = power * time)
- Sometimes there were loads that could not be measured directly (apart from light sources), *e.g.* when there was a mix of free and fixed installations fed from the same fuse. However, most times it was possible to use calculations.
- The temperature was measured in- and outdoor.

In order to make the measurements cost-effective only 40 measurements have been carried out for a whole year. The rest have been measured for a month and then multiplied with a seasonal factor derived from the yearly measurements per appliance. In this paper the seasonal factor used was developed by Enertech. The method has been to develop a second-order function over the year. However, the choice of function influences the resulting annual value quite much, and more analyses will be performed investigating this further.

All in all, measurements were performed in 200 houses and 190 apartments. The measurements started in September 2005 and ended June 2008. The measurements, most of the analyses and reporting has been carried out by Enertech, a French company, in collaboration with YIT, a Swedish electric installer. By means of time resolved measurements, 10 minutes, on an appliance level, detailed load curves on a daily, weekly, monthly and yearly basis were achieved. In addition, details of the household were completed by the occupants, the installers and in some cases by researchers, collected in enquiries. In total there are more than 200 000 million data points. Our ambition is to make the data available over the internet.

Furthermore, the database with the raw metering data will be made publicly available. At present we intend to store the data in SQL format. It will be located at The Swedish Energy Agencies homepage. www.energimyndigheten.se This is also the place were reports will be available.

Overall results

The individual appliances have been grouped together in order to give some overview. Cold, for example, includes; fridge, freezer, fridge+freezer, chest freezer, table freezer and American freezer.

Table 1. The domestic electricity [kWh/yr] for 200 one family houses and 190 apartments.

390 households	One family houses	Apartments
Cold	792	627
Lighting	946	586
Cooking	394	301
Dishwasher	220	207
Laundry	303	187
Audiovisual	434	299
Computer	409	327
Miscellanous	536	506
Not followed	130	351
Total	**4164**	**3087**

Compared with measurements on 66 one family houses from 1994 [4] there is some indication that lighting is at the same level, and “cold” decreased the most. Also laundry and dishwasher decreased to some extent.

A comparison with other countries from ref [10] seems to give similar results. The results from our study were somewhat lower when compared with most of the other countries.

Table 2. The domestic electricity [kWh/yr] for different households

kWh/year	Family 26-64		Couple 26-64		Single26-64	Couple 64-		Single 64-
per;	House	Apartm	House	Apartm	Apartm	House	Apartm	Apartm
household	4143	3710	3358	2404	1742	2918	2139	1682
m²	32	76	26	76	27	23	29	22
person	1109	1187	1619	1202		1459	1070	

As expected, families living in households use more energy than a single retired person in an apartment; in this case the retired person uses 60 % less.

White goods: the relationship between measured data and socio-economic data

We asked ourselves what differentiates the 20% highest energy consumers and the 20% lowest energy consumers – see figure 1.

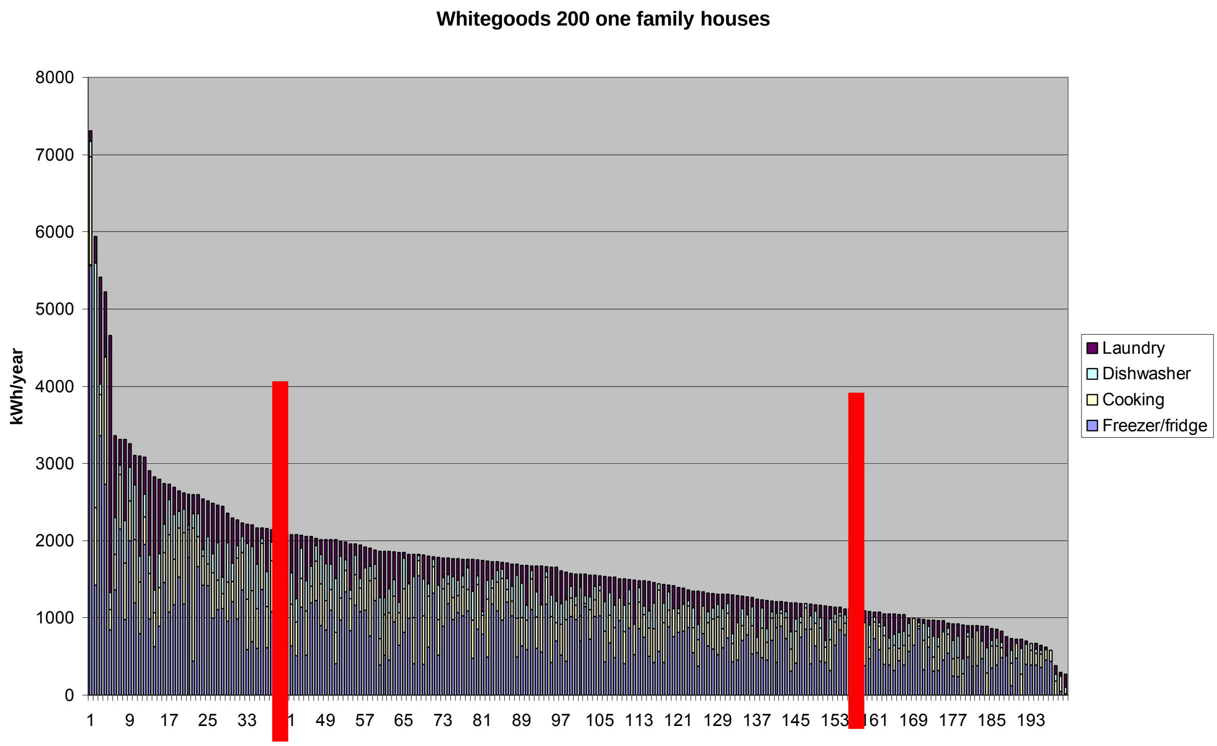

Figure 1. Energy demand for white goods. The average for the 20% high energy consumers is 2992 kWh and for the low energy consumer 842 kWh.

With the help of the enquiries we listed the results in table 3.

Table 3. Indicators for 20% highest and lowest demand of 200 one family houses

		20% highest demand	20% lowest demand
Type of appliance, kWh	Freezer/fridge	1358	373
	Cooking	632	233
	Dishwasher	395	104
	Laundry	607	132
	Sum	2992	842
Number of persons per household	1 person	0	3
	2 person	8	17
	3 person	4	6
	4 person	13	8
Income for the household before tax	More than 4200€	31	14
	3001 - 4200€	3	6
	2500 – 3300€	0	10
	1700 – 2500€	1	5
	800 – 1700€	0	1
N**o.** of white goods/household		7,03	5,9
Age	0-17	39	28
	18-64	69	55
	65+	5	13

Some indicators extracted from the database and enquiries explain the difference as seen in table 3. The next step will be a multiregression analysis, but that is outside the scope of this paper.

There are of course other factors such as the age of the appliance and also deteriorating appliances. For example, some of the highest demand freezers in this study have compressors that never shut off. This can be caused by a faulty thermostat or leaking sealing jointing. The freezer(s) stands for the biggest difference in these two groups. One explanation can be the number of freezers in each household. It is not uncommon in Sweden to have an extra freezer in the basement or garage for keeping the results of hunting, fishing and picking wild berries etc. In this study every second of the highest demand households had 2 freezers and there was only one freezer per household for the low demand households.

Summing up: a household with older, poorer, fewer people per household and having fewer white goods will use less energy. The 20% that use most energy will use three times more than the 20% who use least energy.

Deeper analyses of white goods: label vs field of dishwashers and cold appliances

Background

The energy labelling scheme of white goods has been a success for improving the energy efficiency. The main reason for this is the removal of appliances at the low end from the market, while at the same time development of top level products have been stimulated. Thus, the overall effect of this development is positive, a fact that motivates the ongoing revision and possible extension of the labelling system to other product groups.

However, a key factor of the labelling scheme is the reliability of the system, *i.e.*, that the grades actually corresponds to the promised performance of the appliances. The underlying testing standards aim to provide the guarantee for this, but a problem with the standards might be that they are too simplified [7,8].

In particular, the performance of the appliances can be divided into two groups: fridge and freezers, where the performance is dominated by the technical design, and the rest (washing machines, dryers and dish washers), where the behavioural patterns are at least equally important, since the filling degree and therefore usage may deviate heavily from the one assumed in the standards.

In this section we demonstrate how the data in combination with information on models of the white goods, can be used to check the validity of the label. The following appliances are discussed: dishwashers and cold appliances.

Dishwashers

The measurements give information on the average energy per dish, average number of cycles etc. See figure 2 and 3, where the average number of dishing cycles are presented.

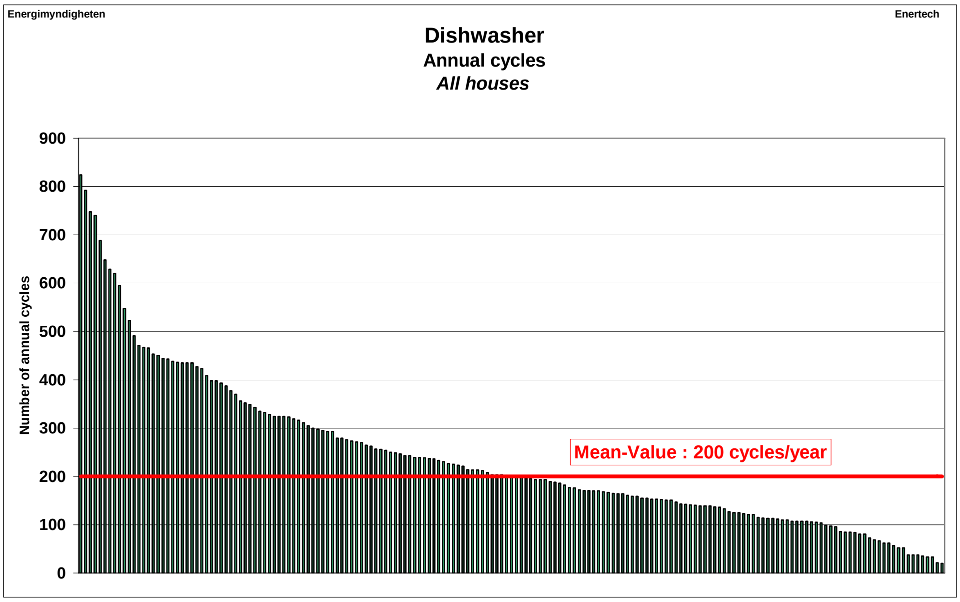

Figure 2. Number of cycles per year for houses. From ref [11]

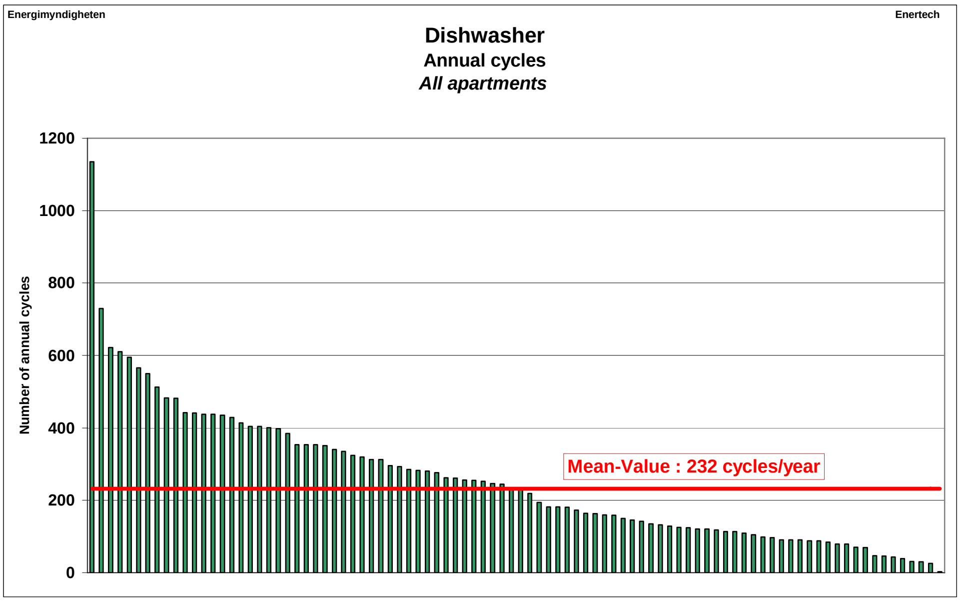

Figure 3. Number of cycles per year for apartments. From ref [11]

That is, the average is 200 cycles per year for houses, and 232 cycles per year for apartments. Compare with the standard for the label, which assumes 220 cycles per year.

More details are given by looking a bit closer on the data; see table 4 where nominal and measured values are compared. The nominal labels themselves – the classes A, B etc – are actually quite in accord with the measurements. However, the number of cycles are often lower than 220 per year. This shows clearly that dish washers (like washing machines, stoves etc) are depending on both the technical performance (energy per dish in this case) and the behavioural patterns.

Table 4. Nominal, measured and calculated label values

Nominal values according to the label			**Measured and calculated values**				
Energy per dish, nominal value[1] [kWh/dish]	Energ y class[2]	Annual consumption , nominal value[3] [kWh/yr]	Energy per dish, measured average value[4] [kWh/dish]	Energy class[5]	Annual consumption , mesured value[6] [kWh/yr]	Calculated nr of actual dish cycles[7]	Annual consumption , calculated value[8] [kWh/yr]
1,4	C	308	1,3	C	73	56	286
1,05	A	231	0,9	A	155	172	198
1,24	B	273	0,6	A	101	168	132
1,24	B	273	1,7	E	244	144	374
1,03	A	227	1	A	117	117	220
1,24	B	273	1,1	B	217	197	242
1,24	B	273	1,4	C	304	217	308
1,24	B	273	1,4	C	441	315	308
1,24	B	273	1,2	B	202	168	264
1,24	B	273	1,2	B	279	233	264
1,8	-	396	1,1	B	109	99	242
1,6	-	380	0,6	A	49	82	132

1 Using the reference program
2 According to the producer.
3 Based on 12 place settings and 220 dishes per year.
4 Average of values during the measurement period (one month – one year)
5 Calculated from eq (A.5), (A.7) and table A.3; see the appendix.
6 Based on either monthly data, scaled to annual values, or annual data
7 Based on the measurements of the annual values and the values per dish
8 Assuming 220 cycles per year.

Cold appliances

Contrary to the case for dishwashers etc, the overall performance of cold appliances is depending mostly on the technical performance in combination with the ambient temperature. The latter effect is clearly demonstrated in figure 4 below, where the energy as a function of the outer and inner temperature can be seen. Thus, from a measurement point of view, it is absolute necessary to establish a seasonal factor function when measuring for a shorter period than a full year.

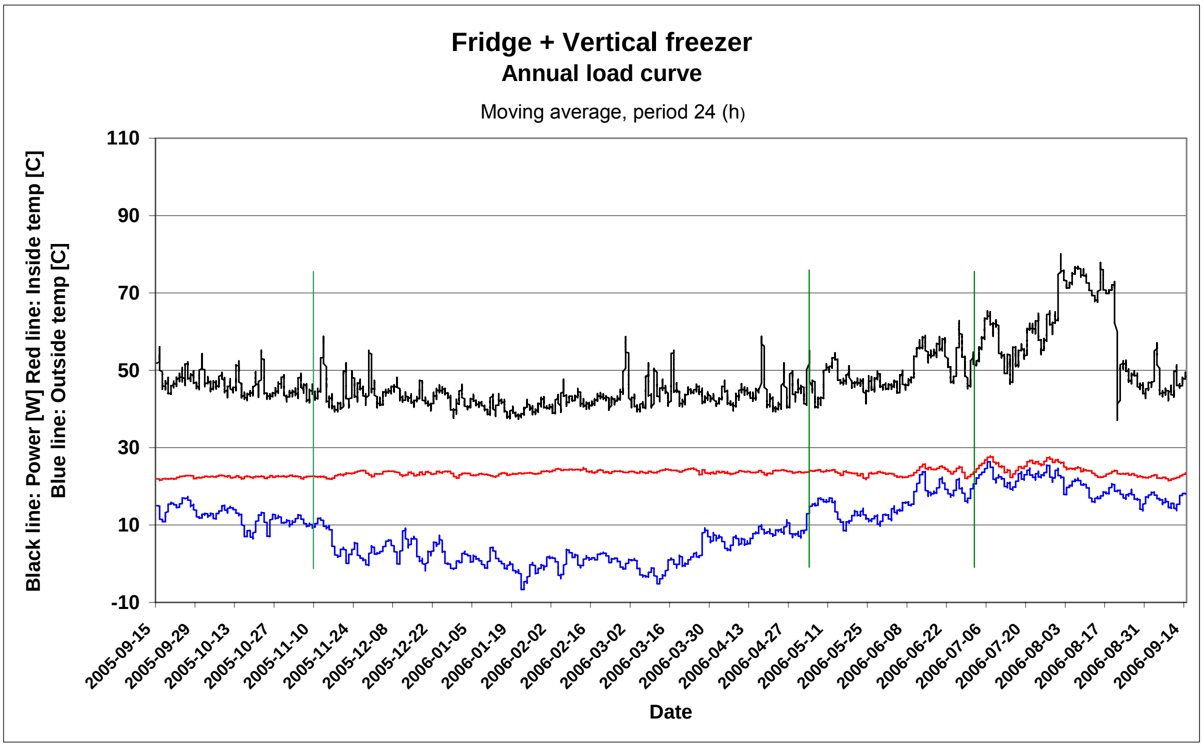

Figure 4. The power consumption of a fridge and freezer compared with the inside and outside temperature.

Note: September 2005- September 2006. Household located in southern Sweden. The green lines are only guidelines for the eye. (The data are filtered: moving average (MA-filter), period 24.)

In table 4, a set of data for different cold appliances are presented where the label is compared with the measured performance. Although this is a small set, the overall impression is that the measured label is again in quite accord with the nominal values. A task in the future is to explore the full set of more than 400 appliances that are labelled.

Appliance and Model year[9]		Energy class and Annual consumption [kWh/yr] according to the *producers*[10]		Measured annual consumption [kWh/yr] [11]			I or Iα[12]		Energy class according to *measurements*[13]	
				No corr.	Correction/ seasonal factor[14]	With corr.	No corr.	With corr.	No corr.	With corr.
1. Fridge/ Cool	2000	***B***	234	246	0,9	273	63	70	***B***	***B***
2. Fridge	1995	***C***	285	138	0,9	153	41	45	***A***	***A***
3. Fridge	1999	***A***	168	144	0,9	160	43	48	***A***	***A***
4. Fridge	2004	***A***	179	186	0,9	207	56	62	***B***	***B***
5. Fridge/ freezer	1996	***B***	372	320	0,9	356	53	58	***A***	***B***
6. Fridge/ freezer	2000	***B***	460	364	0,9	404	57	64	***B***	***B***
7. Fridge/ freezer	2000	***B***	460	465	0,9	517	73	81	***B***	***C***
8. Fridge/ freezer	2000	***B***	478	685	0,9	761	103	115	***E***	***F***
9. Fridge/ freezer	2004	***A+***	303	268	0,9	298	40	45	***A+***	***A***
10. Freezer	1985	***(E)***	584	563	1,1	512	99	90	***D***	***D***
11. Freezer	1995	***D***	547	252	0,9	280	44	49	***A***	***A***
12. Freezer	2004	***B***	281	207	0,9	230	53	59	***A***	***B***
13. Freezer	2004	***A***	306	244	0,9	271	44	49	***A***	***A***

Table 4. Appliances and labels

[9] The exact models are not given here.
[10] From producers data sheets.
[11] Monthly data, upscaled to annual data – which is the reason why corrections may be necessary.
[12] Calulated with eq (A.1) – (A.4); see the Appendix.
[13] According to Table A.1 or A.2; see the Appendix.
[14] Based on Figure 2.

Conclusion and future work

Metering studies are very expensive. Thus the data gathered should be used for further analysis. Examples for possible analyses are to study how consumers use their appliances. This includes studying trends in how household members interact with each other, depending on household size, age of members, social groups etc.

Another object is to study the amount of active and passive use of appliances (for example PC, games or TV), especially taking into consideration that this information can never be gathered through questionnaires. Naturally, the analysis can be used for other fields than energy. In order to maximize the results from such an expensive project, we invite research institutions to carry out studies based on the data produced, mostly from a social science and interdisciplinary perspective. For the purpose, the raw metering data will be made publicly available for future research.

Also the Swedish Energy Agency provides funding for research based on the data.
The results of these campaigns can also provide a relevant input for policy design. Examples are providing parameters for performing life cycle cost analysis, such as number and type of washing cycles per type of household, which are crucial for determining minimum energy performance levels. Another possible use of information from metering projects is for designing market transformation programmes and information campaigns.

The detailed metering was complemented by metering of water consumption, as well as questionnaires on habits not only on energy consumption but also on indirect energy consumption as food, goods and travelling. In addition, a subset of the households counted all their purchases over a year, which were calculated into kWh. The way these results can be used to further explain the total energy consumption will be explored later.

In order to maximize the results from such an expensive project, several research institutions have been invited to carry out studies based on the data produced, mostly from a social science and interdisciplinary perspective.

Finally, another task which will be undertaken is to scale up the values to a national level for Sweden.

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Appendix: The energy labels in brief

Part 1: Fridges and freezers. From directives 1994/2/EG and 2003/66/EG.

Definition of the classes A+ and A++.

The *standardized* annual consumption of an appliance, $SC\alpha$, is calculated as:

$$SC\alpha = M\alpha \times \Sigma\ (Vc\ (25\text{-}Tc)/20 \times FF \times CC \times BI\ ) + N\alpha + CH \quad [kWh/yr] \qquad (A.1)$$

where

- Vc and Tc is the net volume [litre] and temperature [°C] of each cooling space in the appliance

- The values of Mα, Nα, FF, CC, BI and CH are constants given in the standard (and are not presented here).

The energy efficiency index, Iα, is then defined as:

$$I\alpha = 100 \times AC/\ SC\alpha \qquad [\%] \qquad (A.2)$$

where

- AC is the measured annual consumption according to standard test procedures

The energy class is then found in Table A.1:

Table A.1

Energy efficiency index, Iα	Energy efficiency class
30 > Iα	A++
42 > Iα > 30	A+
Iα > 42	A–G

Definition of the classes A to G.

For those appliances where the classes A+ or A++ do not apply, the classes are given as follows.

The *standardized* annual consumption of an appliance, SC, is calculated as:

$$SC = M \times \Sigma (Vc\ (25\text{-}Tc)/20 \times FF) + N \qquad [kWh/yr] \qquad (A.3)$$

where

- Vc and Tc is the net volume [litre] and temperature [°C] of each cooling space in the appliance

- The values of M, N and FF are constants given in the standard (and are not presented here).

The energy efficiency index, I, is then defined as:

$$I = 100 \times AC/ SC \qquad [\%] \qquad (A.4)$$

where

- AC is the measured annual consumption according to standard test procedures

The energy class is then found in Table A.2:

Table A.2

Energy efficiency index, I	Energy efficiency class
I< 55	A
55 < I < 75	B
75 < I < 90	C
90 < I < 100	D
100 < I < 110	E
110 < I < 125	F
125 < I	G

Part 2: Dish washers. From directive 1997/17/EG.

The classes are given as follows.

A reference consumption (C_R) is calculated as

$$C_R = 1.35 + 0.025S \quad \text{if } S \geq 10 \quad \text{[kWh/dish]} \quad \text{(A.5)}$$

$$C_R = 1.35 + 0.09S \quad \text{if } S \leq 10 \quad \text{[kWh/dish]} \quad \text{(A.6)}$$

where S is the number of place settings.

An energy efficiency index E_i is then calculated as

$$E_i = C/\ C_R \quad \text{(A.7)}$$

where C is the measured value of a complete dish cycle.

The energy class is then found in Table A.3:

Table A.3

Energy efficiency class	Energy efficiency index, Ei
A	$E_i < 0.64$
B	$0.64 \leq E_i < 0.76$
C	$0.76 \leq E_i < 0.88$
D	$0.88 \leq E_i < 1.00$
E	$1.00 \leq E_i < 1.12$
F	$1.12 \leq E_i < 1.24$
G	$1.24 \leq E_i$

Residential end-use electricity consumption pattern in Chennai city

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Abstract

Electricity has become an indispensable service to an extent that people cannot carry on day-today household activities without its continuous supply. India witnesses a tremendous increase in demand for electricity due to a rapid growth of its economy which calls for abundant financial investments. Currently the power sector of India exhibits chronic power shortages and intense unreliability. Over the years, India has been driven by the need to increase electricity supply unmindful of the possibilities of demand side management in terms of efficiency and conservation. Managing electricity is beneficial to both consumer and producer. By ensuring efficiency consumers reduce operation costs and improve production efficiency and competitiveness. Above all the public utilities may reduce the need for costly capacity expansion, if energy reductions occur at peak loading conditions.

Electricity offers flexibility and variety of end-use services to households that are widely recognised as an important indicator underpinning economic development and improving quality of life. The composition of electrical appliances and its stock in a household has considerable impact on household electricity consumption. The increased penetration of some of the appliances like air conditioners has much implication for increased residential demand for electricity. In this backdrop the choice is therefore to examine electricity consumption pattern determined by lifestyle change and other socio-economic characteristics of the household. Managing electricity consumption and maximising the efficient electrical technologies depend on the knowledge of end-use pattern of electricity in the household sector.

Household sector is one of the important consumers of electricity in Chennai City. The present paper in a limited way verifies the different kinds of electrical appliances and consumption of those electrical appliances on a daily basis in the form of a layman's on the spot appraisal of the electricity consumption depending totally on the response of the households rather than recorded readings from various electricity measuring gadgets. Against this background data, the stock of electricity appliances possessed by the households and average electricity consumption of these appliances on a daily basis and the aggregate electricity consumption of these appliances on the household on an annual basis has been verified. The paper is based on the household level information collected through a primary survey, which has been carried out by employing a suitably designed questionnaire and this was then used for the survey in 409 sample households in Chennai City of South India. The appliance stock approach is used to determine the contribution of various categories of appliances in the total electricity consumption.

I. Introduction

Electricity has become the most essentials of life to such an extent that people cannot carry on routine household activities without the use of it. Modern society is electricity dependent and the adequate supply of it is a sensitive geopolitical and economic issue. Electricity concerns have long been driven by the need to increase its supply while the demand side of it is taken for granted. The power sector in India exhibits chronic power shortages and intense unreliability that likely to widen the gap between supply and demand further in the foreseeable future owing to the population growth and economic growth. Even if the demand increases at the current rate, it would necessitate new generating capacity involving huge capital investment and environmental degradation, besides increased resource depletion. Hence, there is an important role for Demand Side Management (DSM) of electricity, especially at the household level.

As urbanisation increases, it increases the demand for electricity consumed by the average household. Electricity offers flexibility and variety of end-use services that is widely recognised as an emerging ingredient underpinning economic development and improving quality of life. It offers a number of services like lighting, heating, cooling, cooking, etc to a household with the use of various types of appliances.

The residential consumption pattern of electricity unlike in other sectors is not constant or exogenous. The usual determinant of the household consumption of electricity is income; however, it is a proven truth that income is a weak predictor of residential electricity consumption (Reddy 1990). At the international level there are various studies (Wilson 1971; Anderson 1973) focusing household characteristics and price of electricity on household electricity consumption by analysing cross-sectional data. They found that price charged by the utilities is the major determinant of household consumption. (Houthekar 1993) studied household electricity consumption in UK by keeping the stock of appliances constant while allowed the short run income and prices to vary. (Fisher and Kayson 1962) in their study on residential electricity consumption of the USA established that residential electricity demand is proportional to the stock of electrical appliances. (Parti and Parti 1980) used regression analysis to disaggregate the total household consumption into appliance-wise consumption. Engineering models have been considered for the decomposition of household electricity consumption into different end-uses (Ljones et al, 1992). The primary disadvantage of engineering models is that they are based upon theoretical considerations rather than upon observed consumer behaviour. The other important disadvantage of the use of engineering models is the dependence of direct appliance metering, which is very costly. Engineering models are only appropriate, however, in situations where individual behaviour plays a minor role, for example, heating and cooling in extreme climates. In many households these appliances are used when occupants are at home (Bartels and Fiebig, 1990). Developing a detailed bottom-up approach requires an assembling of appliance stock data from disparate, some times, obscure sources. A metering campaign to derive estimates of average power consumption is conducted when alternative methods are unavailable (Fung and Ugursal, 1998). The French ECODROME project monitored appliance electricity consumption in 20 households over two years. All existing plug loads and electric light circuit were monitored during the first year and at the beginning of the second year all appliances and light bulbs were replaced with most efficient alternatives available on the market. The results indicated that the average annual energy savings per house from the use of efficient equipment is 1800 kWh per year. A similar approach and the methodology of ECODROME were followed by EURECO, which, instead of replacing individual appliances, the measured consumption of currently installed appliances was compared with the most efficient model of similar capacity and function (Silder et al, 2002). (Madlener 1996) uses micro data and econometric single equation models to determine household demand for electricity, gasoline and car fuels. Some study demand for electricity in physical units instead of in value terms (Nesbakken 2001). Many other studies focus on demand for energy and its significance in residential consumption basket and the strong price variations (Schmalensee and stoker 1999; Puller and Greening 1999; Oladosu 2003). Theoretical arguments emphasise that electrical services are important in driving economic development. Ayres and Warr concluded their study by stating that electricity is not merely an outcome of development but it is also a factor contributing to economic development

Direct use of electricity by households allows unprecedented comfort and productivity. The changes in household consumption pattern of electricity go hand in hand with changes in the economic structure of the society to a large extent by the stock of electrical appliances, lifestyle and other socio-economic characteristics of the households. Comfort and lifestyle of people change the consumption pattern of electricity from traditional end-use pattern of lighting and air circulation to more comfort providing use of appliances like air conditioner, refrigerator, space heater, water heater and floor cleaner. The variations in the household demand for electricity in different periods are difficult to predict by the mere use of macro-economic and technical parameters. It is important that the DSM programmes can make feasible solutions to demand problems by assessing the end-use pattern of electricity in a particular city or region. A city with fast changing lifestyles like that in Chennai demand for the adoption of electrical appliances, which apparently increase the consumption of electricity enabling the households to find more leisure time. Hence there is a higher tendency among urban households to acquire more electrical appliances, which increase the consumption of electricity.

II. Objectives

It is the fact that changes in the utility consumption go hand in hand with changes in the economic structure of the society. Estimation of residential electricity demand by end-use pattern is an essential requirement for effective demand-side management planning and implementation. Managing electricity loads and maximising the use of efficient electrical technologies depend on the knowledge of end-use pattern of electricity in the household sector. It becomes the rationale behind the selection of the objectives of the study. The following objectives guide the present study:

1. To disaggregate electricity consumption by energy service and by end-use device among the households.
2. To assess the composition of household stock of electrical appliances according to housing characteristics.
3. To assess the penetration and elasticity of electrical appliances.

III. Methodology and sample selection

The study is based on household level information collected through a survey in Chennai City which was carried out by employing a suitably designed questionnaire. The sample households were selected on the basis of a sample design. The study used multi-stage sampling in order to select the sample households. The first stage was the selection of a sample bill collection centre of electricity in Chennai City. The second stage was the selection of a sample street from the bill collection centre. The final stage was the selection of an electrified household from the selected streets. The sample households chosen for the survey represented four Electricity Distribution Centres of Chennai City: north, central, west and south. The total sample size of the survey constitutes 409 households from a universe of 702086, which appears 0.06 per cent of the total. Thus from 86 streets, 409 households were selected as the sample households of the study. In this study information gathered from 409 households widely scattered in all the ten Corporation Zones of Chennai City. The consumption of electricity by different electrical appliances is estimated on the basis of the information supplied by the household. The input obtained is both for estimating the electricity consumption of different appliances and for household electricity consumption by end-use wise.

The analysis is based on classifying households into those that use single-phase electric connection and those with three-phase electric connection. All electric connections to households in Chennai City have either single-phase (with a 5 amp current corresponding to a 1.15 KVA load) load mostly used for lighting devices or three-phase (one is the 15 amp current corresponding to a 3.5 KVA) load connected using for all household electrical appliances like air conditioner and electric pumpsets.

For the purposes of analysis, simple statistical techniques like percentages and correlation are used. The appliance stock approach is used to determine the contribution of various appliances to total electricity consumption.

IV. Results

A. Household characteristics

It is revealed that 95.1 per cent of the households are headed by male members. The respondents aged between 45 and 50 years claim the largest share of 21.3 per cent. More youth heads are found in households with single – phase electrification while adult headed households are more in houses with three – phase connections. It is found that more households with single – phase electrification have heads in the lower rungs of educational ladder (68.7 per cent have high school education and below) and a majority of the households with three – phase electrification belong to the higher rungs of educational ladder (54.8 per cent graduation and above). It is also found that less than one-fourth of the lower caste households (Scheduled Caste, Most Backward Class) as compared to more than two-thirds of upper caste households have three – phase connection. Nuclear families account for more than four fifth of both single – phase and three – phase households.

A comparison of electric connection in different types of houses reveals that 69.1 per cent of the flats have three-phase connection followed by independent houses and multi-storied houses in the order of 49.5 and 23.4 percentages respectively. When dwellings with number of rooms increase, more number of dwellings is found in the category of three-phase connection. A majority of the dwellings with less than 4 doors are connected to single-phase while a majority of the houses with more than four doors have three-phase connection. More than two-thirds of the houses having an area of 1000 sq.ft or more is connected to three-phase line. Nearly two-thirds of the houses aged more than 30 years have three-phase electric connection. But 61 per cent of the dwellings aged between 5 to 10 years have single-phase connection.

The average rent paid by the households connected to three-phase electricity is Rs.3681.7 as compared to Rs.2641 of the same in single-phase electricity connected houses. It is the general perception that increases in the size of household leads to an increase in the consumption of electricity. But the average household size of the single-phase and three-phase electricity connected households does not make any big difference (4.27 and 4.39 for single-phase and three-phase households respectively). The average household income of the single and three-phase electricity connected households is Rs.7558.83 and Rs.12686.7 respectively. Thus lower income households are connected more in single-phase while the reverse is true in the case of households with higher income. It is found that 71.5 per cent of the households connected to single-phase and 84 per cent of he households connected to three-phase does not use kerosene. Only 13.4 per cent of the total sample households rarely use firewood for cooking or heating purpose. The average monthly household expenditures on electricity, LPG and kerosene are Rs.596.68, Rs.420.6 and Rs.149.9 respectively.

B. Household electricity consumption behaviour

Urban households use multiple fuels for energy production. The shifting from traditional fuels to modern fuels in households occurred over a period of time. It is evident that 57.5 per cent of the sample households electrified their houses 5 to 20 years back. The mean period of electrification of single-phase and three-phase households does not make any big difference; hence significant period of electrification has no significant influence in selecting the connection of households with single-phase and three-phase electricity.

Though the electricity supply situation in Chennai City has improved over the years, the known problems in the distribution system are black-outs, brown-outs and voltage fluctuations. More than one-quarter (26.2 per cent) of the sample households felt power cut only once in a month but the cases of every week and everyday power cut accounted for 15.2 and 1.7 per cent respectively of the total households. Among the coping strategies, candles and emergency lamps are the two important strategies adopted by 83.3 and 53.5 percentages respectively of the total households. Generators and Kerosene lamps are the other two strategies adopted by 0.7 and 13.7 percentages respectively of the total households.

Generally the head of the households are satisfied with the present quality of electricity supply when compared to the situation before two years; however they levelled many complaints against its quality. A majority of them is frustrated with the power services in summer months though they lack awareness about the reasons for service being poor. More than half of the respondents (50.9 per cent) indicated that they would be willing to pay more for reliable and better electricity service and others feel that it is the responsibility of the government to provide them reliable power. Nearly three-fifth (59.1 per cent) of the single phase electrified households are willing to pay more if the reliability of electricity supply is improved to the maximum as compared to 35.5 per cent of the same in three-phase electrified households.

A majority of the respondents in single-phase electrified households felt that using electricity is very dangerous as compared to 46.3 per cent of the same in three-phase electrified households. By contrast, it is learnt that the three-phase electrified households exhibit more positive perceptions about electricity use when compared to single-phase electrified households. As far as the attitude of the respondents towards energy efficiency is concerned, the respondents of the three-phase electrified houses show more optimistic perceptions as compared to the same in single-phase electrified households. They perceive not only energy conservation in terms of appliance efficiency per se, but are also willing to learn in terms of using the appliances more efficiently and ready to substitute the efficient electrical appliances in the place of inefficient ones. Most of them are ready to spend more on better appliances to lower their expenses on electricity. A majority of the sample households is aware of energy conservation as an important issue.

C. Household electricity consumption

The overall household electricity consumption pattern differs in different seasons in a year. For analytical convenience, the calendar year is divided into monsoon season (July, August, September and October) winter season (November, December, January and February) and summer season (March, April, May and June). The physical quantity of electricity consumption of sample households in all the three seasons are obtained separately from the tariff cards of both single-phase and three-phase electrified households in terms of the number of kWh consumed. The electricity consumption in these three seasons by sample households is furnished in Table 1.

Table 1. Household electricity consumption in different seasons in a calendar year (2007) in Chennai City (in kWh)

Seasons	Single - Phase			Three - Phase			Total		
	N	Average Consumption	Average Tariff	N	Average Consumption	Average Tariff	N	Average Consumption	Average Tariff
Monsoon	221	562.4	901.4	188	918.3	1679.2	409	726.0	1259.0
Winter	221	442.0	653.8	188	709.9	1210.0	409	565.2	909.4
Summer	221	562.4	899.6	188	905.9	1655.2	409	720.3	1246.9

Source: Field Survey.

It is found that the average household electricity consumption in the winter season is the lowest in both single and three-phase electrified households. Monsoon season and summer season show no big difference in electricity consumption because of the reason that electricity is used for the heating purpose during the rainy season and cooling purpose during the summer season. In single-phase electrified households, the average consumption of electricity in the rainy and summer seasons are 562.4 and 562.4 units respectively when compared to 726.0 and 720.3 units respectively for monsoon and summer seasons in three-phase electrified households. The variation in the power consumption between single-phase and three-phase electrified households during monsoon, winter and summer seasons is 163.6, 123.2 and 157.9 kWh respectively.

The households are charged progressively for power consumption. Depending on monthly consumption of power, households are grouped into five slabs: slab 1 represents households consuming electricity upto 25 units; slab 2: 26-50 units; slab 3: 51-100 units; slab 4: 101-301 units and slab 5: 301 units and above. The average electricity tariff of the three-phase electrified houses is more than one and a half times as compared to the power tariff of the single-phase electrified households. The difference in the power tariff between single-phase and three-phase households is the least in winter season.

D. Appliance ownership

Households in Chennai City use a wide variety of household electrical appliances to improve their standard of living. The main end-use of electricity for households is traditionally for space illumination. Lighting helps the household members to read, socialise and perform a wide variety of activities. Generally space cooling is done by the use of electric fans and selectively by air conditioners based on the affordability of the households to purchase appliance and pay electricity tariff. Households also posses a wide variety of electrical appliances enhance comfort, entertainment and enrichment.

The pattern of electricity use and appliance ownership of sample households in Chennai City is shown in Table 2.

Table 2. Household ownership of different electric appliances (Percentage)

Electric Appliances	Type of Electric Connection		Total
	Single - phase	Three - phase	
Refrigerator	66.5	94.7	79.5
Storage water heater	9.0	26.1	16.9
Geyser	5.4	23.9	13.9
Immersion heater	15.4	19.1	17.1
Air conditioner	14.0	55.9	33.3
Ceiling fan	100.0	100.0	100.0
Table fan	34.4	44.7	39.1
Pedestal fan	7.7	15.4	11.2
Electric Iron	77.4	84.0	80.4
Acqua guard	8.6	22.9	15.2
Black and white TV	12.2	7.4	10.0
Colour TV	88.2	96.8	92.2
VCD	55.2	62.8	58.7
Computer	16.7	45.7	30.1
Stereo system	22.2	25.0	23.5
Radio	56.6	56.9	56.7
Tape recorder	37.1	49.5	42.8
Electric rice cooker	6.8	24.5	14.9
Electric stove	4.5	11.7	7.8
Electric oven	4.5	17.0	10.3
Electric kettle	1.4	2.1	1.7
Toaster oven	.9	5.3	2.9
Blender and mixer	87.3	96.3	91.4
Electric wet grinder	83.7	95.2	89.0
Coffee percolator	.9	2.1	1.5
Washing machine (Without dry)	8.1	13.3	10.5
Washing machine (With dry)	14.0	32.4	22.5
Electric water pump	33.5	55.9	43.8
Vacuum cleaner	2.3	8.0	4.9

Source: Field Survey.

It is found that almost all the households in Chennai City have electric fans which are almost a necessity. Other popular electrical appliances are the entertainment items such as television, stereo items, tape recorders, VCD, LCDs etc. Refrigerators are found 66.5 per cent of the sample single-phase electrified houses and 94.7 per cent of the three-phase electrified household. It is interesting to note that 14 per cent of the single-phase electrified houses have air conditioner while it is 55.9 per cent of the houses with three-phase electrification. The average number of electrical appliances among the sample households is shown in Table 3.

Table 3. Average number of electric appliances

Appliances	Single - Phase		Three - Phase	
	Mean	**Std. Deviation**	**Mean**	**Std. Deviation**
< 40 watts bulb	1.17	0.97	1.88	1.43
40 watts bulb	1.28	1.10	1.81	1.61
60 watts bulb	0.42	0.87	0.60	1.07
100 watts bulb	0.07	0.35	0.09	0.39
20 watts fluor. bulb	0.27	0.70	0.40	0.69
40 watts fluor. bulb	3.02	1.09	3.38	1.25
Refrigerator	0.67	0.47	0.96	0.25
Storage water heater	0.10	0.33	0.30	0.57
Geyser	0.05	0.23	0.26	0.47
Immersion heater	0.15	0.36	0.19	0.39
Air conditioner	0.16	0.43	0.65	0.64
Ceiling fan	2.82	1.46	3.95	1.83
Table fan	0.38	0.58	0.54	0.66
Pedestal fan	0.08	0.27	0.19	0.48
Electric Iron	0.81	0.49	0.90	0.56
Aqua guard	0.09	0.28	0.23	0.42
Black and white TV	0.12	0.33	0.07	0.26
Colour TV	0.93	0.43	1.02	0.30
VCD	0.57	0.52	0.63	0.48
Computer	0.17	0.37	0.46	0.50
Stereo system	0.22	0.42	0.25	0.43
Radio	0.57	0.50	0.57	0.51
Tape recorder	0.37	0.48	0.49	0.50
Electric rice cooker	0.07	0.25	0.24	0.43
Electric stove	0.05	0.21	0.12	0.32
Electric oven	0.05	0.21	0.17	0.38
Electric kettle	0.01	0.12	0.02	0.14
Toaster oven	0.01	0.09	0.05	0.23
Blender and mixer	0.89	0.37	0.98	0.24
Electric wet grinder	0.87	0.42	0.99	0.30
Coffee percolator	0.01	0.15	0.02	0.14
Washing machine (Without dry)	0.08	0.27	0.13	0.34
Washing machine (With dry)	0.14	0.35	0.35	0.56
Electric water pump	0.35	0.51	0.57	0.52
Vacuum cleaner	0.02	0.15	0.09	0.30

Source: Field Survey.

The data indicate that incandescent 40 watts bulbs are common in both single-phase and three-phase electrified households when compared to all other wattage of incandescent bulbs. It is also to be noted that the number of incandescent bulbs per 100 households is lower in single-phase households when compared to the three-phase electrified households. With regard to the fluorescent tubes, both single and three-phase electrified households use more number of 40 watts and 20 watts tubes when compared to the incandescent bulbs. As far as refrigerators are concerned, there are 76 refrigerators per 100 households in single-phase electrified households with a standard deviation of 0.47 as compared to 96 refrigerators per 100 households in three-phase electrified households with a standard deviation of 0.25. Immersion rod is the most common water heating appliance in single-phase electrified households while storage water heater is the most common appliance followed by geyser and immersion rod in three-phase electrified households.

E. Household income and possession of electric appliances

Households in Chennai City use wide variety of household appliance for the purpose improving their standard of life. Lighting was the main end-use of electricity in the past while electrical appliance for other end-uses like refrigeration, space cooling, heating and household comforts have emerged as the most electricity consuming items recently.

(i) Lighting

Lighting is the most common use of electricity in Chennai City with all households using electric lights. The familiar types of electric lights used are incandescent bulbs and fluorescent tube lights. Rarely households possess compact fluorescent lamps. Tube light are efficient than incandescent lamps and compact fluorescent lamps are efficient than tube lights in terms of light per output per unit of electricity consumed. The most important limitation of the use of tube lights in Chennai City is that they will not burn on or they flicker during times of low voltage. It is a general perception that the stock of household appliances shows a positive relationship with household income. But with regard to lighting, the stock of different types of bulbs and their consumption is largely determined by type of electric connection rather than the level of household income. Hence a comparison is made between household income and the stock of electrical bulbs. The use of incandescent bulbs and tube lights by the sample households in different income groups is shown in Table 4.

Table 4. Household income vs electric bulbs and tubes

Household Income (in rupees)	Single - Phase				Three - Phase			
	Incandescent bulbs		Fluorescent tubes		Incandescent bulbs		Fluorescent tubes	
	Average Number	Wattage of bulbs	Average Number	Wattage of tubes	Average Number	Wattage of bulbs	Average Number	Wattage of tubes
Below 5000	2.7	94.3	3.2	124.2	3.2	84.8	3.6	132.8
5000-10000	2.9	94.6	3.3	123.5	4.8	153.4	4.0	151.3
10000-15000	2.9	84.2	3.1	120.6	4.3	126.8	3.6	131.2
15000-20000	3.4	123.1	3.6	130.9	4.3	148.5	3.6	130.8
20000-25000	2.8	98.3	3.1	118.2	4.2	138.9	3.2	118.6
25000-30000	2.2	72.2	3.2	115.1	4.8	148.8	4.4	151.8
30000&above	3.2	92.7	3.4	121.5	4.9	149.5	4.2	148.8

Source: Field Survey.

All the sample households use both incandescent bulbs and tube lights. But the number of lights and the total wattage of lighting differ significantly between single-phase and three-phase electrified households. Interestingly single-phase and three-phase electrified households tend to use incandescent bulbs frequently in the highest and lowest income groups.

(ii) Entertainment

There has been a rapid proliferation of household entertainment and comfort appliances in Chennai City for the last one decade. The stock of entertainment electrical appliances does not show a clear-cut relationship with the level of household income. Some of the entertainment electric appliances are used more by lesser income households while some others are used by relatively rich. Therefore the percentage of households with different types of entertainment electrical appliances according to the levels of household income is shown in Table 5.

Table 5. Entertainment appliances ownership according to household income

Household Income (in Rupees)	Appliance ownership (per cent of households)													
	Single - Phase							Three - Phase						
	TV	Colour TV	Black & White TV	VCD	Stereo	Radio	Tape Recorder	TV	Colour TV	Black & White TV	VCD	Stereo	Radio	Tape Recorder
Below 5000	100.0	91.4	11.4	45.7	17.1	65.7	42.9	100	96.0	4.0	60.0	24.0	56.0	56.0
5000-10000	97.2	85.9	12.7	56.3	15.5	47.9	33.8	100	98.0	6.0	58.0	26.0	44.0	48.0
10000-15000	98.0	92.0	10.0	58.0	20.0	60.0	42.0	100	97.7	6.8	68.2	22.7	63.6	47.7
15000-20000	100.0	86.2	13.8	69.0	24.1	55.2	31.0	100	97.0	12.1	75.8	18.2	63.6	48.5
20000-25000	91.7	75.0	25.0	41.7	41.7	50.0	16.7	100	88.9	11.1	77.8	22.2	55.6	55.6
25000-30000	100.0	88.9	11.1	55.6	33.3	66.7	44.4	100	100.0	0.0	62.5	37.5	62.5	25.0
30000&above	100.0	93.3	6.7	46.7	46.7	66.7	46.7	100	94.7	10.5	36.8	36.8	63.2	57.9

Source: Field Survey.

The ownership and use of Television is common in almost all households. It is quite interesting to note that the use of black and white television prevails in all the income groups though the proportion of colour to black and white television is 9:1. The other important devices used for entertainment is radio, followed by VCD, tape recorder and stereo. It is observed that all the households with television are available with cable television services irrespective of their income levels.

(iii) Space cooling

The summer months in Chennai are very hot. Temperature rarely falls below 100 degrees Fahrenheit during this period. Therefore households in Chennai resort to the frequent use of fans and air conditioners as a necessity. They serve the dual purposes of providing cooling air and keeping away mosquitoes. All the electrified households have fans.

(iv) Refrigeration and water heating

The use of electricity for refrigeration and water heating has common among middle and higher income households in Chennai City. Old style refrigerators are almost displaced by frost free types consuming relatively more electricity in single-phase and three-phase electrified households.

It is generally perceived that the electric appliance ownership has been rapidly increasing with the increase of income and change in lifestyle. The electricity consumption is largely influenced by weather and climate sensitive electrical appliances.

F. Percentage share of end-use electricity consumption

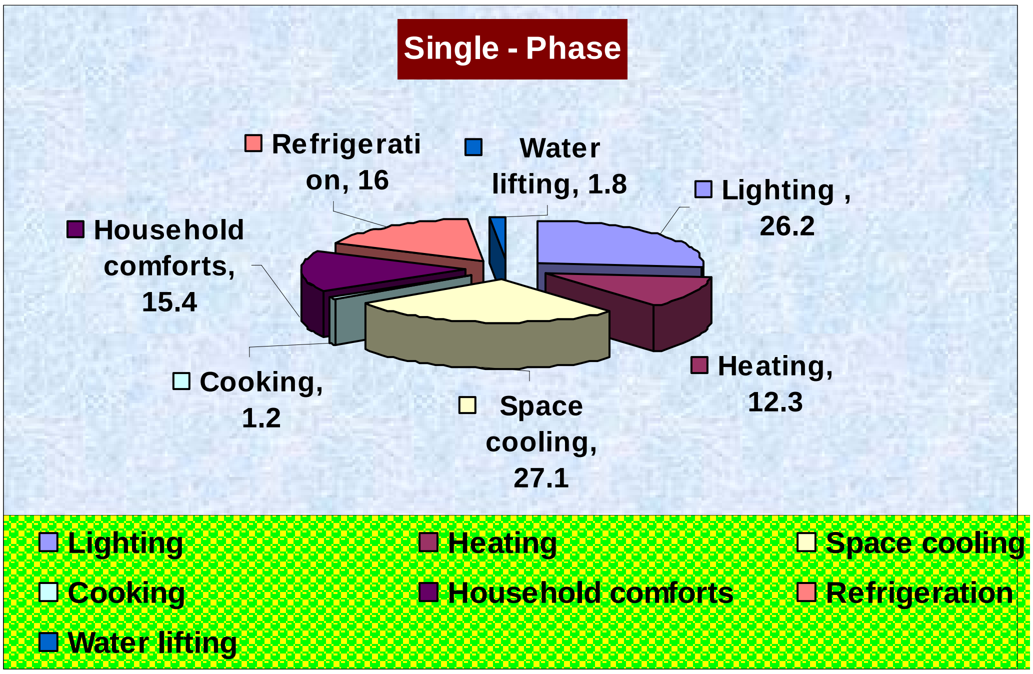
The annual consumption of electricity of different categories of electrical appliances is estimated by using the engineering approach. It is based on sample surveys of variables such as number of appliances, rated power of these appliances and number of hours of usage of these appliances. The estimate of electricity consumption of the appliances mainly depends on the duration of usage of these appliances by the households.

The average annual electricity consumption for different end-uses **(see Appendix 1)** of single-phase and three-phase electrified households is shown in Table 6.

Table 6. Average annual electricity consumption for different end-uses

Types of End-uses	Single - Phase			Three - Phase		
	Average annual household electricity consumption (kWh)	Percentage	Std. Deviation	Average annual household electricity consumption (kWh)	Percentage	Std. Deviation
Lighting (All bulbs & tube lights)	409.2	26.2	15.4	510	16.7	18.0
Heating	192	12.3	20.6	405.6	13.3	30.8
Space cooling	422.4	27.1	61.3	1152	37.8	89.7
Cooking	19.2	1.2	6.2	78	2.6	13.6
Household comforts	240	15.4	16.0	352.8	11.6	17.9
Refrigeration	249.6	16.0	30.2	510	16.7	37.8
Water lifting	27.6	1.8	1.5	39.6	1.3	7.6
Annual Electricity Consumption	1560.0	100.0	104.2	3048	100.0	136.8

Source: Field Survey.



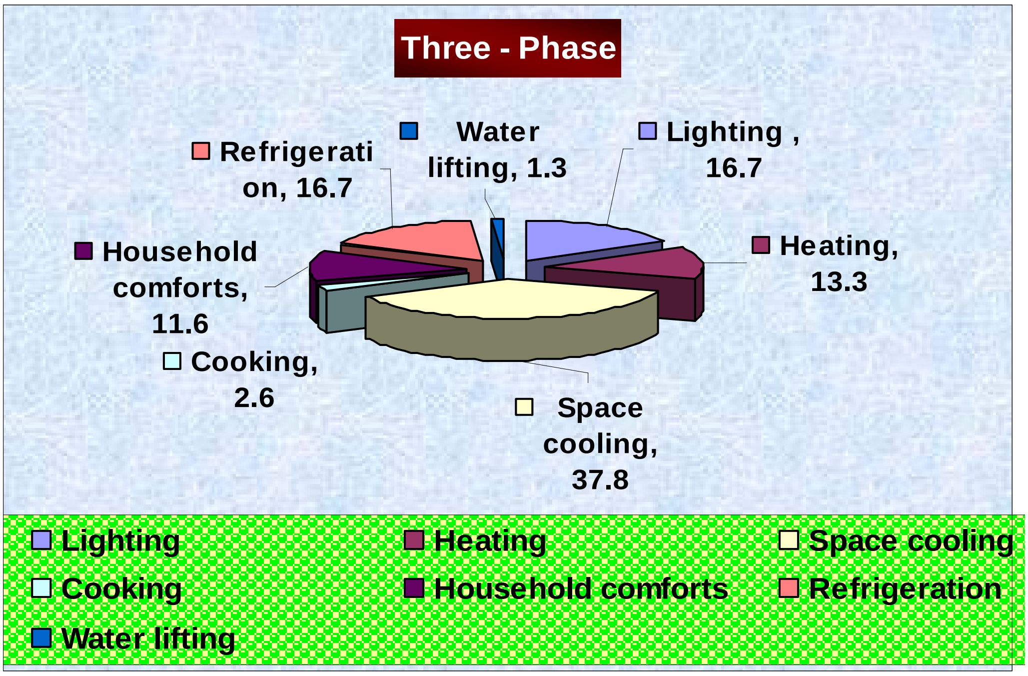


Figure 1: Percentage share of electricity consumption for different end-uses

It is revealed that in both single-phase and three-phase electrified households, space cooling consumes 27.1 and 37.8 percentage respectively of the total average annual consumption of electricity. Three-phase electrified households require more than 10 per cent electricity consumption for the space-cooling end-use than that in single-phase households. The analysis reveals that lighting is the second most important end-use next to space-cooling for single-phase electrified households, with 26.2 per cent of the total electricity consumption accounting for it. The share of lighting in total electricity consumption in three-phase electrified household is only 16.7 per cent. The result shows the big difference in the consumption pattern between single-phase and three-phase households which is that the former uses more percentage share of electricity consumption for the purpose of lighting, household comforts and refrigeration. The use of air conditioners for space cooling in three-phase houses makes all the difference.

The percentage share of the consumption of electricity for different end-uses in every average annual household electricity consumption group would give a better picture of household electricity consumption on different end-uses. Table 7 shows the percentage share of annual electricity consumption for different end-uses in different groups of average annual household electricity consumption.

With regard to the household electricity consumption on end-uses, it is learnt that the proportionate share of electricity consumption on lighting decreases with the increase of the total electricity consumption. Electricity consumption on space cooling occupies the first rank among the end-uses in both types of electric connection but its percentage share increases with the increase in the quantity of electricity consumption. The percentage share of electricity consumption for space cooling in the lowest group of electricity is about 20 per cent which is around 50 per cent in the highest group of electricity consumption. Heating and cooking end-uses have almost the same consumption pattern as of space cooling. Electricity consumption on household comforts has the consumption pattern similar to lighting.

The average household electricity consumption for heating end-use accounts for 12.3 and 13.3 percentage for single-phase and three-phase households respectively. Hence, it is verified that non-heating household uses of electricity account for the major share of electricity in both single-phase and three-phase households.

The consumption of electricity by various household electric appliances will further clarify the electricity consumption pattern of households. Table 8 show the household consumption pattern of electricity by the single-phase and three-phase electrified households.

Table 7. Percentage end-use share according to household electricity Consumption

Annual Electricity Consumption in kWh	Households				Percentage share of total electricity consumption															
	Number		Percent		Lighting		Heating		Refrigeration		Space cooling		Cooking		Water lifting		Household comforts		Total
	I	III	I	III	I	III	I	III	I	III	I	III	I	III	I	III	I	III	
< 900	80	8	36	4	40	28	8	7	11	22	20	21	0	1	1	2	20	20	100
900-1800	84	45	38	24	36	32	12	16	14	15	16	15	1	1	3	2	18	19	100
1800-2700	26	42	12	22	21	20	18	13	24	25	21	27	0	2	2	1	15	13	100
2700-3600	12	32	5	17	23	17	13	13	26	17	21	35	2	5	2	1	13	12	100
3600-4500	6	21	3	11	16	14	9	15	21	11	38	39	0	2	1	1	16	9	100
>4500	13	40	6	21	11	12	12	12	9	16	54	47	3	3	1	1	10	10	100
Total	221	188	100	100	26	17	12	13	16	17	27	38	1	3	2	1	16	12	100

Source: Field Survey.
Note : I indicate single-phase electric connection
III indicate single-phase electric connection

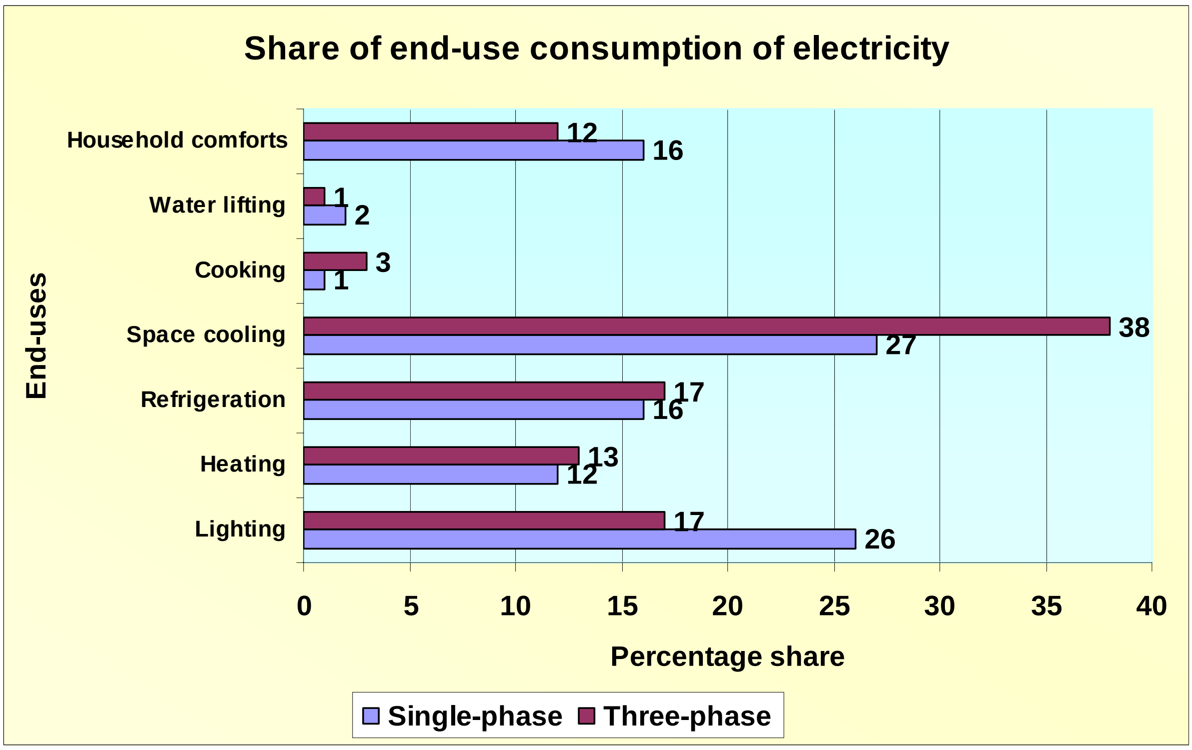


Figure 2: Share of end-use consumption of electricity

Table 8. Household consumption of electricity

Appliances	Single-phase			Three-phase		
	Consumption kWh/yr		Percentage of total	Consumption kWh/yr		Percentage of total consumption
	Per appliance	Per house hold		Per appliance	Per house hold	
< 40 w bulb	33.4	97.7	6.3	30.0	122.7	4.4
40 w bulb	51.0	65.3	4.2	47.6	81.0	2.9
60 w bulb	84.4	35.1	2.3	76.0	38.4	1.4
100 w bulb	150.6	10.9	0.7	162.0	13.4	0.5
20w fluor. tube	13.5	4.5	0.3	13.4	6.2	0.2
40w fluor.tube	65.3	197.1	12.7	64.7	202.2	7.2
Refrigerator	397.5	250.0	16.1	530.4	458.9	16.4
Water heater	323.5	32.6	2.1	282.5	82.6	3.0
Geyser	356.4	19.0	1.2	521.6	112.9	4.0
Immersion heater	255.3	39.2	2.5	205.5	39.1	1.4
Air conditioner	1660.4	254.3	16.3	1589.1	907.8	32.5
Ceiling fan	57.1	161.3	10.4	44.9	161.2	5.8
Table fan	17.9	6.9	0.4	20.8	9.1	0.3
Pedestal fan	15.7	1.3	0.1	17.5	3.0	0.1
Electric Iron	121.3	101.3	6.5	164.0	136.5	4.9
Aqua guard	37.8	3.4	0.2	43.1	9.4	0.3
Black & white TV	98.3	12.0	0.8	125.1	9.2	0.3
Colour TV	99.3	93.4	6.0	122.4	115.4	4.1
VCD	3.4	1.9	0.1	4.6	2.5	0.1
Computer	104.5	17.5	1.1	104.3	43.5	1.6
Stereo system	19.6	4.6	0.3	16.9	4.3	0.2
Radio	10.9	6.4	0.4	10.5	5.9	0.2
Tape recorder	9.6	3.5	0.2	8.8	3.8	0.1
Electric ricecooker	34.4	2.3	0.1	38.2	8.1	0.3
Electric stove	126.5	5.7	0.4	258.1	24.2	0.9
Electric oven	128.3	6.2	0.4	176.2	26.5	0.9
Electric kettle	369.9	3.9	0.3	125.9	2.1	0.1
Toaster oven	98.6	0.9	0.1	100.4	3.7	0.1
Blender and mixer	18.5	16.9	1.1	17.6	16.2	0.6
Electric wetgrinder	44.8	38.6	2.5	42.5	38.4	1.4
Coffee percolator	20.6	0.3	0.0	39.0	0.6	0.0
Washing machine (Without dry)	77.3	6.1	0.4	68.4	8.4	0.3
Washing machine (With dry)	231.8	36.6	2.4	188.0	61.0	2.2
Electric water pump	55.3	18.0	1.2	74.7	32.2	1.2
Vacuum cleaner	56.8	1.3	0.1	64.4	5.3	0.2
Total		1556.0	100.0		2795.7	100.0

Source: Field Survey.

It is evident that the per appliance electricity consumption pattern is the higher for air conditioners followed by refrigerator, electric kettle, geyser in the single-phase households. This pattern is similar for three-phase electrified households. Per household consumption of electricity is also the larger for air conditioners but it is almost four times more in three-phase electrified households. In single-phase electrified households air conditioners share only 16.3 per cent of the average household electricity consumption followed by refrigerator, 40 watts fluorescent tubes and ceiling fan in the percentages of 16.1, 12.7 and 10.4 respectively. With regard to three-phase households, air conditioners share 32.5 percentage of the average household annual electricity consumption followed by refrigerator, 40 watts tube lights and ceiling fan in the percentage of 16.4, 7.2 and 5.8 respectively.

G. Ranking of appliance-wise consumption

Appliance-wise consumption of electricity is estimated by using an appliance census approach. Using the appliance census approach, regression analysis is made on the samples of single-phase and three-phase electrified households separately. The number of electrical appliances selected as predictor variables to run the regression analysis is as many as 35. The annual household electricity consumption is taken as the criterion variable. The linear multiple regressions resulted in some negative and statistically insignificant coefficients which are difficult to interpret.

The determinants of annual household electricity consumption are multi-dimensional in nature. In order to understand the degree of relationship between number of appliance in each category and annual household electricity consumption, rank correlation coefficients have been worked out. The ranking of correlation coefficients are shown in Table 9.

Table 9. Ranking of Correlation Coefficient

Single-phase		Three-phase	
Appliance (Predictor Variables)	**Correlation Coefficient**	**Appliance (Predictor Variables)**	**Correlation Coefficient**
Air conditioner	0.753	Air conditioner	0.745
Storage water heater	0.575	Ceiling fan	0.473
Ceiling fan	0.575	Electric water pump	0.39
Washing machine (with dry)	0.554	Storage water heater	0.362
Computer	0.495	Computer	0.342
Vacuum cleaner	0.49	Geyser	0.338
Electric water pump	0.435	VCD	0.336
40 watts fluorescent tube	0.431	40 watts fluorescent tube	0.334
Colour TV	0.424	Pedestal fan	0.316
VCD	0.413	20 watts fluorescent tube	0.312
Refrigerator	0.41	Less than 40 watts bulb	0.295
Electric oven	0.403	Washing machine (with dry)	0.286
Toaster oven	0.389	Aqua guard	0.283
Electric rice cooker	0.356	40 watts bulb	0.277
Geyser	0.344	Electric oven	0.276
Electric kettle	0.344	Vacuum cleaner	0.27
Less than 40 watts bulb	0.282	Refrigerator	0.221
Stereo system	0.267	Electric stove	0.187
Electric iron	0.256	Colour TV	0.183
20 watts fluorescent tube	0.249	60 watts bulbs	0.175
Electric wet grinder	0.228	Electric rice cooker	0.162
Coffee percikatir	0.215	Table fan	0.16
Blender & mixer	0.21	Stereo system	0.157
Tape recorder	0.197	Toaster oven	0.153
Washing machine (without dry)	0.195	Washing machine (without dry)	0.151
Aqua guard	0.189	100 watts bulb	0.127
Pedestal fan	0.178	Tape recorder	0.126
60 watts bulb	0.175	Electric kettle	0.114
Table fan	0.142	Electric wet grinder	0.089
40 watts bulb	0.104	Blender & mixer	0.085
100 watts bulb	0.087	Coffee percikatir	0.079
Electric stove	0.069	Electric iron	0.072
Immersion heater	0.05	Radio	-0.017
Radio	0.003	Black & White TV	-0.146
Black & White TV	-0.143	Immersion heater	-0.231

Source: Field Survey.

The variables selected are arranged in descending order according to the values of correlation coefficient. Except the number of black and white television, all other variables selected are positively related to annual household consumption of electricity. But it shows a relatively low degree of negative correlation. There are three electrical appliances that are negatively correlated to annual household consumption of electricity in three-phase households. There are identified as the number of radio, the number of black and white television and the number of immersion heater. All these electrical gadgets are generally use by lower income households who consume lesser electricity. All other variables are positively related to annual household electricity consumption. It is interesting to see that only four variables selected under single-phase electric connection and only one variable under three-phase electric connection show high degree of positive correlation. Hence, it becomes a problem in interpreting the impact of these appliances on annual household consumption of electricity.

H. Appliance penetration and elasticity

X_{ij} has been defined as the number of appliances of jth category in the ith household, from which it follows that $Y_j = \sum_i X_{ij}$ is the number of appliances of the jth category in all the N households. Further, $Y_j/N = X_j$ is the average number of appliances of the jth category per household. X_j can also be described as the penetration of the jth category of appliances (Murthy et al 2001).

If the penetration X_j of appliances of the jth category is increased by unity, i.e., one more appliance of this category is added to the appliance stock, then the percentage change in the penetration is $(100x1/X_j)$. In response to this change, the yearly household energy consumption is increased by b_j and the percentage increase in the average yearly household consumption is $(100xb_j/E)$ where E is the average yearly electricity consumption of households. Conventionally, elasticity is defined as the ratio of these two percentage changes. Thus, the appliance elasticity of household electricity consumption is:

$$e = \frac{\text{Percentage change in electricity consumption}}{\text{Percentage change in appliance penetration}}$$

$$= [(100xb_j/E)/[(100x1)X_j)] = [(b_j x X_j)/E]$$

$$\text{Appliance elasticity} = \frac{\text{Consumption of electricity by an appliance x average number of appliances in a household}}{\text{Average electricity consumption per household}}$$

The effects of increases in appliance penetration on future electricity demand can be estimated by using this elasticity. The influence of increases in appliance penetration on future elasticity demand **(see appendix 2)** can be estimated by using elasticity. The elasticity for various electrical appliances calculated for single-phase and three-phase sample households are shown in Table10.

It is found that the elasticity for household appliances of single and three-phase electrified households differ significantly.

The elasticity of 40 watt fluorescent tube lights differs significantly between single and three-phase households. The elasticity of fan in the categories of electric connection could be attributed to the housing area. The elasticity of air conditioner in three-phase household is 0.29 when compared to 0.2 in single-phase households. Hence, it becomes clear that the penetration of air conditioners and refrigerator have more elasticity in three-phase households while the elasticity of tube lights, air conditioners and refrigerator are high in single-phase households.

Table 10. Appliances elasticity

Appliance	Appliance-consumption (kWh/Yr)		Appliance penetration		Elasticity	
	I-phase	III-phase	I-phase	III-phase	I-phase	III-phase
< 40 w bulb	83.7	75.1	1.2	1.9	0.06	0.05
40 w bulb	51.0	47.5	1.3	1.8	0.04	0.03
60 w bulb	84.4	76.1	0.4	0.6	0.02	0.01
100 w bulb	150.6	162.0	0.1	0.1	0.01	0.01
20wfluor.tube	16.5	16.2	0.3	0.4	0.00	0.00
40wfluor.tube	119.3	64.7	3.0	3.4	0.23	0.07
Refrigerator	375.9	536.9	0.7	1.0	0.17	0.17
water heater	327.8	280.2	0.1	0.3	0.02	0.03
Geyser	349.2	513.9	0.1	0.3	0.02	0.05
Immersion heater	255.0	217.0	0.2	0.2	0.03	0.01
Air conditioner	1561.4	1495.1	0.2	0.6	0.20	0.29
Ceiling fan	57.1	45.0	2.8	4.0	0.10	0.06
Table fan	18.2	20.8	0.4	0.5	0.00	0.00
Pedestal fan	16.5	17.9	0.1	0.2	0.00	0.00
Electric Iron	125.1	166.7	0.8	0.9	0.06	0.05
Aqua guard	39.0	43.2	0.1	0.2	0.00	0.00
Black&whiteTV	98.6	128.8	0.1	0.1	0.01	0.00
Colour TV	100.2	124.2	0.9	1.0	0.06	0.04
VCD	3.4	5.1	0.6	0.6	0.00	0.00
Computer	104.5	104.8	0.2	0.5	0.01	0.02
Stereo system	20.6	17.9	0.2	0.3	0.00	0.00
Radio	11.3	10.8	0.6	0.6	0.00	0.00
Tape recorder	9.3	8.5	0.4	0.5	0.00	0.00
Electric rice cooker	34.3	36.4	0.1	0.2	0.00	0.00
Electric stove	125.9	166.8	0.01	0.1	0.00	0.01
Electric oven	137.6	172.9	0.01	0.2	0.00	0.01
Electric kettle	284.7	125.9	0.01	0.01	0.00	0.00
Toaster oven	98.6	100.4	0.01	0.1	0.00	0.00
Blender and mixer	18.9	18.0	0.9	1.0	0.01	0.01
Electric wetgrinder	44.4	42.7	0.9	1.0	0.03	0.01
Coffee percolator	20.7	39.2	0.01	0.01	0.00	0.00
Washing machine (Without dry)	75.2	69.6	0.1	0.1	0.00	0.00
Washing machine (With dry)	261.3	194.9	0.1	0.4	0.02	0.03
Electric water pump	51.6	71.6	0.3	0.6	0.01	0.01
Vacuum cleaner	57.7	63.9	0.01	0.1	0.00	0.00

Source: Field Survey.

The results indicate that both in single-phase and three-phase electrified households' air conditioner ranks first among all the electrical appliances. It accounts for 1561.4 kWh/year in single-phase as compared to 495.1 kWh/year in three-phase households. Most of the consumption intensive electrical appliances belong to the category of weather and climate sensitive end-uses. Eventhough the penetration of air conditioners is not as strong as ceiling fan, the formers' elasticity in both single and three-phase households is very strong. It may be the reason for the sudden spent in the demand for electricity for residential purposes in Chennai City.

V. Conclusion

The household survey of electricity consumption in Chennai City has revealed the pattern of electricity consumption in single-phase and three-phase electrified households, the stock of electrical appliances used by households, the electricity consumption, the degree of penetration of electrical appliances and their elasticity.

The end-use analysis of electricity at the household sector weakened the general understanding that electricity is mainly used for lighting and entertainment. The survey clearly indicated that weather and climate sensitive appliances account for 55.4 and 67.1 percentages of the total household electricity consumption in single-phase and three-phase electrified households respectively. The survey also yielded the appliance elasticity which shows the effect of unit percentage increase in appliance penetration will lead to a change in the annual electricity consumption. The penetration and elasticity of weather related electrical appliances are very high as compared to the same of the appliances for other end-uses. Hence the study recommends for interventions from the demand side without decreasing the energy services and it also caution for an unexpected increase in the demand for electricity by the residential sector in the immediate future as a result of the economic boom and life style changes in the urban sector. Since Chennai City is in the hot climatic zone, households depend on electricity for attaining good indoor-living environment. It is appropriate to mention that the penetration of weather sensitive electrical appliances will help in forecasting the demand for electricity in the short-run.

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Appendices

1. End-use analysis of household electricity consumption

By collecting information pertaining to the consumption of electricity of different appliances, the electricity consumption for different end-uses in the households can be determined. Using the appliance-wise consumption data, electrical energy used for different end-use can be computed by using the formula.

$$E_{im} = \sum_{tj} X_{ijm} \times b_{ijm}$$

where

E_{im} = Consumption of electricity for the mth end-use.
X_{ijm} = Number of appliance of type j in the ith household.
b_{ijm} = Duration of the use of j type appliance in the ith household.

With the help of the above formula, the average annual household electricity consumption of different end-use can be estimated for both single-phase and three-phase electrified households. The consumption of electricity by each appliance in the sample household is obtained by using the appliance census approach. In the appliance census approach, the method used to estimate the annual electricity consumption of the jth appliance in an end-use category is calculated by

$$E_i = \sum_j X_{ij} \times b_j$$

Where
E_i = Electricity consumption of jth appliance in ith household.
X_{ij} = Number of appliance of jth category in the ith household.
b_j = Consumption per appliance of the jth category.

2. Penetration of appliance and appliance elasticity

Appliance penetration and appliance elasticity are the two concepts used to analyse household consumption of electricity. As noted earlier X_{ij} is the number of appliances of jth type in ith household. If y_j is the number of appliances of the jth category in all the N sample households. Thus:

$$Y_j = \sum_i X_{ij}$$

Further,

$$X_j = \frac{Y_j}{N}$$

Where

X_j = Average number of appliance of the jth category per household.

X_j can be referred as the penetration of jth category of appliances. If X_j (penetration of appliance of jth category) is increased by unity or one more appliance of this category is added to the appliance stock, than the percentage change of penetration is $100 \times 1/X_j$.

As a result of penetration of the appliance, the yearly household energy consumption is increased by b_j and the percentage increase in the average annual household consumption is equal to $100 \times b_j / E$.
Where
E = The average annual electricity consumption of households.
The elasticity is therefore defined as the ratio of these two percentage changes. The appliance elasticity of household electricity consumption is equal to:

Percentage change in electricity consumption

$$e = \frac{}{\text{Percentage change in appliance penetration}}$$

$$e = \frac{\frac{100 \times b_j}{E}}{\frac{100 \times 1}{X_j}} = \frac{B_j \times X_j}{E}$$

Potential

Potential for CO2 mitigation in the Hungarian residential buildings

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Abstract

The major part of final energy consumption and CO2-emissions is to be found in the residential sector in the countries of Central and Eastern Europe. However, research on the scope and associated costs of energy-efficiency measures and CO2 mitigation opportunities is very limited and fragmented in the region. Such research would be the key for designing evidence-based efficiency and climate policies: a profound understanding of the CO2 mitigation potential and a detailed knowledge of such opportunities would help policy-makers and private investors design the most effective strategies for use of efficiency and mitigation investments.

This paper aims to address this gap in knowledge and summarizes the results of research aimed at quantifying the potential for CO2 mitigation in the Hungarian residential sector by 2025. The paper first reviews the results of a detailed bottom-up model of energy consumption and emission forecast in the Hungarian residential sector and then identifies the key energy-efficiency and fuel switch options from the demand side in domestic buildings. It estimates and analyses the potential for CO2 mitigation and costs resulting from the application of these technologies. The key outcome presented by the paper is the supply curve of conserved CO2, which characterizes the potential savings from a set of mitigation measures as a function of the cost per unit of CO2.

Introduction

The application of energy efficiency and low and zero carbon technologies[1] is one of the main steps to sustainable energy development and the key to limiting the effect of climate change. The European Union Action Plan for Energy Efficiency [1] demonstrates that the energy saved through improved energy efficiency (referred as to “negajoules”) is greater than the energy produced by any individual production technology, and can therefore be considered as a significant primary energy source. Therefore, using mitigation technologies may potentially allow substituting fossil energy resources and avoiding the growing demand for energy. Such a shift would not only bring a wide array of co-benefits for society but would rarely require extra costs [2, 3].

In light of this picture, the buildings sector plays an increasingly important role. This is because, first, buildings contribute significantly to growing global energy consumption and associated greenhouse gas (GHG) emissions and, second, this sector provides abundant low cost opportunities for energy savings and GHG emission reductions. Research [4] implemented for the IV Assessment Report of the Intergovernmental Panel on Climate Change [5] identified 29% of the global business-as-usual carbon dioxide (CO2) emissions in 2020 available for cost-effective reduction in the buildings sector; more than half of this potential is locked in residential buildings.

Nevertheless, many opportunities for energy efficiency improvement in the buildings sector are not covered well by existing policies [6]. This is especially true for transition economies whose strategies for energy efficient development concentrate mainly on the efficiency of industry and the power supply sector. This is due to the fact that efficiency potential in buildings is spread among dwellings as separate units and fragmented among end-uses [7]. Many policy designers simply do not have good enough information to develop a comprehensive strategy for this sector. According to the best knowledge of the author, as of March 2008 there were only four case studies covering the buildings sector of countries of Central and Eastern Europe (CEE) and the Former Soviet Union (FSU) within the last ten years [see 8, 9, 10, 11].

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[1] Hereafter referred as to the mitigation technologies.

The aim, the objectives and the task of the research

The previous section shows that whereas the buildings sector can potentially play an important role for energy conservation and climate change mitigation purposes, it is difficult to design buildings-related policies. This is due to the lack of knowledge of how large the potential for GHG mitigation is in this sector; what energy end-uses and technologies secure this mitigation; whether or not it is economically feasible; and which options should be promoted to easily ensure this mitigation.

This paper presents the selected results of the author's PhD dissertation which addressed this gap in knowledge placing a special focus on the residential buildings of Hungary. This sector has been consistently the largest final energy consumer in the country since 1991 and due to this fact and the high carbon intensity of fuels used in the sector, it emits the largest share of total national CO2 emissions, 30% [12].

The overall dissertation research aim was to assist the evidence-based design of the new policies targeted at CO2 emission reductions in the Hungarian residential buildings sector. More specifically, the research goal was to estimate and to analyze CO2 mitigation potential in the Hungarian residential sector and the associated costs resulting from the application of energy efficient technologies and practices as well as the use of fuel switch options at the point of energy demand.

Hence, the research objectives were:

- To estimate the baseline (business-as-usual) CO2 emissions of the Hungarian residential sector in the future
- To identify the key mitigation technologies and practices applicable in the residential sector of the country
- To estimate the CO2 emission mitigation potential existing in the Hungarian residential sector from the application of identified individual options and associated mitigation costs
- To estimate the total CO2 mitigation potential of the Hungarian residential sector as a function of the costs of CO2 mitigation technologies.

To achieve these objectives, the task of the dissertation research was to develop a bottom-up model[2] which allows estimation and analysis of CO2 mitigation potential in the Hungarian residential sector and associated costs based on presently available data.

Research design and methodology

Overall research design and procedures

Figure 1 presents the overall process of the dissertation research. A spreadsheet-based analysis was applied to the research as the most appropriate tool which allows variation of modeling methods dependant on the available data. Due to space limits, the present paper does not go into the details of calculation procedures; they are extensively discussed in [13].

Method used: a supply curve of CO2 mitigation

The principal output of the research is a supply curve of CO2 mitigation. The curve characterizes the potential CO2 reductions from a sequence of mitigation technological options as a function of marginal costs per unit of mitigated CO2. The main advantage of the supply curve analysis is that it provides comprehensive, easy-to-read information on suggested efficiency technologies, their costs, their potential energy (CO2) saving and the best schedule for their implementation [14]. Another advantage of the supply curves is that estimates of the potential for CO2 emission reduction are already adjusted for the effects of overlapping options that are targeted at the same energy end-uses.

[2] Bottom-up model is a method of system analysis through combining estimates of its components.

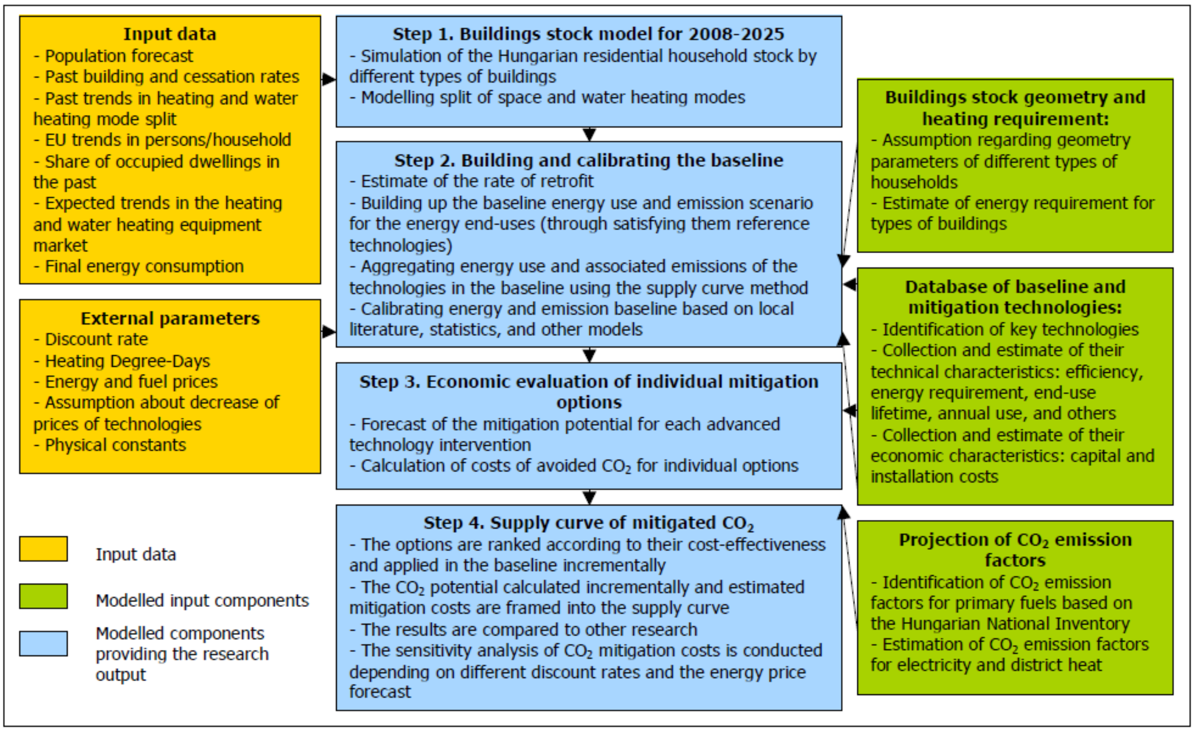


Figure 1 Research design

The marginal costs of CO_2 mitigated of a technology ($MCCO_{2i}$) are estimated as the annualized investment costs of the technological intervention ($\Delta AIC_{j,i}$) deducting the sum of saved costs in year i ($EC_{j,i}$) per unit of CO_2 mitigation in year i ($\Delta CO_{2_{j,i}}$) (see Equation 1). Investment costs take into account only additional costs associated with advanced options, i.e. they exclude costs associated with the reference case (Equation 2). Investment costs required for the technological intervention in year i consist of capital costs of the technology and associated installation costs. The annualized investment costs calculated as the product of investment costs into the technological intervention and the annuity factor of this option (a_j) as used and explained in Equations 2 and 3. Saved costs in year i due to the technological intervention imply only saved energy costs (Equation 4). The saved energy costs were calculated based on final energy savings ($\Delta FE_{j,i}$) and the fuel price for the residential end-users (including the value added tax and the energy tax) in year i.

(1) $MCCO_{2\,j,i} = \dfrac{\Delta AIC_{j,i} - EC_{j,i}}{\Delta CO_{2\,j,i}}$

(2) $\Delta AIC_{j,i} = a_j \times AIC_{j,i} - a_{reference} \times AIC_{Reference,i}$

(3) $a_j = \dfrac{(1+DR)^{n_j} \times DR}{(1+DR)^{n_j} - 1}$, where DR is a discount rate and n_j is the technology end-use time

(4) $EC_{j,i} = \Delta FE_{j,i} \times \mathrm{Pr}\,ice_i$

As with other methods, the supply curve method has also a number of limitations which should be noted when interpreting the results. One of them is that constructing supply curves requires a significant amount of input data which are often uncertain and that the identified potential is strictly linked to the identified list of measures for a specified point of time. Another limitation is that the economic feedback to sectoral advances (such as the energy price feedback from the supply side) is not modelled. Furthermore, the supply curves capture only sequential and marginal technological opportunities and often miss the systematic and integrated opportunities. Finally, only one of mutually exclusive options can be presented on the curve.

Data sources used

The data used to reconstruct the present energy balance is collected from several sources. Regarding electric energy end-use, the data was taken from electricity use metering campaigns conducted by Central European University [31], and such sources as the Status Report on Electricity Consumption and Efficiency Trends [32], the task reports of the Ecostandby project [33] and other references. Regarding thermal energy end-use, the data was collected from the publications of the Hungarian Statistical Central Office, the task reports of the Ecohotwater project [23], the EURIMA/ECOFYS report [8], interviews with experts, and other references.

The database of efficiency and low carbon technologies is created based on such comprehensive publications as the latest IPCC Assessment Report [5], energy encyclopedias [2], labelling and standardization programme reports, equipment catalogues and pricelists, reports, market reviews, and presentations of production associations and consultancies, and interviews with experts (please see the dissertation [13] for the detailed reference list).

Limitations of the developed model

Besides the limitations of the research inherited from the modelling method and described above, there are other opportunities to improve the research results. This is for instance, consideration of benefits beyond the value of saved energy and the costs associated with overcoming barriers for efficiency penetration and fuel switch. Assessment of the rebound effect was limited to the consideration of the energy consumption growth due to installation of advanced heating solutions which cover a larger heating area (from premise to central dwelling heating). A more detailed rebound effect assessment, therefore, could be applied.

While the author tried to cover as many mitigation options as possible, their number was limited to only those which provide undoubtedly the largest potential for CO2 mitigation. Thus, the improvement of the thermal envelope and exchange of space heating solutions in the buildings constructed from 1993 to 2008 is left out because these buildings are quite new and have lower potential for improvement than other types of buildings. Similarly, the exchange of heating technologies in single-family and multi-residential buildings constructed after 2008 is not considered because heating solutions in these buildings are up to the newest market technologies. Those shares of space heating solutions that are not significant are left out precisely due to their low significance. Options such as the exchange of doors and better insulation of pipes delivering district and central heat and water inside buildings are also omitted because these options are expected to result in significantly lower potential than that of other technological options assessed in the research. The efficiency improvement of miscellaneous electrical appliances and equipment, which includes other appliances than refrigerators, freezers, washing machines, and lights, is not assessed because they contribute cumulatively only c. 15% to the residential electricity consumption (though standby power reduction of TV- and PC- related appliances is covered). Due to a lack of data, options related to cooking, motors (lifts), and air-conditioning are not studied. Finally, non-technological options for CO2 mitigation were not included in the pool of the mitigation technologies assessed.

The buildings stock model

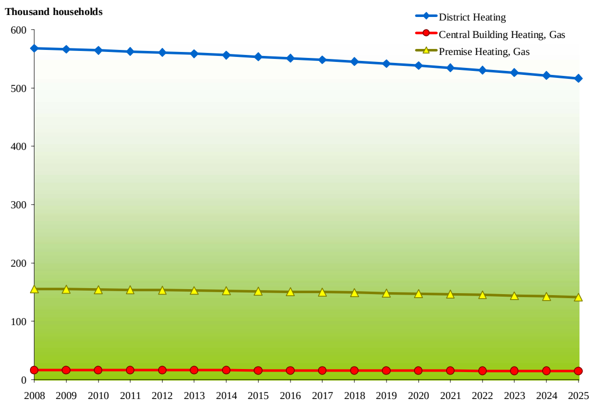
The building stock model represents a separate complex element of the research aimed to assist the estimate of thermal energy savings. For the modelling purposes, the Hungarian housing stock is split into five buildings types, which possess different architectural and/or thermal characteristics. These are:

- Multi-residential traditional buildings constructed mainly at the end of the 19th century and during the inter-war years
- Multi-residential buildings constructed using industrialized technology (including panel, block, and cast buildings) built after the 2nd World War until 1992

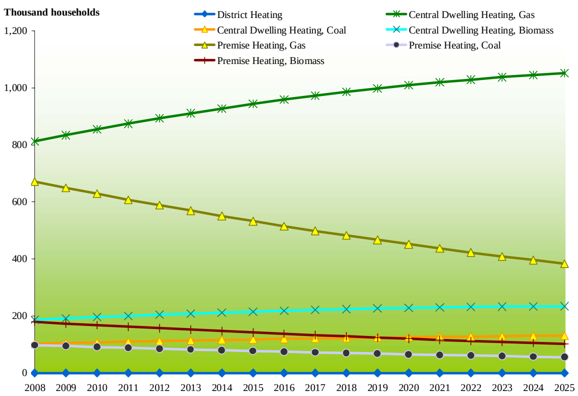
- Single-family houses in suburban and semi-urban areas constructed until 1992 (i.e. before the Buildings Standard of 1991 was applied)
- Multi-residential buildings and single-family houses constructed during 1993 – 2007
- Multi-residential buildings and single-family houses which will be constructed after 2008 until the end of the projection period, i.e. 2025.

The projection of the household stock by types of buildings is based on such inputs as the population forecast [15], the past construction and cessation rates of the dwellings stock [16], and the information and statistics from such sources as [17, 15, 18]. The projection of heating modes is constructed using reference to sources such as [12, 16, 17, 18, 19, 20, 21, 22]. The projected split of heating modes in households of different types of buildings except those built in 1992 - 2008 is presented in Figure 2 (the structure of space heating in households built in 1992 – 2008 is assumed based on 2005 data as not changing during the projection period).

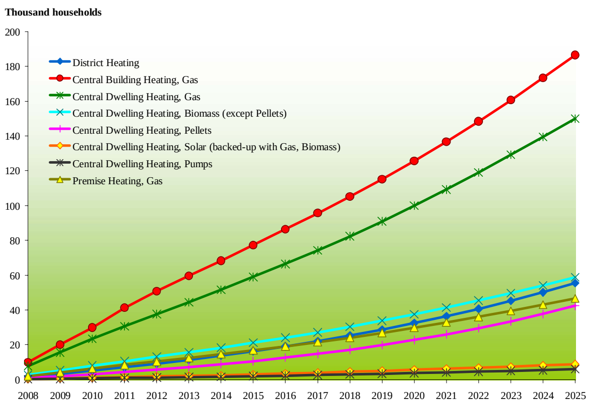
Traditional buildings



Industrialized buildings



Old single-family houses



New single-family houses&multi-residential buildings

Figure 2 Space heating modes in households of different building types

The projection of the stock of dedicated water heating appliances, water heating appliances linked to space heating systems, and the number of households with district and central building hot water is constructed based on [18, 23], and the projection of combined space and water heating systems (included into some heating solutions in Figure 2). The projected stock is presented in Figure 3.

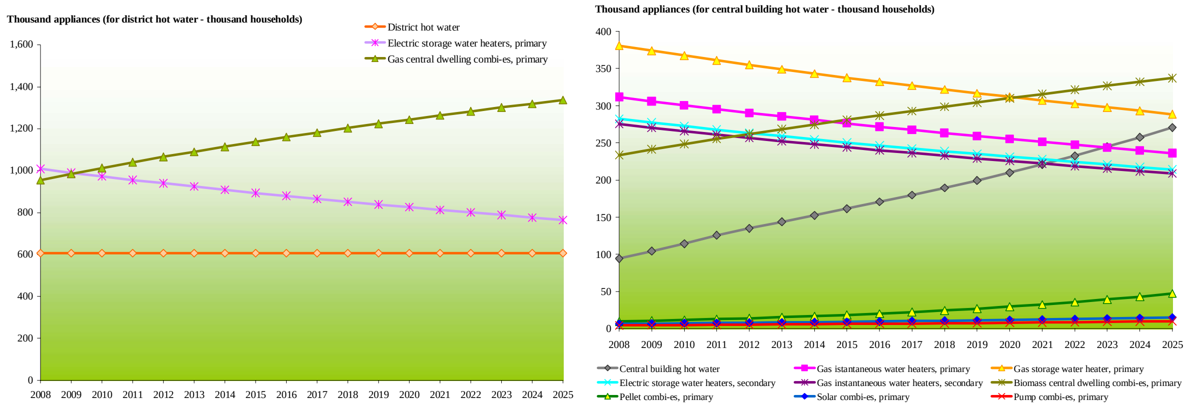


Figure 3. Water heating solutions – the number of systems, top three (left) and excluding top three (right)

Projections of baseline energy consumption and associated CO2 emissions

For the purposes of the research a reference scenario as close as possible close to the business-as-usual case is considered. This section describes the main assumptions applied to develop the reference energy consumption and associated CO2 emissions

Assumptions on the reference case retrofit

Modeling the reference scenario for the thermal energy end-uses assumes that evolution of thermal technologies occurs quite slowly and that their technical and financial characteristics in the future will stay approximately the same as they are today. The reference scenario assumes that the retrofit of the thermal envelope is undertaken for multi-residential traditional buildings, multi-residential buildings constructed using industrialized technology, and old single-family houses (constructed before 1992). The reference rate of insulation of roofs, basements, and external walls, window exchange and weather stripping is assumed to be constant and on the level of that in 2003 – 2004, i.e. c. 1% of the household stock/yr. (based on [23]). The exchange of space heating solutions in the reference case occurs due to their expired lifetimes and to the trends forecasted in the previous section. The reference scenario assumes zero penetration rates for heating controls and individual heat meters in relatively old buildings, i.e. traditional and industrialized buildings as well as single-family houses constructed before the 1990s.

In the reference case, the water heating technologies are exchanged if their lifetime expires. The technical and financial characteristics of water heating solutions are assumed constant. The scenario assumes that the retired technologies are either exchanged with solutions of the same class (for example, a retiring storage water boiler with a more efficient new storage water boiler) or with standard gas and biomass boilers for space and water heating. Regarding water saving fixtures, it is assumed that they are not installed in the reference case.

The reference scenario models the turnover of the major electrical appliances such as refrigerators, freezers, clothes washing machines. The principal difference in modelling the electrical and thermal technologies was that the technical characteristics of the electrical options change quicker than those of the thermal options. Thus, if the efficiency of standard space and water heating solutions was assumed as constant from 2008 to 2025, the efficiency of electrical appliances driven by the EU labelling and standardization programs was changing during the modelling period. Regarding the financial characteristics, it was assumed that the costs in real terms of the reference and the best available appliances do not change over time. In other words, the presently efficient appliances are becoming cheaper in the future and the newer, more efficient appliances are taking over their price. The reference scenario also models the exchange of lights due to their retirement. Reference energy consumption other than that for space and water heating, refrigeration, freezing, clothes washing, and lighting was modelled in aggregate terms due to the limited background data.

The start year energy consumption and its calibration

Once the methodology, calculation procedures, and assumptions were defined and documented, the input parameters were inserted into the spreadsheets to calculate the final energy consumption and associated CO2 emissions, first in the start (base) years 2004 - 2008 and then to 2025. Upon modelling the base years, it appeared that the final energy consumption calculated per technology and aggregated at the energy end-use level and then at the sectoral level does not correspond to the sectoral balance as reported by national statistics and the PRIMES model [12, 24]. For this reason, the disaggregated input parameters were reviewed again until the research forecast and the national statistics matched.

Forecast of the baseline sectoral energy consumption and associated CO2 emissions

Figure 4 presents the results of modeling the sectoral energy consumption and associated CO2 emissions. The Figure illustrates that the final energy consumption for space and water heating barely changes from 2008 to 2025. This is because the efficiency improvement of thermal energy use is closely negated by the growing number of households. The final energy consumption of appliances and lights is growing over the projection period boosted by the growing number of miscellaneous electrical appliances. The overall result of the energy baseline forecast is that the final energy consumption of the residential sector is expected to grow from 81.9 TWh in 2008 to 84.2 TWh in 2025.

Figure 4 demonstrates that the sectoral CO2 emissions are expected to decline until 2015 (mainly due to decreasing emission factors of electricity and district heat) but then they are likely to rise again, reaching the 2008 level by the year 2025. The CO2 emission growth is caused by the increasing demand for electricity multiplied by its growing CO2 emission factor (from 2015) due to the installation of new lignite power plants [30].

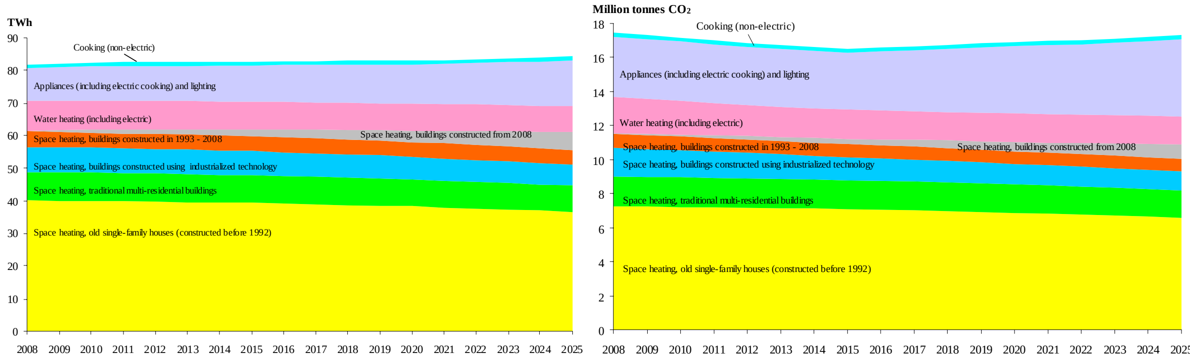


Figure 4 Energy consumption and CO2 emissions projected in the reference case, 2008 – 2025

Economic evaluation of mitigation options and their aggregation to the supply curve of CO2 mitigation

Summary of mitigation technological options

Table 1 lists the key energy efficiency and fuel switch technologies applicable in the residential sector of Hungary which were identified in the research. This list is the subject to limitation described in the methodological section.

Table 1 Efficiency and fuel switch options investigated in the dissertation

Mitigation options	Households in				
	Multi-residential traditional buildings	Multi-residential industrialized buildings	Old single-family houses (constructed before 1992)	Buildings constructed from 1993 to 2007	Buildings constructed from 2008
Thermal envelope					
Insulation of walls, roofs, and cellars		X	X		
Exchange of windows	X	X	X		
Weather stripping of windows			X		
Application of the passive energy design					X
Heating efficiency and fuel switch					
Exchange of central building standard gas systems with central building condensing gas systems	X	X			
Exchange of premise and central dwelling gas systems and premise and central dwelling coal systems with central dwelling condensing gas systems	X		X		
Exchange of premise and central dwelling gas systems and premise and central dwelling coal systems with space and water heating pumps			X		
Exchange of premise and central dwelling gas systems and premise and central dwelling coal systems with pellet space and water heating systems			X		
Exchange of premise and central dwelling gas systems and premise and central dwelling coal systems with solar thermal space and water heating systems backed-up with pellets			X		
Heating controls					
Installation of thermostatic radiator valves (for district and centrally heated households only)	X	X			
Installation of programmable thermostats (except households with district and central heating and those having coal and biomass heating systems)	X		X		
Installation of individual heat metering (for district, central heated households only)	X	X			
Water heating					
Efficiency improvement of combined space and water heating systems (according to the options described in the space heating opportunities)	X	X	X		
Exchange of dedicated water heating appliances with more efficient appliances of the same class (electric storage, gas storage, gas instantaneous water heaters)	X	X	X	X	X
Installation of water saving fixtures (showerheads and sink faucets)	X	X	X	X	X
Electrical appliances and lights					
Higher efficiency refrigerators and freezers	X	X	X	X	X
Higher efficiency clothes washing machines	X	X	X	X	X
Reduction of electricity consumption of TV- and PC- related appliances in low power mode	X	X	X	X	X
Exchange of incandescent lamps with CFLs	X	X	X	X	X

Assumptions of economic analysis

The economic evaluation of applying the mitigation options was conducted based on calculative procedures described in the methodology. Analysis of the methodology shows that the CO2 mitigation costs are the most sensitive to the discount rate chosen and the cost of energy and fuels projected over the modelling period. The research is constructed on the assumption that the major part of the costs for energy conservation and CO2 mitigation is paid for by the households and some of these purchases are supported by government programmes (e.g. building renovations). Therefore, the discount rates from the households' and government's perspective was estimated at the level of 6%. Energy and fuel prices in Hungary were collected on the date of the research running, i.e. as of December 2007. They are presented in Table 2 In agreement with other pieces of research, which focused on the CEE region [8, 25], energy prices are assumed to grow by 1.5%/yr. in real terms.

Table 2 Energy and fuel prices for the residential end-users of Hungary, December 2007

Fuels	Energy price, EUR/kWh	References
Natural gas	0.044	Estimate based on [26]
Agripellet	0.030	Estimate based on [27]
Brown coal	0.024	Estimate based on [26]
Firewood	0.012	Estimate based on [27]
District Heat	0.041	Estimate based on [28]
Electric energy	0.155	Estimate based on [26]

Assumptions on the retrofit in the mitigation scenario

The scenario which implies the realisation of all mitigation options is referred to the mitigation scenario. In this scenario, the advanced technologies replace the reference technologies exchanged due to their stock turnover. They also replace some of the technologies currently installed and which will remain until 2025. The technical and financial characteristics of the thermal efficiency technologies do not change over time except the additional construction costs of passive energy buildings (with space heating requirement of 15 kWh/m^2) decrease to half, the investment costs into the renewable energy solutions (pellet burners and solar thermal) go down to their 70%, and investment costs into heating pumps and low-emissivity windows low down to their 80% by 2025.

First, it is assumed that the thermal envelope of all household stock, which is not retrofitted in the reference scenario and which remains at least until 2025, is retrofitted from 2008 to 2025. The stock is retrofitted by the same number of households per annum, i.e. the number of retrofitted households per year is the total stock divided by seventeen years. The technological options aimed to improve the thermal envelope retrofit of the existing buildings are the same as in the reference case. Regarding the households to be constructed from 2008, it was assumed that their whole stock would be constructed following the passive energy design.

Regarding the space heating solutions, it is assumed that the old single-family houses (constructed until 1992), traditional and industrialized buildings install advanced space heating solutions, namely condensing gas boilers, or pellet boilers, or solar thermal systems backed-up with pellet boilers, or heat pumps for space and water heating instead of the reference technologies. As with the thermal envelope improvement, the stock is retrofitted by the same number of households per annum. The only exception is made for the premise gas heating. This is one of the most economical and efficient space heating systems in Hungary and it is likely that a share of households would prefer to leave this system in place. It is also important to mention that due to infrastructural and spatial barriers only half of single-family houses can switch from the reference technologies to pellets or solar heating backed-up with pellet boilers, similarly only half of single-family houses can switch to ground-source heating pumps [29].

One of the easiest and most beneficial technological options is installation of space heating and water demand controls. It was assumed that households with district or central building heating are retrofitted with thermostatic radiator valves (TRVs) and all other households except those fuelled with coal and traditional biomass are retrofitted with programmable thermostats. Also, installation of individual heat exchanges and heat meters was applied to households with district or central building heating. All water heating system and appliances are retrofitted with low-flow fixtures. All water heating systems and appliances are retrofitted with low-flow fixtures. The number of households retrofitted with space heating per annum until 2025 is the same as the number in which the thermal envelope is retrofitted. The installation of water saving fixtures is a very simple option and it is assumed that it is possible to apply this option to the whole stock within five years.

For the electrical appliances modelled, the penetration rates in the mitigation case are the same as in the reference case. For the mitigation case, the purchased appliances are the best (presently known and estimated) available on the market for the projected year. It is assumed that the costs in real terms of the reference and the best available appliances do not change over time i.e. the current appliances become cheaper and the newer appliances become more expensive. The mitigation case focuses on the exchange of only these six lamps. The exchange of lights is a very simple option and therefore is carried out on the whole stock in the first year of the modelling period.

Research results: evaluation of the key individual CO_2 mitigation options

This section describes the results of the bottom-up assessment applied to mitigation options independently from each other. This information is useful for the design of policy tools in targeting a particular option and for the households which prefer to and are able to exchange a particular technology. The economic evaluation of the mitigation options is subject to limitations described in the methodology. Figure 5 illustrates the potential CO2 savings and costs which result from the installation of individual mitigation options.

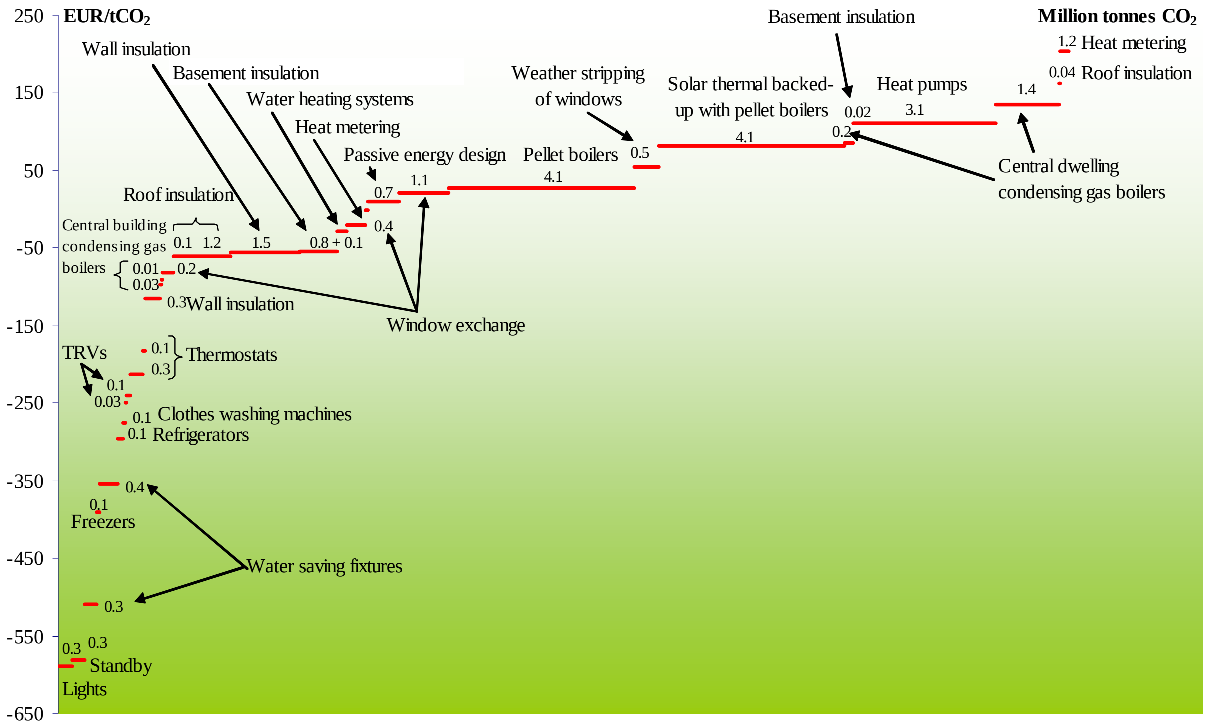


Figure 5 Potential and costs of individual options for CO2 mitigation in 2025

Notes: 1) Some thermal technological options are applied to different types of buildings and they are referred to several times in the figure. 2) The potentials from individual options cannot be simply added together because of possible double-counting if the options are targeted to the same baseline technologies and energy end-uses.

Figure 5 shows that technological options supplying the potential for CO2 mitigation at negative costs are available for each building type and each energy end-use. The top negative-cost measure in terms of cost-effectiveness is the exchange of incandescent lamps with CFLs. It is followed by the reduction of electrical consumption of TV- and PC- related appliances in the low power mode and efficient appliances such as freezers, refrigerators, and clothes washing machines, the application of which is justified by the high price of electricity in Hungary. Installation of heat and hot water demand controls such as low-flow fixtures, TRVs and programmable thermostats ranks the third. Many options aimed at insulation of building components (walls, basements, and roofs) and weather stripping or exchange of windows are characterized with negative mitigation costs as are actions towards installation of condensing central building gas boilers. Installation of improved water heating systems and individual central and district heating meters in traditional buildings are the last in the list of measures with negative costs of CO2 mitigation. The application of passive energy design to buildings constructed from 2008 is also attractive with the mitigation costs below 20 EUR/tCO_2. The rest of the options are above 20 EUR/tCO_2. In terms of the quantity of CO2 reductions, the improvement of the thermal envelope, fuel switch and efficiency improvement of heating systems in old single-family houses (constructed before 1992) are able to supply the largest potential in the residential sector. The application of passive energy design to buildings constructed from 2008 and improved water heating systems and installation of water saving fixtures also can cut a significant amount of CO2 emissions.

Countrywide potential for CO_2 mitigation and its supply curve

Figure 6 illustrates the results of the bottom-up mitigation assessment of the mitigation options conducted with the supply curve method. As described in the methodology, the advantage of the supply curve method is that it allows an estimation of the total potential to be made without double-counting the mitigation potential supplied by individual options targeted at the same baseline technologies and energy end-uses (for instance, insulation improvement reduces the need for space heating and, thus, also reduces the energy saving potential from installation of more efficient heating systems). Therefore, the potential estimates described in this section can be added together.

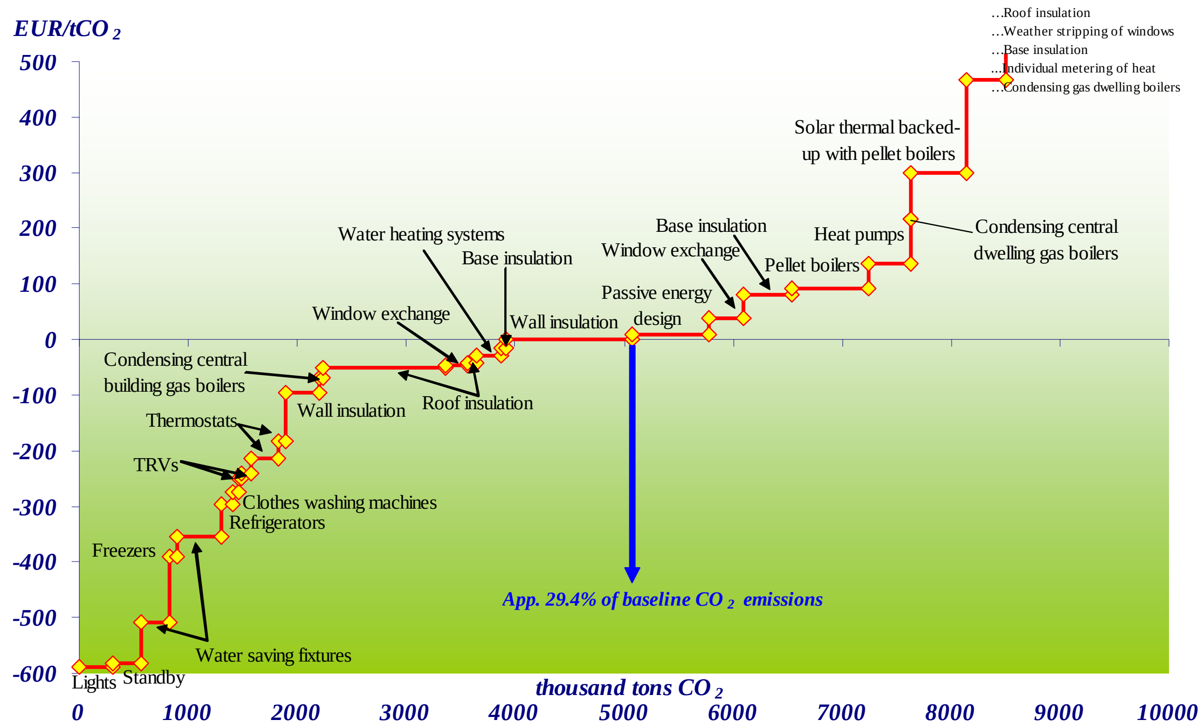


Figure 6 Supply curve of CO2 mitigation for the residential sector of Hungary in 2025

Figure 6 demonstrates a wide range of opportunities for negative- and low- cost CO2 mitigation in all studied types of residential buildings. In general, the thermal options supply the most significant savings in both terms of absolute values as well as the share of their baseline emissions compared to the electrical efficiency options.

Figure 6 shows that there is a potential for CO2 mitigation at negative cost in 2025 with various technological options, such as efficient appliances and lighting technologies, space heating and water flow controls, TV- and PC- related equipment with reduced electrical consumption in low power mode, construction according to passive energy design principles and many insulation options. If all these options were implemented, they would cumulatively reduce CO_2 mitigation by 5.1 million tonnes in 2025. This is about 29% of total CO_2 emissions emitted by the residential sector of Hungary in 2025. Implementation of the mitigation options at negative cost of CO_2 would result in energy savings of 22.1 TWh/yr., which is about 26% of the total final energy consumption of the residential sector in 2025. Realisation of this potential would require total investment over the period 2008 – 2025 of about 9.6 billion EUR but would save 17.1 billion EUR in energy costs.

The CO_2 mitigation potential in cost categories, the associated energy savings, the required investment costs and the associated saved energy costs are presented in Table 3 . The technical potential achieved due to the implementation of all investigated measures is estimated to be as high as c. 50.5% and 42% of the sectoral baseline CO_2 emissions and final energy consumption in 2025. In absolute terms, these savings represent about 8.7 million tonnes of CO_2 and 35.3 TWh/yr. The total investments over 2008 – 2025 needed to realize the maximum potential are about 29.0 billion EUR and they return 25.7 billion EUR in terms of saved energy costs.

Table 3 Summary of results: CO_2 mitigation potential in cost categories, associated energy savings, investments and saved energy costs

Cost categories of CO2 mitigation costs, EUR/tCO2	Cumulative CO2 mitigation potential		CO2 mitigation potential by cost category		Cumulative energy savings		Energy savings by cost category		Investments over 2008-2025, billion EUR		Saved energy costs 2008 – 2025, billion EUR	
	BL share	Million tCO2/yr.	BL share	Million tCO2/yr.	BL share	TWh/ yr.	BL share	TWh/ yr.	Total	By cost category	Total	By cost category
< 0	29.4%	5.1	29.4%	5.1	26.3%	22.1	26.3%	22.1	9.6	9.6	17.1	17.1
0 – 20	33.4%	5.8	4.0%	0.7	31.8%	26.8	5.5%	4.7	13.6	3.9	19.0	1.8
20-50	35.3%	6.1	1.9%	0.3	33.7%	28.4	1.9%	1.6	15.0	1.4	19.8	0.8
20 – 100	41.6%	7.2	6.3%	1.1	36.2%	30.5	2.5%	2.1	18.1	3.1	21.9	2.1
>100	50.5%	8.7	8.9%	1.5	42.0%	35.3	5.7%	4.8	29.0	10.9	25.7	3.8

Conclusion

The climate change challenge is at the top of the political agenda worldwide. For designing effective policies to meet the challenge, evidence-based knowledge of the potential for energy efficiency and low carbon opportunities is necessary. This research addresses this need and supplies the information on the potential for cost-effective reduction of CO_2 emissions in the residential buildings of Hungary.

To address the questions stated in the research, the author constructed a bottom-up, technology-rich model. The author developed a forecast of the reference final energy consumption and associated CO_2 emissions of the sector from 2008 to 2025. Then, the key CO_2 mitigation opportunities in the sector available on the Hungarian market were identified and economically evaluated as if they were installed individually and in sequence. The principal outcome of the research is a supply curve of mitigated CO_2 which characterizes the potential savings from a set of CO_2 mitigation measures as a function of the cost of mitigation technologies per unit of CO_2.

The paper concludes that the final energy consumption of the residential sector is expected to grow to 84.2 TWh in 2025, whereas the sectoral CO_2 emissions decline until 2015 but then they rise again to reach c. 17.3 million tonnes CO_2 in 2025. The technological options considered to reduce the reference energy consumption and associated CO_2 emissions include the improvement of the thermal envelope of selected types of existing buildings, the application of passive energy design to newly constructed dwellings, the installation of high efficiency and low carbon space heating solutions, the installation of heating controls and individual heat meters, the exchange of dedicated water heaters and combined space and water heating solutions, the installation of water saving fixtures, and the exchange of electrical appliances and lights with more efficient alternatives. The analysis of space heating and insulation opportunities is conducted separately for the building types with different architectural and thermal characteristics. The model does not consider the improvement of the thermal envelope and heating systems of buildings constructed during 1993-2008. Also, the research leaves for future research several mitigation options. These are the consideration of efficient cooking, air-conditioning, motor (lifts) and small electrical appliances. This research does not consider the effect of more efficient biomass heating systems because biomass is referred to as a sustainable source of energy and is thus reported with zero CO2 emissions.

Next, the results of the analysis of the individual mitigation options installed separately are presented. This is useful if the information about a particular technological option is needed. The research concludes that technological options with the potential for CO2 mitigation at negative costs are available for all building types and all energy end-uses. The paper shows that there are thirteen top priority options which are able to mitigate more than 1% of reference sectoral CO2 emissions at negative cost. These are the exchange of incandescent lamps with CFLs, the reduction of electricity consumption of TV- and PC- related equipment in low power mode, the installation of water flow controls, the installation of programmable thermostats in single-family houses (constructed before 1992), the improvement of water heating systems, a few insulation options (for walls, basements, and roofs) and the exchange of windows in different types of buildings.

The research concluded with the potential for CO2 mitigation as a function of costs for the investigated technological mitigation options. The advantage of the supply curve method is that it allows the estimation of the total potential while avoiding double-counting of the mitigation potential supplied by individual options targeted to the same baseline technologies and energy end-uses. The supply curve analysis concludes on a wide range of opportunities for negative cost CO2 mitigation in all studied types of the residential buildings. The figure depicts that technological options such as efficient appliances and lighting technologies, heating and water flow controls, equipment with reduced electricity consumption in the low power mode and many insulation options provide potential for CO2 mitigation at negative cost in 2025. If negative cost options are implemented, they can reduce CO2 by 5.1 million tonnes in 2025; this is approximately 29% of the reference CO2 emissions of the Hungarian residential sector. The total technical potential that would result from the implementation of all investigated measures is estimated as c. 50% of the sectoral reference CO2 emissions in 2025 or 8.7 million tonnes of CO2/yr.

The results of this research described above may be instrumental for designing such policy tools as capital subsidies and grants, energy performance contracting, the Joint Implementation Mechanism of the Kyoto Protocol, an energy efficiency certificate scheme and others. The database of mitigation options and the information about saved energy costs from the installation of the explored options may be useful for information awareness and education campaigns. The research results have been already used in preparation of the National Climate Strategy for 2008 – 2025 [34] and the design of the Green Investment Scheme in Hungary. The research may help set up the target for the post-Kyoto regime or the EU emission reduction commitment and contribute to the design of the Energy Efficiency Action Plan of Hungary and other sustainable strategies of the country. In addition to the practical application, the research contributes to the theoretical knowledge on CO2 mitigation modelling in economies in transition.

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Predictions for the contribution of residential lighting to the carbon emissions of the UK to 2050

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Abstract

The publication, in 2007, of the Energy White Paper saw the UK government commit itself to reducing the country's CO_2 emissions by 60% by 2050. In November 2008, the government took this a step further when The Climate Change Act came into law, committing the UK to an 80% reduction of 1990 levels by 2050.

By 2007, lighting in the UK residential sector required around 17 TWh of electricity and resulted in the emission of 9 million tonnes of CO_2. This paper describes and projects changes to these emissions between 1990 and 2050 and explores the extent by which the commitments of the government may be met in the residential lighting sector. The forecasting is modelled on two bases: (1) projected demand for artificial lighting in terms of lumen-hours per head of population; and, (2) anticipated changes, through both policy intervention and technology change, in the luminous efficacy of the installed base of lighting technologies.

The results of this analysis show that substantial reductions can be made to lighting related energy consumption in the residential sector. The extent of these reductions is such that lighting should not only more than contribute towards its share of the government's carbon reduction commitments but also be able to meet these goals ahead of target.

Introduction

In November 2008, the UK government became the first in the world to commit itself to a legally binding framework to tackle climate change when it passed into law The Climate Change Act. Under the Act the country is committed to reducing its 1990 CO_2 emission levels by 80% by 2050.

This paper examines the potential role of policy intervention and technological change in the domestic household lighting sector in helping to meet this target.

The models described in the paper consider the installed stock of lighting in any given year and therefore reflect the lag between any implementation of policy measures and improvements in best available technologies.

Demand for Light

In this paper, demand for light in the UK domestic sector is derived from the product of population and per capita demand for light.

For the purposes of this paper, behavioural change, such as more turning off of lights when not required, is not considered. Furthermore, technological change not directly related to lamp technology – such as in increased levels of occupancy sensor based switching, or a move toward more natural day-lighting – is excluded.

The per capita demand for light is assumed to continue to follow a logistic curve based on historical changes in demand.

Population

The population of the UK remained fairly stable for the twenty years prior to 1990, growing by 0.175% per year. Over the past few years, the annual rate of growth in population has increased to around 0.5%. On this basis, the government is predicting that by 2050 the population will have risen from a current figure of 61 million to 77 million. The models used for this paper make use of UK government historical trend figures [1] together with its latest projections [2].

Lumens per Capita

The demand for artificial lighting in houses has existed for centuries. The introduction of electric lighting saw the demand begin to grow exponentially – chiefly as a result lower costs. More recently, the rate of growth in demand has begun to slow. Drawing on previous work on the demand for lighting in the UK [3], historic growth appears to fit to a logistic curve. Extension of the curve provides projections for future demand (Figure 1).

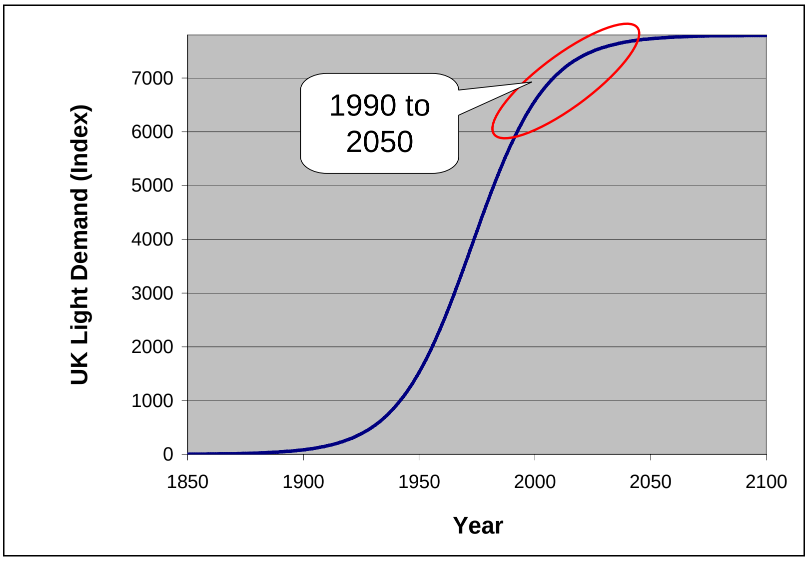

Figure 1: Demand for Artificial Lighting in the UK

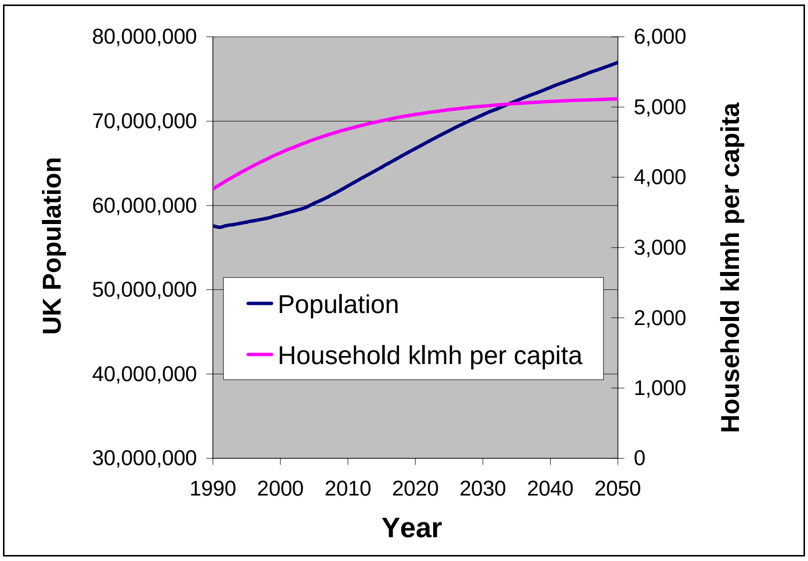

Figure 2: Growth in Population and in per Capita Lighting Demand

Overall Lumen Demand

The proportion of overall UK artificial light going into the domestic sector is estimated on the basis that in the late 1990's each UK household was estimated to consume approximately 10 million lumen-hours per year – equating to 4,300 million lumen-hours per capita [4]. On this basis, approximately 20% of UK demand is taken to be for household lighting – the remainder being for industry, commercial buildings, and street lighting.

Figure 2 compares growth in population with growth in per capita demand, and Figure 3 shows the product of the two to provide a picture of expected overall lumen-hour artificial lighting demand for the UK domestic sector.

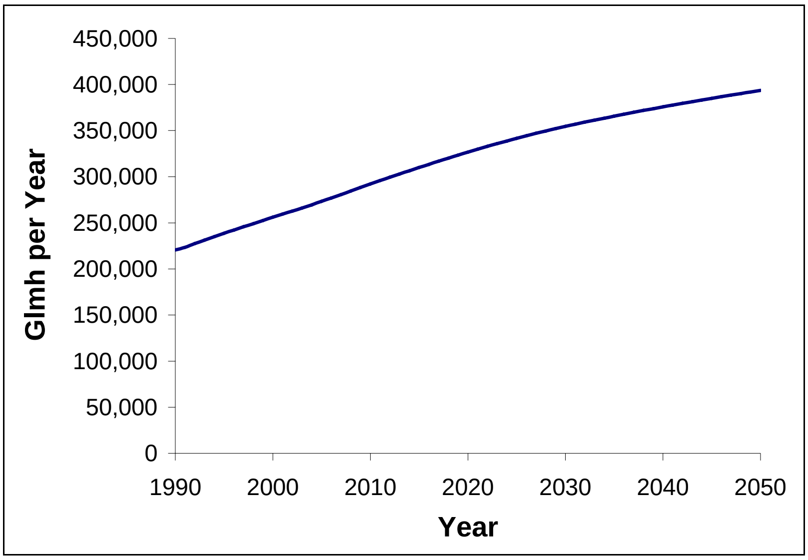

Figure 3: Demand for Artificial Lighting in the UK Domestic Sector (1990 to 2050)

Efficiency of Light

The efficiency of artificial lighting may be described in terms of luminous efficacy and expressed in Lumens per Watt (lm/W). Filament-based light sources have low efficacies (typically 8 to 15 lm/W), whereas discharge-based light sources have higher efficacies (typically 30 to 100 lm/W). Historically, UK household lighting has mainly been provided by filament-based light sources and this is reflected by a low overall efficacy. Based on stock models [5], it is estimated that between 1990 and 2005, the average installed efficacy of household lighting rose only very slightly, from around 14.3 to 15.6 lm/W. More recently, the efficacy has been increasing more rapidly through greater uptake of compact fluorescent lamps: by 2008, the figure was closer to 17.4 lm/W. This trend is set to accelerate.

Policy Incentives

In May 2007, the government published its White Paper on Energy describing measures that would be taken to tackle climate change and ensure the future security of energy in the UK. In September of the same year, there was an announcement that the country's major lighting suppliers were, in 2008, to begin a voluntary phase-out of most tungsten-filament lamps. The timetable for change is shown in Table 1.

Table 1: Voluntary Phase-out of Tungsten Filament Lamps in UK

Type of Lamp	Phase-out Year
150W GLS	2008
100W and 75W GLS	2009
60W GLS	2010
40W and 25W GLS as well as 60W candle and golfball bulbs	2011

The phase-out does not mean the lamps described will be prohibited from sale but does mean that consumers find will such lamps more difficult to source. Compact fluorescent lamps will be offered (often at highly discounted rates – through measures such as CERT) as alternatives. Further into the future it is expected that regulation will be introduced via the EU EcoDesign Directive and that this will remove almost all tungsten-filament lamps from the market by 2012. This will leave households with two main choices of lighting source: compact fluorescent and halogen. Most halogen lamps are, at present, little more efficient than tungsten-filament bulbs and the Directive is expected to target these too, such that only the most efficient remain available for sale after 2012 – these will be Xenon-filled, or infra-red coated.

Technological Change

While in the immediate future the domestic lighting market looks set to be dominated by compact fluorescent and more efficient halogen lighting, it is widely expected that solid-state electronic lighting (through LED or OLED technologies) will become the standard in the long-term. The use of solid-state technology as a white light source is still very much in its infancy. This is expected to change as costs come down, and light quality and efficiency improve. The US DoE is undertaking a programme to deliver commercially available "white light" LEDs with efficacies of 200 lm/W by 2025 [6]. For the purposes of this model, it is assumed that solid-state lighting makes a serious entry into the market in 2014 and grows to dominate it by 2040. It is assumed that by this point all lighting will be solid-state with a luminous efficacy of 200 lm/W.

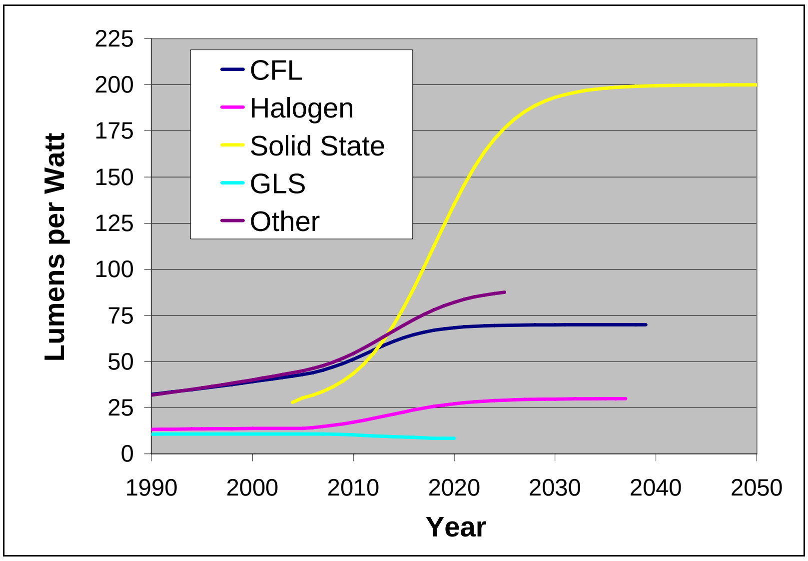

Figure 4: Assumed Changes in Efficacies of Installed Lighting Technologies

Figure 4 shows the changes in luminous efficacy of the five categories of lighting considered in this paper:

- Compact Fluorescent (CFL) is expected to improve over time as manufacturers seek to make them more attractive to the consumer. Efficacies have been de-rated to reflect research on warm-up times, lamp lumen maintenance, and manufacturer over-ratings [7]
- Halogen is expected to improve significantly in response to expected regulation
- Economically competitive, quality “white light” (CRI: 90+, CT ~3000K) Solid State is expected to reach 150 lm/W shortly after 2020 and peak at 200 lm/W
- GLS tungsten-filament lamps will fall in efficacy before leaving the market owing to the fact that the more efficacious higher power lamps are to be the first to go
- Other lamps include discharge lighting such as fluorescent strips and metal halide. Efficacies of installed stock are expected to increase to around 80 lm/W

The overall change in luminous efficacy over time resulting from policy intervention and technology change is shown in figure 5. The change, over time, in the proportion of light contributed by each of the five sources is shown in Figures 6 and 7.

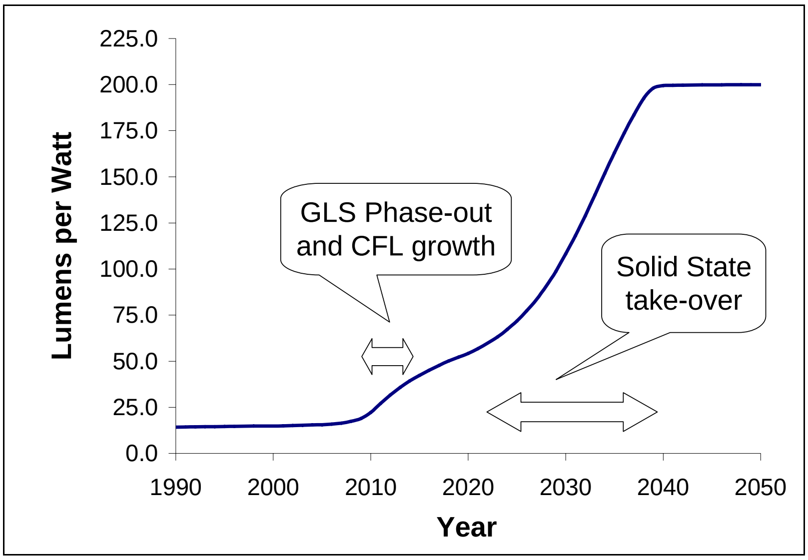

Figure 5: Overall Change in Installed Luminous Efficacy of Domestic Lighting

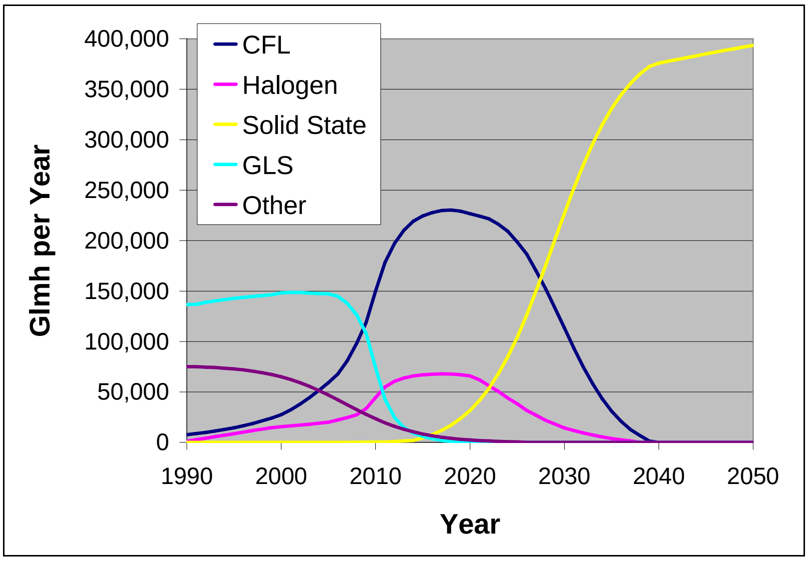

Figure 6: Household Lighting Contribution by Type of Light Source

The future stock levels are modelled on the substitution of tungsten filament lighting by CFL, halogen, and solid state, and continued trends in the downward demand for other types of lighting.

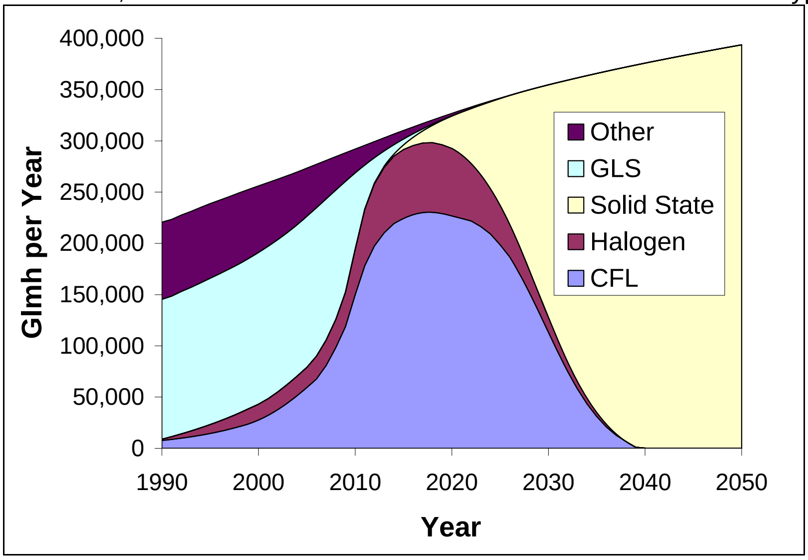

Figure 7: Make up of Household Lighting Demand by Type of Light Source

Penetration of Solid State lighting is modelled on a Bass Diffusion assuming market entry in 2014 with final total saturation of lighting demand, and based on Coefficients of Innovation (P) of 0.005 and Innovation (Q) of 0.25. The numbers used for the coefficients are low compared with other products but typical of lighting technologies [8]. A comparison of assumptions for changes in efficacy and indexed cost per lamp lumen is provided in Figure 8. The price of solid state lighting is expected to be lower, on an installed lumen basis, than GLS by the early 2020s: at the same time, the efficacies are expected to be at least fifteen times higher. Owing to the similarities in technology, together with industry-growth related economies of scale, the cost/efficacy development of Solid State lighting is widely expected to follow a pattern not dissimilar to that of Moore's Law with computer chips [9]: the product of efficacy and cost is assumed to halve every three years (with Moore and computer chips, the product of number of transistors per chip and cost has been observed to halve every *two* years).

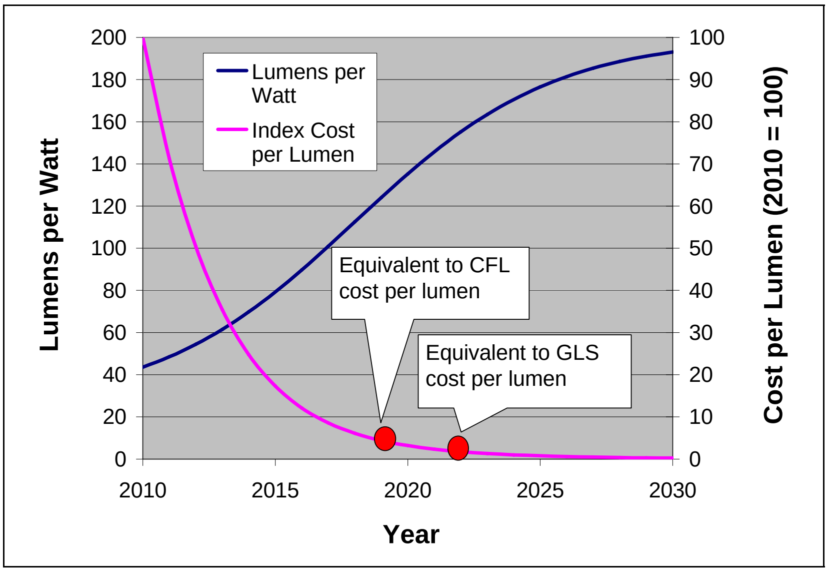

Figure 8: Solid State “white light” Efficacies and Indexed Costs over Time

Energy Savings

Division of the light output of each source (in Glmh per year) by the luminous efficacy (in lm/W) of each source provides figures for their energy demand (in GWh per year). The changing energy demand resulting from the changing use and changing efficacies of the five light sources is shown in Figures 9 and 10.

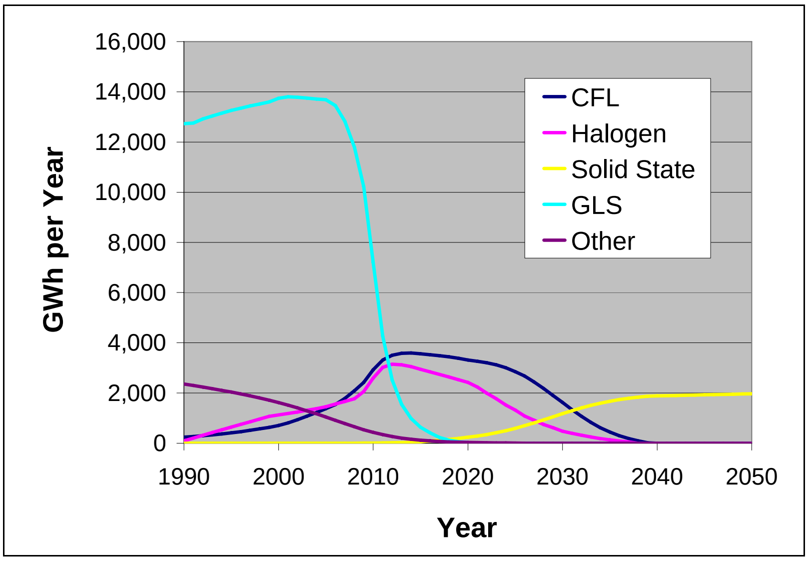

Figure 9: UK Household Energy Demand by Individual Light Sources

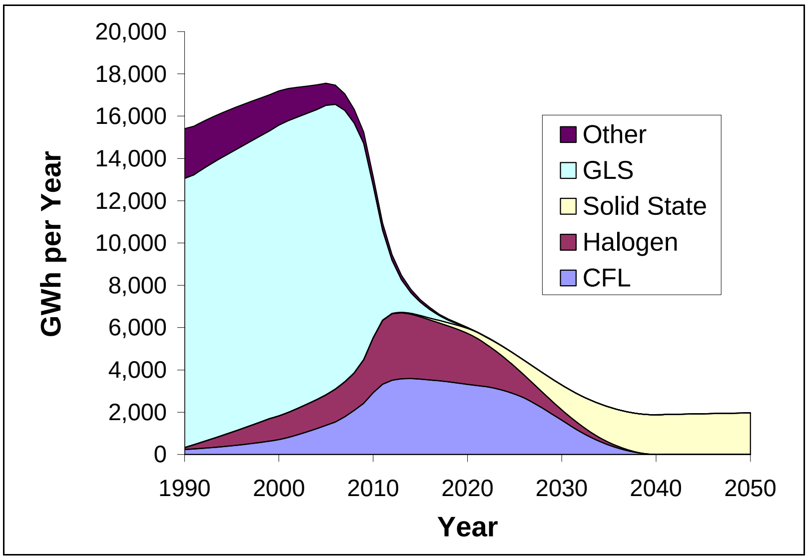

Figure 10: UK Household Energy Demand by all Light Sources

Discussion

The results show that there is the potential for an 80% reduction in 1990 baseline energy required for domestic lighting in the UK by 2031 and that this reduction could increase further to 87% by 2050. These reductions are based on the assumption that solid-state lighting becomes the sole lighting technology in use by 2040 and that by that time it has reached a luminous efficacy of 200 lm/W. Such a scenario would require a revolution in lighting, with the substitution over a 25 year period of all existing traditional filament and arc based lighting technologies by electroluminescent solid-state technology. Such a revolution is not without precedent: electrification of houses led to the rapid demise of candles, paraffin, and gas-lighting.

This paper assumes the *substitution* of existing indoor lighting with solid-state technologies and consideration is not given to *supplementation*. At present, the great majority of solid-state lighting is used in niche fixtures – it is still a niche industry – and so may be considered a supplement. However, there are limits to the amount of light a household will require and these, hopefully, are reflected in the analysis of historical and future demand for lighting. Furthermore, it is possible that the very flexibility of solid state lighting fixtures is such that their lumen outputs come to be better utilised than those of conventional lighting fixtures – the bare lamps of which are often shaded, leading to reduced lamp-lumen to illuminance ratios.

The implications for meeting the 80% CO_2 reduction target are linked to the energy savings that would be achieved by the scenario here described – but not directly. The extent by which an 80% plus reduction in electrical energy demand affects domestic lighting related CO_2 emissions will depend on at least two external factors:

- Carbon intensity of electricity – at present this is over 0.5 $kgCO_2$ per kWh, in the future this is hoped to change downwards with less carbon intensive forms of generation
- Carbon intensity of heating and cooling – this is important, since indoor lighting contributes towards the heating of buildings. Any reduction in the heat energy dissipated through lighting will affect the heating and/or cooling requirements for buildings

Further work could help establish the additional savings that could be achieved through behavioural change and technology changes such as better use of daylight in buildings.

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Energy savings potential in the use of residential lighting

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Abstract

How big is the savings potential in Swedish householder's use of lighting? A phase-out of incandescent and other inefficient lamps is being implemented in several countries, and as a part of the eco-design directive of the EU. The Swedish Energy Agency has been conducting measurements in detail, principally covering every lamp, in 400 households 2005-2008. Based on monitoring data realistic estimations of the savings potential is made. Aggregated data, and a combination of measurement data in detail and interview data is used for a limited number of households.

Lighting consumption differs between different types of households. Using measurement data three aspects are investigated: 1) Are female householders more thrifty than male? Female and male single person households are compared; 2) Single person households uses more energy than bigger due to loss of co-use. How big is this loss? This is of interest since the number and share of single person households are increasing in many countries. 3) Do pensioners have a lower consumption than younger people? Will future generations of pensioners raise consumption? This is estimated on actual pensioners at the time of measurements, and a younger generation brought up during the 1950s and 1960s.

Introduction

In many countries, a phase-out of incandescent lamps is proposed or decided. The committee for eco-design within the European Union has prepared a phase-out of the sale of inefficient lamps (based on their efficacies, measured in Lumens per Watt), which is proposed to begin in September this year. This should be seen as part of a large program of reducing carbon dioxide emissions, since about 80 per cent of power production within EU is based on fossil fuels. Saving electric energy in the residential sector would contribute to that.

Reductions seem to be hard to achieve, however. Despite energy efficiency programmes at EU and national level, electricity consumption has grown. Bertoldi and Atanasiu point at several factors behind this growth: a growing number of appliances, both of new and old types; increased hours-of-use for some appliances; larger dwelling sizes; an older population spending more time at home.[1]

Thus two tendencies are at work at the same time—one reducing end-use, and another increasing it. An obvious example from Sweden is the decision to introduce digital-TV, forcing many homeowners to buy a set-top box for the purpose in 2006 and 2007, and the eco-design directive in 2008 of limiting stand by-consumption on such appliances to 1 Watt. In this paper I will analyze these tendencies using data from Sweden, with special focus on residential lighting. Data comes from measurements of electricity consumption in 400 households, arranged and collected by the Swedish Energy Authority. Consumption data for each lamp, as well as other appliances, was logged in 10 minute intervals. Added to this, interviews were made with a limited number of households. I will also discuss social structure and change in social structure, based on official statistics.

A study of nine households

Detailed quantitative data coupled with large numbers of interviews results in a huge amount of information. Therefore only a small number of households could be studied. What is lost in possible generalization to the whole population is gained in detail.

Consumption of electric energy for lighting is a complex matter. In order to give a structure to the findings I will begin with a simple formula: Electric energy consumed for lighting = Number of lamps x Wattage x Hours-of-use.

The number of lamps differs significantly between households: depending not only on the area of the dwelling, but also on the type of house and on culture. Detached houses generally have a garden, where outdoor lighting is often installed. Out-door lighting at the garage, at the entrance, etc. is paid for by the homeowner. Residents in apartments in multi-family houses, on the other hand, make use of lights in the stairwell, in the common laundry and other collective areas, but they do not pay for it directly. Therefore it can be hard to make a fair comparison between these two types of living. However, the asymmetry may be eliminated to some extent by excluding outdoor lighting.

Secondly, most of the householders interviewed emphasized “cosiness” as important when they were asked about their choice and use of lighting. This is perhaps an indication of a Nordic lighting culture, comparable to the Norwegian habits shown in a famous article by Wilhite et al.[2] There is a tendency toward the installation of many small lamps, often in windows, for the sake of creating a nice and warm atmosphere in the home. This may make Swedes particularly open to new types of decorative lighting, such as glowing stripes to put around trees, and small halogen lamps retracted in the ceiling. It is an old custom in Sweden to put special Christmas lights in windows during December. This kind of “cosy” lighting may well be extended to new forms of decorative lighting. But “cosy” also means a preference for tea lights and candles – although in the interviews, some respondents (including a disabled man and families with children) expressed concern about fire.

Another aspect affecting the number of lamps is the difference between lamps and lighting points. A single lighting point may contain a number of lamps. This goes for the fashionable retractable halogen spotlights we could see at our visits in the nine homes. While each individual lamp had 20W, the user actually turned on 120 or 160 Watts.

Turning now to lamp efficacy, another discrepancy between single-family and multi-family houses must be taken into account. As a rule, property-owners of multi-family houses install fluorescents in the kitchen and in the bathroom—this goes with the rented apartment and is not the choice of the householder. Householders in detached houses generally choose all lighting themselves.

In the nine households taken together there were 316 lamps measured.[3]Of these 316 lamps 53% were incandescents, 27% halogens, 13% linear fluorescents, and 8% CFLs. A majority of the lamps, 64%, had wattage in the range between 20 and 49 (27% from 0 to 19, and 2% 100W and above). Lighting points had bigger shares for higher wattage classes (see Table 1 below), an illustration of the effect of serial coupling.

Interviews revealed that power (in Watts) was associated with intensity of light, also among households with one or a few CFLs installed. Wattage is taken as a guide for replacement, so that a 40W-bulb replaces a broken 40W. Watt is not directly associated with electricity consumption. This is an important aspect when energy efficiency measures are to be considered. I will get back to this in the concluding discussion.

In dwellings with a large area it is possible install a larger number of lamps and higher sum of Watt, while a smaller area in general limits installations. But when only one or two persons live in a detached house, as was the case with a retired couple, the number of lamps used at the same moment in time or during a 24-hour period, is quite small. All of the households studied used only a minor share of the maximum wattage possible to use, including the household consisting of two adults and a small child living in a small apartment. This family used 24% of its potential wattage at its highest single point in time, while the older couple had a maximum of 5%. Over a longer period between 2 and 11% of installed wattage was used (Watt-used = Wh per day/Hours-of-use per day).

Hours-of-use is dependent on presence in the home. As a rule both men and women are employed (77% women and 83% men) and thus spending time outside their homes.[4]Even though the housewife has disappeared, presence in the home may have increased due to work from home in some occupations. A retired couple spent more time at home than a young working couple did. However, retirees can be active away from home as well, and young parents use parental leave benefits when their children are small. In fact, a family with three children had the highest estimated presence in the home.

The effect on lighting due to absence from home is modified by the use of timers. One respondent, a young single woman, regularly used a timer for turning on a lamp in the living room before coming home from work in the late afternoon. A more frequent use of timers, though, was for turning on and off lamps at predetermined hours during the evening (in the garden or indoors) when residents were at home. One reason for this was to scare off burglars, but more often for the atmosphere these lights brought.

Table 1. The number of lamps, lighting points and average hours-of-use in four classes of wattage for nine households.

Wattages	Lamps	Lighting points	Hours of use
1-19	85	26	3.5
20-49	203	73	2.4
50-99	21	37	1.5
100-	7	24	1.4

Aggregated data for nine households. Hours with decimals.

Lighting points with lower wattage are used longer than lighting points with higher wattage (see Table 1). To a certain degree this is explained by the longer hours for CFLs. While incandescent lamps and halogen lamps were lit 1.8 hours per day, and fluorescents, 2.1 hours, CFLs were used twice as long, or 4.2 hours per day.

This is not an indication of a "rebound effect", though. Possibly incandescents have been replaced with CFLs in lighting points with long burning hours regardless of lamp type used. Only one person, a young single woman, said that it was acceptable to use a CFL for more hours than an ordinary lamp. A careful study of this householder's use of one of her four CFLs over a month showed that it was impossible for her to undo the saving from replacing an incandescent with a CFL. It would have required 39 hours per day. There may be a rebound effect, but it is certainly limited.

A surprising finding was that a single lighting point consumed a very big part of total electricity consumption for lighting purposes—in one case 53% and in another 73%. In both cases a fixture very popular in Sweden, called Uplight, was used, combining one halogen lamp of 300W directed at the ceiling, and one for reading of 50W. Since the upward lamp is used for background light it is used for a longer time than what is usual for the households in question.

Information in detail from the nine households makes it possible to simulate the magnitude of savings if all remaining incandescent lamps were replaced by CFLs. The realism in this is that actual hours-of-use and actual number of lamps installed is the base for the simulation. I have assumed that the general recommendation that, for example, a 40W incandescent can be replaced by a 9W CFL holds, and that there is no rebound. The latter assumption can be questioned because interviews with householders showed dissatisfaction with the delay in reaching full illumination, and this may in turn lead people to avoid turning them off as they would have done with other types of lamps.

The simulation resulted in a substantial reduction in consumption of electric energy for lighting. Reductions varied between 16 and 78%. From this small sample it is dangerous to generalize, however, but a possible level of reduction at 50% seems probable.

Table 2. The level of energy consumption for lighting after simulated replacement of remaining incandescent lamps in nine households. Per cent of actual level.

Household	Simulated level
Single young	55
Single middle-age	22
Single old	78
Couple young	40
Couple middle-age	41
Couple old	54
Family young	39
Family middle 3	84
Family middle 5	70

CFLs are easy to find in many shops in Sweden, and at affordable prices. It is possible to find them in shape and form suitable for existing fittings. However, CFLs contains mercury, one of the most poisonous substances we know. A better alternative would be Light-Emitting Diodes, LEDs. This is not a realistic option today for Swedish households, however.

The supply of LED-lights in Sweden today is limited from a substitution point of view. What is offered now, in Spring 2009, are clamp, table, wall, pendant and floor lamps with a concentrated ray of light and a cold, blue colour of the light. Only one bulb-shaped LED with a screw-socket was found. The cold blue light and intensity of light comparable to that of a 15W incandescent lamp, diminishes its role as a substitute. Fixtures are mostly very small and quite far from ordinary design standards. LED spotlights seem to be a possible substitute for halogen spotlights retracted in the ceiling.[5]

The supply is also broad from an extending-the-use-of-lighting point of view. Many LED-items are meant for complementary and extended use, for example stripes to be placed in staircases, thin plates to be retracted in the bathroom floor, or in the shape of stones to be put in the garden. Such items may have aesthetic value, and their energy consumption is marginal, but they do not replace high wattage lamps.

The situation for the supply of LED today will most probably change in the years to come. LED-lights are developing quickly, including adaptation to AC without additional device, and offer a potential for very low energy consumption.[6] LED-modules at 1 or 2W and with a warmer light can in the future replace conventional lighting for many purposes. In view of such prospects for LED the CFL seem to be a transitional solution.

Social change

Electricity consumption in the residential sector has grown in the long term. Electric heating increased from 9 TWh in 1978 to 24 TWh in 1987, and then decreased to 17 TWh in 2000 (the same in 2005). Household electricity, excluding heating but including electricity use in collective spaces in multi-family houses, increased from 17 TWh in 1985 to 27 TWh in 2003 (26 in 2005).[7]

A growing consumption may be the result of an increasing number and increased use of electrical devices in the home. For example, loading batteries for a large number of mobile telephone terminals, diffusion of broadband equipment, introduction of plasma display TV-sets, etc. However, new technology may not be the only cause for increasing consumption. I will here analyze changes in the social structure (household structure in regard to the number of people and to age distribution) and a possible difference between men and women.

Households comprise different numbers of people, one person, two persons etc. Dwelling area and basic equipment is not proportionate to the number of persons. Single person households have lighting, TV etc., which is often used collectively in households with more than one person. Thus a changing distribution on different household sizes influences consumption not only for new technology but also for mature items.

Furthermore, two different household structures result in different number of households when the total number of people is given. A thought experiment can clarify this. Let us assume a country with 10 million inhabitants. In one extreme case there are 5 million one-person households and 1 million five-person households. This gives a total of 6 million households. In another case there are 2 million five-person households. This gives a total of 2 million households. Thus, in the first case there will be a need for 6 million dwellings, and in the second case 2 million. And not only the dwelling, but all items and services that is associated with the current standard of living.

In Sweden the distribution of household size has changed in the long term. The share of small households, especially those with one person, has increased since 1945, while the number of the biggest households has decreased. There are probably many reasons behind this development. Gainful employment among women is one important aspect, changes in legislation concerning divorce is another, changes in the care for the elderly away from institutionalized living is a third, improved financial support for students and for pensioners are other aspects.

Table 3. Distribution of household size in Sweden 1945, 1965, 1985 and 2007. Thousands.

Year	**Number of persons**				
	1	**2**	**3**	**4**	**5+**
1945	298	518	533	369	364
1965	620	770	585	479	323
1985	1325	1151	498	493	203
2007	1920	1328	451	475	192

Source: Statistics Sweden. Censuses 1945-1985. Household economy 2007.

The household structure in many other European countries follows the same pattern, even though data and definition of “household” differs somewhat. Data covering 25 European countries comparing the distribution of the early 1980s with the early 2000s, shows only one exception to this tendency (Estonia). In Greece, the share for one-person households increased from 15 to 20% between 1981 and 2001, while the share for five and more-person households decreased from 16 to 11%. In Hungary the equivalent figures were from 20 to 26% (one person) and from 11 to 9% (five or more).[8]

From the monitoring study, electricity consumption for lighting in different household sizes has been used for a counterfactual estimation. Data shows that electricity consumption is bigger in larger households, but not in proportion to the number of people. This is an indication of a loss of co-use of lighting, and this loss will add to the growth of consumption beside an increasing number of households due to a growth in population and other causes for increasing consumption.

If Sweden had the same household structure in 2007 as it did in 1980, electricity consumption for lighting would have been 0.34 TWh (12.5%) less than it actually was. Furthermore, if other countries follow the same path when it comes to household structure as Sweden has, it would be interesting to estimate what this would mean in terms of electricity consumption. Using Swedish electricity consumption data and comparing the factual Greek household structure with that of the Swedish, the aggregated consumption increases with 1 TWh or 36%. Using the same procedure for Hungary, the increase is 0.7 TWh or 24%.

However, the absolute level of the figures should not be taken as fixed facts. Data for different groups must be weighted according to population statistics first—but relative values for different households sizes hold.

Another aspect on change in the household structure is the growing share for the elderly. Data from the monitoring study is used, but in this case the whole data set cannot be used since the number of households with older people are very few in household sizes with more than two persons. I have defined the elderly as those with an age of 65 years or more at the time of measuring, and I will compare them with households in the age between 18 and 64 years. Since the monitoring study comprises only a few elderly living in detached houses (which has become common in Sweden for this age group), I have added two-person households, excluding those with one member below the age of 65.

Table 4. Electricity consumption for lighting and for all purposes in old-aged and middle-aged one- and two-person households and type of dwelling. KWh per year. Index.

Household type	Lighting	All cons.	Index all	Observations
Older in house	619	2624	82	17
Middle in house	983	3205	100	26
Older in apartment	422	1606	79	20
Middle in apartment	469	2021	100	55

Older = 65 years of age and above. Middle = 18-64 years.

There seem to be a difference between households with older and with younger people. Intuitively this is not obvious. Eyesight usually gets worse when people get older and therefore more light is needed. Older people sleep less than middle-aged people. Pensioners stay at home more, and the elderly are used to incandescent lamps and are latecomers when new types of lighting is introduced. In favour of the hypothesis that the elderly consume less electricity we find three factors. Pensioners have lower income and are therefore forced to economize. Secondly, older people have grown up under poorer conditions, and by habit they continue to economize on lighting and other uses of electricity. Thirdly, older people move from larger to smaller dwellings where less electricity is used.

However, the result in Table 4 is not robust considering the small sample and the wide spread among households. Individual differences are very large, so that middle-aged households show a low consumption, while older householders have high (the lowest value for middle-aged households in detached houses was 683, and the highest value among the elderly in the same type of dwelling was 2142).

Are there systematic differences between men and women? It has been shown that men use the car more often than woman, and therefore consume more fuel.[9] What about electricity? Gender roles tell us that women cook more and men use the computer more. If women are more concerned about creating a nice atmosphere at home by the choice of light, what would that mean in electricity consumption for lighting? Traditional gender roles exist, but individual differences are actually bigger than the difference between the average man and the average woman. Is it possible to detect gender differences in the measurement study?

In this part I have picked out only one-person households. This clears away doubts concerning compromises between men and women in mixed households. Furthermore, only households in multi-family houses, because observations are few of households in small houses, and because there are different conditions in the two types of dwellings.

Table 5. Electricity consumption among male and female one-person households. KWh per year.

	Light	Fridge	Cook	Dish	Wash	AuVi	Comp	Other	Total
Men	484	493	117	12	17	363	285	321	2093
Women	385	555	185	44	28	184	80	334	1818

Fridge = refrigerator, freezer, chiller. Cooking = stove, oven, microwave oven, and other cooking utensils. Dish = dishwasher. Wash = washing machine in apartment, not in common laundry. AuVi = audiovisual equipment, stereo, TV, video, set-top box, DVD, etc. Comp = computer, printer, broadband equipment, etc. Other = non-separable and not specified.

Table 5 shows 13% lower consumption for the average woman in single-person households participating in the monitoring study (and 20% lower for lighting). The table also reflects traditional gender roles in that electricity consumption among women is higher for storing food, cooking, dishing and washing, while men consumes more energy for audiovisual and computer-related equipment. The difference between men and women concerning lighting is harder to explain.

The spread is big, even when observations are narrowed down to singles in multi-family houses. The maximum value for lighting was 1078 kWh per year, while the minimum value was 77. The maximum value for all other electricity consumption except lighting was 8812, while the minimum value was 708. Differences between individual households are huge. And there is no correlation between consumption for lighting purposes and all other purposes. A correlation coefficient of 0.15 is close to zero, and indicates a non-correlation. Such huge differences appear all over—when data is arranged according to gender, number of people in the household, type of dwelling, appliances or area. Based on 187 observations of households living in detached houses correlations between area and lighting, area and all other consumption, and area and total consumption, gave correlation coefficients in the range of 0.13 and 0.17! The main lesson from the monitoring study is that consumption of electricity varies greatly between individual households.

Concluding discussion

The main lesson from the monitoring study is that consumption of electricity varies greatly between individual households. Dispersion is huge. This does not mean that there are no patterns or correlations at all. The loss of co-use in smaller households, higher consumption in dwellings with larger areas, gender patterns and differences between older people and younger, may very well exist, but these patterns are hard to detect and prove since they drown in a sea of individual differences.

Why such a large dispersion? Probably the correlation runs not between social or subjective aspects on one hand, and energy on the other. It is mediated. People do not use energy, they use lamps, computers, washing machines etc., and these items require electricity in order to function. Technology comes in between the user and energy consumption. Let U stand for user, T for technology, and E for electricity, then relations could be illustrated in this way:

(U–T)–E

The parenthesis marks the using aspect, the active, conscious use by men and women of appliances in the home. Electricity is outside of this relation, something secondary, an effect of technology use, not use directly of electricity (or other energy carriers). Interviews with households revealed this clearly. Such things as “Watt” and “kilowatthours” is something heard of, but not reflected upon, and often confused with each other. The lack of energy-awareness has been shown in many studies.

Neither purchase nor use of appliances is free from the play of chance. Kevin Lancaster introduced the concept of “characteristic of goods”.[10] This concept is helpful in our understanding when it comes to purchase. There are several characteristic of a single item, power and energy is just one of them, beside size, price, design, colour of light, etc. It is probable that choice of lamps and other appliances must fit in a particular place in the dwelling, which means that size, design and function is prioritized before energy efficiency.

Use of electric equipment is often instrumental. Appliances are used in order to prepare a meal, read a newspaper, buy tickets on-line etc. They are not used according to energy consuming criteria, criteria sometimes not even known by the user.

From an energy efficiency policy perspective this is not a bad thing. If the energy characteristic of a good is downplayed in purchase and use, then regulations such as phase-out of inefficient variants will be successful. If “efficient” means that the consumer acquires the same function, design, price etc., at a lower rate of energy consumption, then the user will buy them and use them.

However, this is not a solution to the problem of innovations. During later decades we have seen several new items diffusing among the population, and there seem to be no reason why this should stop. This points at the need for energy criteria to be present already from the start in the innovation process. A reasonable rule would be a replacement rule, saying that a new type of TV, for example, must be at least as efficient as the existing one before release on the market. LED is a positive thing as a substitute, but not as a complement.

If such regulations are implemented and successful, dispersion in consumption among households will decrease. A narrower dispersion in supply will lead to a narrower dispersion in use. Variation due to gender, age, household size, dwelling type and area, individual hobbies, lighting culture and other rational factors, will appear more clearly.

Due to the large “chance” variation it cannot be proven that other factors contributes to the overall variation. However, there are indications that households with older people have a lower consumption. The elderly seem to consume less electricity both for lighting and total electricity (where “total” excludes heating and hot water), and in detached houses as well as in apartments. Looking at gender it seems as men consume more than women, when singles of both sexes living in multi-family houses were compared. Men had higher consumption for use of audiovisual, computer and lighting appliances, while women had higher on storing food, cooking, dishwasher and washing machine. Traditional gender division of labour in the home thus seems to exist even in single-person households.

The elderly’s share of total population has increased or is increasing in many countries, not only in Europe. A lower level of consumption among the elderly may seem comforting from an energy savings point of view. However, it cannot be settled by this study alone that the elderly is a generation or a phase in the life cycle. If the lower consumption level is associated with a phase, then prospects for lower levels in the future can be argued for. If the lower level is associated with historically lower levels of consumption, then the level will disappear when new generations of people reach retirement age.

Another change in household structure is associated with the number people in the household (household size). In Sweden, change has been radical during the last 50-60 years. One-person households have increased to such an extent that they are by far the largest category today, while bigger households have decreased. This tendency can be seen in other European countries too. Household structure influences consumption. All households must have a basic material standard, including electric appliances, which means that material necessities per person increase. In smaller households, co-use is lost, and at a given number of individuals in the population there will be a larger number of households when the share for small households is big. This seems to be a slow but firm tendency contributing to an increase in consumption in the future.

Leaving social structure and going down to the study of individual households a big potential for energy savings has been detected, at least when it comes to lighting. A phase-out of incandescent lamps, replaced first by Compact Fluorescent Lamps, and in the future, Light-Emitting Diodes, will reduce electricity consumption radically. Even though differences between individual households are big, and the sample studied small, it is highly probable that replacements will succeed and give the intended result. A counteracting tendency, though, is a possible rebound effect. If CFLs and LEDs do not perform the same qualities of light as conventional lighting, or if the use of lighting will be extended, then hours-of-use may increase and reduce energy savings.

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[1] Paolo Bertoldi & Bogdan Atanasiu, *Electricity Consumption and Efficiency Trends in the Enlarged European Union. Status Report 2006.* Institute for Environment and Sustainability, 2007. European Commission, Directorate-General, Joint Research Centre, EUR 22753 EN. European Communities, 2007.

[2] Harold Wilhite, Hidetoshi Nakagami, Takashi Masuda, Yukiko Yamaga & Hiroshi Haneda, ”A cross-cultural analysis of household energy use behaviour in Japan and Norway”, *Energy Policy,* vol. 24, no 9, 1996, 795-803.

[3] At our visits in respondent’s homes we registered a larger number of lamps than on the installation sheet used by the firm doing the actual monitoring, amounting to the sum of 391. Visits were made approximately one year after measuring period, so residents may have made changes in the meantime. But it is not probable that a bathroom with no window would have been without lighting, or that no lamps in the bedroom had been monitored while lamps in all other rooms had.

[4] Statistics Sweden, *Women and men in Sweden 2008. Facts and figures.* SCB, 2008.

[5] The supply of LED was mapped through study of homepages published by Ljusexperten, IKEA and Clas Ohlson in February 2009. New LED-supply was mapped from homepages published by Philips Sweden and Osram Sweden.

[6] For an example of AC adaptation see http://www.optoga.se, ”Acriche”.

[7] Updated time-series from Mats Bladh, *Hushållens elförbrukning.* Tema-T Working Paper, 291. Department of Technology and social change, Linköping university, 2005. Collective electricity consumption in multi-family houses is not included in ”household electricity use” in statistics published by the Swedish Energy Agency.

[8] *Housing Statistics in the European Union 2004.* National Board of Housing, Building and Planning, Sweden & Ministry for Regional Development of the Czech Republic. Boverket, 2005, p 23.

[9] Annika Carlsson-Kanyama & Anna-Lisa Lindén, ”Energy efficiency in residences—Challenges for women and men in the North”, *Energy Policy* 35 (2007) 2163-2172. Annika Carlsson-Kanyama & Riitta Räty, *Kvinnor, män och energi: makt, produktion och användning.* Rapport FOI-R-2513-SE. FOI, 2008.

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EcoTopTen scenarios for sustainable consumption – reduction potentials due to the use of energy efficient products

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Abstract

In March 2005 the EcoTopTen campaign (see www.ecotopten.de) started with the aim to regularly deliver market surveys of the most energy efficient products for private households in Germany, including product groups like e.g. heatings, cars, household appliances, computers and TV sets. Since then market surveys for 25 product groups were published and updated regularly.

In the herewith presented study it was analyzed what reduction of greenhouse gases, primary energy demand and costs households can achieve by using EcoTopTen, respectively by the use of the energy efficient EcoTopTen products in different product fields relevant for private households.

In order to calculate the reduction potential five household types were defined: (1) the average household using average products; (2) the efficient household, using EcoTopTen products except for food and textiles; (3) the double efficient household, the same as (3) but using all products in an efficient way; (4) climate efficient household, the same as (3) but using smaller products (smaller car, TV set etc.); (5) sustainable household the same as (4) but additionally using EcoTopTen food and textiles.

The results show that an average household with two persons is able to reduce its greenhouse gas emissions by up to 73 percent or 9,5 tons CO_{2e} equivalents per year only by using EcoTopTen products (efficient household). An additional 4 percent greenhouse gas emission can be saved by changing behavior (double efficient household). Fortunately the reductions come along with cost savings of up to 980 Euro respectively 1290 Euro per year and household.

Introduction

EcoTopTen is a major initiative for sustainable consumption and product innovations in mass markets initiated by Öko-Institut in Freiburg, Germany. In its first phase the EcoTopTen research project [1], [2] was sponsored by the Federal Ministry of Education and Research. The consumer information campaign [3] started in 2005 and was sponsored by the German Ministry of Food, Agriculture and Consumer Protection and the Legacy for the Future Foundation. The current phase of the EcoTopTen campaign [4] is sponsored by the Deutsche Bundesstiftung Umwelt (DBU), one of Europe's largest foundations that promotes innovative and exemplary environmental projects. At regular intervals, the scientists produce recommendations of high-quality 'EcoTopTen products' – all of which offer good value for money and top environmental performance. These recommendations are published on www.ecotopten.de, one the elements of the campaign. Since 2005, market surveys for 25 product groups were published and updated regularly (see table 1).

Within the market surveys EcoTopTen delivers information on the purchase prices and on further annual costs, such as for electricity or water needed for using the products. In order to allow comparison, typical products on the market that fail to meet the EcoTopTen criteria are also presented. These market overviews should put consumers in a position to take quick decisions in favor of sustainable products. The campaign also provides clues on how to use these products in a way that saves money and reduces negative environmental effects.

Table 1: Analyzed product fields and associated product groups within EcoTopTen

EcoTopTen Product fields	Associated product groups
Building & Housing	Condensing boilers (gas) Wood-pellet heating systems Energy-saving lamps Low energy houses (prefabricated construction)
Mobility	High-mileage car fleet. Best-in-class schemes for: Small cars / Mid-range cars / Family cars / Mini-vans Car sharing Bicycles (safe and low-maintenance)
Eating & drinking	Full range of organic groceries with umbrella label
Refrigerating, Cooking, Dishwashing	Refrigerators & Freezers Gas & Electrical cookers Dishwashers
Clothing	Full range of textiles (organic & fair-trade standards)
Laundry washing & drying	5-kg, 6 kg and “intelligent” washing machines Tumble driers (heat pump driers, gas driers)
Information & Communication	Virtual answering machines PCs / notebooks Flat panel displays Printers
TV & Co.	CRT and flat panel TV sets
Electricity	Certified green electricity
Investment	Sustainable funds Old-age-provision products

In the herewith presented study [7] it was analyzed in several scenarios what reduction of greenhouse gases, primary energy demand and costs households can achieve by using EcoTopTen, respectively by the use of the energy efficient EcoTopTen products in different product fields relevant for private households.

In an additional step two future scenarios were developed which showed the reduction potential of all 2-person-private households in Germany taking into consideration the observed environmental consciousness of the people and their declared willingness to behave environmental friendly.

Methodology

In order to calculate the reduction potential five household types were defined: (1) the average household using average products; (2) the efficient household, using EcoTopTen products except for food and textiles; (3) the double efficient household, the same as (3) but using all products with changed behavior in an efficient way; (4) climate efficient household, the same as (3) but using smaller products (smaller car, TV set etc.); (5) sustainable household the same as (4) but additionally using EcoTopTen food and textiles.

For the five household types it was calculated how much energy they consume and how much greenhouse gases they emit in one year by the use of the products under consideration. The energy consumption and global warming potential due to the production of heatings, cars, washing machines etc. was not taken into consideration. For the calculation of the life cycle costs the costs for purchase (exception: purchase or rent for houses/flats was not considered) <u>and</u> for the use were considered.

Definition of household types

For the calculation of the reduction potentials five types of model households with 2 persons per household were defined. They can be sketched in the following way:

(1) The ***average household*** represents a German 2-person household, which is close to the statistical average with 2,1 person per household. It was assumed that this household uses conventional products newly bought in 2007/2008.

(2) The ***efficient household*** uses EcoTopTen products (e.g. energy saving lamps, A++ fridge, efficient heating etc.) except for food and textiles. The choice of products and the further assumptions for this household type were made in a way that the efficient household reduces its energy consumption and its emission of greenhouse gases with similar life cycle costs and no loss in quality and convenience compared to the average household.

(3) The ***double-efficient household*** uses the same products as the efficient household. Additionally this household uses the products more efficiently and behaves more environmental friendly (room temperature lowered by 2 degrees, moderate car operation, washing machine is only operated full). The choice of products and the further assumptions for this household type were made in a way that the double-efficient household without too much expenditure still achieves the same level of quality and convenience as the efficient household. The energy consumption is reduced as well as are the emissions of green house gases and the life cycle costs.

(4) The ***climate efficient household*** is similar to the double-efficient household but shows distinct changes in behavior (e.g. uses a smaller car, a smaller TV set etc.) and a fast implementation of energy saving measures (e.g. low energy standard of house/flat). The choice of products and the further assumptions for this household type were made in a way that the climate efficient household is again able to lower its costs and further reduce its energy demand and greenhouse gas emissions.

(5) The ***sustainable household*** looks the same as the climate efficient household but additionally buys EcoTopTen food (biological agriculture and fair trade) and textiles (biologically grown cotton, toxproof and fair trade). Both, food and textiles do not influence the energy consumption of the use phase but focus on biodiversity and social conditions during production. As these products are more expensive then conventional ones, the life cycle costs of this household type are higher then the ones of the climate efficient household.

Data base

The calculation was done on the bases of the EcoTopTen market surveys and purchase recommendations. Additionally statistical data on average 2-person households and user behaviour according to experience or on the bases of empirical data were used. The data are differentiated by the following four areas:

- Heating (including warm water)
- Mobility
- Electricity
- Food and textiles

In 2006 there were 12.6 million 2-person-households in Germany, 48 % of them owned the house/flat they lived in and 52 % were tenants. The average size of the house/flat of tenants was 34 % smaller then the one of the owners. The average living space per 2-person household in 2006 was 94.4 m².

Heating (including warm water)

Concerning heating, the EcoTopTen product groups wood pellet boilers and gas condensing boilers were considered. They substitute for conventional boilers on the bases of oil (alternative I) resp. gas (alternative II). Prefabricated houses were not included as the share of newly built houses is very low, 2006 being only 0.55 % of the stock. For the climate efficient and the sustainable household it was assumed that the thermal energy demand of the houses/flats is only 70 kWh/m²*a, representing low energy standard.

Table 2: Average annual thermal energy demand of German 2-person households in 2005 (owners and tenants).

Household type	Specific annual thermal energy consumption	Annual thermal energy consumption		Explanation
		Owners	Tenants	
Unit	kWh/m²*a	kWh/a	kWh/a	-
Average household	193	22,190	14,593	Statistical average
Efficient household	193	22,190	14,593	Statistical average
Double efficient household	177	20,265	13,328	10 % less then statistical average
Climate efficient householdf	70	8,036	5,285	Good energy standard
Sustainable household	70	8,036	5,285	Good energy standard

Mobility

The subsequent table 3 summarises the assumptions made concerning mobility and the data bases used. The sustainable household is not shown in the table because for mobility there are no differences compared to the climate efficient household.

Table 3: Overview on the assumption and data bases made for 2-person households concerning mobility

	Average household	Efficient household	Double efficient household	Climate efficient household
Definition	Average car, compact size	Average EcoTopTen car, compact size	Average EcoTopTen car, compact size, moderate driving	Average EcoTopTen car, small size
Basic data	1 car/household 12,000 km/a share of diesel cars: average of newly licensed cars in 2007	1 car/household 12,000 km/a share of diesel cars: average of EcoTopTen compact cars	1 car/household 12,000 km/a share of diesel cars: average of EcoTopTen compact cars 20 % less fuel consumption due to moderate driving	1 car/household 9,000 km/a share of diesel cars: average of EcoTopTen small cars 20 % less fuel consumption due to moderate driving
Data base for primary energy demand and global warming potential	Own calculations on the bases of EcoInvent V2.01 and the CO_{2e}-emissions during use			
Data base for total annual costs	Market survey EcoTopTen 2007, typical product	Market survey EcoTopTen 2007, average of EcoTopTen compact cars	Market survey EcoTopTen 2007, average of EcoTopTen compact cars. 20 % less fuel consumption	Market survey EcoTopTen 2007, average of EcoTopTen small cars. 20 % less fuel consumption

Electricity

The subsequent table shows the assumptions made concerning electricity using appliances. The sustainable household is not shown in the table because for electricity there are no differences compared to the climate efficient household.

Table 3: Overview on the assumptions concerning electricity using appliances in 2-person households, differentiated by the five model household types (data sources: EcoTopTen market surveys)

EcoTopTen product groupse	Average household	Efficient household	Double efficient household	Climate efficient household
Energy saving lamps	25% Energy saving lamps , 75% incandescent lamps	75% Energy saving lamps , 25% incandescent lamps	75% Energy saving lamps , 25% incandescent lamps + lights off	See double efficient household
Refrigerators & Freezers	Fridge-Freezer, energy efficiency class A, size: 210 l cooling, 55 l freezing	Fridge-Freezer, energy efficiency class A++, size: 210 l cooling, 55 l freezing	See efficient household	Fridge-Freezer, energy efficiency class A, but smaller: 145 l cooling, 17 l freezing
Dish washer	Typical product on the market (60 cm)	Average of EcoTopTen dish washers (60 cm)	See efficient household	See efficient household
Gas & Electrical cookers	Electric cooker (cast iron), energy efficiency class oven: B	Electric cooker (ceran), energy efficiency class oven: A	See efficient household	EcoTopTen gas cooker (energy efficiency class oven: A)
Washing machines	Average EcoTopTen washing machine	Average EcoTopTen washing machine	Average EcoTopTen washing machine, economic use	See double efficient household
Tumble dryer	Typical product on the market, energy efficiency class C, Spinning speed: 1200 rpm	Average EcoTopTen tumble dryer, energy efficiency class A, Spinning speed: 1200 rpm	See efficient household	Average EcoTopTen tumble dryer, energy efficiency class A, Spinning speed: 1400 rpm
19 inch Computer flat screen, Average Energy Star certified displays	19 inch Computer flat screen, Average Energy Star certified displays	19 inch Computer flat screen, Average Energy Star certified displays	19 inch Computer flat screen, Average Energy Star certified displays, Switched off when not used	17 inch Computer flat screen, Average Energy Star certified displays, Switched off when not used
Desk top PCs and Notebooks	Average desktop PC, 25 % higher energy demand then allowed for Energy Star 4.0, cat. B	desktop PC, 25 % limit of Energy Star 4.0, cat. B	desktop PC, 25 % limit of Energy Star 4.0, cat. B Switched off when not used	Notebook, Energy Star 4.0 cat. B
Printer	Inkjet printer (MFD), high Standby energy demand	Inkjet printer (MFD), low Standby energy demand	Inkjet printer (MFD), low Standby energy demand Switched off when not used	See double efficient household
TV Set	Typical product on the market (LCD) with 32 inch	Average EcoTopTen TV sets, (LCD) with 32 inch	Average EcoTopTen TV sets, (LCD) with 32 inch Switched off when not used	Average EcoTopTen TV sets, (LCD) with 26/27inch Switched off when not used

Food and textiles

As the use phase of food and textiles was already considered in the product group cookers, washing machines and tumble dryers, these product groups will be included in the calculations only on the bases of purchase costs. For all household types - except for the sustainable household - conventional food and textiles are purchased. The sustainable household on the other side purchases biologically grown food and textiles made from biologically grown cotton that are toxproof and fair traded.

As neither for bio-food nor for fair traded textiles from biologically grown cotton average prices could be obtained, only a rough estimate on the purchase costs could be done: 20 % higher prices for bio-food and 10 % higher prices for bio-textiles.

Definition of future scenarios

On the bases of the five household types described above two possible future scenarios for the year 2020 were developed. The aim of these scenarios was to show to what extent these household types could be present in the year 2020 in Germany and what effect this would have on the overall primary energy demand and the emission of greenhouse gases as well as annual costs: What are the saving potentials?

Two surveys from 2006/2007 [5], [6] that focussed on the extent of environmental consciousness and environmental behaviour in the German population were – in a deliberately simplifying manner - used as a bases for the scenarios. The following figure and table show the assignment of the results from the surveys in the form of "*environmental types of people*" to the five household types described above.

		Environmental behavior	
		Not environmental sound	**Environmental sound**
Environmental consciousness	**low**	38% environmental ignoramus ***= average household***	14% independent environmentalists ***= efficient household***
	high	22% environmental rhetoric's ***= average household***	26% consequent environmentalists ***= equal shares of double efficient, climate efficient and sustainable household (8.7 % each)***

Figure 1: Overview on the four environmental types from [5] and their assignment to the five household types defined above.

Although the surveys relate to the years 2006 and 2007 it is clear that even the share of people that was found to have a high degree of environmental friendly behaviour did not yet to a fully extent implement every energy efficiency measure under consideration here (e.g. good energy standard of houses/flats, A++ fridges/freezers). Against this background the modelling of the future scenarios was simplified: It was assumed that today (status quo) all 2-persons households belong to the type average household. A complete realisation of environmental behaviour in the household types beyond the average household (e.g. efficient household, double efficient household) will only be achieved in 2020.

For the future scenarios no dynamic development was included. This means that neither technologies nor energy demand of devices or cost assumptions (e.g. possible development of the price for electricity) change in the scenarios. The same is true for the electric grid.

Table 4: Overview of the five environmental types from [6] and their assignment to the five household types defined above.

Market segment	Europe, 8 countries (percentage)	Germany (adults, percentage)	Assignment to household types
LOHAS (Lifestyle of Health and Sustainability)	18%	17%	Sustainable household
Naturalities (focus on nature and health, no ambition for politics)	24%	23%	Equal share of double efficient and climate efficient household
Drifters (environmental and social consciousness is there but behaviour deviates)	18%	21%	Double efficient household
Conventionals (passive from point of view of environmental and social topics, mainstream behavior like energy saving and recycling)	22%	19%	Efficient household
Unconcerned (no relationship to environmental and social topics)	18%	20%	Average household

Results

Reduction potential on household level

The results show that an average household with two persons is able to reduce its greenhouse gas emissions by up to 73 percent or 9.5 tons CO_{2e} per year only by using EcoTopTen products (efficient household). An additional 4 percent greenhouse gas emissions can be avoided by a changed behavior (double efficient household). Fortunately the reductions come along with cost savings of up to 980 Euro respectively 1,290 Euro per year and household.

The subsequent figure 2 shows the reduction potential for greenhouse gas emissions and all household types on the bases of 2-person households that own their house/flat and that substitute an oil heating (average household) by an EcoTopTen wood pellet heating (all other household types). The most impressing reduction potential results from the heating as a wood pellet heating shows significant lower CO_{2e} emissions then the oil heating (only 34 instead of 380 gCO_{2e}/kWh). In comparison to the owner households the results for the tenants' households show less reduction potential concerning heating: tenants' households houses/flats are systematically smaller which results in a lower energy consumption.

Concerning mobility also significant reductions can be achieved. Here especially the choice of an EcoTopTen car is beneficiary (efficient household). So, no quality or convenience restrictions are encountered in that case. Still further reductions are achieved by moderate driving (double efficient household) and the choice of a smaller car (climate efficient and sustainable household).

Concerning electricity the reduction potentials seem to be smaller then for heating and mobility but still are significant. In order to demonstrate the contribution of the different product groups here figure 3 shows a differentiated picture.

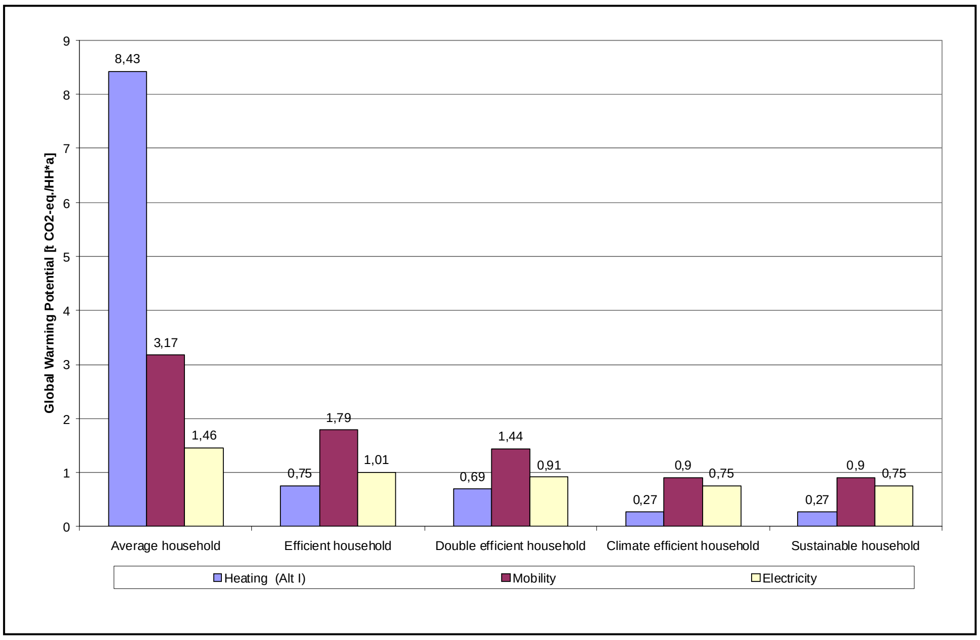

Figure 2: Annual greenhouse gas emissions in 2-person households (owners), differentiated by household type: Alternative I, conventional oil heating (average household) is substituted by wood pellet heating (efficient household etc.)

For electricity the reduction potential is between 0.4 tons CO_{2e} per year (efficient household) and 0,7 tons CO_{2e} per year (climate efficient and sustainable household) compared to the average household (see figure 3). It is striking that all product groups contribute to the reduction although to a different extent: The highest reduction potential is achieved by using energy saving lamps (47 to 57 percent reduction); fridge-freezers (34 to 53 percent reduction), tumble dryers (43 to 49 percent reduction), computers (21 to 66 percent reduction) and TVs (40 to 56 percent reduction). The determined reduction potentials are valid for owner households as well as for tenants.

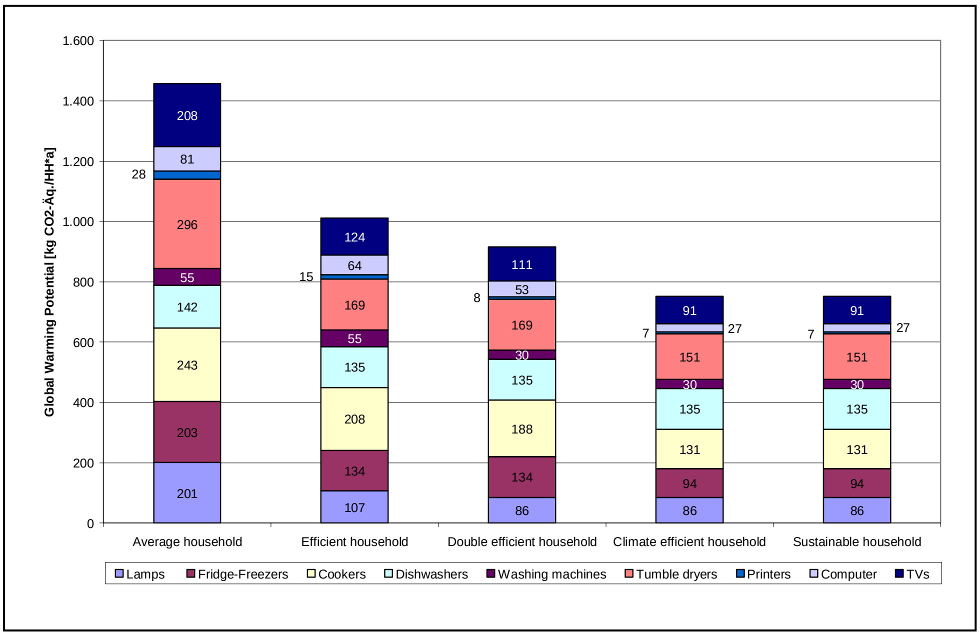

Figure 3: Annual greenhouse gas emissions from electricity using devices in 2-person households, differentiated by household type.

Future scenarios: Reduction potential for Germany

The subsequent table 5 shows the results for the different future scenarios 2020. In order to determine the maximum reduction potential possible it was assumed in a visionary scenario that all households comply with the climate efficient households. The average household (Status Quo) was taken as reference.

Table 5: Results of the analysed future scenarios: primary energy demand, greenhouse gas emissions and annual costs

	Unit	**Status Quo: 100%average households**	**Future scenario I**	**Future scenario II**	**Vision: 100%climate efficient households**
Annual primary energy demand	PJ/a	1,831.0	1,537.8	1,378.0	696.1
Absolute reduction	PJ/a	0	293.2	453.0	1.134.9
Relative reduction	**%**	**0%**	**16,0%**	**24,7%**	**62,0%**
Annual greenhouse gas emissions	Mio t CO_{2e}/a	133.9	101.6	85.3	36.7
Absolute reduction	Mio t CO_{2e}/a	0	32.2	48.5	97.2
Relative reduction	**%**	**0%**	**24,1%**	**36,3%**	**72,6%**
Annual costs	billion Euro/a	194.2	184.2	179.0	150.0
Absolute reduction	billion Euro/a	0	10.0	15.2	44.2
Relative reduction	**%**	**0%**	**5,2%**	**7,8%**	**22,8%**

The highest reductions can be achieved in the visionary scenario: Concerning greenhouse gas emissions, the reductions in the visionary scenario achieved by all 12,6 million 2-person households in Germany correspond to 9.6 percent of the overall emission of greenhouse gases in Germany in 2004. It has to be noted in this context that part of the greenhouse gas emissions calculated in the different scenarios will occur outside Germany as they originate from processes in other countries. If all 39,2 million German households (2005: 2,1 persons/household) would comply with the climate efficient household 30 percent of greenhouse gas emissions in Germany could be avoided!

The reduction potential for primary energy demand is in a similar range then the one for greenhouse gas emissions. Only cost saving potentials are significantly lower. But still: 23 percent cost savings can be achieved in the visionary scenario.

Future scenario II shows significant lower reduction potentials (between 8 percent and 36 percent compared to the Status Quo) then the visionary scenario but still higher ones then future scenario I.

Conclusions

The results of the modeling of the households and the future scenarios allow the following conclusions:

- The use of EcoTopTen products alone leads to a significant reduction of primary energy demand and greenhouse gas emissions in private households: In the efficient household, which gets by without behavioral changes, reductions between 18 (2-person household, tenants; alt. II: gas condensing boiler) and 73 percent (2-person household, owner; alt. I: wood pellet heating) compared to the average household can be reached.

- Further reductions are only possible with additional changes in behaviour as they were assumed for the double efficient household: moderate driving, lowered room temperature, consequent switch off of electronic applainces etc.. The reduction potential for primary energy demand and greenhouse gas emissions is between 27 and 77 percent compared to the average household.

- In the climate efficient household, significant smaller impacts are achieved by the use of “smaller” products: a small car instead of a compact car; a TV with 26/27 inch instead of 32 inch, a smaller fridge-freezer etc.. But most of all the energy standard of the house/flat is much better then in the average household (thermal energy demand: 70 kWh/m²*a instead of 193 kWh/m²*a). Primary energy demand and greenhouse gas emissions are lowered by 60 to 85 percent compared to the average household.

- It is very pleasing for consumers that none of the analysed household types has to face higher annual costs compared to the average household. In contrary: the reduction potential for the annual costs is between 6 to 7 percent in the efficient household; between 8 to 9 percent in the double efficient household; between 21 to 24 percent in the climate efficient household and still between 16 to 18 percent in the sustainable household. One important restriction had to be made: Costs for renovations of houses/flats to reach an energy standard of 70 kWh/m²*a of thermal energy demand were not included in the calculations. Therefore the cost savings of the climate efficient and the sustainable household are smaller in reality if such renovations have to be made. Strictly speaking these renovations fall out of the range of EcoTopTen.

- Extrapolated to all 39 million households in Germany a reduction of between 10 and 15 percent greenhouse gas emissions can be achieved. Given that still between 60 percent (scenario 1) and 41 percent (scenario 2) of households stay in the category average households and do not use energy efficient products a huge reduction potential still waits to be realized.

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Developing Countries I

Positive impacts of energy efficiency on the electricity services to the urban and peri-urban poor

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Abstract

One billion people, growing at a reported rate of 5% per year, live in poor urban and peri-urban areas throughout the emerging and developing countries.

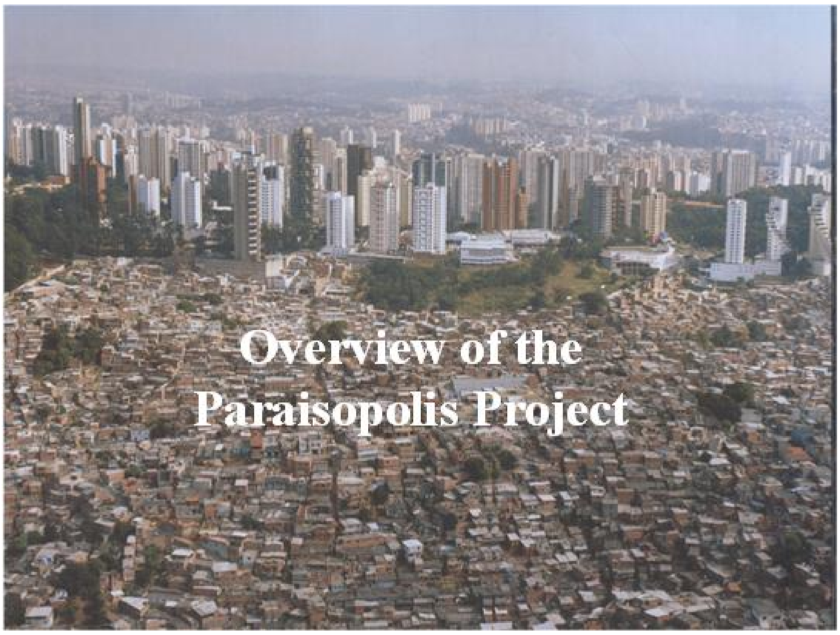
This paper shares experiences, economic and social studies on innovative, socially responsible and cost-effective approaches, to expanding and/or improving access to energy efficient electricity services in poor urban neighborhoods, especially in the megacities of the developing world.

The paper highlights the pilot project in the favela (slum) of Paraisopolis, Sao Paulo, Brazil. The project was conducted by a team that included AES Eletropaulo (local electric utility), the United States Agency for International Development (USAID), the International Copper Association (ICA), Brazilian partners from industry and appliance manufacturers. It could count on the support of the local community.

The project focused on the safety and reliability of energy supply and use, and demonstrated the benefits to stakeholders of high levels of energy efficiency. The paper reviews challenges, sustainability aspects, socio-economic conditions, regulatory and institutional factors, technical solutions.

The financial analysis concluded that actions and investments undertaken yield very attractive results, both from the perspective of the utility and the customers. The affordability of power can improve substantially, due to the reduction of energy losses by the installation of new appliances, lighting, re-wiring and other measures.

The paper concludes that the case for replication around the world is strong and deserves adaptation of the model by local utilities and governments, and where required, should attract financial support from development banks and agencies. AES Eletropaulo has already replicated lessons learned and regularized almost 300,000 connection customers as of April 2009.

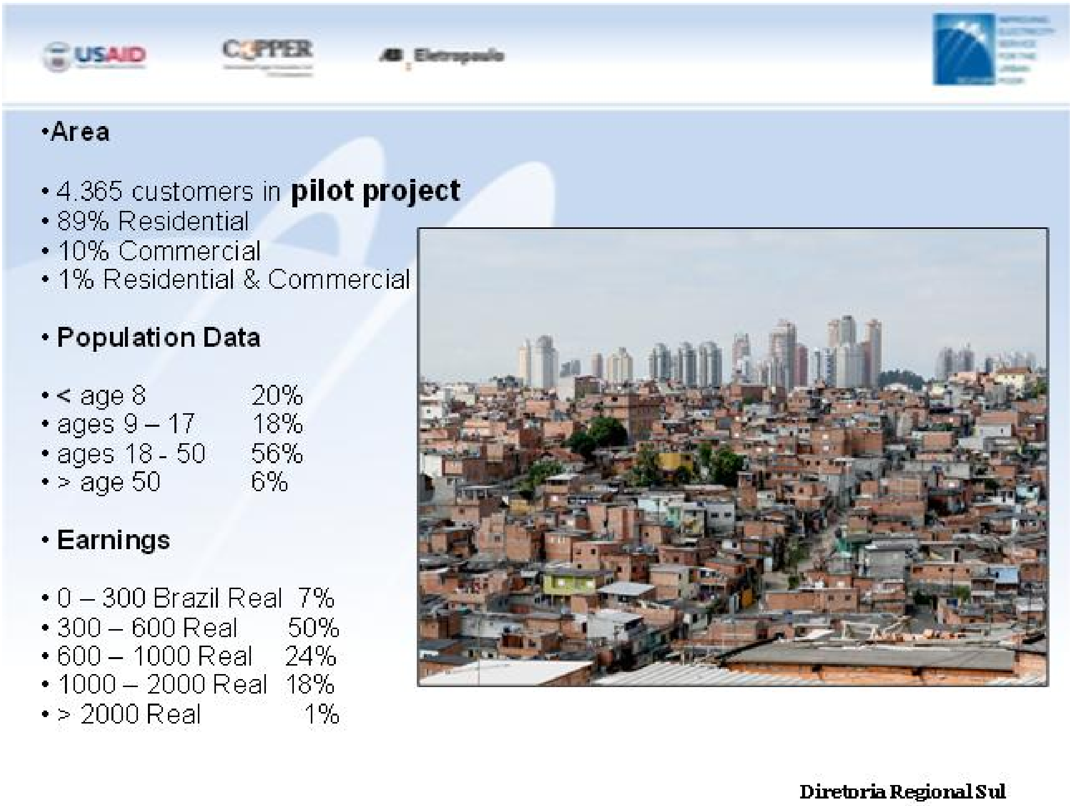


In Brazil, 52 million people or some 29% of the population live in favela's. They have no regular access to electricity, or if they have access, there may be theft of power, unsafe wiring conditions, and waste of energy due to very poor energy efficiency conditions of appliances and lighting systems.

In Sao Paulo region serviced by AES Eletropaulo, there are some 2000 slums with more than 1.5 million people. In slums where improvements have not yet taken place, more than 50 houses are destroyed on average each month due to electrical files.

The project site was chosen after a careful review of several cities with visits to local communities and their utilities.

The type of customers, ages and income are summarized in the table below. Note that at the time, the minimum wage was 380 Real.



Before project implementation in Paraísopolis, the second largest “favela” (poor urban “slum” area) in São Paulo, Brazil, the quality of electricity service was very poor: almost all the households and businesses had illegal electricity connections, were exposed to dangerous network and wiring conditions and did not pay for service. Households and businesses consumed, what are considered for this population, high amounts of electricity – on average 250 kWh/ month – due to the very poor condition of household appliances and electrical equipment (especially refrigerators and electric water heaters for showers), and the lack of price signal to encourage consumers to use electricity wisely.

Global Development Alliance

Through a Global Development Alliance partnership with the International Copper Association (ICA), USAID and ICA teamed with AES Eletropaulo to develop, test, and evaluate customized approaches to regularizing electricity service in a target area of Paraísopolis. The pilot was the first to be launched under the USAID-ICA Slum Electrification and Loss Reduction (SELR) program, which was initiated in October 2005 on the theme of regularizing and improving electricity service to low income communities.

In addition to the pilot in Paraísopolis, plans for replication and adaptation to local conditions have been developed for such places as Mumbai, India and Dakar, Senegal and it is hoped that by the following EEDAL conference, implementation in these and other cities will be reported on.

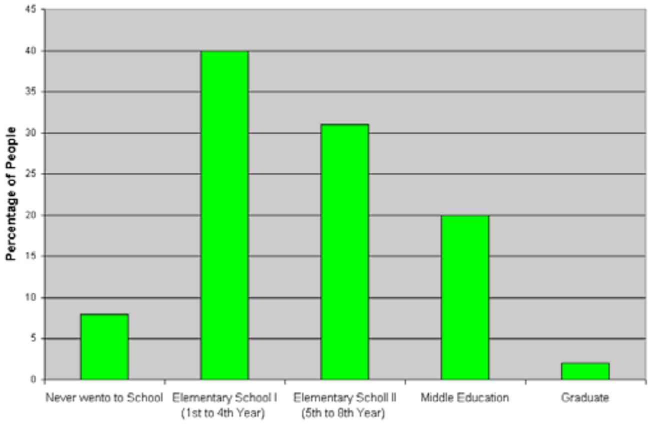
The Problem

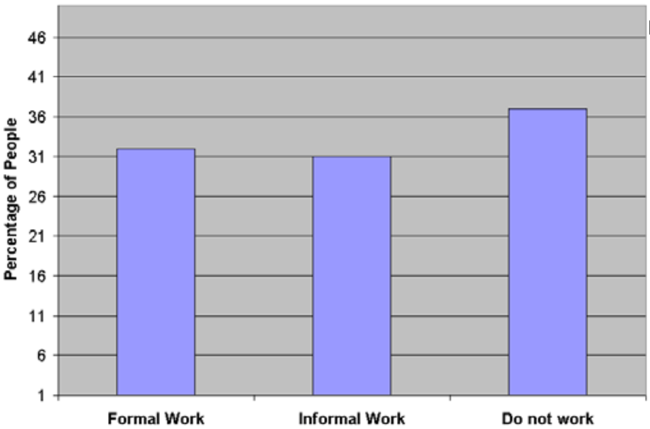
The selected pilot area covers two neighborhoods (Antônico and Centro) within Paraísopolis, a favela with approximately 20,000 households in the middle of São Paulo. This target area includes 4,365 low income households and businesses (of which 60 households had small home businesses and 423 were stand-alone commercial enterprises of varying sizes and types of services/sales).

Like most other favelas, Paraísopolis is an informal community which lacks many municipal services and is home to families that migrated from rural areas over the years. Located in a large ravine, Paraísopolis has a physically challenging geography and is surrounded by middle- and upper-income residential areas.

The community was serviced by inadequate and unreliable supply of power due to low efficiency transformers and undersized non-standard cables. Connections to households and commercial establishments was found to be illegal. Internal home wiring was in very unsafe conditions leading to fires and electrocutions. Appliances and lighting used way too much energy and were not well maintained. Side streets, alleys and parks had no public lighting, leading some people to install their own street lighting outside their homes, which they left on 24 hours a day, since there was no cost to doing so.

Socio-economic conditions





no work

Although the land is publicly owned, the Paraisopolis households have occupied it for over 50 years and the São Paulo city government is currently implementing a land tenure program to register residents and transfer title to them.

As a first step in the regularization program which legalizes the electrical connections, AES Eletropaulo contacted community leaders to work with them on the scope and scale of the project. The utility then held a series of community meetings to educate residents about the program, bill payment, their energy consumption and measures that could be taken to reduce electricity usage.

Identifying, registering and numbering the individual households and businesses was sometimes a challenging task given the narrow, winding streets and alleys; the fact that multiple families often live in a single home; the lack of street names; and parallel registration efforts being made by the municipality and other service companies.

Community involvement

Fifteen community campaigns were carried out over several months and were supplemented by door-to-door visits by community "agents" hired by AES Eletropaulo, and by utility staff to each household both pre- and post- regularization. As residents previously did not have to pay for electricity (except in some cases to get their illegal connection), these campaigns were important to educate consumers on the importance of paying, understanding their electricity bill, and implementing efficiency measures that could be undertaken to reduce co

The electric utility AES Eletropaulo undertook the registration of all customers and numbering of the houses. Mini-audits were conducted by Technolight in more than 4.000 houses, and in 70 commercial enterprises, and finally a customer satisfaction survey took place.

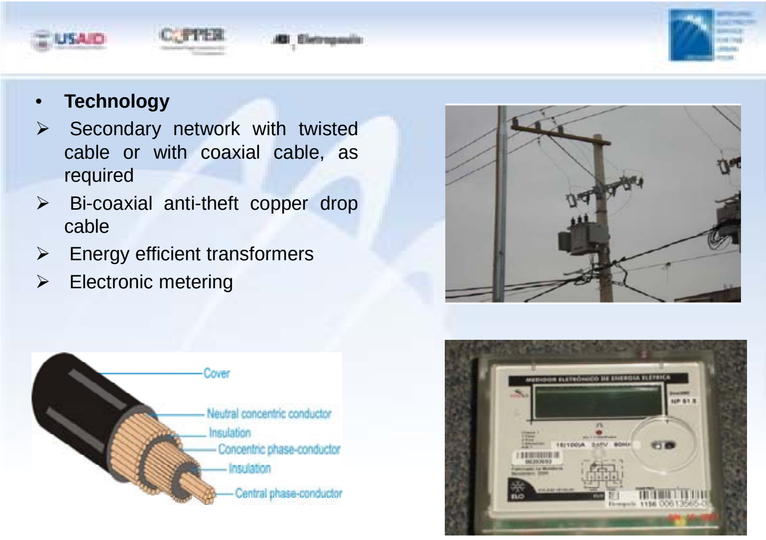
Upgrading of the distribution network

Under the project, the distribution network was also upgraded and households and businesses were metered. The households were not charged a connection fee and any debts owed were forgiven. A key component of the SELR program was the use of new technologies and techniques to reduce theft and improve the energy efficiency and reliability of the distribution network, in addition to improving the energy efficiency of appliances and lighting, described in a next section. The network upgrades included the following:

- Using bi-coaxial cable in the new service drop to each individual meter.

- Introducing electronic metering for large commercial consumers to allow easy disconnect or "social cutting" in the case of non-payment. 475 electronic meters with remote control were installed.

- Replacing 12 conventional and overloaded distribution transformers with energy efficient transformers.



Actions to reduce the consumption of costumers

- Replacement of 9.588 incandescent lamps, ranging from 40 to 200W, with Compact Fluorescent Lights (CFL). This saved on average 38 kWh per month in each household.

- Replacement of 497 old high power consuming refrigerators to high energy efficiency models, among the poorest households. The old models consumed as much as 100 to 150kWh/month. The replacements meet Class A, the highest energy efficiency label based on the Procel standard, the Brazilian national electricity conservation program within Eletrobras, and are rated at 23kWh/month for a 300 liter volume. The average measured savings were 48kWh/month/customer. Old refrigerators were removed for recycling and professionally removing the refrigerants, so that they could not be used again.

- 496 houses rewired to code or better-than-code sized wiring.
(in homes: 2.5mm2 for supply, 4mm2 for water heating)
This saved on average 11kWh/month, but mainly
guaranteed a safe supply of power.

Before After

- Energy efficient shower water heaters saved 18 kWh/month where installed. After the pilot in the roll-out phase to other homes in Paraisopolis and other slums, solar water heating has been installed, where the construction allowed for it.

- 505 public lightning points, which not only contributed to reducing energy consumption in the neighborhood (equivalent savings of 4 kWh/month/home), but provided an improved sense of security.

Given the high level of consumption by households and the urgent need to reduce their usage and enhance the affordability of service, the project undertook a number of measures to increase household efficiency. These encompassed energy audits by Technolight of every household to identify energy efficiency opportunities, the replacement of three incandescent bulbs with efficient compact fluorescent bulbs in each home, the replacement of refrigerators in bad condition, and rewiring by certified electricians of homes with especially poor internal wiring in households that met low-income criteria. An audit of a sample of commercial customers provided the project with the information needed to make recommendations on the energy efficiency measures these customers could adopt to reduce their bills. Because receiving and paying an official document, namely the electricity bill, allows people to show an address and with the proof of payment, allows them to receive credit to buy goods and secure employment. As of April 2009, the net outcome is that a majority, on average 88% over the already improved slums or some 300,000 connected homes and businesses, now pay their bills.

Project budget

USAID, AES Eletropaulo, ICA and its local affiliate, Procobre, worked closely to ensure a coordinated approach to project design and implementation. A ‘responsibility matrix’ was prepared which presented the project components and indicated the organization that was responsible for funding and implementing each task. AES Eletropaulo picked up the bulk of the project costs, including the distribution network upgrades, metering, consumer registration, and with ICA paid for new refrigerators; ICA arranged for the efficient transformers with the support of the manufacturer Itaipu, for the coaxial distribution and service drop cables cost-shared with the wire and cable company Nexans, and the rewiring of households, as well as the preparation of a financial model; USAID covered the community campaign costs, audits of each household and selected commercial customers, purchase of CFLs (cost-shared with AES Eletropaulo), post-project survey, and efficiency recommendations to targeted commercial customers. Total direct project costs were about US$1.8 million at the average rate of exchange over the project period. This amount does not include pre- and post-project activities.

The Outcome

Data on pilot project results are presented in the box on this page. A consumer poll, conducted after project completion and several months of billing, showed that a majority of the regularized families in the pilot area were highly satisfied with their better quality service and the assistance received in improving their household energy efficiency.

Of the 400 households surveyed, 62% rated their overall satisfaction with the project as a 9 or 10 on a scale of 1 to 10. Not surprisingly, this percentage increased to 98% for those who received a new refrigerator and were re-wired and to 80% for those who were only re-wired. The majority (88%) of the households considered the quality of the electricity service to be good or very good after project implementation compared to only 17% before the project. Eighty-nine percent of the households would recommend the program to other residents.

The energy efficiency measures taken in the households and distribution network are expected to yield annual energy savings of over 2 million kWh. On the early stages of the project implementation, bills to households and businesses were even capped at 150 kWh to help households transition to paying for service as well as to educate them about their actual consumption levels and charges once the cap is removed. It is expected that additional savings will accrue (but additional bad debt may also occur) when larger consumers start to experience the true cost of their consumption.

After project implementation, AES Eletropaulo began to collect a significant amount of new revenue from consumers who had not previously paid for their electricity consumption. Annual billing is expected to reach over $920,000; and the bad debt rate hovered around 33%. This bad debt rate is relatively high and is due to the large number of commercial customers with high consumption levels that are unable or unwilling to pay. The bad debt rate is expected to decrease, based on experience in other areas, as AES Eletropaulo implements its ‘social cutting’ program and enforces collections.

However, while survey results show that nearly a third of households took a ‘great effort’ to pay their electricity bill, 56% said that if budgets were tight, they would select to forgo paying this bill. This is a challenge to project sustainability and needs to be taken into account by AES Eletropaulo as it rolls out of the SELR program to hundreds of thousands of additional favela households in São Paulo. A sustained level of dialogue with and education of communities is part of the roll-out plan.

As of April 2009, almost 300,000 illegal connections in over 750 slums in the Sao Paulo area have been serviced and legalized, meaning the quality of life for over 1.1 million people has already been improved. AES Eletropaulo invested to-date Real 97,740,000 in the grid and Real 56,600,000 in energy efficiency, with a pay-back of 1.6 years and a bad debt rate reduced to only 12%.

Summary of pilot	
Measure	**# installed or completed**
Conventional meters and posts installed	4460
Remote meters	475
Pre- or post regularization door-to-door visits by community agents	8594
Community and school events (# events; # attending)	27 events with 4906 attending
Replacement of inefficient incandescent light bulbs with efficient compact fluorescent bulbs (CFLs)	9588 CFLs
Refrigerator assessments completed	2598
Inefficient refrigerators replaced with PROCEL A-rated as needed	497
Wiring safety assessments completed	2433
Rewiring of unsafe internal wiring and fixtures and replacement of electric water heaters	496
Replacement of individual outside lights with public lighting	505 (472 in alleys, 33 in main streets)
Commercial audits and recommendations made	70

The business case

The total investment in the pilot project reached about US$1.8 million. The financial analysis, shown in the table below, concludes that the simple payback is 1.5 years, with a range, depending on optimistic and pessimistic projections of local conditions, from 1.4 years to 2.8 years.

The savings totaled 229,000 kWh/month. The savings per household fully participating in the pilot were 1200kWh per year or a 40% reduction from previous practices. A 50% potential reduction in consumption proved viable.

In addition, streets became safer at night, hazardous conditions in rewired homes disappeared, consumption of power became more affordable and satisfaction in the community was high, and jobs were protected due to safeguarding the economic viability of commercial enterprises.

Table – Financial Analysis of Pilot Project – Paraisopolis

Investments (in Brazil Real$)		Revenues	
1-Assets (utility)		**1- Billing (Collection)**	**Value R$ - First Year**
Customer registration	15,992	Annual post-regularization metered billing (collection)	2,255,439
Electrical project planning	14,722		
Primary distribution network (Poles, cross-pieces, etc)	79,437	Bad Debt rate	32.3%
Secondary distribution network (cables and accessories)	606,675	Minus: Annual Bad Debt	728,238
Contract work on distribution lines	529,492		
Efficient transformers	105,900	Minus: Collections before regularization (2% of billing)	64,443
Conventional transformers	6,310	**Net Revenues**	**1,462,758**
Public lighting	127,758		
Copper Co-axial cables	392,850		
		2 - Subsidies/ Incentives	
Meters (conventional)	185,947		
Meters (remote)	121,800		
Communication network for remote meters	15,000	Tariff subsidies for low income household, based on average consumption	219,176
Sub-Totals	**2,201,883**	**Additional Revenue**	**219,176**
2 – Customers		**3 - Capital Gain**	
Standard material for connection (box, grounding, fuses)	305,550		
EE Refrigerators (replacements)	298,200		
CFL Lights (material and labor)	79,421	Avoided costs due to saved energy (based on sell tariff)	659,939
Home re-wiring	383,134	**Sub-Total**	**659,939**
Door-to-door visits, community campaigns, lectures at schools…	62,134		
Mini household audits	40,280		
Sub-Total	**1,168,719**	**TOTAL REVENUES (First year)**	**2,341,873**
3 – Other investments		*Note: Total Revenues – 10 years*	15,029,343 *NPV: 12,877,462*
Commercial audits	57,630	**PAYBACK (years)**	**1.5**
Consumer survey	67,000		
Sub-Total	**124,630**		
TOTAL INVESTMENTS	**3,495,233**		

Total number of customers considered	**4,365**
Monthly energy savings	**kWh/month**
Public lighting	19,258
Household CFLs	165,497
Refrigerators	23,856
Re-wiring	5,456
Efficient transformers	6,151
Showers	8,928
Total monthly savings	**229,146**

Conclusion

It is clear from the outcomes and the financial analysis, even if conditions and bad debt would worsen, that the pilot project in Brazil shows that the approach to regularize the electrification of the slums, by involving the community, by addressing safety and energy efficiency, by creating a broad partnership of public and private stakeholders, is correct. It is therefore worthwhile replicating. In fact, the Brazilian regulator ANEEL proposed a program to replace as many as 10 million inefficient refrigerators in the country. AES Eletropaulo has also added the replacement of the electric shower water heating systems by solar water heating where building conditions permit, further reducing the demand on power and the monthly utility bills.

The unique partnership created to develop and implement the pilot project, as described in this paper, could serve as a model for other communities, not just in Brazil, but throughout the world. AES Eletropaulo and other Brazilian utilities are continuing programs to properly electrify poor urban and per-urban areas, and to reduce the technical and commercial losses of electrical energy. For example, by April 2009, as a result of the pilot and its business case, AES Eletropaulo has already implemented the lessons learned, technical, social and environmental, into close to 300,000 homes and businesses with their own capital investment of some US$90,000,000 to-date yielding a payback of 1.6 years on average.

The project partners remain available to provide guidance with the adaptation and customization of this pilot to local conditions and full-scale replication, to help with the dissemination of these and other results of similar projects around the word, and to provide advice on partnerships and financing.

Indeed, key requirements to success are strong commitments from the local community and electric utility, the creation of a (preferably public-private) partnership to scope out, support and implement all required actions that have promise of making a positive difference in the quality of life and benefit all stakeholders. Finally, these partnerships are to successfully seek and obtain the necessary financing, internal and external.

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Solar Water Heating in South Africa

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Abstract

South Africa has large coal reserves, which have led to low-cost electricity. This has stimulated the development of energy-intensive industries, including mining, mineral extraction, and processing, but has thwarted incentives to save electricity. The 2002 World Summit on Sustainable Development held in Johannesburg created awareness of the need for clean energy and energy efficiency.

Unparalleled economic growth and the electrification of 3.5 million homes in the past decade have led to hitherto unprecedented power shortages. This dilemma provides an impetus for energy efficiency and the use of renewable energy. This paper will discuss national strategies aimed at reducing electricity demand and improving energy efficiency while reducing green-house gas emissions.

In most South African homes, water is heated by coal-generated electricity in a 'geyser', where it is then stored for later use. This practice provides an excellent opportunity for using renewable energy. In solar-thermal panels or evacuated tubes, water can be adequately for domestic use in the summer months. During cloudy days or winter months, water may be pre-heated, drawing electric power only to increase the water temperature to a recommended 55°C. An even lower setpoint of 49°C Is used in the United States to save 15% compared to 55°C. The average factory setpoint in the United States has nlow been reduced to 49°C. Prior to 1984 the factory setpoint was 60°C. The decrease to 49°C was motivated by anti scalding limits adopted by many states, led by Florida and Washington.

The paper investigates the merits of solar-water heaters in South Africa and gives reasons why little progress has been made in the past decades. New initiatives to promote solar-water heaters are outlined based on international strategies which have been effectively for large-scale use of solar-water heaters.

Introduction

Over the past decade or two, South Africa has actively been engaged in improving the living conditions of previously disadvantaged South Africans. In poor households, energy costs account for a large percentage of a household's budget. For sound political, social, and economic reasons, the price of electricity has been kept as low as possible. This did, however, limit the extent to which capital could be raised for increasing generating and distribution capacities. During 2005, when some outages were caused by low reserve capacity and a combination of faulty conditions, it became abundantly clear that South Africa could not wait any longer before increasing its generating capacity. At times, it became necessary to resort to load shedding. This practice sent a clear message to commerce, industry, and the general public that a country-wide energy supply shortage was imminent.

It was easy to blame government, the national utility company, municipal distributors, and a variety of other organisations and people for this supply shortage. Early warnings had allegedly been ignored, but the fact remained that South Africa found itself in a serious situation. Once an exporter of electricity, South Africa was now faced with the problem of not being able to offer a secure power supply to new industries and would-be foreign investors. Planned increases in generating capacity do not address immediate supply problems. Government has therefore resorted to urgently promoting energy savings through demand side management (DSM), improving energy efficiency (EE), and promoting alternative, renewable sources of energy. It therefore comes as no surprise that the government has set a target for renewable energy to contribute 5,000 Gigawatt hours (GWh) – ie/ betweem 2 and 4 percent -- of total energy consumption by 2013. South Africa annual electricity use in 2006 was 211,000 GWh. The growth rate from 1986 to 2006 was 2.45% per year. With no DSM programs, the SA annual electricity use in 2013 would be 250,000 GWh, and 2% of the estimated usage in 2013 would be 5,000 GWh and not 10,000 GWh (which would represent 4% of estimated usage in 2013). Solar water heating could contribute up to 23% of the savings required by this target.

Eskom, South Africa's main utility, is supporting this drive through the large-scale introduction of solar water heating as it is one of the most effective renewable-energy sources available.

Conventional ways of heating water in South Africa

Most houses in South Africa have an electrically-heated hot-water cylinder, commonly called a 'geyser', which provides hot water. Since very little energy is used for space heating, the geyser is normally the largest single consumer of electricity in the home, as shown in Table 1.

Table 1 : Average electricity consumption in South African homes [1]

Application	Suburban (%)	Township (%)	Informal settlements (%)
Water heating	**46**	**30**	**18**
Cooking	15	33	14
Fridge/freezer	15	11	24
Lights	11	13	28
Space heating	4	2	4
Washing clothes	2	5	0
Other appliances	6	5	11

Source: Harris et al. 2008.

The average monthly suburban residential electricity usage for water heating is 46% (see Table 1). This has motivated a number of municipalities to introduce peak-demand control (i.e.,"ripple control") to remotely turn off electric water heaters during peak electricity demand periods. "Ripple control" enables geysers to be switched off remotely during the peak demand periods between 06:00 and 08:00 in the mornings and 18:00 and 20:00 in the evenings.

The reason for going to such lengths, which are still electricity-bound, is because South Africa has very low supplies of natural gas and bottled gas, which are both relatively expensive and cumbersome. Hence, one finds only a small number of gas hot-water cylinders.

A paper presented by one of the authors at the EEDAL 2006 conference outlines the hot-water load in South African households and the effect of controlling it. [2] The graph in Figure 1 shows a typical load of domestic geysers which was measured in a typical municipality.

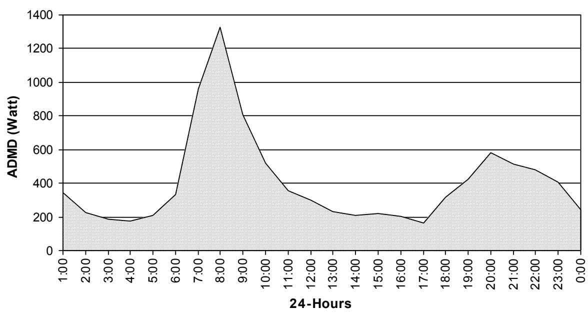

Figure 1: The ADD of the controllable load, hot-water cylinders, of a municipality [2]

The findings reported in a paper presented at the Domestic Use of Energy Conference in 1998 [3] show that 660 W can be saved per geyser during the time of maximum demand in the evening, and about 1000 W can be saved during the morning peak. This means that a decade ago, when there were about 2,4 million geysers installed in South Africa, approximately 1,6 GW could potentially have been shifted away from the evening peak and 2,5 GW from the morning peak. The use of solar water heaters (SWHs) can, of course, reduce the peak load by the same amount, and at the same time, SWHs can also reduce the total energy used. Load control cannot do this. Replacing electrical geysers with SWHs in South Africa, with its an abundant sunshine, will then save approximately 6 kWh per day per geyser, or potentially about 5 000 GWh per year if most geysers were replaced with SWHs.

SWHs, although proven and feasible, are found in low numbers, mostly remote areas lacking electricity. Authorities have only very recently prioritized solar hot-water heating. A logical starting point is the government-subsidised economic housing development scheme. At present, local manufacturers only make approximately 300 000 units annually. They are inexpensive, small 150-litre units which will supply hot water, provided that the sun shines every second or third day. These obvious limitations have led to the development of hybrid options.

Since 2009, South Africa has also been experiencing an energy shortage, implying that peak load shifting by itself does not solve the country's entire problems. According to the literature[1-15] numerous utility and statewide incentive programs in the United States have been implemented to replace standard showerheads with low-flow energy efficient units (6 to 10 Litre per minute Lpm) [12] In one such program, Bonneville Power Administration purchased over $1.2 million worth of showerheads, aerators and adapters for Seattle City Light and other regional utility customers between 1992 through 1995. The program installed 300,000 units in single-family homes and reported an average saving of 300 kWh per year from showerheads, and 15 kWh per year from bathroom faucet aerators in single-family residences, representing a 3% savings in average electric hot-water energy savings. A similar study in Wisconsin reported an impact of 226 kWh (equivalent) per unit from showerheads, and 56 kWh (equivalent) per unit from faucet aerators in residential installations. The study[13] reported the incremental costs to the user were R22.5 per showerhead and R5.0 per faucet aerator. San Diego Gas and Electric Company with co-funding from the San Diego Water Authority, ran a successful program distributing as many as 84,600 showerheads between 1990 and 1992[14]. Another study claims annual household savings up to 17,000 gallons of water with electric savings from showerheads of 237 kWh[12].

As a demonstration project to the public, the CPUT installed 50 aerated shower roses in the same number of apartments in Cape Town. Early results suggest a saving of 16 per cent of residential water usage and a corresponding average monthly electricity bill saving of 7 per cent. Tests on a Measurement and Verification basis are continuing by Eskom.

Need for efficiency and solar water heating in South Africa

Apart from experiencing a marked shortage of electricity in the country, the present government has become attuned to global trends, including encouraging the use of efficiency and renewable energy for environmental reasons. The 2006 World Summit on Sustainable Development held in Johannesburg had a big impact on governments around the world, and the host nation was no exception. The world forum did help tremendously to promote initiatives such as energy efficiency and the switch to renewable energy. Nations attending the World Summit on Sustainable Development, held at Johannesburg from 26 August to 4 September 2002, agreed to a plan of implementation that included ways to eradicate poverty. Quoting key passages from page 12 of the report, the nations would:

Page 12, item 10. Strengthen the contribution of industrial development to poverty eradication and sustainable natural resource management. This would include the following actions at all levels

(e) Provide support to developing countries for the development of safe low-cost technologies that provide or conserve fuel for cooking and water heating (such as water saving showerheads and aerators). Comment: Water and energy efficient showerheads and aerators can save 10% of water heating electricity use.

Page 23: (i) Accelerate the development, dissemination and deployment of affordable and cleaner energy efficiency and energy conservation technologies, as well as the transfer of such technologies, in particular to developing countries, on favourable terms, including on concessional and preferential terms, as mutually agreed.

Page 106: "44. The following were highlighted as important issues in the various areas.

- The importance of energy conservation and efficiency and the need to integrate these into existing policies and consumption patterns.

- The importance of clean energy and health linkages.

Page 107: "45. The following main energy objectives were also highlighted :

- *Energy for poverty alleviation.* …..
- *Energy conservation and energy efficiency.* …..Indicative energy efficiency goals were mentioned as useful instruments for reaching energy efficiency.
- *Promotion of renewable energy.* Many agreed that a target of increasing modern renewable energy sources to 10 per cent of the energy mix by 2010 or 2015 is reachable and useful. ….
- *The use of policies and economic instruments.* Many mentioned the need to reduce subsidies that do not promote clean energy technologies or renewable energy.

It is clear from the above citations that solar water heating should be promoted and implemented in South Africa as far as practically and financially possible.

Although South Africa cannot claim to be a country that has implemented many initiatives to ensure wise and effective use of energy, there is a noticeable increase awareness and evidence of change in recent years. The reasons that energy efficiency and renewable energy have not been effectively promoted in the past are a) energy is relatively cheap in South Africa and b) South Africa has always had large energy reserves in the past. This has attracted investments in energy-intensive industries such as mining, and mineral processing.

Another reason why energy has to be used wisely together with a switch to renewable energy wherever possible and economically viable, is because South Africa is experiencing a serious power shortage. Twenty years ago South Africa had a large generating reserve margin of about 40%, but this has steadily declined to a critical generation deficit over the past decade.

- Over the last 10 years, the reserve margin in South Africa has been steadily declining due to increasing demand and only limited additional generation capacity.
- In 2006, there were incidents of regional load shedding due to network inadequacies and insufficient regional generation resources.
- In early 2007, the South Africa's first incident of load shedding occurred due to the inability of operational generation capacity to meet electricity demand.
- After successfully navigating the winter peak demand period (~37 GW), during the generation maintenance season in October, November, and December 2007, there were several incidents of load shedding.
- In January 2008, there was load shedding almost daily for 2 weeks, leading to a Government declaration of a national power emergency and a plan of action on 25 January 2008.
- This had a severe impact on production levels in all sectors of the economy and dented the image of not only Eskom but also South Africa as a whole.

These power outages occurred because of generating, transmission and distribution faults, and plant maintenance. South Africa's reserve margin of the generating capacity remains insufficient and almost non-existent at times. Although decision-makers, government, and the national utility are blamed for the power outages, commerce, industry, and the wider public now realise that the only way out of the present predicament is for everyone to use energy more efficiently. However, the savings needed to achieve a sufficient generation reserve margin of around 10 percent in the medium term is difficult to achieve. Only 2 to 3 percent was achieved by the end of 2008. It is clearly not enough, so an aggressive conservation programme has been developed in an effort to intensify energy conservation. This programme is needed for at least 5 years while the generating capacity is increased. It is hoped that by that time, South Africans will realise that energy conservation and renewable energy sources are imperative to conserve available resources and limit damage to our environment.

The power conservation programme uses the following methods in an effort to sustainably meet energy needs:

- Financial incentives to reduce the use of energy by the introduction of stepped electricity tariffs based on historic baseline consumption,
- Communicating to industry and the public the need to conserve energy by means of aggressive marketing, advertising, discussion, and consultation,
- Soliciting co-operation from large electricity users
- Subsidising energy conservation projects, e.g. the installation of water and energy efficient showerheads, aerators, dishwashers, clothewashers, and SWHs, and
- Cogeneration and the introduction of feed-in tariffs.

It is clear that the above factors attempt to create the environment in which installing efficiency measures and solar-water heaters is an obvious step for the consumer, government, and the electricity supplier. Nevertheless, there are a number of factors hindering the widespread introduction of efficiency and SWHs.

Perceived resistance to using SWHs

The annual solar radiation in South Africa ranges from 1450 kWh/m^2/yr to 1950 kWh/m^2/yr, as shown in Figure 2, which is appreciably more than the radiation in Europe, for example.

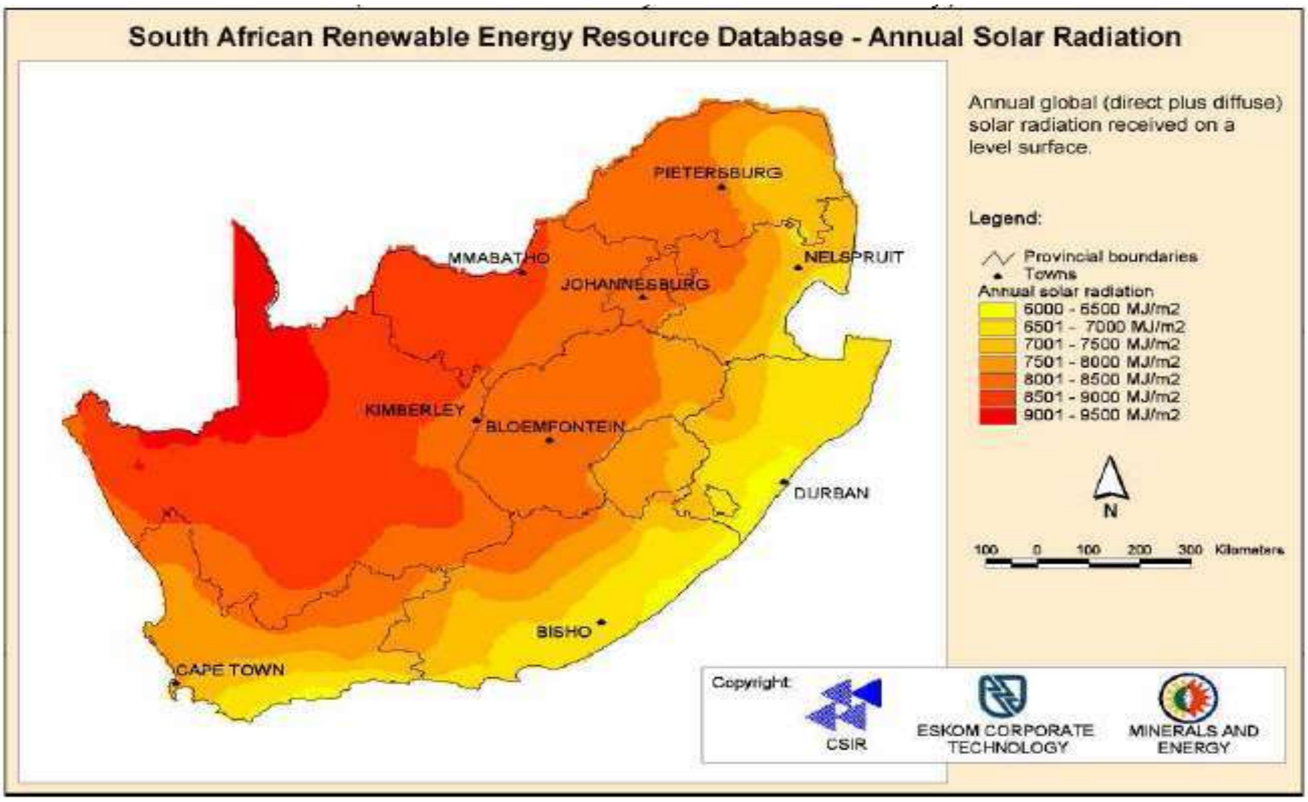

Figure 2: Annual Solar Radiation in South Africa [4]

In spite of an abundance of sunshine, only a very small percentage of South African households have SWHs. There are currently an estimated 4.2 million conventional geysers in South Africa [5]. Unfortunately, the exact number of SWHs is unknown, but industry has been installing between 4000 and 7000 units per annum since 2006. A fair estimate appears to be 16,500 SWHs, or only 0.4 per cent of the total.

Many countries with much less sunshine than South Africa, such as Israel, Germany, Australia, and the United States, all use SWHs extensively. Despite a 20 percent government subsidy for the cost of installing SWHs, South Africans have neen slow in adopting SHWs for the following reasons.

- The low electricity tariffs in South Africa make it difficult for renewable energy to compete.
- This low cost of electricity translates to a very long (10 to 15 years) payback period for those installing SWHs.
- There is a limited number of manufacturers in the country.
- Perceived low quality due to the unfortunate malfunctioning of SWHs in the 1980's when non-frost resistant materials were used.
- Manufacturers now need a stamp of approval by the South African Bureau of Standards (SABS), who took years to test and publish their specifications.
- There are limited testing facilities in the country.
- High cost of SWHs prevails, due to low production volumes and low demand.
- Shortage of qualified manpower to install SWHs on a large scale.
- Present incentives are insufficient to motivate the public to install SWHs.
- SWHs are perceived to blemish the architectural appearance of the house.

Lessons learnt from Israel

Gershon Grossman, Ofira Ayalon, Yifaat Baron and Debby Kaufman claimed in 2007 that [6] :

> "In **practice, despite the availability of sunlight in Israel, the use of solar energy to produce heat, amounts to only one tenth of its potential and is utilized mostly for heating water at private dwellings. A government regulation, enacted under the planning and construction law in 1980, requiring the placing of solar water heating systems in new private dwellings, greatly advanced the usage of solar energy. This regulation along with the positive, cumulative results that followed has placed Israel first in the world in the use of solar energy per capita (3% of the primary national energy consumption). There is no enforcement mechanism directed towards commercial and public institutions. There is no reference in the law to the industrial sector, which consumes process heat for producing hot water or steam (some in relatively low temperature).** As can be seen, it is possible to further lower the cost of solar thermal industrial systems for most of the business sector. Yet, there is still only marginal use of solar heat systems in industry when compared with the domestic sector. One reason for that is, without a doubt, the Israeli tax system. A private consumer, who uses a sun-heated water tank, saves his/her out- of-pocket electricity expense while the business consumer saves on his taxed expense. Combusting polluting fuels to produce heat is considered a deductible business expense, but investing in a solar-thermal system will be amortised (and deducted) over a ten year schedule, making the return on investment not economic."

Gershon Grossman [7] reported that the solar collector and water heating industry continued to improve its products for export, while maintaining its domestic business. With approximately one million systems installed in Israeli homes, the domestic replacement market alone accounts for about 100,000 systems per year. This makes Israel (present population of 6 million) the world leader in per capita use of solar energy. Israel's National Infrastructure Ministry estimates solar panels for water-heating already satisfy 4% of the country's total energy demand [8].

Incentives to increase efficiency and the use of SWHs in South Africa

The government now has a programme in place targeting the widespread efficiency and use of SWHs. The authorities intend to purchase and install 12 000 units to stimulate demand and to boost the hands-on training programmes of installers (consider including efficient showerheads and aerators). Other relevant aspects, discussed during the SWH workshop of the annual Domestic Use of Energy (DUE) conference, held in Cape Town from 15 to 16 April 2009, will be referred to in the presentation.

With reference to Table 1, two main types of SWH are being promoted [1]. Small (50-litre) stand-alone SWH, intended for economic housing schemes and for areas that are not yet connected to the electricity grid, as shown in Figure 3. They are close-coupled, roof-mounted solar collectors with a horizontally-mounted storage tank located immediately above the collectors. The potential use of this system is large, even in South Africa, which leads with 86 percent of its population having access to electricity. In most African states this figure is less than 10 percent.

Figure 3 : Affordable SWHs for economic housing in Somerset West near Cape Town

Larger, more sophisticated 200-litre SWH with timers, in which electricity may be used as 'top up' to reach the required, pre-set temperature at pre-selected times [9]. Such solar-electric hybrids may be a combination of different collectors (panels or evacuated tubes) and conventional geysers. An inexpensive prototype was developed and tested by the Energy Institute [9]. Extended tests over 10 years in Cape Town led to an average monthly savings on the electricity bill of 36 per cent. The electric power supply could be switched off entirely from November through to May each year. The pay-back period in 2003 was 2.5 years. This system is now being rolled-out more widely, but costs have gone up appreciably.

Other overseas SWH systems to consider are one- or two-panel (or evacuated tube) systems with dedicated 200-litre or 440-litre solar storage pre-heat tank in series with 200-litre conventional geyser. This system is prevalent in the United States and Germany and can be either passive open-loop thermosyphon, active closed-loop glycol, open-loop direct forced circulation, and closed-loop drainback systems. [12]

South Africa does have a subsidy system in place where homeowners receive a subsidy if they install a solar water heater. The source of the funding for this subsidy is the saved capital cost of providing new generating capacity. Table 2 shows the cost of building new power stations and compares it with the subsidy given per kWh saved for efficient showerheads, aerators, and SWHs. In 2007, the average cost of installing SWH in South Africa was approximately R1950 to R4950 (Prasad [12].. The average cost is R35 for efficient 6 Lpm showerheads and R5 for efficient 4 Lpm aerators (Niagara Conservation 2009) [13]. A subsidy of R 3500 per kW is available for installing SWHs. A subsidy of R35 for efficient 6 LPM showerheads and R5 for efficient 4 LPM aerators should be made available. This amount also applies to other DSM initiatives such as efficient showerheads and aerators. The subsidy is calculated according to the efficiency and expected kW demand saved for the installation and ranges between R1950 and R4950 per SWH installed (R10 = US$1, approximately).

Table 2 : Cost comparison between Installing SWHs; Subsidy for DSM projects; and Building new power stations [10] and [11]

Power source	Capacity (MW)	Cost (Rand)	R/kW
Open Cycle Gas Turbine	1 000	5,000,000,000	5 000
Coal-fired (Medupi)	4 500	78,000,000,000	17 333
Nuclear	3 600	120 000 000 000	33 333
DSM subsidy – Eff. showerheads 6 Lpm Efficient aerators 2 Lpm		 35 5	3 500 35 5
SWH subsidy per geyser		1 950 to 4 950	3 500 R/kW of solar?

The DSM and SWH subsidies from the national utility are 30 to 80 percent less than the cost for new fossil-fuel supplies (see Table 2), With expected electricity demand shortages expected to last 5 years, the cost of SWH is especially attractive Even with the subsidies, the initial cost and installation of a SWH is high compared to the cost of energy saved by the customer, since the subsidy does not cover the cost of installation entirely. The cost of electricity in South Africa has been very low because very little was spent on increasing the generating capacity. This has meant that the selling price of electricity does not reflect the actual cost of the electricity.

The way ahead for SWHs in South Africa

The need for energy efficiency renewable energy will only increase as time goes on due to environmental issues and the depletion of conventional energy sources. This will increase the cost of conventional energy. At the same time, technological development and mass production will decrease the cost of energy efficiency and renewable energy measures. Economic and environmental pressures will soon guide and eventually drive the adoption of energy efficiency and renewable energy. Without these pressures, it is already clear that energy efficiency and SWHs in South Africa are economically viable, even if they are not yet being implemented on a large scale. In the short term, however, there is considerable pressure to use non-conventional forms of energy due to the shortage of generating capacity in the country; but, the payback period for the consumer for SWH is about 10 years and less than one year for efficient showerheads and aerators. The payback for SWH period is a bit long, but it will decrease because the price of electricity will rise sharply during the next few years. This increase in energy pricing will likely accelerate the introduction of energy efficiency and SWHs in many homes. There are obstacles to overcome, but there are too many forces nationally, and internationally, encouraging South Africans to accelerate the widespread implementation of energy efficiency and SWH technologies.

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On-line use rate meters for solar cookers and "Hot Box" heat retention cookers in Developing Countries: Concept, tests, verification of output data and field test methodology

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Abstract

A recurring question: are solar cookers really used? Use rates, in particular for "non-fuel" appliances such as solar cookers and "Hot Box" heat retention devices, are difficult to establish. Moreover, use rate figures from conventional monitoring techniques have often been subject to doubt. To arrive at more reliable data, metering devices for the use rate of solar concentrators, of solar box cookers and of Hot Box cookers have been developed in the framework of a GTZ/ProBEC project and are presented here.

These "use meter" devices record:

- the evolution of food temperature, ambient temperature and irradiance, for solar cookers,
- and the evolution of food- and ambient temperature, for Hot Boxes.

Automatic data evaluation yields the number of cooking cycles, the corresponding cooking time, the quantity of food cooked, the reduction of fuel consumption and an estimate of GHG emission compared to other cooking techniques.

Metering results were compared with actual conditions and found to be in reasonable agreement.

The methodology of a field test to be conducted is presented.

Keywords: Developing countries; cooker use metering; tests.

Topics:

5. Focus on Developing Countries and Economies in Transition:

10. Programme Monitoring & Evaluation

Introduction

Most of the GHG emissions related to domestic cooking are caused by the use of traditional fuel/appliance couples in developing countries, such as wood-burning 3-stone fireplaces. The main reasons for this dominance are high number of users, low efficiency and incomplete combustion emitting potent GHGs.

The replacement of traditional stoves and fuels by cleaner fuels and more efficient cooking devices is one obvious potential solution; another being "non-fuel" appliances such as solar cookers and "Hot Box" heat retention devices. A recurring question remains: are these devices really used ? Use rate figures from conventional human monitoring techniques have often been subject to doubt. To arrive at more reliable data, metering devices ("use meters") for the use rate of solar concentrators, of solar box cookers and of Hot Box cookers have been developed in the framework of a GTZ/ProBEC project and are presented here.

What is a use-meter?

A use-meter is an automatic recording device for the use of appliances. It is meant to be read out at more or less regular intervals, like an electricity meter. Automatic evaluation software calculates use rate, load, number of successful service cycles, and allows – by comparison with baseline data – to estimate impacts in terms of energy savings and GHG emission reductions. Carbon incentive schemes can be based on use-meter data.

The details of the Solar cooker Use Meters (SUM) have been published in Grupp et al. [1]. A similar device for the recording of temperature in wood stoves has been developed and tested by Ruiz-Mercado et al. [2].

Application 1: Hot Boxes

A Hot Box or Hot Bag is a heat retention cooking device. It cannot be used as a stand-alone system to replace other cookers, but uses residual heat to complete cooking or to keep food warm in the time span between cooking and serving. The cooking process is started on any stove and after some time of conventional cooking, the pot is removed and placed in a Hot Box. After this, the cooking process is finished on a stove if necessary. Ideally, the food can be eaten without using any more fuel. The principle is that the pot is placed in an insulated container.

Hot Boxes come in many variations; they can be zero-cost devices e.g. holes in the ground filled with straw, or stylish manufactured devices, double-purpose chairs, blankets-in-buckets…

They are particularly adapted to the following conditions:

- Food needing long simmering times
- Food preparation taking place several hours in advance
- Cooking processes needing no constant supervision.

Hot Boxes have specific drawbacks:

- They can pose a sanitary risk if food is forgotten inside for too long.
- Acceptance can be low - anecdotal evidence from war-torn countries like post-WW2 Germany shows that Hot Boxes are used when energy is scarce, but quickly discarded when commercial energy becomes available again.

Hot Boxes can cause fuel savings and GHG emission reductions only if they are used. A way to establish use rates objectively and on-line is the Hot Box Use Meter (HUM) developed in the German framework of this project. HUM results can serve as a basis for carbon incentives. The validity of the corresponding assumptions will be checked in a field test.

The Hot Box Use Meter (HUM) physics for the determination of pot load

The objective of this exercise is to determine the mass of food in a pot placed in a Hot Box, by measuring the evolution over time of the temperature of the food (more precisely, the temperature of the pot bottom). It should be noted that the following presentation is somewhat simplified but sufficiently detailed for the present purpose.

If a “thermal mass” Thm defined as:

$$Thm = m * cp \quad (1)$$

with m the mass of food and cp the specific heat, is cooled from temperature T1 at time t1 to temperature T2 at time t2, the corresponding thermal energy difference E can be written:

$$E = E1 - E2 = (T1 - T2) * Thm \quad (2)$$

With E1 the thermal energy at time t1 and E2 the thermal energy at t2. The corresponding power P can be written:

$$P = E / t \quad (3)$$

with t = t2 – t1.

If this thermal mass is placed in an insulated container (e.g. a Hot Box) with a linear loss coefficient K, the power P of the heat loss is:

$$P = K * ((T1 + T2) * 0.5 - Ta). \quad (4)$$

Thus, using eq 2 to 4 :

$$(T1 - T2) * Thm / t = K * ((T1 + T2) * 0.5 - Ta) , \quad (5)$$

or :

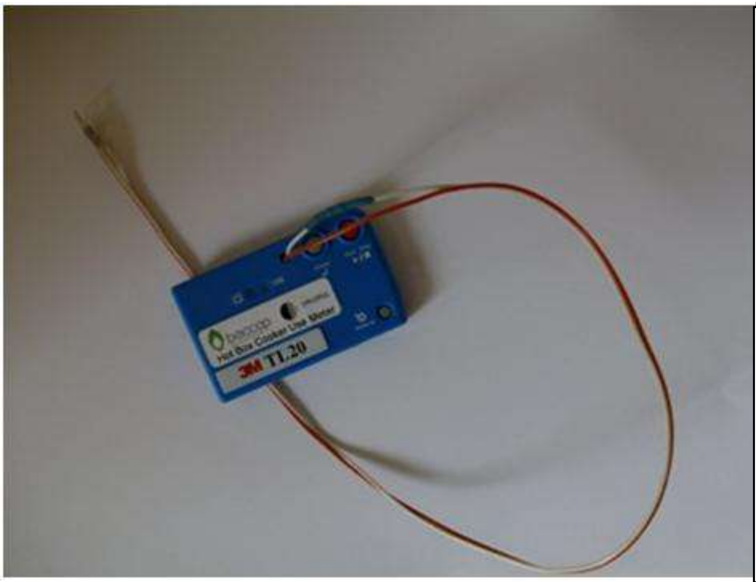
$$Thm = K * ((T1 + T2) * 0.5 - Ta) / ((T1 - T2) * t). \quad (6)$$

Equation 6 is used for the determination of Thm.

The Hot Box Use Meter (HUM)

The HUM can be compared to a conventional meter (such as electricity or water meters), with the one great difference that it is not meant to *make users pay for the energy they consume*, but *pay them for the energy they **don’t** consume.* To this end, a HUM has the following functions:

- to measure automatically the parameters needed for the determination of pot load (see eqs 1 to 6 above),
- to store the data and the times and dates in a memory,
- to transfer these data into a laptop computer for automatic evaluation.



The HUM is based on a mass-produced low-cost platform (the 3M TL20 data logger). It is fitted with a NTC external temperature sensor, placed under the pot bottom.

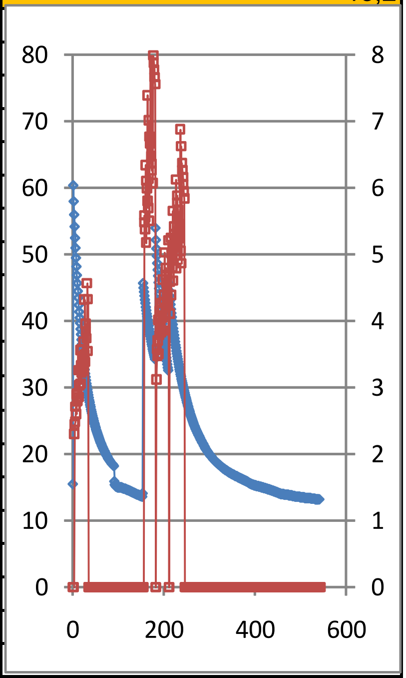
The Hot Box “Wonder Bag”: note at the bottom the HUM in the read-out position. In normal use, the HUM is protected by a belt.

Example of HUM results and comparison with “real” values

Automatic evaluation software has been developed in the framework of this project. A selection of inputs and outputs is shown on the next page.

The yellow fields denote inputs, the orange fields outputs.

The diagram shows on the X-axis: time in 15 minute intervals; on the Y-axis: pot bottom temperature (blue data points): on the Z-axis: thermal mass in litre water equivalent (red data points).

HUM hot box use meter	
input parameters	**Meter output**
Specific hot box savings	Number of cycles
0,50	4,0
Linear loss coefficient W/K	Average thermal mass (kcal)
-0,5	4,82
Mth empty pot:	Average net thermal mass (kcal)
0,34	4,48
	Total safe use duration (hours)
Cooking input parameters	0,25
Net heat input (MJ/mp)	Per cycle use duration (hours)
1,21	0,06
Mth/mp:	Corr per cycle use dur (hours)
0,5	0,06
Max p cycle use duration (h)	Meal portion equivalent
2	0,50
	Wood savings MJ/mp
Evaluation inputs	6,05
Logger interval (min)	Total kg CO2 saved
15	0,30
Lower Limit T for Mth calculation	CO2 Carbon value bonus $
30	0,006
Upper Limit T for Mth calculation	min indoor ambient Temp
80	13,2
Mth minimum for average:	
2	
Mth maximum for average:	
10	
CO2 Carbon value bonus $ / ton	
20	
3 Stone fire efficiency	
0,1	
T safety minimum	
60	
GHG (CO2eq)	
wood 3stone	
kg CO2/mp	
0,8	
non-sustainable wood	
0,5	
kg nonCO2/mp	
0,2	
Total	
0,6	

The measured value for the average net thermal mass was 3.17 kcal which is about 30% off (mainly due to the thermal mass of the hot box which was not included, and the unavoidable variation in the linear loss coefficient of a soft hot box). The number of cycles was 4.

Application 2: Solar Cookers

In analogy to the Hot Box Use Meter (HUM) (see above), a solar cooker use meter (SUM) is a device for the automatic metering of solar cooker use. It logs date and time, pot bottom temperature, ambient temperature and solar irradiance (by a photodiode). Again, the change rate of the pot content temperature in comparison to the net input respectively output power (calculated using the linear collector equation) allows for an objective determination of thermal mass over time. This yields a reliable estimate of the quantity of food cooked in the metered solar cooker, of fuel saving and GHG emission reduction caused by the use of solar cookers compared to 3-stone/wood or other fuel/appliance couples.

The basic physics involved is described in Grupp et al. [1]. It is not reproduced here.

The SUM in this project phase has been developed for field tests, in two versions, corresponding to two solar cooker models available in RSA: the SunStove solar box cooker, and the K14 solar concentrator.

The K14 solar cooker fitted with the SUM.

The SunStove SUM

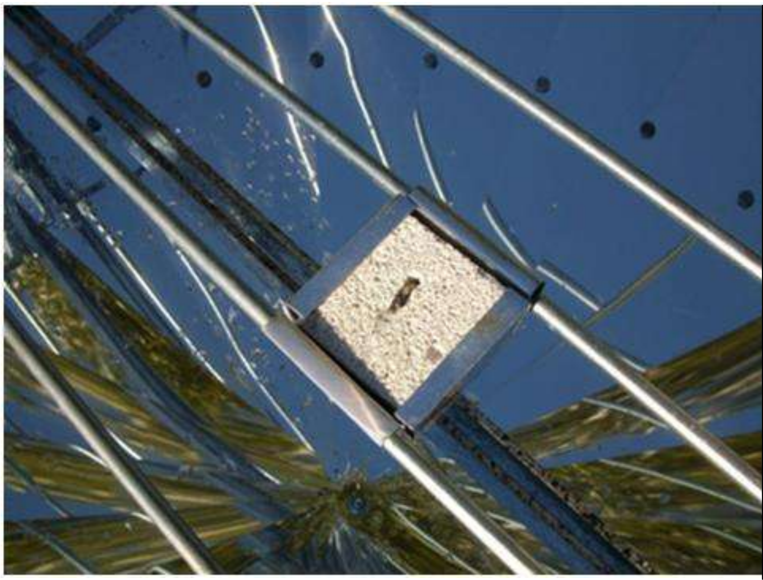
The 2000 version SunStove is shown below. The corresponding SUM consists of an absorber plate, fitted with a glued thermocouple sensor connected to the logger unit. All sensors were calibrated *in situ*.

Top view of the SunStove solar box cooker produced in South Africa, fitted with two original pots and the SUM baseplate. The sensor cable (top), connects the base plate sensor with the SUM. Ambient temperature and irradiance sensors are integrated in the SUM housing.

The SunStove SUM.

The K14 SUM

The K14 SUM is based on the same data logger as the SunStove SUM described above and features an external thermocouple mounted in the centre of the cooker focal area, shielded against stray radiation by a reflector-protected cellular concrete basis, the thermocouple being in direct contact with the pot bottom (see photo below). As for the SunStove, the sensor reading was calibrated by comparison with a thermocouple placed in the water in the pot. The SUM unit is fixed in a normal position relative to reflector plane and photodiode opening.



Detail view of pot bottom sensor. Note the reflective casing protecting the cellular concrete.

The K14 SUM with its external sensors for pot temperature, ambient and irradiance.

Conclusions

A new monitoring technique for the use rate of « clean » domestic cooking appliances in Developing Countries, in particular solar cookers and hot boxes, is introduced.

One of the challenges of cooker use metering is the automatic determination of the food thermal mass (mass times specific heat) in the pot. It is shown that thermal mass can be measured as the thermal power going into the pot divided by the corresponding temperature increase rate. The necessary data are recorded by small metering devices, labeled “HUM” (Hot box use meters) and “SUM” (solar cooker use meters).

As key result, the number of meal portions having gone through successful cooking cycles is calculated.

A baseline study of the reference region can be conducted at the outset (alternatively, generic input figures can be used), to determine the average number of cooked meal portions per capita and annum, the net fuel consumption and the GHG emission per meal portion, as well as the average cooker efficiency. This allows to calculate fuel savings and avoided GHG emissions caused by the respective solar cooker or Hot Box.

Efficient incentives will be needed, based on reliable cooker use figures. It is also interesting to reduce the cost of monitoring yet improve the reliability of the results. Both requirements are met by the HUM and SUM systems.

So, should users be paid to use their cookers? Definitively yes: their clean cooker use is a benefit for us all. And also, as Agnes Klingshirn [3] puts it, why should the rural poor in developing countries be the only ones to finance their energy system without any help?

There is no doubt that these incentives are justified.

Annex 1: HUM/SUM Field test concept

The field test component is identical for HUM and SUM; it has the following objectives:

Verification of the precision of HUM/SUM results under real-life use conditions:

- This can be accomplished by the placement of a HUM/SUM unit and the respective appliance in one or two test households, situated in an easily accessible location.
- Constant presence of a monitor (data collection officer) taking down all cooking related activities during two consecutive days, reading out of the HUM/SUM results at the end of his stay.
- Evaluation of HUM/SUM data and comparison with human monitor data. Qualitative analysis of error margin.

Establishment of typical HUM/SUM use rates and analysis of the incentive value of HUM/SUM based market introduction measures:

- Contract two traders, manufacturers or distributors as partners in the field test.
- Select one low-income, one intermediate income environment.
- Estimate “prospective” mass production price and sell appliance units to the traders at this price; attention should be paid not to “spoil” prices of similar products on the real market.
- HUM/SUM units are not sold and remain the property of the project
- Define a prospective carbon value
- Regular read-out of HUM/SUM, evaluation and explanation of results to users and traders.
- Payment of carbon value to the user, either in cash, or in pay-back of appliance credit, or in credit pay-back for other appliances, e.g. SHS micro lighting modules.

Annex 2: Development procedure

The HUM/SUM development took place in three steps:

1. Concept development, in tests of prototypes using an 8-channel universal data logger, a Kipp&Zonen CM11 pyranometer, Pt 100 and K-type thermocouple sensors
2. Product development, using autonomous platform loggers, with NTC, K-type thermocouples and photo-diode sensors, in comparison with the equipment under 1.
3. Development of meter read-out and evaluation software.

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Promotions of Compact Fluorescent Lamps (CFLs) by Utility-Bill-Payback Scheme in Vietnam

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Abstract

We implemented a demonstration program for promotion of Compact Fluorescent Lamps (CFLs) in Vietnam by Utility-Bill-Payback (UBP) scheme in 2006 with sponsorship from the Ministry of Economy, Trade and Industry, Japan (METI). More than 1,500 CFLs were distributed to about 700 households in two villages located in Hanoi suburban area. Installation of CFL was strictly limited to replacement of incandescent lamp.

The study was based on an ESCO scheme premise that electricity expenses saved by use of CFLs should be larger than a monthly installment payment payback of the CFL costs. In order to obtain a relatively short payback period the program was restricted to incandescent lamps with average daily use of more than 3 hours. Due to actual regulation it was not possible to invoice everything on one bill. Use of two bills (for electricity consumption and for payback of installment of CFLs) made it difficult to understand for many customers as installment payment schemes are unfamiliar in Vietnam. Detailed explanation of the program scheme enabled customers to understand the merit of participation in the program. According to the customer satisfaction survey, more than 90% customers realized electricity saving after introducing CFLs.

Introduction

In Vietnam power outage frequently occurs due to the rapid increase in electricity demand by over 15% per year associated with the high economic growth rate during the past few years and this causes a serious social issues. To cope with the tight power demand-supply balance, the government establishes target to promote energy efficiency along with buildup of power stations and revision of electric rate structure. EVN (Electricity of Vietnam) encourages peoples to replace incandescent lamps by LFLs (linear fluorescent lamps) as a part of electricity saving measures. Under these circumstances, EVN has carried out a subsidy program to promote CFL by the support from the Work Bank [1] [2]. Although this program has succeeded in diffusing CFLs and raising people's awareness of CFL, there are some defects such as procurement of a unique type of CFL from a manufacturer and replacement of even LFL by CFL. As far as the World Bank scheme is premised, it would be likely that the anticipated electricity saving and peak cut can not be realized and that the further diffusion of CFL can not be expected after the subsidy ends.

The buildup of power stations as a countermeasure to cope with the tight power demand-supply balance is time-consuming and considerably expensive. On the other hand, energy saving, especially diffusion of promotion of CFL and household appliances as a demand side measures can be rapidly and cost-effectively realized, and also self-reliant wider diffusion free from subsidy system can be expected by means of ESCO scheme.

Therefore, this study carries out a demonstration project of CFL promotion by means of ESCO scheme. From the project we analyze effect on electricity saving, impact on the power suppliers and customer satisfaction and make proposals for the scheme for self-reliant development of the ESCO - CFL promotion.

Penetration Status of Lamps

We selected Bắc Ninh province as a project zone, which is situated north-east from Hanoi. Agriculture has been the major industry of this province with a million of population, but several industrial complexes are recently developed. We selected for our project two communes Nghĩa Đạo and Tân Lãn, which did not experience the World Bank CFL promotion project.

The preliminary survey was carried out for households in these two communes to figure out number of occupant and also number, type, wattage and hour of usage of lamps each household owns. The questionnaire sheets were distributed to 1604 households, of which 1284 households (80%) replied. The high percentage of replies would owe to the fact that the PC1 (Power Company 1: power distribution company) staffs visited each household to provide a detailed explanation on the project. The average number of occupant is 4.3 and the number of lamp is 5.5, of which incandescent lamp, LFL and CFL accounts for 65%, 33% and 2%, respectively. The average annual electricity consumption is 628kWh/household, which is about 15% of Japan's average.

Based on the screening criteria that exclude households without any incandescent lamps, incandescent lamps with daily usage less than 3 hours and incandescent lamps over 100W, we selected 704 households (1515 lamps) to be replaced out of 1284 households (7079 lamps). Our project targets incandescent lamps exclusively as replacement of LFLs by CFLs in general doesn't generate any savings unless the lumen output is lowered. In addition, incandescent lamps with daily usage no shorter than 3 hours are selected for the reason that ESCO scheme targets frequently used lamps. Out of 1515 incandescent lamps, 1269 lamps are 60W and below and 246 are over 60W. Table 1 shows average number and type of lamps owned in each room in a house.

Table 1. Ownership of lamps per household (average for 1284 households)

		Total	incandescent			LFL	CFL
			total	=<60W	60W<		
Whole	W/unit	43.4	48.2	42.0	81.6	35.4	21.1
	unit	5.53	3.59	3.03	0.56	1.81	0.13
Living Room	W/unit	41.6	50.9	45.1	82.0	39.2	19.5
	unit	1.42	0.34	0.28	0.05	1.05	0.03
Bed room	W/unit	39.3	46.9	40.1	81.9	29.8	23.9
	unit	1.15	0.65	0.55	0.11	0.46	0.04
Kitchen	W/unit	45.4	47.1	41.6	81.1	28.5	18.7
	unit	0.97	0.89	0.77	0.12	0.06	0.02
Corridor	W/unit	50.1	54.4	44.8	81.0	34.4	18.2
	unit	0.75	0.60	0.44	0.16	0.14	0.01
Rest room	W/unit	39.2	44.3	41.6	76.1	25.1	21.7
	unit	0.31	0.23	0.21	0.02	0.05	0.02
Garden	W/unit	47.5	51.3	43.6	97.1	28.3	20.0
	unit	0.11	0.09	0.08	0.01	0.01	0.00
Well	W/unit	42.8	44.1	41.4	92.7	25.3	35.5
	unit	0.24	0.22	0.21	0.01	0.02	0.00
Livestock barn	W/unit	45.4	45.8	40.7	80.0	30.4	17.3
	unit	0.58	0.56	0.49	0.07	0.01	0.00

CFL Procured

We procured CFL manufactured by TOSHIBA. Since the World Bank project provided a unique wattage of CFL, 15W in case of replacement of smaller wattage than 60W/75W of incandescent lamps lower savings are generally generated but the customer received more lighting output. Our project included two wattages of CFLs, 13W and 18W for incandescent lamps less or equal 60W and over 60W, respectively.

Based on the results of the preliminary survey, we procured 1620 CFLs including 1350 13W CFLs and 270 18W CFLs. According to the World Bank project, 5% of CFLs were broken within a year due to voltage fluctuation of grid power, and approximately equivalent rate of spare are prepared for our project. Since only CFLs with screw socket were procured, lock type sockets were in some cases replaced by screw type sockets.

Upon distribution of CFLs to households, PC1 staffs explain again how the ESCO scheme functions and make an installment payment contract between PC1 and customers. This contract obligates customers to pay for CFLs on a monthly basis and provide them with product guarantee during installment period.

Lighting Load Profile

The lamp monitoring survey was carried out for 2 months from October in order to figure out the electricity saving and peak cut effect by CFL introduction. Since it is difficult to directly measure power consumption of lamps due to power line structure in houses and specifications of electrical measurement devices, bulb surface temperatures were monitored so that ON/OFF profile can be detected. The power load curve and electricity consumption are obtained from multiplying ON/OFF profile by wattage of lamp.

As ESCO scheme targets frequently used lamps, average usage rate for more than average and for less than average are identified separately. Table 2 shows average daily usage hour in major 5 rooms (living room, bed room, kitchen, corridor and well). Monitored usage hours are 30 ~ 40% shorter than usage hours answered in questionnaire of the preliminary survey.

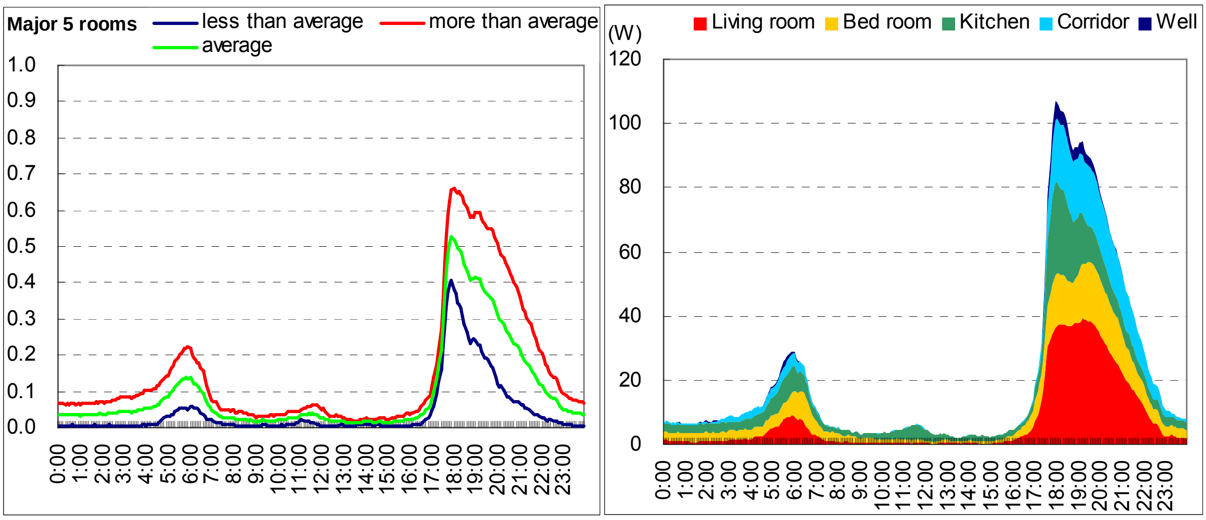
Table 2. Hour of Daily Use for Major Rooms in House

		Living Room	Bed Room	Kitchen	Corridor	Well
Hour of use (h/day)	Average for monitoring survey (A)	2.3	2.1	2.2	2.4	1.1
	Average for more than average	3.4	4.1	4.0	3.4	—
	Average for less than average	1.2	0.9	1.3	0.9	—
	Preliminary questionnaire survey (B)	4.1	2.9	3.0	3.2	3.0
Ratio(=A/B)		56%	71%	75%	75%	38%

The left graph in the Figure 1 presents average hourly usage rate of lamps per household. We apply the average for more than average and the average for less than average to the lamps with usage hour answered in preliminary survey over 3 hours and less than 3 hours, respectively. The right graph shows the lighting load curve for 5 major rooms. Table 3 shows average number and wattage of lamps per household at initial situation for 5 major rooms. An average household consumes 0.52kWh of electricity per day for lighting.

Table 3. Average Number and Wattage of Lamps per Household at Initial Situation

(5 major rooms)		Total	incandescent			LFL	CFL
			total	=<60W	60W<		
W/unit	Average	*43*	*49*	*42*	*82*	*36*	*21*
W/unit	3h=<	*43*	*49*	*43*	*82*	*37*	*21*
W/unit	3h>	*43*	*48*	*42*	*82*	*33*	*21*
unit	Total	4.53	2.70	2.25	0.45	1.73	0.10
unit	3h=<	2.77	1.49	1.23	0.26	1.21	0.06
unit	3h>	1.77	1.21	1.01	0.19	0.52	0.04
kWh/day		*0.52*	*0.34*	*0.24*	*0.09*	*0.17*	*0.01*



＜Lamp Usage Rate＞ ＜Lighting Load curve＞

Figure 1. Average Lamp Usage Rate per household and Lighting Load Curve for major 5 rooms

Rate System of Installment Payment

As the demonstration project mainly targets low income households, the monthly installment payment amount should be set so that the total amount of electricity bill and CFL monthly installment payment not be increased compared with the month before CFL introduction. Considering the fact that installment payment system is not widely infiltrated in Vietnam, CFL cost was set, with 20% reduction from market price, at 17,600VND for 13W and 24,000VND for 18W.

Great majority of households in the two communes in Bắc Ninh province consume less than 100kWh electricity per month and the applied electricity rate is lowest level, 550VND/kWh. Since the preliminary survey result revealed there are 85% of incandescent lamps that more than 2kWh/month of saving corresponding to 1,100VND/month is expected, the monthly installment payment amount was set at 1,000VND for 13W and 1,400VND for 18W during 18 months. The payback period was thus 17-18 months.

Electricity Saving

Due to the survey (see Table 3), the 5 major rooms in the home are in average equipped with 4.53 lamps including 2.70 incandescent lamps, 1.73 LFL and 0.10 CFLs. The incandescent lamps are including 2.25 with wattage less than 60W and 0.45 more than 60W. 1.49 of these lamps are used more than 3 hours daily and 1.21 lamps less than 3 hours/day.

We categorize electricity saving by CFL into two cases, one of which is the electricity saved when the all incandescent lamps are replaced in the major 5 rooms in house, the other one is the electricity saved by means of the ESCO scheme premise that electricity expenses saved by CFL should be larger than CFL monthly installment payment for incandescent lamps with daily usage of at least 3 hours.

The demonstration project realized 0.16kWh/day reduction in electricity consumption by replacing 1.18 incandescent lamps (0.99 are less than 60W and 0.19 are more than 60W) with more than 3 hour daily usage. Additional 0.04kWh/day of decrease can be achieved by replacing the rest of incandescent lamps with more than 3 hour daily usage (0.31). The ESCO scheme potential accounts for 0.20kWh/day out of 0.24kWh/day of the potential saving (see Table 4).

Under the assumption that the whole 16 million households in Vietnam are similar to the household in this study in terms of possession and usage of lamps, the electricity saving potential is

1.4 billion kWh/year, of which 1.2 billion kWh/year would be achieved by application of ESCO scheme (Figure 2). Figure 3 shows lighting load curve variation by CFL introduction per household.

Table 4. Electricity Saving Effect by CFL

		Per household		Per unit
		Per day	Per year	Per year
ESCO scheme effect	(1.49 units)	0.20 kWh/day	74 kWh/year	49 kWh/unit
Replaced in the project	(1.18 units)	0.16 kWh/ day	59 kWh/ year	50 kWh/ unit
The rest	(0.31units)	0.04 kWh/ day	15 kWh/ year	46 kWh/ unit
Potential	(2.70 units)	0.24 kWh/ day	89 kWh/ year	33 kWh/ unit

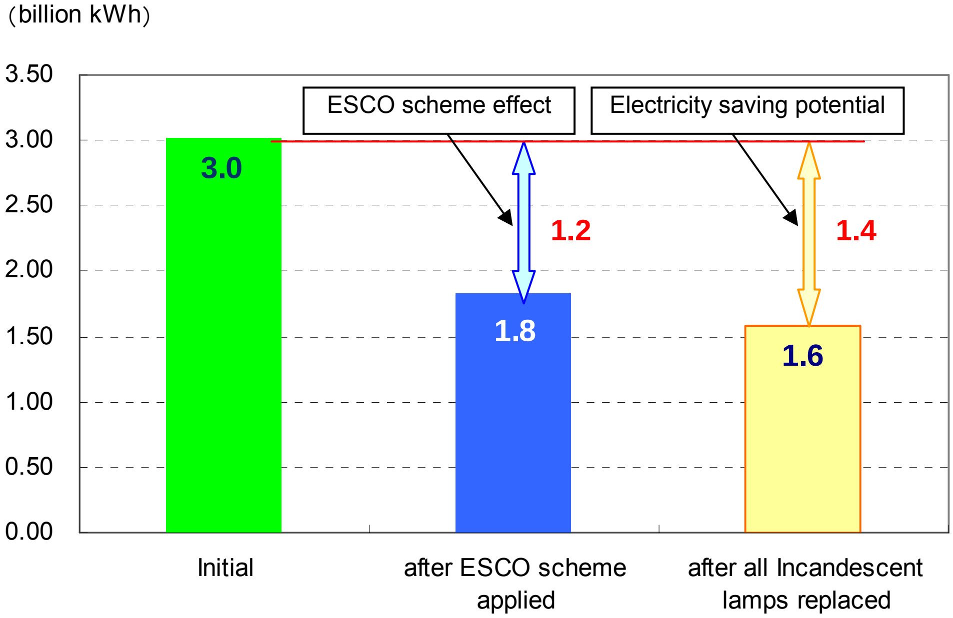


Figure 2. Electricity Saving Effect by CFL in whole Vietnam

Peak Cut

ESCO scheme yields greater peak cut effect than the method in which incandescent lamps are randomly replaced by CFL, since the ESCO scheme limits to the lamps frequently used. Figure 1 shows that the average usage rate at 18:00 for the lamps more than average is 65.9%, while the average usage rate is 51.8%, which means ESCO scheme has a peak cut effect 1.27 times as much as the random selection. The difference in wattage between the incandescent lamp less than 60W (average 43W) and CFL (13W) multiplied by the number (1.23) yields 36W reduction. The difference in wattage between the incandescent lamp more than 60W (average 82W) and CFL (18W) multiplied by the number (0.26) yields 17W reduction. The total reduction 53W multiplied by 65.9% yields 35W (5min) peak cut, corresponding to nationwide 540MW (1 hour). If incandescent lamps with usage hour less than 3 hours/day are included, the peak cup potential is estimated to be 51W (5min), corresponding to nationwide 730MW (1 hour).

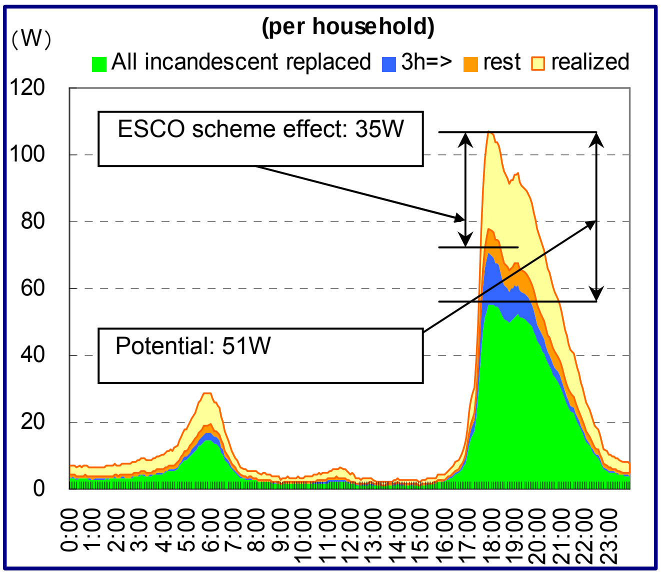


Figure 3. Lighting Load Curve Variation by CFL introduction (per household)

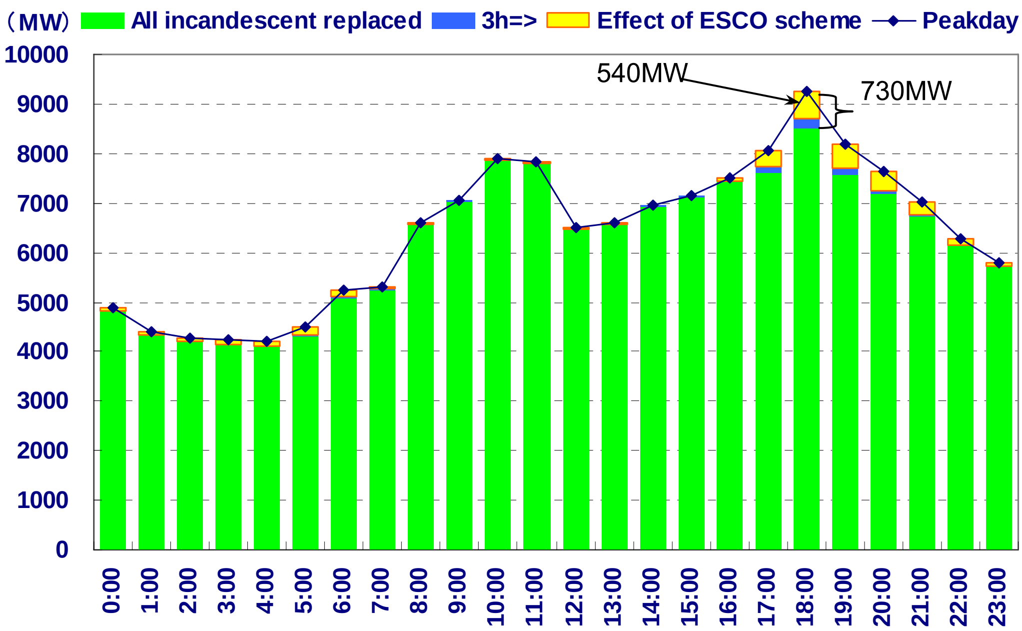


Figure 4. Nation wide Load Curve Variation by CFL Introduction

Table 5. Peak Cut Effect for whole of Vietnam

Number of household	Incandescent (>3h/day)	Peak cut effect
16million	24million	540MW

Economic Effects on Power Suppliers

Reduction in negative net worth of power distribution company: The electricity rate for residential sector in Vietnam is held exceptionally low level from the view point of social welfare assistance and the peak time rate is 550VND/kWh for the household consuming electricity less than 100kWh per month, while the whole sale electricity price at peak time is 688.1VND/kWh. Due to this electricity rate structure, PC1 is suffering from negative net worth for peak time period (18:00~22:00). Since the lighting demand coincides with the grid peak time, the negative net worth can be alleviated by replacing incandescent lamps by CFL. The effect contributed from the lamps with more than 3 hour daily usage is estimated 1600VND/unit.

Improvement in generation reserve margin of EVN: Electricity saving is greatly expected to be a quick remedy in short time for shortage of power supply capacity for EVN. Especially in the northern part of Vietnam as a PC1's service area where the construction of coal fired power station is behind schedule, LOLE (Loss of Load Expectation) which indicates the supply reliability falls far below the standard level (24 hours) into 115 hours as of the end of 2005. The effect of CFL introduction by ESCO scheme on peak cut is estimated to be 540MW in nationwide, of which northern part would account for 245MW. The generation reserve margin is expected to be substantially improved from -11.4% to -5.0%.

Aversion of risk to increase power procurement cost: EVN is procuring electricity from China to cope with the power shortage, at a price of 4.5cents/kWh exceeding the procurement price from domestic power stations. The electricity import contract with China obliges to purchase electricity even at the time other than peak time, which causes procurement cost elevation. If power shortage continues at the present pace, it is highly likely that power procurement cost increases. Promotion of CFL diffusion contributing to power demand reduction in the peak time period has an effect on aversion of risk to increase power procurement cost.

Fund procurement easing: Huge investment to power stations are required in order to meet the maximum power demand growing 15% annually and fund procurement will be a key issue for the power sector. The peak cut impact of ESCO scheme CFL diffusion promotion, 540MW, matches a third to fourth of the annual power demand growth. It is considerably important to throw back the fund demand for the period until 2010 where it is predicted that securing of financing will be tight due to power stations construction.

The ESCO scheme targets exceptionally incandescent lamps whose daily usage is more than 3 hours and yields great grid power peak cut effect. Under the circumstances where the northern part of Vietnam is suffering from power shortage, ESCO-CFL diffusion promotion that has immediate effect on the power sector and no burden on the customers is substantially attractive measures.

Customer Satisfaction

We carried out questionnaire survey on customer satisfaction with CFL (brightness, light color and flickering), opinion on ESCO scheme (lump-sum payment or installment payment, installment period), and interest in applicability of the ESCO scheme to the other household appliances. The questionnaires were distributed to 704 customers who experienced introduction of CFL, of which 661 customers replied. In addition a group interview was held with 5 customers. The customers experienced three months CFL use and fee collection twice at the time when the survey was worked out.

The survey results show that 80 ~ 90% of customers are satisfied with CFL's brightness and light color. Though 90% are not satisfied with the flickering, 93% of them do not realize any trouble in the daily life.

Regarding the ESCO scheme, 91% realize decrease in electricity bill due to introduction of CFL, and 85% feel the monthly payment amount reasonable. As a whole, the ESCO scheme is recognized as an effective method for low income households, in the same time, it is regarded as the second best scheme due to complexity of process, mental burden stemming from long payment period and preference of lump-sum payment to installment payment if possible.

Regarding applicability of the ESCO scheme to the other household appliance, about 90% hope to buy energy efficient type. 60% hope installment payment since they can not afford by lump-sum payment.

Verification ESCO-CFL Scheme

(1) Electricity expenses and CFL monthly Installment payment amount

The demonstration project aims at promoting CFL by curbing the CFL monthly installment payment below the electricity expenses saved by CFL introduction. Therefore it is important whether customers realize reduction in the total of electricity bill and CFL monthly installment payment amount. Although the customers have experienced bill collection only twice when customer satisfaction survey was carried out, 91% of them feel reduction in the total amount. It can be regarded that the initial objective has been achieved.

(2) Installment period

Although there were not accrued amount of CFL payment for three months, the customer satisfaction survey shows that a large number of customer feel 6 to 12 months are preferable for the installment payback period. This would derive from customers' discomfort feeling at being burdened with debt in status quo where installment system is unfamiliar in Vietnam. Individual collection of the CFL installment fee and the electricity bill in the demonstration project makes customers to feel the debt burden more strongly. If CFL installment fee collection is incorporated in electricity bill collection on a unique bill, then this collection system can prevent customers from being conscious of the debt and installment period would not matter. However, revision of electricity bill requires long time tangled bureaucratic procedures with ministries concerned.

(3) Monthly Installment payment amount

According to the results of the customer satisfaction survey, 55% answer 2000VND and 13% 3000VND as the allowance of monthly payment amount. No one answers less than 1000VND.

The demonstration project set CFL monthly fee at 1400VND for 18W and 1000VND for 13W. Even though the cost incurred by installment system operation is added, the monthly installment fee is still equal or less than 2000VND and customers would not be unsatisfied.

(4) Satisfaction with CFL

The customers are greatly satisfied with CFL's brightness and color of light. In addition, mobility and needlessness of electric fixing work exhibit advantage over LFLs. These facts will strongly support further increase in the introduction number of CFL, in spite of the high price compared to incandescent lamps and LFL.

(5) Opinion on the ESCO scheme

As customers feel discomfort at the long installment period, there is tendency that they will choose lump-sum payment if they can afford. They allow the monthly payment fee up to 2000 to 3000VND and prefer the installment period from 6 to 12 months.

Regarding household appliances, 90% customer hope to purchase energy efficient type. It can be said that the ESCO scheme would function more effectively in case of purchase of energy efficient household appliances which are much more expensive than CFL.

Proposal for CFL Promotion by ESCO Scheme

(1) Selection of Incandescent lamps to be replaced & confirmation of installation of CFL

Daily usage more than 3 hours: In order to realize the significant effects expected by the ESCO scheme, it is highly required to select incandescent lamps whose daily usage is declared to be more than 3 hours. If less frequently used incandescent lamps or LFLs are selected to be replaced by CFLs, the expecting effects are extremely overshadowed. Although preliminary survey is ideal method to figure out number and wattage of incandescent lamp, the nationwide survey arises huge cost and time. For this reason, quick simple survey by staffs of power distribution companies upon meter reading or customers' electricity bill payment would be a realistic method in case of full-fledged development of ESCO-CFL scheme.

Confirmation of installation: In the demonstration project, PC1 staffs visit each household for fixing of CFL, which leads automatic confirmation of installation. A system of check like this is necessary in case of full-fledged development, otherwise CFLs may be fixed replacing less frequently used incandescent lamps. This undermines the expecting effect. Especially, in case socket type difference requires electric work, power distribution companies' staffs should help customer to fix CFL.

(2) CFL quality and specification

Quality: The annual rate of failure of TOSHIBA's CFL caused by grid power voltage fluctuation is expected 3% in the demonstration project, lower than 5% recorded for OSRAM's CFL in the World Bank project. However, CFLs with high resistance to voltage fluctuation are required in case of full-fledged development of ESCO-CFL scheme. Additionally package offering with screw socket is also necessary, since lock type socket is popular in Vietnam.

Guarantee: The demonstration project provided high quality CFL and also product guarantee. The guarantee during the installment period is necessary.

(3) ESCO scheme

Payment method (amount & period): The installment period is desirable to be 6 to 12 months to alleviate customers' discomfort. It is also important to build bill collection system that combines electricity bill and CFL monthly installment fee so that customers are not so sensitive to the debt, even though revision of electricity bill requires long time tangled bureaucratic procedures with ministries concerned.

Adding the cost incurred by installment system, like direct expenses and management cost, to the monthly amount set in the demonstration project yields 2100VND (18W) and 1600VND (13W). These prices are still within the customers' allowance.

Since some customers seem to prefer lump-sum payment if they can afford it, then there is not need to persist on the concept of ESCO scheme. This might origin from people feeling unsure about a not real ESCO scheme with payment by two invoices. It is recommended to prepare several combinations of ESCO schemes with different monthly fee and thus payback period as well as lump-sum payment.

Information service: There is information service that provides customers with data on electricity consumption in a month, last month and the month in the last year, so that the customers can easily recognize electricity savings. The demonstration project did not provide such service and customers can not know their consumption data. According to electricity consumption data of customers provided by PC1, there is not large difference between a month (with CFL) and the month in the last year (without CFL). In spite of these facts, 90% customers realize reduction in electricity bill. It is believed that this result was led by the detailed explanation of the ESCO scheme concept by PC1 staffs penetrating into the customers.

Considering time and cost required to collect, provide and manage customers electricity consumption data, it is crucial to launch nationwide advertisement on ESCO scheme so that CFLs and appliances are to be diffused effectively by raising customers awareness towards ESCO scheme.

(4) Applicability of the ESCO scheme to household appliances

Since 90% customer hope to purchase energy efficient type, it can be said that the ESCO scheme would function more effectively in case of purchase of energy efficient household appliances which are much more expensive than CFL.

However, it is not as simple as CFL case to figure out the electricity consumption, electricity saving and peak cut effect of the refrigerator and air-conditioner, which are expected to be diffused hereafter, since their electricity consumption varies depending on the ambient temperature. Load research are required to identify electricity saving and to set the monthly installment payment fee.

Concluding Remarks

We carried out a demonstration project for ESCO scheme CFL diffusion promotion in Bắc Ninh province Vietnam, in which 1515 incandescent lamps used by 704 customers were replaced by TOSHIBA CFLs. The features of the projects are;

- ESCO scheme driven replacement of incandescent lamps used at least 3 hours/day
- 13W and 18W CFLs replacing incandescent lamps less than 60W and more than 60W, respectively

According to the results of lamp monitoring survey on 127 lamps in major 5 rooms and also number, wattage and usage hour of lamps in universe 1284 customers, electricity saving effect, peak cut effect and economic impact on power suppliers by CFL introduction are estimated;

- Saving potential per household is 89kWh/annum, of which ESCO scheme effect is 74kWh. Throughout Vietnam, 1.4 billion kWh/annum, of which ESCO scheme effect is 1.2 billion kWh, corresponding to 6% of the whole national electricity consumption
- Peak cut potential throughout Vietnam at 17:00-18:00 is 730MW, of which ESCO scheme effect is 540MW
- A customer saves 27,500VND annually
- Negative net worth in power distribution company (PC1) and power production company (EVN) is reduced.
- Power generation reserve margin is improved in northern part of Vietnam by ESCO scheme effect.
- Alleviate the risk to increase power procurement cost caused by import from China and throw back fund demand required for power station construction

As the ESCO-CFL scheme yields considerably great impacts on both customers and power suppliers immediately and cost-effectively, the scheme should be promoted widely in Vietnam to cope with tight power demand-supply balance. In the process of promoting the ESCO scheme, overarching point is to build framework for nationwide advertisement to raise peoples' awareness on the scheme, for quick simple survey to figure out frequently used incandescent lamps and for confirmation of CFL installation.

The UBP scheme as a DSM for not only CFL but also home appliances, being relatively tangible for customers and having great impact on electricity saving and peak cut, can be expected to be common in developing countries where residential energy consumption are expanding rapidly.

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A Breath of Fresh air: protos the plant-oil stove

Samuel N. Shiroff,

BSH Bosch und Siemens Hausgeräte GmbH

Kami cooking with a protos plant oil stove

Like everyday, Kami is preparing the evening meal. The usual routine starts earlier in the day with the collecting of fire wood. The fire is then slowly set to cook the staple rice. This is inevitably accompanied by a smoky kitchen, and Kami's slight cough is proof that this is not the first time. This evening however, the air is clear and her daughter doesn't have to rub her eyes from the sting. Kami is using her brand new protos plant oil stove with coconut oil as the fuel.

The plant oil cooker with "protos" technology, developed by BSH Bosch und Siemens Hausgeräte GmbH (BSH), is conceived to be more than just another appliance. Using its core engineering competence and more than 40 years experience designing and building world-class cooking appliances, BSH has developed a product that enables people in developing nations to grow their own energy for clean, low-cost, healthy cooking.

The shift away from use of wood, charcoal, and costly, imported petroleum-based fuels to locally grown agricultural products has the potential to create jobs, to generate economic value in poor regions, to preserve the environment, and to even save lives. This is the protos vision.

Current habits pose health risks and endanger the environment

Everybody cooks, but not everyone cooks in the same way. Poverty and access to alternatives remain the main barriers to the adoption of cleaner and more environmentally friendly ways of cooking. While those in wealthier countries generally use electricity or gas stoves, more than 2.5 billion people around the world still use the older, less efficient and unhealthy fuel sources such as wood, charcoal, kerosene, and other biomass [1]. The World Health Organization (WHO) estimates that 1.6 million people, mostly women and children, die each year as a result of exposure to indoor air pollution, often a result of burning wood or charcoal for cooking [2]. Kerosene, also poses a significant risk of injury because it is highly flammable.

In countries where local prices have adjusted to recent high international energy prices, the shift to cleaner energies for cooking has actually slowed and even reversed as people revert to collecting wood or burning other biomass. Without new energy concepts, the number of people depending on biomass as household energy will increase to about 2.7 billion by 2030 [3].

Related environmental aspects and their adverse effects on humanity

During the last two centuries, the global atmospheric concentration of carbon dioxide has increased by more than 30% [4]. Human industrial activity in the form of power generation, transportation, heating and lighting each have played a significant role. However, the largest single source of greenhouse gas emissions is a result of deforestation. Forests and wetlands absorb and store CO_2 and other greenhouse gases and naturally regulate the atmosphere. As billions of people try to find wood, charcoal or other biomass for cooking on a daily basis, significant pressure is put on the remaining forests where they live. Between 200 - 500 kilograms of wood are needed per person per year to fulfill such cooking requirements as a result of the very low efficiency of the three-stone fires or simple stoves that are used to burn it.[5]. The environmental impact on both biodiversity and climate is significant.

Using Expertise, Innovation, and Teamwork to Find an Alternative

BSH Bosch and Siemens Hausgeräte GmbH is the world's third largest manufacturer of home appliances globally and the market leader in Europe. With approximately 39,000 employees in over 40 countries, BSH operates on the pillars of technical innovation and quality, environmental protection, and social responsibility.

Did you know:
Cooking on an open fire yields over 70 times the EU standard of harmful air pollution emissions.

As a world leader in innovation for domestic appliances, the development of a plant oil cooker, a project for renewable energy that originally began in 1998 at the University of Hohenheim in Germany, was a challenge that caught the attention of BSH.

"In 2003, when BSH learned about this new technology, we decided it presented a very interesting (technological) challenge for us," explains the Senior Vice President of sales for emerging markets Dr. h.c. Dirk Hoffmann. "Concurrently, we believed that if we could develop a product for the `bottom of the pyramid,` we would not only be helping to make significant and sustainable improvements in these people's lives, but it would also provide BSH with some unique insights into a market that we do not currently serve with our conventional products."

Dr. Ing. Elmar Stumpf, chief designer of the plant oil cooker at the University of Hohenheim, was then brought on board to make the next advances in the technology. He explains, "Although some real progress had been made in Hohenheim, the product was not ready for a mass market. With the resources and the teamwork at BSH, the team was able to improve the performance, life-span, and most importantly, to reduce the costs so that protos could ultimately be offered at a price that 'the bottom of the pyramid' could afford."

Using plant oil as a fuel

Plant oils offer an alternative cooking fuel resource, providing an independent, sustainable energy supply and alternative to wood. Tests found that the hydrocarbon emissions of the protos plant oil stove were 370 times lower than that of an open fire with comparable output [6].

Jatropha Curcas grows in marginal land and produces non-edible oil-bearing seeds.

Several oil plants originate in the tropics and subtropics, growing in areas unsuitable for food crops, and are often cultivated on wastelands or intercropped with other agricultural products. Examples of these oil plants include the castor oil plant and Jatropha, or Physic nut tree.

Many of the tropical and subtropical countries have traditional methods for harvesting the plants and extracting the oil from them. Today, Malaysia and India already produce a large number of plant oils. The Philippines produce coconut oil, but many trees are cut down and not replanted. There is also large potential for jatropha oil in Africa, Central and South America, India, the Caribbean, and Pacific islands, and large-scale jatropha plantations are currently planted or planned in South Africa, China, and India to provide feedstock for bio-diesel production.

In addition to wood and charcoal, many people living in developing countries cook with kerosene stoves. While more efficient and somewhat less polluting, kerosene releases large amounts of CO_2, and is often highly subsidized; creating a budgetary strain in developing countries that competes with priorities such as education and infrastructure. Although many countries that subsidize kerosene also have large plant oil production, existing kerosene cooking stoves do not do not function with plant oils.

The innovative technology behind the protos cooker makes it possible to use all plant oils that are liquid at ambient temperatures as fuel. This includes pure, i.e. unrefined, plant oils and even used frying oil; the full range of both edible and inedible plant oils such as coconut oil, jatropha, sunflower oil, rapeseed oil, cottonseed oil, peanut and most other oils can be burned in protos with just a simple filtering process to remove the largest of particles.

One of the major environmental benefits of cooking on a protos stove is that the CO_2 released by burning plant oil is equal to the amount that is absorbed by the plant through the photosynthetic process. In other words, the process is greenhouse gas (GHG), or “carbon,” neutral. When used to substitute fossil fuels (e.g. kerosene, gas), it is possible to significantly reduce CO_2 emissions in the order of 2.5 tons per 1000 liters of kerosene replaced. In many countries, wood and charcoal are harvested through processes that are not sustainable. The use of protos and thus substitution of such non-sustainably harvested wood or charcoal can result in a reduction of CO_2 emissions of between three to seven tons per cooker per year.

The use of cookers fueled by kerosene poses an additional safety issue. As opposed to kerosene, plant oils are tri-glycerols of fatty acids, with distinct chemical and physical properties, and different combustion characteristics than those of kerosene. The viscosity, i.e. thickness, of plant oils can be up to 30 times higher than that of kerosene. The flash point of plant oils ranges from 180 to 300ºC, compared to 80ºC for kerosene [7]. This means that the operating risks of kerosene are much higher due to its easy inflammation. Accidents with kerosene can prove fatal whereas an accident with plant oil would likely just be messy.

Considerations when using plant oil as a fuel

A plant oil cooker for the poor presented some brand new challenges to BSH. Dr. Hoffmann explained, “Although we have always made adjustments in design, size and other changes needed for different market specifications of electricity or gas, we never before put much thought into the source of the fuel. With plant oil, this is different.”

BSH makes a clear policy of stating that it will not introduce protos in markets where it cannot be assured of the sustainability of plant oil, in terms of both environmental and social factors. This means that BSH pays special attention that the plant oil used for its technology is harvested sustainably. The production of plant oil should neither come at the expense of areas rich in bio diversity, nor encourage monocultures, i.e. farming of a single crop.

Protos User Training in Arusha, Tanzania

But actions speak louder than words. Tanzania is one of Africa's poorest but increasingly best governed countries, and from 2005 trough the end of 2007, BSH, along with the German Society for Technical Cooperation and Development (GTZ), conducted a very successful field test during which over 800 customers expressed interest in purchasing the cooker only after just seeing it. Unfortunately, promises of increased local quantities of plant oils in 2005 never materialized in 2007. The price of plant oil was higher than alternative fuels, and it was calculated that selling 800 cookers might, in fact, drive up the cost of edible oils. In a region where people still struggle to purchase basic necessities, BSH stuck by its principles and promised to refrain from selling the cooker where the supply of oil did not meet sustainability criteria. As a result, the project was put on hold until more plant oil becomes available.

Innovation and technical challenges

Scientists and engineers have been working on protos since 1998, and what seems to be a simple product has needed years of intensive research and development to become what it is today.

For example, the vaporization and combustion of plant oils in a simple stove involves more than 10,000 different chemical reactions that are different for each type of plant oil, depending on its origin, quality, and means of extraction. In the burner of the stove, a combustion temperature of up to 1400 °C is reached, which ensures continued vaporization and combustion with very low emissions. However, this high temperature means that special heat-resistant materials must be used in the stove construction.

A further challenge is presented by the residues of plant oils, which are more than 100 times those of kerosene. “People in rural settings may have the ability to press their own oil, but they don’t have the infrastructure to refine it,” explains Dr. Stumpf. “Our challenge was to make a cooker that would burn oil that had been filtered in a simple manner and that required no refining. This isn’t oil you buy in the store. It is a very simple and low cost fuel.” To protect the vaporization tube from clogging, special burner geometry is required to maintain a specified temperature profile and minimize soot formation. After overcoming this challenge as well, the product was ready to bring to market. Nevertheless, soot formation cannot be completely eliminated; it remains necessary for users to occasionally clean the burner in order to ensure it does not clog. It is a fast and easy process that must be undertaken two-three times per week and takes about five minutes.

How protos works

The basic principle of the protos cooker resembles the kerosene pressure stoves typically used in developing countries, except of course that it runs on plant oil.

The protos cooker consists of a tank, a pump, a frame, a valve, a fuel line, and an innovative burner. The tank is filled with plant oil. The burner is pre-heated with a small amount of alcohol or other available fuel source. Through the application of the pump, the tank is pressurized to approximately one bars (onex atmospheric pressure). The oil rises into the vaporizer where the heat of the flame converts the liquid into a gaseous mixture. The gas flux emits from a nozzle into a burning area, where it mixes with the surrounding air and burns in a clean, blue flame. The power output of the flame can be adjusted with a valve in the fuel line.

The Latest Design of the Protos Plant Oil Cooker

Ready for its Customers—bringing protos to the market

There are as many as four billion people in the world who live on less than US two dollars a day [8]. This constitutes the majority of people on the planet; when viewed through the lens of economic consumption they have recently started to be referred to as the “bottom of the pyramid.”

Professor C. K. Prahalad, in his book The Fortune at the Bottom of the Pyramid: Eradicating Poverty Through Profits, pointed out the fact that the poor at the bottom of the pyramid represent value-conscious consumers. If companies see them as partners and customers, they can establish win-win scenarios: the poor become actively engaged consumers and the companies provide products and services that they want, while concurrently generating additional profit. In collaboration with governments and social organizations, large firms can create large and fast growing markets at the bottom of the pyramid (BOP).

Prahalad argues that in order to succeed in the BOP market, it is necessary for private sector businesses to overcome some of their dominant logical assumptions [9]:

1. The poor at the bottom of the pyramid cannot afford products and services.
2. The poor have no use for products sold in developed countries.
3. People in undeveloped countries do not pay for technological innovations.

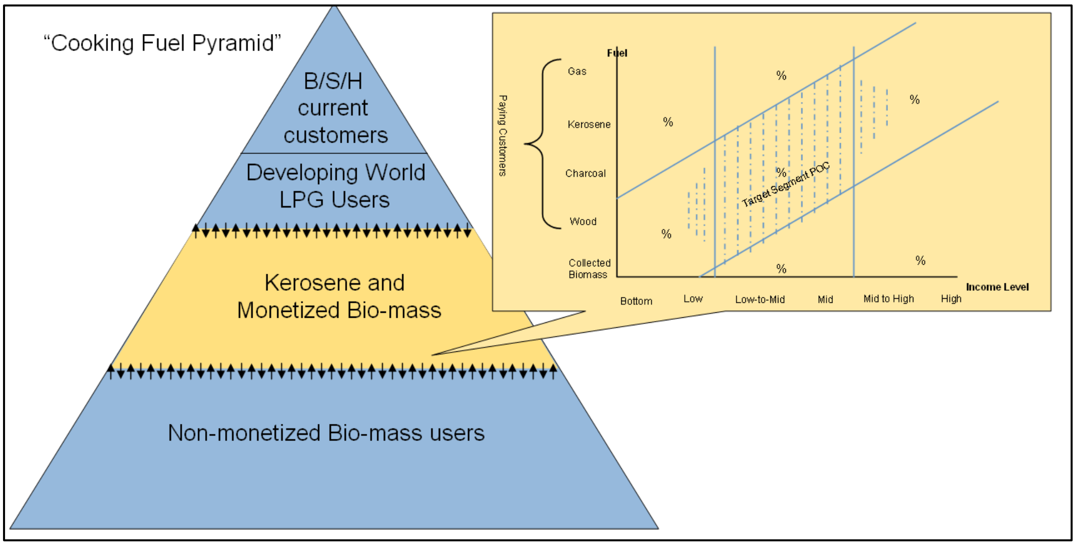
4. The BOP Market is not critical to growth of multi-national corporations.

5. Market based solutions cannot reduce poverty.

BSH realizes that the BOP market has the potential to be an important engine of economic growth and global trade. With the development of the protos plant oil cooker, BSH acts on C. K. Prahalad's vision of "eradicating poverty through profits." For example, production of the plant oil stove will be done locally, including the service, maintenance, and the production of the needed plant oil. This is an essential part of BSH's strategy to bring added value to the developing countries by creating a local market that leads to employment and economic growth. This way, the customers are not only looked upon as consumers, but as business partners and even as contributing innovators. For BSH, the goal is to covers its own cost of production and overhead. However, BSH clearly recognizes that all other local partners involved in the cooker and plant oil supply chains must be able to make a reasonable economic profit, otherwise the project will not be sustainable.

Considerations before going to market: Covering the cost gap

Poor households have a lot in common, but they are by no means a homogenous group. Research conducted by BSH indicates that in most circumstances only families that were already using a monetized fuel (i.e. paying for it) would be willing to switch to protos. Moreover, although the cost of the stove itself must be reasonable, the most important cost criteria would be cash flow requirements and the cost per meal calculation. BSH protos project leader Samuel Shiroff explains, "Using plant oil as a fuel source in protos needed to be at a lower cost than the current alternatives. Here, plant oil has a large advantage over kerosene because protos is as much as 50% more efficient. Thus, a family must purchase only one liter of plant oil for every two liters of kerosene. The advantage is immediately clear. In terms of LPG stoves (liquefied petroleum gas), the efficiency levels are quite similar, but the difference lies in the issue of cash flow. Cooking with LPG requires the purchase of a large tank which may last a week to a month. This requires significant cash on-hand and that is often simply not the way that many people manage their money. Plant oil, on the other hand, can be purchased in small quantities – essentially on a per-meal basis."



BSH primarily sells high-end goods to customers for whom price is not necessarily the sole criteria for the decision-making. It is clear, however, that protos' target customers, who constitute a different market segment, might not be able to pay even the cost of production. At the same time, like all customers, they want a user-friendly, well designed, and durable product. Satisfying these requirements while achieving this and economic sustainability—that is, not losing money on each unit sold—requires innovative business models.

Forming partnerships with organizations and institutions that specifically dedicate funding for projects promoting health and the environment is part of the solution. BSH recognizes that there are foundations, charitable organizations, companies, and even governmental organizations that see a real benefit to filling the necessary cost gap so that the end-user is able to afford the stove.

Thus, BSH has implemented two business models. The first, traditional model simply sells the cooker for a price which covers production cost and overhead. The second involves a price for the end-user below the cost of production, with the cost gap filled via the purchasers of "additional services" provided by protos, such as health, environmental, or local economic benefits.

In terms of environmental service, when fossil fuels like kerosene, wood, or charcoal that are not harvested sustainably are replaced with carbon neutral plant oils, it is possible to generate carbon credits—which also suffice to cover the cost gap.

Within the context of carbon credits, BSH has submitted a methodology (NM 005), to the UNFCCC, which is responsible for the clean development mechanism of the Kyoto Protocol. Although still in the approval process, the methodology should make it possible to at least receive voluntary carbon credits which, as part of a project with a positive social benefit for the poor, can provide adequate revenue to dramatically lower the cost of the stove and expand the number of people who can afford it.

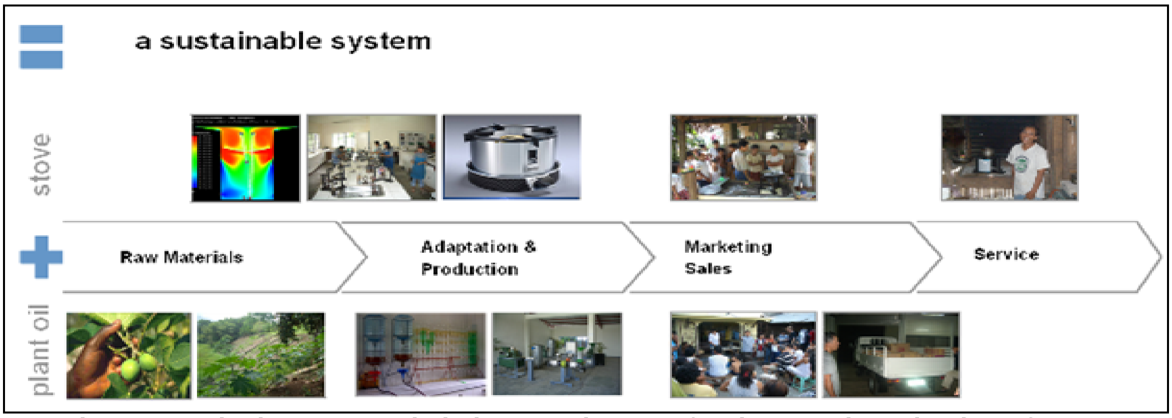
Field tests and pilot projects

Since 2003, protos has been undergoing field testing in Guatemala, the Philippines, Sri Lanka, India, Tanzania, and Indonesia. However, the most extensive pilot projects began at the end of 2004 in the Philippines. Together with Leyte State University (now renamed Visayas State University) BSH included more than 100 families in urban and rural areas in the initial test of the plant oil stove.

As part of the testing, different methods of plant oil production were explored together with the University of Hohenheim in Germany, where the original R&D for protos occurred. The result was the creation of a rural production center for plant oils at the cooperative level.

When the test concluded in April 2006, BSH introduced protos to the broader public with commercial market availability on the islands of Leyte and Samar in the Philippines. This was a major milestone in the development of protos. Since then, more than 700 units have been purchased.

In the first stages of development and field-tests, BSH worked with the GTZ and the Deutsche Investitions- und Entwicklungsgesellschaft mbH (DEG) to take advantage of their expertise in dealing with development related-issues. This partnership taught a clear lesson about the need to have knowledgeable partners who know the end-users well. Whereas BSH did not have this type of experience and infrastructure, it is clear that, as BSH introduces protos elsewhere, local assistance is a must for protos' success. As a result, BSH market introduction model requires cooperation with project partners who have the capacity and local knowledge to create the necessary infrastructure and manage a protos introduction sustainably.



Ensuring a sustainable supply chain is a requirement for the local introduction of protos

Continuous innovation: protos II—the next generation

Although BSH had created a market-ready product, the company never stopped working to improve the plant oil stove. As with all products, there is always scope to improve user friendliness, improve efficiency and lower costs. To this end, customer feedback has played a large role. At the end of 2007, prior to bringing mass production of the first generation protos stove on-line, BSH achieved a quantum-leap in the technology. The protos generation II has a new design and brings with it a 40% cost reduction, 30% efficiency increase and a dramatic improvement in user friendliness with easier cleaning and quieter operation.

The only downside to developing a whole new generation of protos is that it caused a disruption in the planned production schedule and thus and the time-line for large-scale market introduction. Although waiting for a new generation meant a 12-month delay, it was decided that the purchase costs, and especially the reduced operating costs, were such strong arguments for poorer customers that it would be irresponsible to sell them the first generation when the second offered so many advantages. As Samuel Shiroff explains "With the understanding that our users have limited amounts to spend on consumer goods, and that even a subsidized protos might require a micro-loan, we decided that dramatic increase in fuel efficiency and lower cost of production made our decision to wait until protos II was ready the right one."

The Future of protos—Plans to Expand as Demand Increases

BSH is in the process of making protos as widely available as possible. To this end, the company has established a partnership with a local manufacturer in Indonesia where protos will be produced. Initial plans are to manufacture several thousand units beginning in the second half 2009 and then to expand as demand increases. In the near future, all orders will be filled out of this first production facility. Currently, there are more requests for cooperation projects than can actually be filled, and BSH remains open to additional production partners. However, the integral ingredients must continue to be assured: a sustainable supply chain, bio-diversity of farming, and good treatment of workers. As Shiroff elaborated, "No doubt there is a lot of enthusiasm for this product in a lot of places around the world. Without trying to dampen this energy, we are very much focused on making sure that we follow clear guidelines and only introduce protos where we know it will be used in a sustainable manner."

The Power of protos: The Triple Bottom Line

Cleaner, safer, environmentally friendly: Jumi using her protos generation II plant oil cooker.

The protos technology clearly does more than heat up a meal. It is the triple bottom line that makes protos such a unique and innovative product. From an **economic** standpoint, it is the creation of local jobs and income opportunities through local production of protos, product maintenance, and plant oil farming—with a special focus on working conditions. Furthermore, it offers the prospect of shifting current governmental kerosene subsidies to oil production. From an **environmental** standpoint, it is the reduction of CO_2 emissions, which helps curb deforestation, thereby helping to prevent global warming, land erosion, desertification, and flooding. Last, but certainly not least, from a **social/ health** perspective, it is the prospect of cooking with no risk of explosion and the reduction of indoor air pollution—ultimately saving lives.

"We are very excited about protos," said Jumi shortly after completing the training, "the plantation will provide us with the fuel which is lower than kerosene and I no longer have to drive 40 minutes to get it. The stove cooks fast and it definitely does not have the bad smell of kerosene. I think our food will taste better too."

Additional information is available at www.plantoilcooker.com or contact protos@bshg.com.

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Lighting

Do new types of Energy Saving Lamps change the markets?

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Alice Pirgov

GFK Retail and Technology GmbH

Abstract

Compact Fluorescent Lamps (CFLs) have been available for 24 years. However, the energy saving lamp, in comparison to the incandescent lamp, was not able to attract an adequate amount of consumer acceptance over many years. Since CFLs can make a considerable contribution to climate protection, new EU Guidelines will be implemented to phase-out the energy inefficient incandescent bulbs and promote the switch to climate and budget friendly CFLs.

Nevertheless, over the past few years, the sales of CFLs have experienced a strong upward trend. This development, coupled with a growing significance for CFLs within the consumer retail market, will be illustrated using data from the GfK Retail Panel Germany, surveyed and monitored by GfK Retail and Technology.

The main intention of this paper is to demonstrate the necessity of energy efficient lighting and the benefits attainable for environment, consumers, trade and industry. A further comparison between CFL and incandescent lamps will additionally eliminate some of the widespread misconceptions regarding some product properties of energy saving lamps.

The last chapter reveals information concerning price trends and product diversifications which will further promote energy efficiency. The first results of these trends are depicted with data from the GfK German Retail Panel.

1. Introduction

19% of the global energy consumption and 14% of the European energy consumption is contributed to lighting. Hence, lighting usage is responsible for producing a massive share of CO^2 emissions.

Consumers can make a contribution to climate preservation and save money simultaneously.
Through the usage of more energy efficient lamps, e.g Energy Saving Lamps, or Compact Fluorescent Lamps (CFLs), a yearly reduction of 4,5 tons of CO^2 could be attained in Germany. From a global standpoint, the efforts to combat CO^2 emissions would be supported by an annual decrease of over 450 mio. tons of CO^2.
Additionally, private households are becoming more aware of the costs incurred by increasing energy costs on their budgets. Although, CFLs require a higher initial purchase investment than incandescent lamps, CFLs burn an average of 8,000 – 12,000 hours. The standard light bulb, in comparison, burns an average of 1,000 hours. Incandescent lamps effectively use 5% of the energy required to generate light. The remaining portion (95%) of consumed energy is diverted into heat. Energy saving lamps produce an identical light yield using only about 25% energy and are therefore substantially more efficient than incandescent lighting products.

The following eaxample for cost comparison will further demonstrate the efficiency of CFLs: The electricity costs of operating a 100 Watt incandescent light bulb for 8,000 hours are ca. 125 EUR. The initial purchase investment is ca. 1 EUR. Considering a life span of 1,000 hours, and an operating time of 8,000 hours, the total acquisition costs are 8 EUR. The total costs of burning a 100 Watt incandescent lamp for 8,000 hours are ca. **133 EUR.**

The electricity costs of operating a 20 Watt CFL lamp, which delivers the same light intensity as a 100 Watt incandescent bulb, over a time period of 8,000 hours are ca. 24 EUR. The initial purchase investment of ca. 15 EUR is considerably higher, but this investment is more cost economic in the long-run, because the lamp has an average life span of over 8,000 hours. Consequently, the total costs of using a 20 Watt CFL are ca. **39 EUR**.

Based on actual estimates for Germany, private households could yearly save over 1,3 billion EUR by simply switching to energy saving lamps.

Illustration 1: Compact Fluorescent Lamp

CFLs can be perceived as an innovation of the conventional Fluorescent Lamps (FLs). In comparison with FLs, CFLs are smaller and deliver higher lighting intensity. The design and construction of CFLs have become compacter and deem as reliable substitutes for traditional light bulbs.

2. Impact of consumer preference on the retail market for lighting products

Has the Climate Change Debate already made an Impact on Consumer Choice and Retail Assortment of Lighting Products? Data taken from the German Retail Panel monitored by GfK Retail and Technology will indicate the power of consumer behaviour on the market.

Energy saving lamps have been on the market since 1985 – for 24 years. Initially, the consumer acceptance of this lamp type was very low for more than 20 years. Some of the misconceptions surrounding the first generation of CFLs are as follows: strange design and shape, the "cold" light colour illuminated and the amount of time needed for the lamp to reach its maximum lighting capacity. These were some of the reasons why consumers hesitated to change their purchase behavior. Conversely, the demand for halogen lamps increased as the commercial lighting manufacturers penetrated the market with low-price luminaries which operated on energy guzzling high volt halogen lamps.

Until 2006, energy saving lamps merely reached a 7 % share in units in Germany. On the other hand, a 20% share in value was reached. At this time two/thirds of the total market volume for lighting products was still dominated by the incandescent light bulb using a technology invented over 100 years ago.

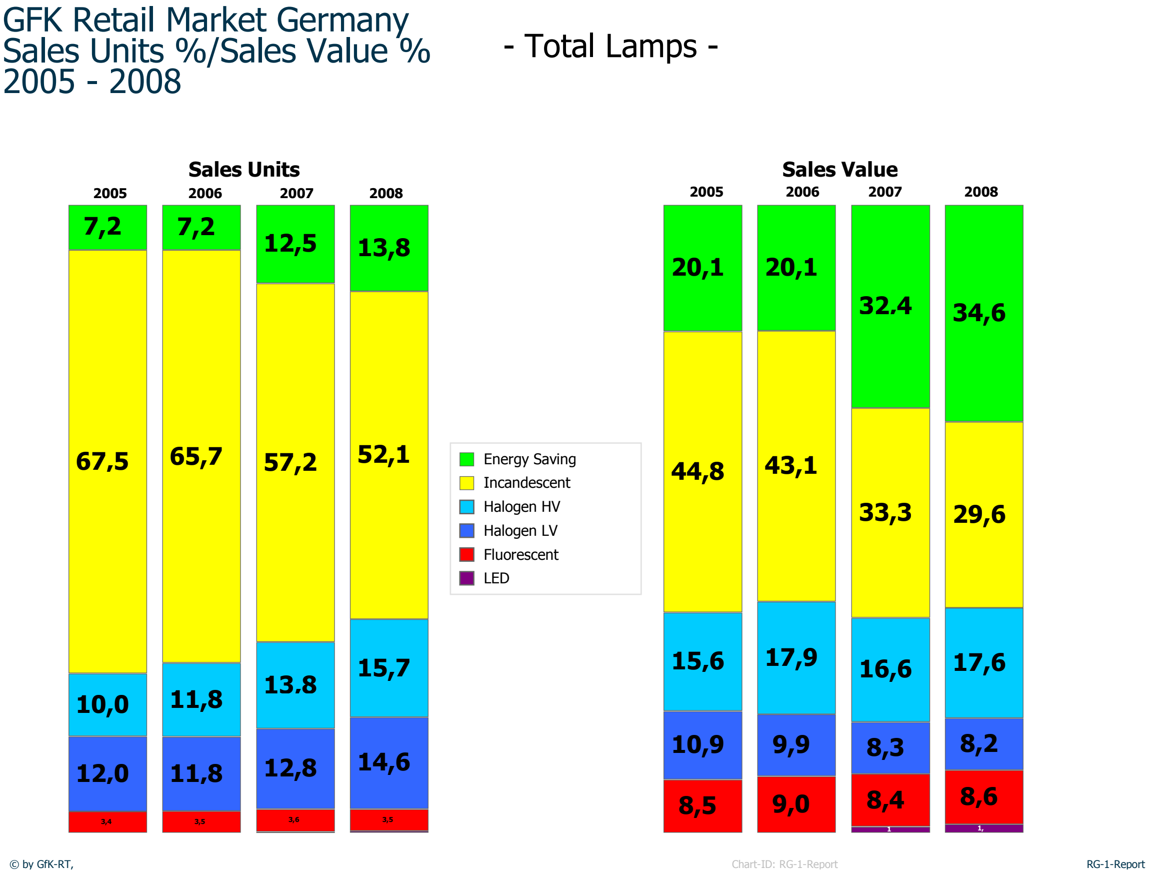

Illustration 2: Market Shares of Lamp Types

The call for change began in February, 2007, as the media pushed the proposal of the australian government to “ban the bulb” and promote the switch from the old light bulb to modern energy saving CFL lamps. This profound announcement and “pledge” to the environment had an immediate effect on the European market. The sales of CFL lamps in Europe skyrocketed in March, 2007. This development was also recorded on the German market (cf. Ill. 3). The sales growth rate in EUR for March/April 2007 soared to 143%. Over the course of 2007, the total growth rates of CFL lamps for sales value and sales volume were +91% and +73%, respectively. This increase, in turn, led to a total volume increase in the consumer lighting sector of 18,4 %. In 2007, the turnover share of 32% for CFL lamps almost matched the share of incandescent lamps (cf. Ill. 2). Considering the share of units sold, CFL lamps are still far behind those of incandescent and halogen lamps. In 2007, the CFL lamps reached a market volume share of 12,5% compared to 7,2% in 2006 (cf. Ill. 2).

However, the development within this product group tapered off in 2008, and twelve months after the initial begin of the growth phase, sales records declined by 26% for the reporting period March/April 2008 (cf. Ill. 3, Period March/April).

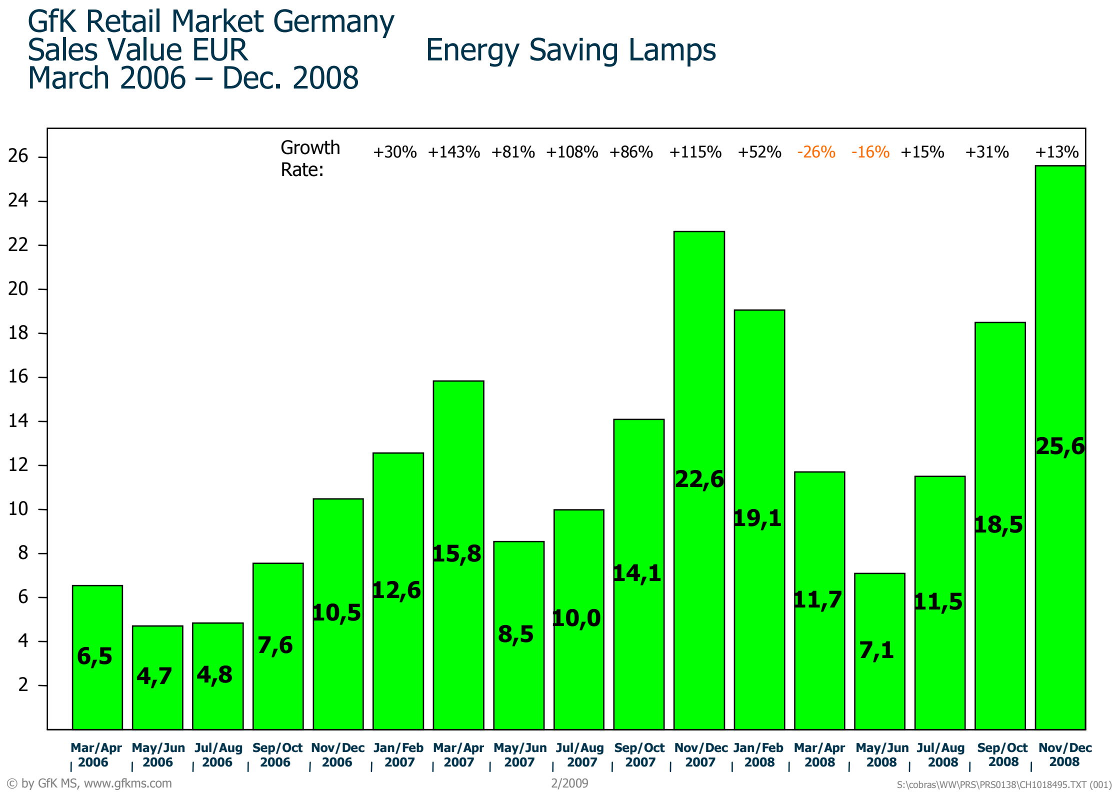

Illustration 3; Market Volume in EUR / Growth Rate in %

In June, 2008, the European Commission announced intentions to incrementally phase-out incandescent lamps. This announcement led, once more, to an increased demand for CFLs in the months July/August of +15 %, in September/October of +31 % and in November/December of +13%. Over the course of 2008, a moderate growth rate of 12 % for CFLs was recorded in relation to turnover on sales units and sales value.

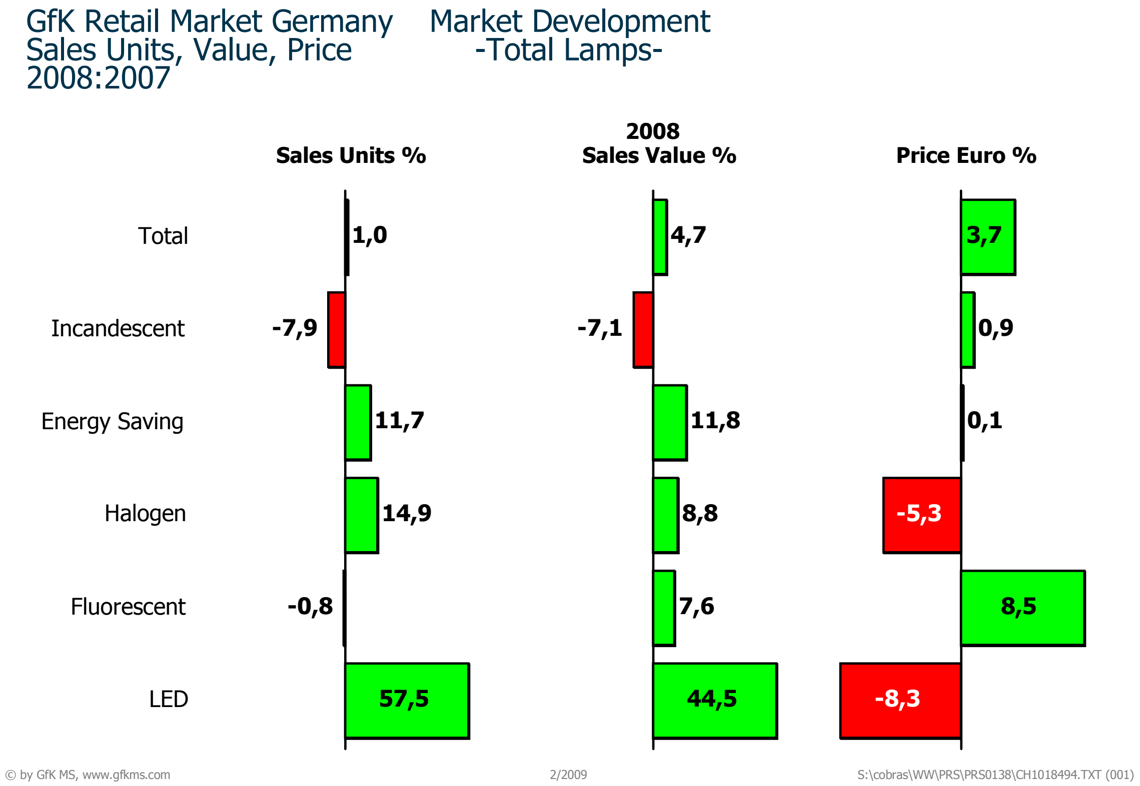

Illustration 4: Accumulated Growth Rates 2007:2008

The market development clearly illustrates the necessity of political power to reach the goals of conserving energy. Policy changes will be induced and these will definitely change the product assortment offered by the lighting industry; and with it, consumer demand for energy efficient alternatives.

3. Products to be Phased-Out – Step-by-Step:

In December 2008, a concensus was reached within the European Commission to incrementally ban the distribution and sales of energy inefficient lamps in the European Union (EU). Step 1 of the phase-out plan will begin as of September 01, 2009. This step prohibits the distribution and sales of all frosted incandescent lamps (with the exception of those labeled with Energy Efficiency Label (EEL) – Class A) and clear incandescent lamps labeled with 80 (or higher) Watts. The incremental measures will annually increase the range of clear incandescent lamps which are to be phased-out of the market until 2012. After September 01, 2016, all lamps with EEL Class C or lower will be banned fromthe market.

PHASE	Date:	The future distribution of the following lamps will be prohibited
1	September 01, 2009	Frosted lamps* (exception: EEL Class A bulbs) Clear lamps >= 80 Watts (W)
2	September 01, 2010	Clear lamps > 65W
3	September 01, 2011	Clear lamps > 45W
4	September 01, 2012	Clear lamps > 7W
5	September 01, 2013	Increasement of quality standards
6	September 01, 2016	Lamps with EEL Class C

Illustration 5: Indicative table for Lighting Product Phase-Out (simplified version)

The results of the measures taken by the European Commission are clearly a win-win-win-win situation.

The winners are:

- The environment through a massive reduction in carbon emissions.
- The consumers with lower electricity bills.
- The lamps industry producing new energy efficient products.
- Retail with increased sales revenues (cf. Ill. 8).

4. Developments within the Lamp Industry

The energy saving lamp has become more attractive for consumers because of new designs, sizes and shapes which have been introduced into the market over the past few years. The initial market launch of the first generation CFLs over 24 years ago, was that of a large, tubular-shaped lamp which did not fit into most light fixtures. This strange and unpractical design has been further diversified, and the lighting industry now offers other lamp shapes like those of a standard bulb, a candle and also reflector lamps. Consumer awareness of these lamp types is growing, because these CFLs “look like” incandescent bulbs. However, the compact tube-shaped CFL, still manages to reach a 62 % share of the market because this lamp shape offers a definite price advantage over the newer CFL types/shapes.

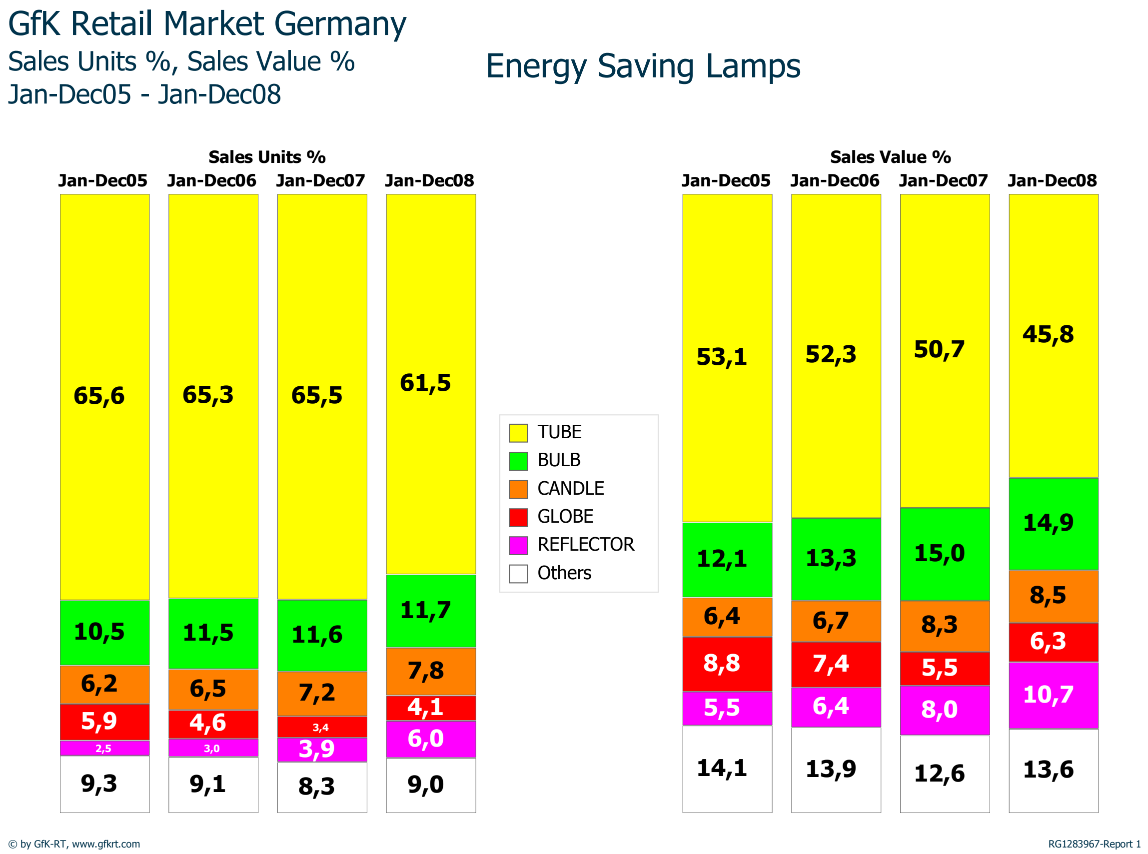

Illustration 6: Market Share per Type/Shape

These new types/shapes offer a larger potential for retail sales proceeds. Currently, the average price of a reflector type energy saving lamp is priced above 10 EUR (cf. Ill. 7).

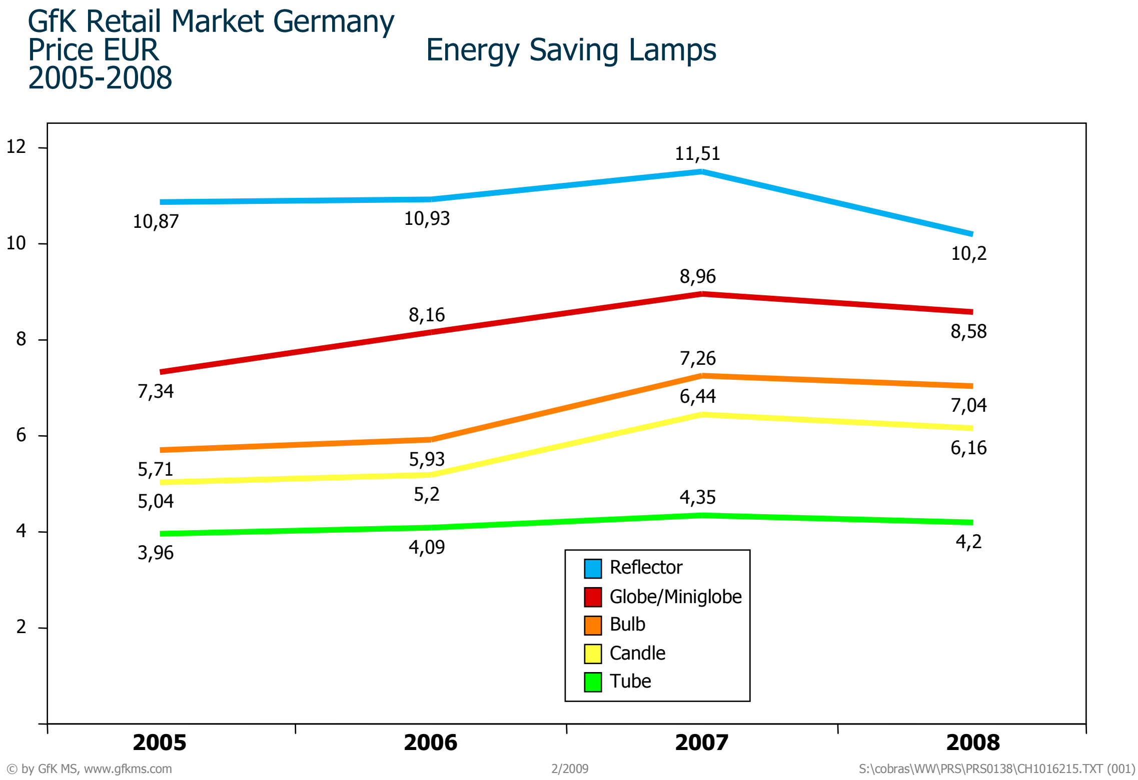

Illustration 7: Price Development per Type/Shape

As a result of the abolishment of import taxes on CFLs, it is more than probable that a price-drop will occur within this segment.

The price trend over the past years for halogen lamps shows how the price spiral turns down when the market is dominated by “No-Name” brands. In Europe, however, brand named CFLs, FLs and LEDs still hold a large portion of the market share. This is the reason why the prices of CFLs, FLs and LEDs have remained stable. This results in higher retail sales revenues (cf. Ill. 8).

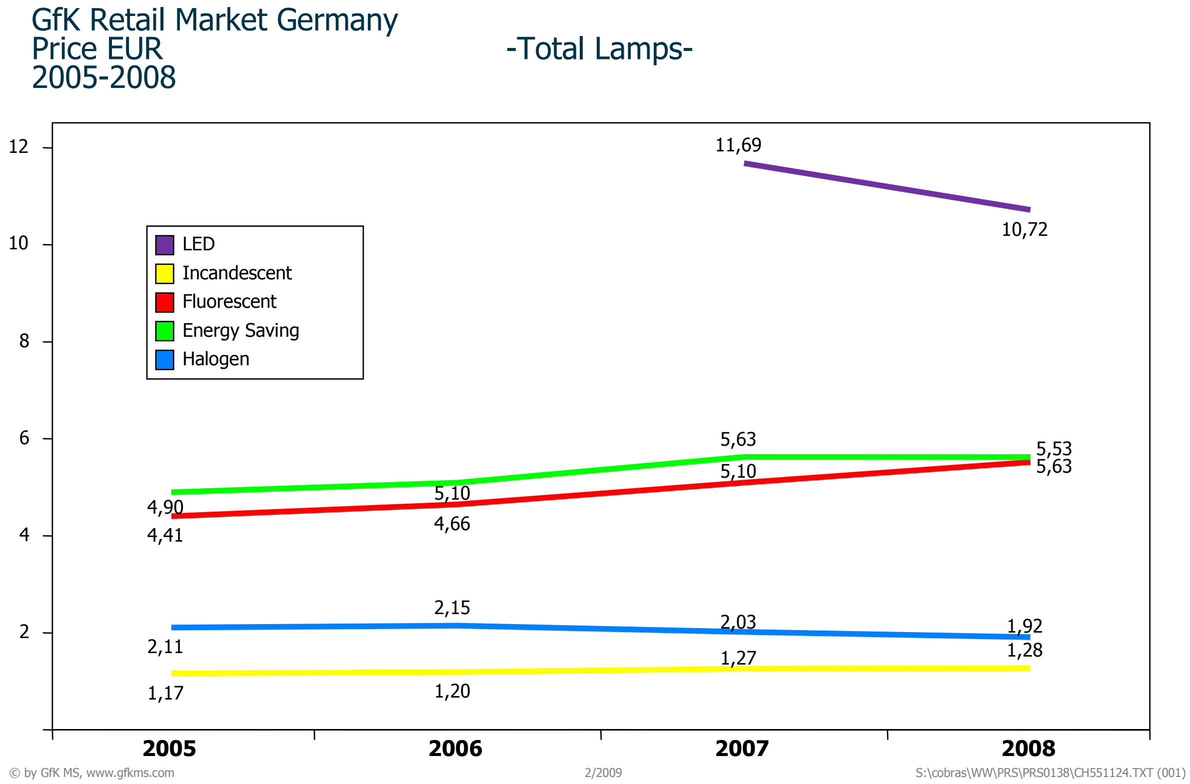

Illustration 8: Price Development per Type

6. Other product trends to further promote energy efficiency

Energy saving halogen lamps have been on the market since the end of 2007. These lamps save 30 - 50 % energy in comparison to regular halogen lamps. For example, a 35 Watt standard halogen lamp can be easily replaced with an energy saving halogen lamp. The current market share of 7 % for the energy saving halogen lamp is quite small compared to the the remaining halogen lamp segment, but will certainly grow.

Light-emitting diodes (LEDs) are also a good alternative when replacing energy guzzling incandescent and/or halogen lamps. This segment, however, is still in the development phase of the product life cycle.GfK Retail and Technology has been tracking this product segment since 2007. The growth rate for LEDs in units sold for 2008 reached 57,5% (cf. Ill. 4). Presently, the market share of LEDs based on total market volume is 0,2 % (cf. Ill. 2). The importance of this product category will definitely increase quickly. These lamps produce a bright light and are extremely energy efficient. The average price of more than 10 EUR per LED is much more costly than other lamps.

7. Summary

The political intervention of the EU Commission to combat climate change endorses the widespread acceptance and usage of CFLs. The implications of this offensive are not only to deliver an enormous contribution to the reduction of carbon emissions, but also to help the private sector in the reduction of costs allocated to energy consumption. Retail and industry will likely profit from dynamic forces - like product diversity coupled with gradually decreasing prices. Consequently, the steps implemented by the EU will lead to a win-win-win-win situation for the environment, industry, retail and consumers. The EU guidelines facilitate in setting precedence and paving the way for consumers to make the switch from traditional energy guzzling lamps to energy efficient lamps.

The EuP preparatory study for the eco-design of domestic lighting

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Abstract

In the framework of the Directive on eco-design of Energy-using-Products (EuP) of the European Commission, different product specific preparatory studies were carried out or are in progress, including one on domestic lighting (Lot 19) which is the subject of this paper. The approach used throughout this study is the Methodology for Eco-design of EuP (MEEuP), which prescribes the way the life cycle oriented environmental assessment is carried out.

The analysis comprises the assessment of the current situation including the definition of the product category, a market analysis, user behaviour aspects, a systems analysis and an environmental assessment of the current products. Based on above description of the current situation, the improvement potential is analysed considering life cycle costs and especially the point of least life cycle costs for the consumer.

Finally, are defined technical options, which are feasible and available in the market to improve the environmental performance.

The study is split in two parts: 1) non directional light sources and 2) household luminaires at system level and directional lamps, e.g. halogen reflector lamps and LEDs. This paper highlights key findings of the first part of the preparatory study (non directional lighting sources) accomplished November 2008.

1. Product definition and scope

The first step of the study includes the categorisation and definition of products within the scope as well as identification of key parameters for the selection of relevant products for the assessment analysis during the next steps of the study. A 'domestic lighting' product system is defined as in standard EN 12665 contains a “lamp” defined as “source made in order to produce an optical radiation, usually visible” and a ”luminaire” defined as an “ apparatus which distributes, filters or transforms the light transmitted from one or more lamps”. Coloured lamps typically used for decorative purposes are excluded. Many so-called 'domestic lighting' products are also used in other areas (e.g. hotels, shops, offices) and thus are included in the study.

Technical lighting requirements (e.g. illuminance levels) are not specified by the consumer before installation according to technical standards, therefore

The focus in part 1 has been on the lighting NDLS (Non Directional Lighting Sources) technology that is most commonly used in the domestic market covering:

- GLS-F = frosted incandescent lamps
- GLS-C = clear incandescent lamps
- HL-LV = Halogen 12 V lamps
- HL-MV = Halogen 230 V lamps
- CFLi = Compact fluorescent lamps with integrated ballast
- WLEDi = White Light Emitting Diode lamps with integrated power supply.

LFL (Linear Fluorescent Lamps) are also used in the domestic sector but they were not considered because they were addressed in the finished EuP preparatory studies (lots 8 and 9 on Office and Street Lighting). Several acronyms are used today but those were agreed with the sector federation (ELC) in the beginning of the study.

The main general lamp and luminaire performance specification parameters included in the study is the Luminous flux Φ [lm] during 1 hour of operation, it is the so-called 'functional unit' of the study.

Other important product parameters are: Lamp power [W], Lamp Survival Factor (LSF), Operational lifetime, Lamp Lumen Maintenance Factor (LLMF), Colour Rendering Index (CRI), Colour temperature Tc, starting time, warm-up time, power factor, lamp dimensions and sockets, and functional elements (e.g. dimming control, presence detector and control).

Lighting test standards or guidelines related to the functional unit, resource use (energy, materials, ..), safety and others are described and gaps analysed with reference to EN (ratified by either CEN or CENELEC), IEC and CIE.

Existing legislation and agreements at European Community level are described e.g. including the environmental directives (RoHS, WEEE), energy efficiency directives for ballast for fluorescent lighting, energy labelling of domestic lamps and award of eco-label to lighting bulbs, the European Quality Charter for CFLi and electromagnetic compatibility (EMC).

2. Market Analysis

The MEEuP methodology used to assess the environmental impact requires the following market parameters:

- number of households for each member state and EU27
- the installed stock of different lamps: most recently, in the past (Kyoto reference) and in the future with business as usual
- annual lamp sales
- division on non-directional and directional lighting sources
- the weighted average wattage per lamp type
- average product life
- average operational hours per lamp type and year.

Generic market data is derived from Eurostat. The volume of sales and trade of a product group is described by Eurostat's product-specific statistics including production, export and import. The apparent EU-27 consumption is calculated as Production + Imports – Export. Looking at the development in the 5-years-period 2003-2007, the major changes in apparent consumptions (sales) are:

- GLS lamps (of which most are used in the domestic sector) topped in 2005 with sales close to 1300 million lamps and a reduction to 1000 million in 2007.
- CFL (CFLi+CFLni) have gradually increased from 145 million in 2003 to 426 million in 2006 and 628 million in 2007. A considerable part of these lamps are CFLi used in the domestic sector.

Besides Eurostat, these data were retrieved from literature research, recent and on-going EU R&D projects, consultation of ELC and major retailers, expert inquiries and estimations based on the data collected.

The study includes many results about the major manufacturers (ELC) sales in EU27. Some of the most interesting results are:

- GLS sales are distributed as follows: one third 60W, nearly one third 40W, 12% 100W and above 100W less than 1%.
- HL-LV sales are distributed as 29% 10W, 38% 20W and 33% >20W.
- HL-MV sales are distributed as 7% 25W (yearly growth very high), 21% 26-50W, 32% 75-100W and 39% ≥ 200W.
- CFLi sales are distributed as 4% ≤ 7W, 16% 8-10W, 34% 11-14W, 15% 15W and 32% >15W.

The EU R&D project REMODECE has provided actual survey data for 11 EU countries under which Sweden, UK and JRC [Bertoldi and Atanasiu, 2007]. This made it possible to calculate the EU-27 average stock lamps per household in 2007 shown in Figure 1. The stock per country varies a lot.

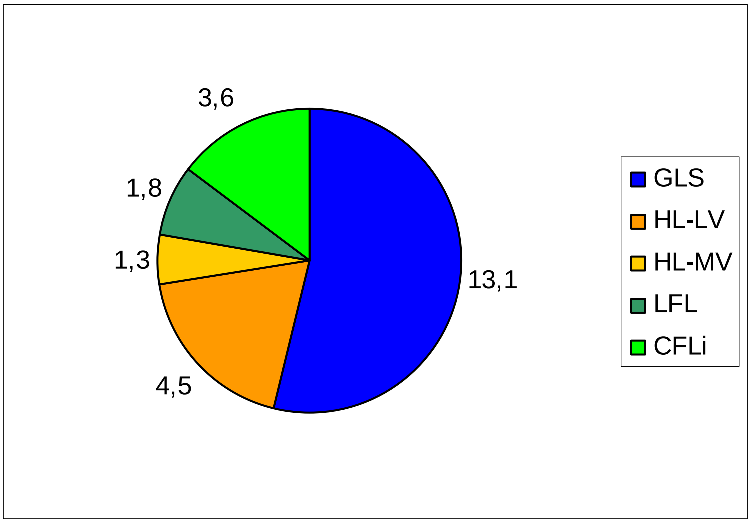

Figure 1: Average stock of 24.3 lamps per household in 2007 for EU27

EU R&D measurement campaigns results and estimates for non-domestic use, have formed the basis for calculation of the average operational hours per lamp type. Lamp life hours are based on information in the manufacturers lamp catalogues. The above data have been used to calculate a business-as-usual forecast of the sales and stock lamps per year until 2020 including replacement sales and expected changes/trends in sales. The forecast of stock per year is shown in Figure 2.

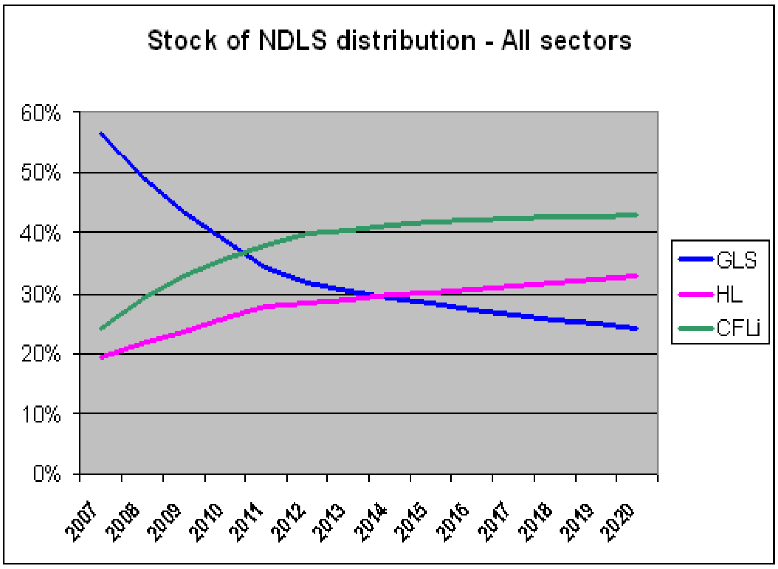

Figure 2: BAU (Business as Usual) forecast of NDLS stock of lamps including all sectors

The major market trends forming the background for the above figure 2 Business As Usual (BAU) forecast were:

- During installation of new kitchens, bathrooms or verandas, designers, manufacturers and installers have a large influence by including lighting solutions in the rebuilding, furniture and appliances and they mostly propose halogen lighting. This policy also typically increases the number of lighting points per household.

- Growing welfare in general increases the number and use of lighting points often because the living space per capita increased (e.g. by a growing number of people living alone) or simply because more light sources are installed. One could fear that there is no natural limitation on this growth rate because the eye is able to adapt to a broad luminance range and daylight levels are by far not yet reached in domestic lighting. However, complains in some new installations about glare and overheating of the room can limit this growth rate.

- There is also a trend of market shift from HL-LV (12 V) to low wattage HL-MV (230 V), mainly because the installation work is easier because no transformer is needed.

- In the domestic sector, HL-MV with high wattage are used in up-lighters (floor and wall), spots in the hall/staircase/entrance, outdoor lighting and in do-it-your-self working lamps (typically 300 and 500W lamps in floodlights). Those lamps are also sold with luminaires at low cost and hence pure 'lamp' sales data lags behind.

- GLS are replaced by CFLi due to the public awareness of the climate change problems and the rising energy prices. In both 2006 and 2007, CFLi sales have increased very fast. Anyway, in the BAU forecast it is expected that CFLi sales stop increasing in 2008 due to the large increase in the use of halogen lamps (replacing GLS), the long lifetime for CFLi and the fact that some customers have a few lighting points left where they prefer to keep the GLS due to barriers for use of CFLi or because of the GLS has little usage such as in cellars, staircases or storage rooms and where full lighting is also immediately needed.

Futhermore the market analysis section also includes collection of products prices, electricity rates, interest and inflation rates for use in the calculations in the next step of the eco-design EuP methodology.

3. User behaviour and local infrastructure aspects

A first section is devoted to real life efficiency and quantification of relevant parameters.

Service providers (property developers, kitchen and bathroom designers, furniture and appliance manufacturers) have a growing influence on the energy used in the domestic homes because lighting is an integral subcomponent of the design and installation. Else the users typically buy and install the luminaries and lamps. The main objectives for installing electric lighting systems are providing a suitable visual environment with the “right light at the right time at the right place”, safety and security, creating atmosphere and being a part of attractive interior design. The visual performance of the eye varies with people and the eyes deteriorate with age so we need a higher quantity of light and more care has to be taken to avoid glare – a point that is often neglected in the design.

The choice of an appropriate colour rendering and colour appearance (temperature) of a lighting source should largely be determined by the function of the room to be lit but it also involves contours of surfaces and contrasts plus psychological aspects as warmness, relaxation and clarity.

User influence on final lighting energy consumption is primary related to presence of users in the home and automation is more and more used: outdoor lighting control, security lighting schemes, presence detection and dimming control.

The lower power factor for CFLi could cause a higher current with around 5% more losses in the grid. Therefore a correction factor ‘Lamp Wattage Factor LWFp’ is introduced in the study.

The lumen output of a lamp deteriorates during its lifetime. The decrease is not equal for all lamp types and therefore Lamp Lumen Maintenance Factor (LLMF) data from the CIE 97 report[1] are used in the study. Newly available CFLi test data did show lower average performance but are not used because there was also a lack of real European test data for GLS and Halogen lamps.

A second section is related to End of Life (EoL) behaviour and focuses on mercury which is an essential component in CFLi.

The RoHS-directive restricts the mercury content to 5mg but the EU lamp manufacturers supply lamps down to 1.4 mg. The WEEE-directive obliges the manufacturers to take back used products so that they can be recycled. The impression from co-operation with the partners in the EU R&D project ENERLIN is that the recycling system for collection of mercury from lamps is in most countries not implemented properly, especially for the residential sector. A large part of the consumers don’t even know that a CFLi contains mercury and that they should give back the disposed CFLi for recycling. Information from the manufacturers does not seem to be enough. It would be better to require that it is mandatory to be able to return disposed CFLi’s at the points of purchase as some countries are about to implement.

A third section describes the influence of local infrastructure.

An important and potential limiting factor is the electrical installation because the Electrical wiring might create a control system lock-in effect. Two-wire installations with electronic control switches (e.g. dimmers, presence detectors, ..) designed for GLS lamps that require a minimum wattage might include lock-in effects as installation of efficient lamps below the minimum wattage might create problems e.g. by drawing excessive current for internal power supplies which might cause overheating and reduce the lamp life significantly or the control might not work correctly. Lamp manufacturers have developed lamps that do overcome this problem, they are implemented in the more expensive dimmable CFLi lamps or HL-MV lamps with integrated electronic transformer. Standardisation is available but there are currently no provisions for compatibility.

As noted in 2 there might also be a luminaire socket and space lock-in effect, i.e. certain sockets and the available space in the luminaires are not compatible with efficient light sources (e.g. HL-MV with R7s or G9 caps).

A final section describes potential barriers and restrictions to possible eco-design measures.

[1] Technical Report CIE 97: “Guide on the maintenance of indoor electric lighting systems”, edited by the International Commission on Illumination

A barrier might be created by the low quality of the CFLi's and it has been the focus of several eco-label or quality charter initiatives including one initiated by EU. This is also the fact for the correctly correlated lamp power of a GLS and a CFLi. In some EU countries, lists are produced with 'good quality' CFLi's that fulfil the requirements of the European CFL Quality Charter.

The user should know how to replace incandescent lamps by CFLi's giving the same amount of light (lumen). Unfortunately, the manufacturers generally do not give correct information about this replacement. Most manufacturers admit this but have over the years continued to claim that it is not so important. The customers often say "CFLi's don't give good lighting" while this with respect to lumen output often mean that 'they do not give enough light'. The new version of the European Quality Charter (July 2008) proposes that e.g. a 60W GLS (with initial lumen output 710 lumen) is replaced by a CFLi with 850 lumen (20% more). This is equal to an easily understandable "rule of thumb" for an equivalence of 4:1 where a 60W incandescent lamp will be replaced by a 15W CFLi. This requirement compensates for the lower real life performance of the CFLi compared to GLS due to lower LLMF (ageing factor), temperature effects, potential influence from lamp position and a compensation for the low start performance due to warm-up time. For the calculations in the study, a more accurate equivalence is used.

The new version of the European Quality Charter also requires that the 80% level is reached within 60 seconds. A barrier for reduction of the warm-up time is that manufacturers nowadays use amalgams in the CFLi's in order to reduce the influence of ambient temperature on the light output of a lamp during normal operation. This amalgam technology that is also necessary to produce the more compact types, increases the warm-up time.

Other barriers are the previously described control system and space lock-in effect.

Finally also alleged negative health effects could create barriers. The study reports that no studies have given evidence of alleged network pollution by harmonic interference and negative health effects due to electromagnetic radiation. The European Commission (DG SANCO) has initiated the expert group SCENIHR that has made a report on light sensitivity health issues that could be related to optical radiation (UV).

4. Technical analysis existing products

For the definition of the Base-Case (see 5) as well as for the identification of part of the improvement potential (see 7), a general technical analysis of current products on the EU-market is done.

This technical analysis for a selected number of representative, non-directional lamps is made for all phases of their complete lifetime: the production phase, the distribution phase, the use phase as well for the product as for the system and the end of life phase.

For a number of non-directional lamps, incandescent, halogen and compact fluorescent with integrated ballast, Bills of Materials (BOM's) are analysed with special attention to mercury content.

Annual resources consumption for energy and lamps are rated during product life, in accordance to the appropriate test standards. The influence of the power factor and/or external power supply is converted in correction factors: LWFp for the power factor and LWFe for an external power supply or ballast.

Finally, the input data for the environmental assessment of the end-of life processing of the lamps are defined.

5. Definition of the Base-Case

A base-case is "a conscious abstraction of reality". The description of the base-cases is the synthesis of the results of tasks 1 to 4. The environmental and life cycle cost analysis are built on these base-cases throughout the rest of the study and it serves as the point-of-reference for task 6 (technical analysis of BAT), task 7 (improvement potential), and task 8 (policy analysis).

As discussed in task 1, a wide range of non directional light sources are available and task 2 highlighted that their sales amounts are significant. Therefore, 6 base-cases were considered to be representative of the current European market (considering all sectors, not only the domestic one), and their technical and economical characteristics are presented in the following table.

Table 1: Description of the NDLS base-cases

	GLS-C	GLS-F	HL-MV-LW	HL-MV-HW	HL-LV	CFLi
Wattage (W)	54	54	40	300	30	13
Annual operational hours (h/y)	505	551	538	536	705	800
Lamp lifespan (years)	2.50	2.50	3.33	3.33	6.00	7.50
Lamp efficacy (lm/W)	11.0	10.6	12.0	17.3	14.5	43.0
Lumen output per lamp (lm)	594.0	572.4	480.0	5177.3	435.0	559.0
Product price	0.60 €	0.60 €	5.50 €	3.00 €	3.00 €	4.63 €

The environmental impact assessment over the whole life cycle (production, manufacturing, distribution, use and end-of-life) of these six bases-cases was then carried out using the EcoReport tool, a simplified Life Cycle Assessment tool.

For all the base-cases, the environmental impacts of the production, distribution, and end-of-life phases are negligible for most of the indicators compared to the use phase. As the lumen output and the lifetime of the lamp types differ, a comparison of the base-cases both for the environmental and economic assessments was done per lumen and per hour.

For two main environmental impact indicators (GER (gross energy requirement) and mercury emissions to air), Figure 3 and Figure 4 show the results per lumen and per hour for the 6 base-cases with reference to the base-case GLS-F. As expected, incandescent lamps, being the least energy efficient, have the highest magnitude of impacts. Regarding the GER, i.e. the total energy consumption, as more than 90% of this impact occurs during the use phase, and as GLS lamps have the lowest lamp efficacy (and the CFLI, the highest), incandescent lamps require the most energy to provide 1 lumen during 1 hour. Conversely, with the best efficacy, the base-case CFLi allows a reduction of almost 75% in energy consumption compared to the base-case GLS-F (see Figure 3).

Mercury emissions to air for lamps could occur mainly during two stages of the life cycle; during the use phase for the production of electricity (0.016 mg Hg/kWh), and during the end-of-life (EoL) for bulbs containing mercury (i.e. CFLi). Due to emissions occurring at its end-of-life (3.2 mg[2]) the base-case CFLi does not have the lowest amount of mercury emissions (per lumen and per hour) during its entire life cycle even if it is the most efficient lamp type. The reduction is 'only' of 10.9 % compared to the base-case frosted incandescent lamp. As shown in Figure 4, the base-case HL-MV-HW is the 'best' lamp when focusing on mercury emissions. However, improvements can be expected for recycling CFLi in order to increase the share of CFLi recycled (20 % nowadays). Therefore, if all CFLi were recycled, this lamp type would be the best choice in terms of mercury emissions due to low electricity consumption per lumen and per hour.

[2] Assuming that a typical CFLi contains 4 mg of mercury and that 80% of CFLi are not recycled.

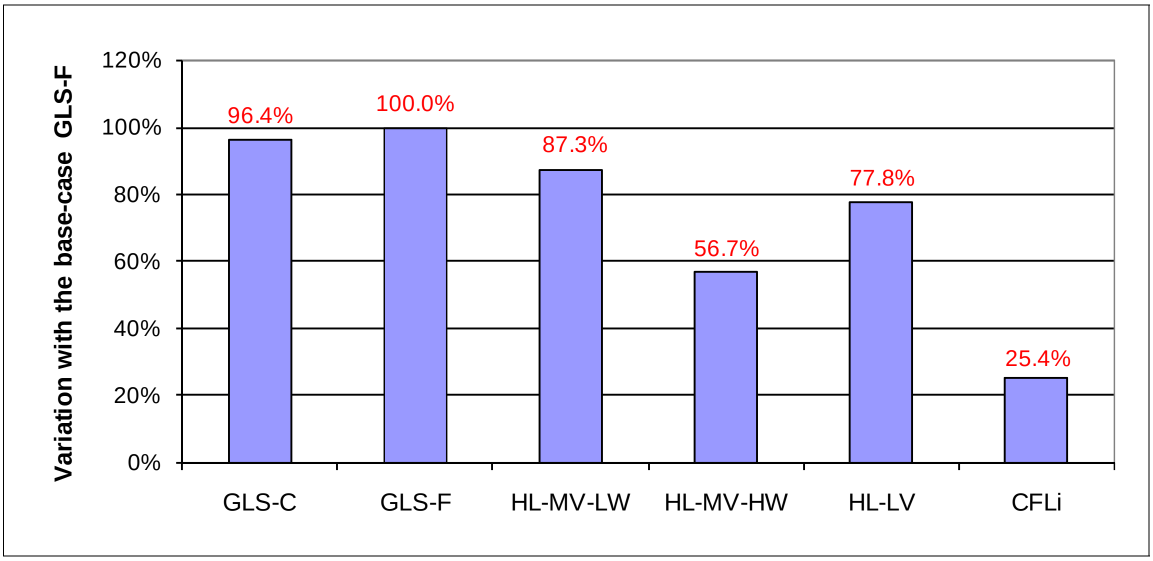

Figure 3: Comparison of the base-cases for the GER indicator

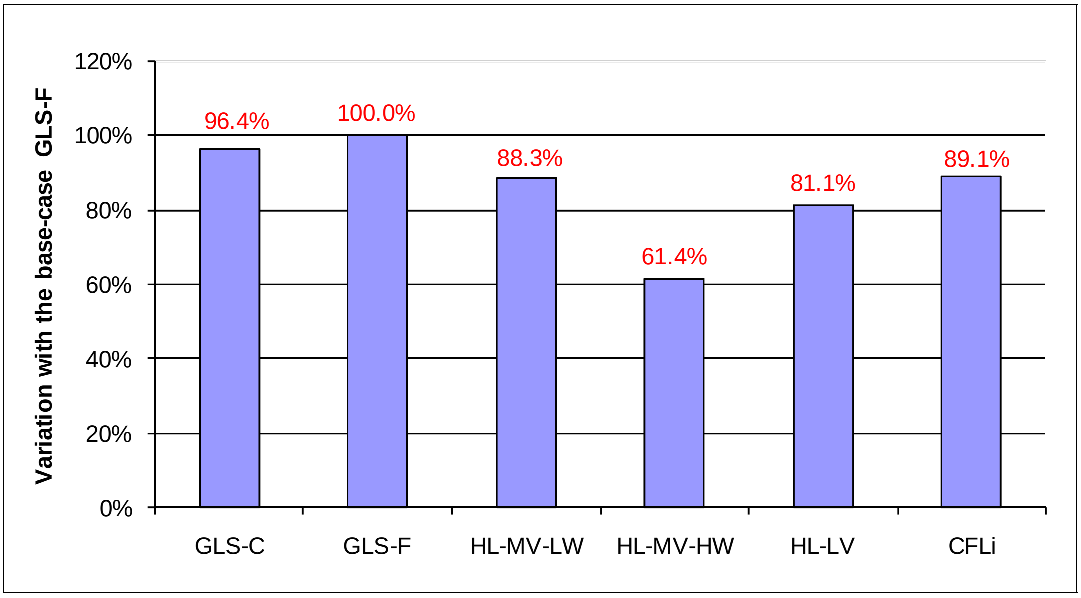

Figure 4: Comparison of the base-cases for mercury emissions over lifetime

The economic assessment carried out present the life cycle cost (LCC) per lumen and per hour for each base-case, as highlighted in Figure 5. It is clearly visible that the use of the base-case HL-MV-LW implies the highest cost over lifetime (product price + electricity cost): 19.89×10^{-6} €. Due to its relatively high purchase price (5.5 €), its life cycle cost is even higher than the LCC of the base-case GLS-F ($15.02\text{x}10^{-6}$ €). On the contrary, the base-case HL-MV-HW presents a significant reduction compared to the base-case HL-MV-LW (- 55.2 %) due to its low product price even with a high wattage (300 W), and the typical CFLi have the lowest LCC thanks to its long lifetime and high lamp efficacy.

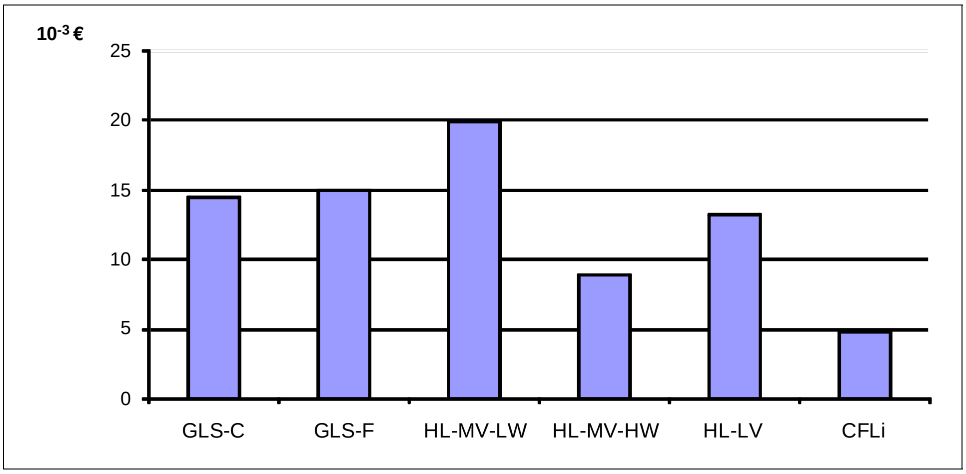

Figure 5: Life Cycle Cost per lumen and per hour

Assuming that all the products have the same impacts as the base-case of their category, it is then possible to extrapolate in order to assess the environmental impacts at European level. Table 2Table summarises the total electricity consumption (during the use phase) of each base-case. Therefore, the total electricity consumption in 2007 of non-directional lighting sources which are in the scope of this study and used in all sectors (not only the domestic sector) is about 112.5 TWh, of which 58.6% is due to the use of incandescent lamps.

Table 2: Total electricity consumption for the year 2007 for all sectors

Base-case	EU 27 stock electricity consumption in 2007 for all sectors (TWh)	Share of the total electricity consumption of the 6 lamp types
Base-case GLS-C	16.92	15.0%
Base-case GLS-F	49.09	43.6%
Base-case HL-MV-LW	2.89	2.6%
Base-case HL-MV-HW	19.22	17.1%
Base-case HL-LV	13.11	11.7%
Base-case CFLi	11.23	10.0%
TOTAL	**112.47**	**100.0%**

6. Technical analysis BAT and BNAT

The Best Available Technology (BAT) and Best Not yet Available Technology (BNAT) that can be implemented on product or component level is described in this chapter. It also analysed potential limitations created by Intellectual Property (IP).

Many of the BAT products are already available on the market, but are less frequently used because of their purchase price. This is the case for CFLi's with enhanced efficacy, very long lifetime and much less mercury than required by the RoHS directive (1.4mg instead of the maximum allowed 5mg).

A following item is the dimmability of all kinds of lamps, also for CFLi's; special attention is given to the compatibility of all those lamps with the currently installed dimmers and electronic switches.

For CFLi's, also other improvement technologies are considered: amalgam technology that allows size reduction, the use of triphosphor and multiphosphor lamps for better colour rendering, lamps with different colour temperatures, lamps with electronic circuits for direct start, shorter warm-up time, power factor control and adaptation to line voltage fluctuations..

Next items concern the improvements for halogen lamps. For the mains voltage halogen lamps (HL-MV), a xenon filling gas results in an energy saving of over 20% compared to an incandescent lamp with the same lumen output. These lamps are brought on the market with cap types R7s, G9 as well as E14/27 or B15/22d.

For the low voltage halogen lamps, a considerable improvement can be obtained by applying an infra-red coating on the small bulb (GY4/GY6.35). A further application of this technology is the introduction of halogen lamps with caps E14/27 or B15/22d where the small infra-red coated bulb is combined with a built-in electronic transformer; the result is a retrofit lamp for standard incandescent lamps but with an energy saving of almost 50%. Applicable patents are expired (> 20 years), however the product is still rarely found on the market. The above three types of BAT were used as improvements of the base-cases and thus in the different scenarios calculated in tasks 7 and 8.

The possibility to replace high wattage incandescent or halogen mains voltage lamps with HID lamps is also considered but this requires a luminaire replacement which is related to part 2.

High lumen output (>400 lm) LED-retrofit lamps with caps E14/27 or B15/22d, OLED-lamps, incandescent lamps with enhanced light output by using photonic lattice and mercury free dielectric barrier discharge lamps where not yet available technology on the market at the time of the study and as a consequence they where therefore only mentioned as possible Best Not yet Available Technology (BNAT).

7. Improvement potential

Based on the results of the environmental assessment of the base-cases carried out in task 5 and on the BAT presented in task 6, the aim of the task 7 is to assess the improvement potential for the 6 base-cases by replacing one base-case with an improvement option. Indeed, in opposition to most of other EuP preparatory studies, improvement options do not aim at replacing or adding a component allowing reducing environmental impacts, but to replace the base-case with another type of lamp.

Further, this task allows analysing the monetary consequences of the options in terms of Life Cycle Cost for the consumer, their environmental costs and benefits and pinpointing the solution with the Least Life Cycle Costs (LLCC) and the Best Available Technology (BAT).

As in task 5, the analysis of the base-case with its improvement options is done per lumen and per hour to allow a fair comparison. The outcomes of the comparison for each base-case are provided in the following tables. Numbers in red correspond to the lowest environmental impacts (GER and mercury emissions to air) and to the LLCC.

The EcoReport analysis show that most of the environmental impact indicators, as well as mercury emissions to air, decrease by implementing one (or several for the base-case CFLi) improvement option(s), due to their electricity saving potential. Further, for all base-cases except the HL-MV-LW, the option presenting the highest reduction in energy consumption corresponds to the LLCC option.

The higher the lamp efficacy, the lower the mercury emissions to air for all lamps, except for CFLi as mercury is also emitted during EoL. Therefore, replacing an incandescent lamp (GLS-C or GLS-F) with a CFLi is not the best solution when focusing on mercury emissions. Nevertheless, using a CFLi instead of a typical GLS-C or GLS-F reduce the total energy consumption of about 74%, and the LCC of about 69%.

Regarding CFLi, improvement options exist to extend the lifetime of the lamp (10000h or 15000h instead of 6000h), enhance the lamp efficacy (+12% compared to the base-case), or reduce the mercury content (2mg instead of 4mg).

Table 3: Key results of the improvement option analysis for the base-case GLS-C

Option	Option description	Product lifetime (h)	Wattage (W)	GER per lumen per hour (J/lm/h)	Mercury emissions per lumen per hour (ng Hg/lm/h)	LCC per lumen per hour (10^{-6} €)
0	Base Case GLS-C	1000	54	1045	1.45	14.47
1	Replacement with Xenon HL-MV	2000	42	760	1.09	12.84
2	Replacement with HL-MV with infrared coating and electronic transformer	4000	30	547	0.78	10.44
3	Replacement with CFLi	6000	13	276	1.34	4.62

Table 4: Key results of the improvement option analysis for the base-case GLS-F

Option	Option description	Product lifetime (h)	Wattage (W)	GER per lumen per hour (J/lm/h)	Mercury emissions per lumen per hour (ng Hg/lm/h)	LCC per lumen per hour (10^{-6} €)
0	Base-Case GLS-F	1000	54	1085	1.51	15.02
1	Replacement with Xenon HL-MV-LW	2000	42	760	1.09	12.84
2	Replacement with CFLi	6000	13	276	1.34	4.62

Table 5: Key results of the improvement option analysis for the base-case HL-MV-LW

Option	Option description	Product lifetime (h)	Wattage (W)	GER per lumen per hour (J/lm/h)	Mercury emissions per lumen per hour (ng Hg/lm/h)	LCC per lumen per hour (10^{-6} €)
0	Base-Case HL-MV-LW	1500	40	947	1.33	19.89
1	Replacement with Xenon HL-MV-LW	2000	33	833	1.18	20.69

Table 6: Key results of the improvement option analysis for the base-case HL-MV-HW

Option	Option description	Product lifetime (h)	Wattage (W)	GER per lumen per hour (J/lm/h)	Mercury emissions per lumen per hour (ng Hg/lm/h)	LCC per lumen per hour (10^{-6} €)
0	Base-Case HL-MV-HW	1500	300	615	0.93	8.91
1	Replacement with Xenon HL-MV-HW	2000	230	495	0.75	7.17

Table 7: Key results of the improvement option analysis for the base-case HL-LV

Option	Option description	Product lifetime (h)	Wattage (W)	GER per lumen per hour (J/lm/h)	Mercury emissions per lumen per hour (ng Hg/lm/h)	LCC per lumen per hour (10^{-6} €)
0	Base-Case HL-LV	3000	30	844	1.22	13.29
1	Replacement with HL-LV with infrared	4000	20	668	0.96	13.25

	coating					

Table 8: Key results of the improvement option analysis for the base-case CFLi

Option	Option description	Product lifetime (h)	Wattage (W)	GER per lumen per hour (J/lm/h)	Mercury emissions per lumen per hour (ng Hg/lm/h)	LCC per lumen per hour (10^{-6} €)
0	**Base Case CFLi**	6000	13	**276**	**1.34**	**4.84**
1	**Less mercury**	6000	13	**276**	**0.87**	**5.35**
2	**High lamp efficacy**	6000	13	**246**	**1.20**	**4.42**
3	**Long lifetime**	10000	13	**239**	**0.86**	**4.40**
4	**Very long lifetime**	15000	13	**236**	**0.69**	**3.98**
5: 1+3	**Less mercury + Long lifetime**	10000	13	**239**	**0.60**	**4.56**

The implementation of one or several options could be limited by the related increase in the cost for buying the lamp. Indeed, without any life cycle thinking the buyer would not necessarily purchase an improvement product instead of an average one (base-case) due to the higher product cost.

Further, it has to be noticed that a base-case can be replaced with a lamp, identified as an improvement option for reducing life cycle cost and environmental impacts, whereas the light quality is not always exactly similar, e.g. a GLS-F (Colour Rendering Index, CRI 100) replaced with a CFLi (CRI 80).

More details can be found in the project report [1].

8. Scenario Analysis

Different policy scenarios 2007-2020 are drawn up to illustrate quantitatively the improvements that can be achieved through the replacement of the base-cases with lamps with higher energy efficiency at EU level by 2020 versus a business-as-usual scenario (reference scenario). Eight scenarios (including the BAU scenario) have been analysed in order to provide an assessment of various alternative policy options. These scenarios differ from one to another according to the number of Tiers (1, 3 or 5) in the implementation of the legislation and to the replacement lamp for each base-case.

The general principle of the environmental analysis for the scenarios is that the total annual lumen needed for each base-case (obtained in the BAU scenario) has to be kept constant and it is the key parameter to estimate changes in sales when switching from a base-case to its improvement option(s). In the BAU scenario, the total number of lamps in the domestic sector was assumed to constantly increase from 18.21 in 2006 to 23.88 in 2020, i.e. an increase of +31%.

Figure 6 presents the evolution of the stocks of the 6 lamp types from 2007 until 2020 for the BAU scenario (on the left) and for the BAT scenario (on the right) which corresponds to the most ambitious scenario, i.e. all lamps are replaced with CFLi since 2009. Therefore, with this ‘improvement’ scenario, all incandescent and halogen lamps are totally removed from the EU market from 2012, which is obviously an extreme scenario. The two scenarios show the playing field for the more realistic scenarios in between.

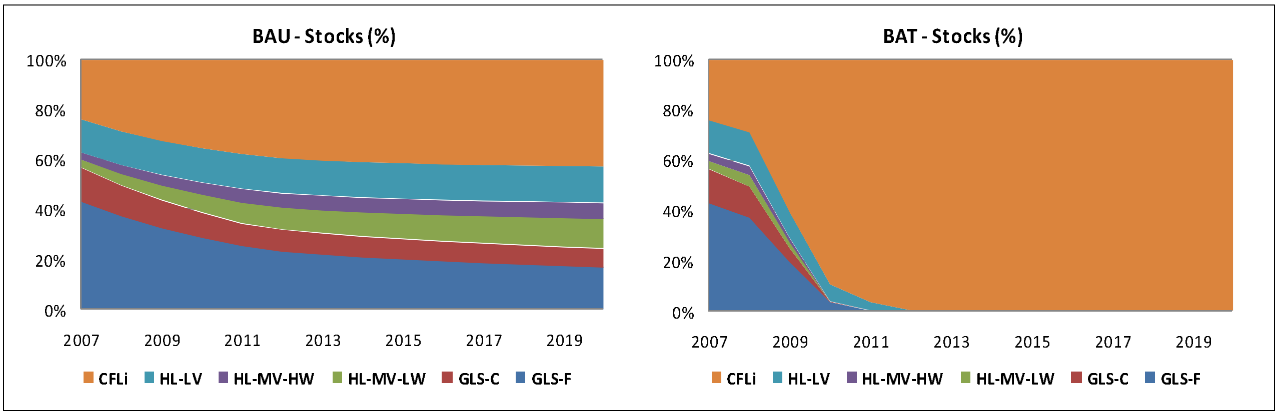

Figure 6: Evolution of lamps stocks (in %) for the BAU and BAT scenarios

Based on the analysis of the eight scenarios (BAU + 7 'improvement' scenarios), some environmental impacts (electricity consumption, CO_2 emissions and mercury emissions) in 2020 are presented in the Table 9, including variations both in units and in % with reference to the BAU scenario. As expected, the BAT scenario allows the highest reductions, with a decrease of 87 TWh, 37 Mtonnes of CO_2 emission, and 19 tonnes of mercury emission.

One has to take into consideration that in some scenarios, a base-case is replaced with a lamp that also requires luminaire replacement, e.g. the base-case HL-MV-LW (socket G9) with a CFLi. Environmental impacts due to the luminaire replacement are not assessed and thus not taken into account in the scenario analysis. This will be done in the Part 2 of the study.

Table 9: Environmental impacts in 2020 for each scenario

		Electricity consumption (GWh) in 2020	CO_2 emissions (kton) in 2020	Mercury emissions (kg) in 2020
BAU	Value	134,736	57,936	3,139
	Difference to BAU	*0.0%*	*0.0%*	*0.0%*
BAT	Value	47,544	20,444	853
	Difference to BAU (units)	*-87,192*	*-37,493*	*-2,286*
	Difference to BAU (%)	*-64.7%*	*-64.7%*	*-72.8%*
Option 1 Fast	Value	48,270	20,756	1,444
	Difference to BAU (units)	*-86,465*	*-37,180*	*-1,695*
	Difference to BAU (%)	*-64.2%*	*-64.2%*	*-54.0%*
Option 1 Fast B	Value	48,336	20,784	1,165
	Difference to BAU (units)	*-86,400*	*-37,152*	*-1,974*
	Difference to BAU (%)	*-64.1%*	*-64.1%*	*-62.9%*
Option 2 Clear B Fast	Value	95,999	41,279	1,609
	Difference to BAU (units)	*-38,737*	*-16,657*	*-1,530*
	Difference to BAU (%)	*-28.8%*	*-28.8%*	*-48.8%*
Option 2 Clear B Slow	Value	83,841	36,052	1,466
	Difference to BAU (units)	*-50,894*	*-21,885*	*-1,673*
	Difference to BAU (%)	*-37.8%*	*-37.8%*	*-53.3%*
Option 2 Clear C Fast	Value	101,677	43,721	1,656
	Difference to BAU (units)	*-33,058*	*-14,215*	*-1,484*
	Difference to BAU (%)	*-24.5%*	*-24.5%*	*-47.3%*
Option 3 Slow	Value	112,681	48,453	2,123
	Difference to BAU (units)	*-22,055*	*-9,484*	*-1,016*
	Difference to BAU (%)	*-16.4%*	*-16.4%*	*-32.4%*

Finally task 8 also includes: recommended eco-design requirements that are the precursor for future EuP regulation, suggestions for the appropriate implementation and a brief qualitative analysis on its potential impact on industry and users. More details can be found in the project report [1].

References

[1] Preparatory Studies for Eco-design Requirements of EuPs - Lot 19: Domestic lighting - Part 1 - Non-Directional Light Sources (for the study see: http://www.eup4light.net)

[2] European Compact Fluorescent Lamps Quality Charter – revision 2008 – not yet published (see: http://re.jrc.ec.europa.eu/energyefficiency/CFL)

CFLs in the USA – Market and Technical Status Report

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Abstract

For almost two decades U.S. energy efficiency programs have promoted the distribution, sale and installation of screw-base compact fluorescent lamps (CFLs) as an important energy efficiency measure. As energy efficiency programs have changed and grown, the dominant position of CFLs as the primary source of claimed energy savings has only become more entrenched. The typical U.S. energy efficiency program provider (electric utility, state or provincial authority and others) typically attributes over 50% of claimed kWh savings in any given year to CFLs promoted by the program.

Ongoing research can now shed some light both on the size of the remaining potential for growth in CFL's share of the screw-base market, and also the actual performance in terms of CFL efficiency and longevity.

CFL Market Performance

Growth shipments and market share for medium screw base CFLs

U.S. consumers are very satisfied with CFLs. In a 2007 survey of over 100,000 households, 80% of U.S. CFL owners regardless of age or gender say that they believe CFLs are as good as or better than incandescent lamps. [1] U.S.CFL shipments have grown tremendously, from 21 million lamps in 2000 to 397 million units in 2007; this increase represents a compound annual growth rate of 52 percent for eight years [2], CFLs have captured an increasing share of the market for medium screw-based lamps, growing from 1% to 23% between 2000 and 2007, or about 3 percentage points a year. [3] However, the U.S. lighting market is far from transformed. While a 23% market share is substantial, obviously, three of every four lamps purchased are still incandescent and the installed based is still dominated by incandescent lamps.

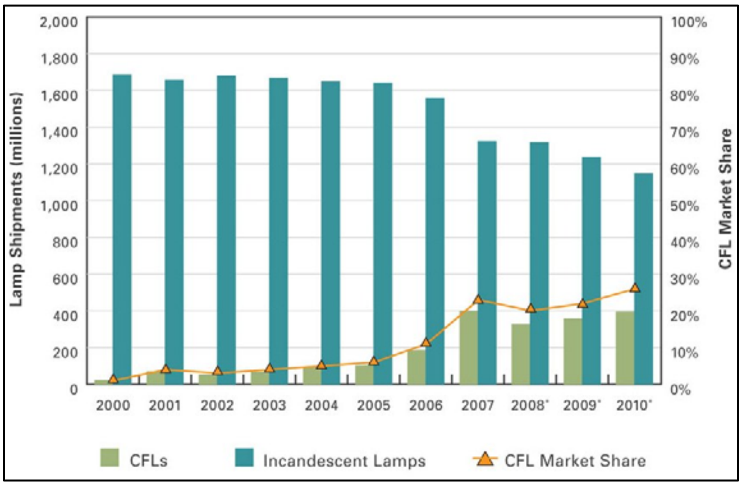

Figure 1: CFL and Incandescent Lamp Shipments by Year

Based on partial 2008 shipment data and intelligence from manufacturers and retailers, we estimate that CFL shipments fell by about 10% in 2008 due to the global financial crisis and the decline in the U.S. housing market. Consistent with this unexpected flattening of CFL shipment growth in the U.S., we assumed CFL shipments will remain roughly stable through 2010 as shown in Figure 1.

CFL Market Model

The ultimate measure of lighting market transformation from an energy consumption perspective is not market share but socket saturation—the proportion of medium screw base sockets that are filled with CFLs (the U.S. has relatively few other types of electric lighting sockets in residences). However, up until now there have not been reliable estimates of U.S. CFL socket saturation. With few exceptions, previous assessments of socket saturation were based on customer self-reported data obtained from telephone surveys with no on-site audit verification. Customer self-reported data have been demonstrated to be highly unreliable for estimating CFL saturation. [4][1] Saturation studies (both surveys and audits) have also tended to be limited in geographic scope, and therefore have not given a complete picture of the size and diversity of the U.S. market. At the request of the U.S. Department of Energy (DOE), D&R International developed a methodology and model built on a set of reliable empirical data sources to ensure a more accurate understanding of the extent of CFL socket saturation in the U.S. as a whole.

Baseline Data

We began with baseline data obtained from a national lighting market study conducted by the U.S. Department of Energy. [5] This study, the most comprehensive overview of the U.S. lighting market, provided us with a complete inventory of buildings, medium screw based sockets, and installed lighting, including both CFL and incandescent saturation.

For each year of the model, we calculated a simplified national lighting inventory in four steps, by:

1. Introducing additional buildings (replacement or new) and their associated medium screw based sockets.
2. Retiring/Removing installed lamps (incandescent and CFL) that would need to be replaced due to failure.
3. Introducing new CFLs to be immediately installed.
4. Introducing new incandescent lamps to fill any remaining sockets.

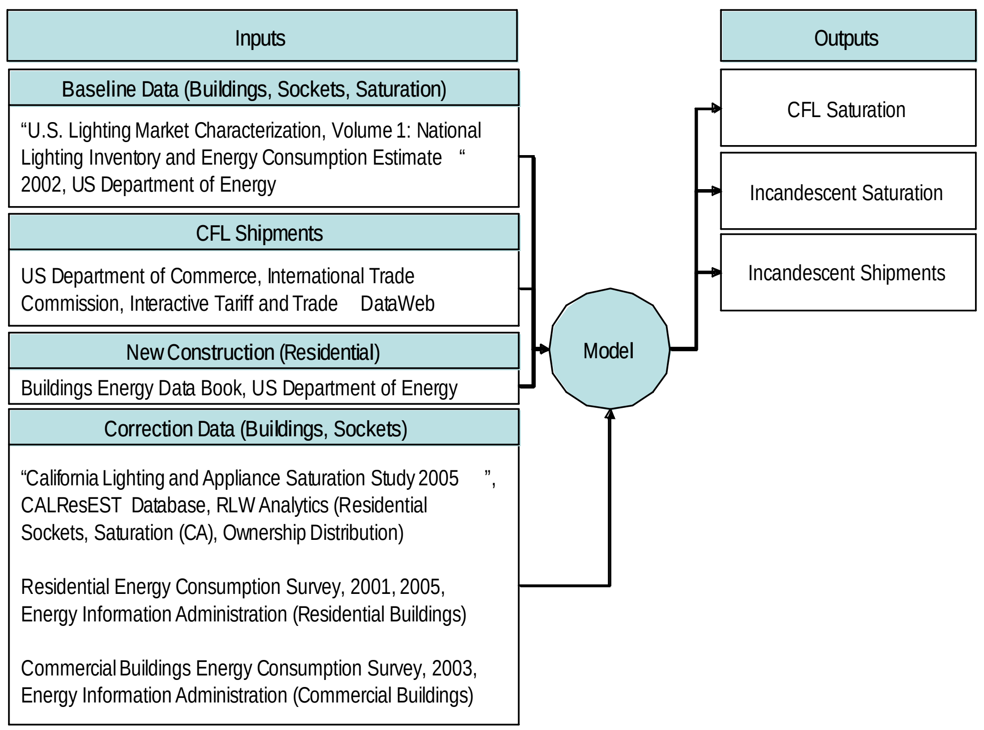

Figure 2: U.S. CFL Market Model

We then used the model's outputs to calculate CFL saturation (by dividing the number of CFLs installed by the number of sockets) and CFL market share (by dividing the introduced CFLs by the

[1] In [4], the authors evaluated the accuracy of phone survey responses with on-site audits and found that only 25% of respondents had accurately answered the question, "How many CFLs do you have in your home?" 50% underreported the number of CFLs and 25% over-reported.

total number of lamps introduced, both CFL and incandescent) for each year. The model's mechanics are shown in Figure 2.

Subsequent Year Annual Data

Step 1) Additional Buildings and Sockets Information

New homes were added to the model by using annual home starts data from the U.S. Buildings Energy Data Book. [6] Years beyond 2007 were leveled at 2 million homes per year. New commercial and industrial buildings were calculated by holding the 2001 ratio of buildings by sector constant, with the assumption that a growth in housing stock would lead to an equal relative growth in commercial and industrial stock.

Data points were cross-checked against the Residential Energy Consumption Survey (RECS) [7] and the Commercial Buildings Energy Consumption Survey (CBECS) [8], both conducted by the U.S. Energy Information Administration. By cross checking against RECS, we derived an estimate that 50% of new home starts in the U.S. during this period were replacement units, and 50% were new homes built where there had been no homes before.

Lamp sockets in buildings were estimated by multiplying the number of buildings by the baseline number of sockets per building, as derived from our baseline data. We assumed that the number of sockets per building remained constant from year to year. The value for residential sockets per building was cross checked against the "California Lighting and Appliance Saturation Study 2005". [9]

Step 2) Lamp Retirement/Removal

CFLs were retired/removed from the model assuming an actual service life that was the same as the typical average rated lifetime of 8,000 hours for ENERGY STAR qualified CFLs, and an estimated maximum lifetime of 16,000 hours[2] [10] Due to usage differences between sectors (established from [5]), the maximum lifetime in years ranged by sector from 2 years (industrial), to 4 years (commercial) to 14 years (residential). As a simplification, we assumed that the retirement/removal rate would be even over time, at 50%, 25%, and 7% annually for industrial, commercial and residential CFLs respectively. In addition, we calculated retirement/removal in annual batches.

Incandescent lamps were similarly retired/removed using an average lifetime of 1000 hours, and a maximum lifetime of 2000 hours.

Step 3) Introducing new CFLs for installation.

Attempts to estimate total U.S. CFL sales from retailer data have not been successful. Despite several attempts, to our knowledge no one has been able to successfully capture this data. Therefore we estimated new CFLs based on data from the International Trade Commission, Interactive Tariff and Trade DataWeb, U.S. Department of Commerce [2]. This database tracks annual import shipments of CFLs for 2000-2008 and contains the most complete information on the number CFLs introduced into the U.S. market each year, since nearly all CFLs sold in the U.S. are imported.

In practice, we know that not all CFLs in stock are immediately installed, and studies have found that U.S. households stock a significant number of CFLs to use for future replacements. However, we are aware of no studies that have determined when these stockpiled CFLs are installed. Therefore, when accounting for the number of CFLs installed, we assumed that 68% of CFLs in inventory would be installed, while the remaining CFLs would remain stockpiled. [11] While our estimates may thus understate the level of CFL saturation, the purpose of the model was to calculate the most likely current scenario for saturation.

We also assumed that the distribution of CFLs between sectors would occur proportionally to the baseline distribution. To ensure that no sector would receive more CFLs than it could actually absorb, we assumed a maximum potential saturation of 80% for each sector. The distribution and cap served to reflect that industrial and commercial facilities were earlier adopters of CFL, and that by 2008, each

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[2] Calculated by doubling the rated lifetime.

would have already absorbed their maximum potential lamps, and that the majority of future shipments would be distributed to the residential sector.

Step 4) Introducing new incandescent lamps for installation

We estimated incandescent shipments by filling the remaining empty sockets after projecting CFL penetrations as above. This estimate assumes that lamp manufacturers and retailers produce to meet market need, and attempt to minimize over-production and over-stocking as much as possible.

An incidental output of the CFL market analysis is an estimate of the cumulative impact of current and historic CFL shipments on the sales of incandescent lamps in the U.S. Since CFLs last seven to ten times longer than conventional incandescent lamps, each installed CFL reduces future demand for incandescents significantly. As an independent test of the accuracy of its model, DOE shared its estimates of incandescent shipments with companies that manufacturer both CFLs and incandescent lamps. These manufacturers confirmed that DOE's estimate of the decline in incandescent sales was accurate.

U.S. CFL Socket-Saturation

National Socket Saturation

Despite dramatic market growth, the percentage of all U.S. residential medium screw-based sockets filled by CFLs is still low, even in regions with successful and long-standing energy efficiency programs. Although we believe that the commercial and industrial sectors are mostly saturated, enormous potential for savings remains in the residential sector. The residential sector contains 90% of screw-based sockets, but our model predicts only 12% of those sockets contain CFLs, or on average 4.52 CFLs per U.S. household.[3]

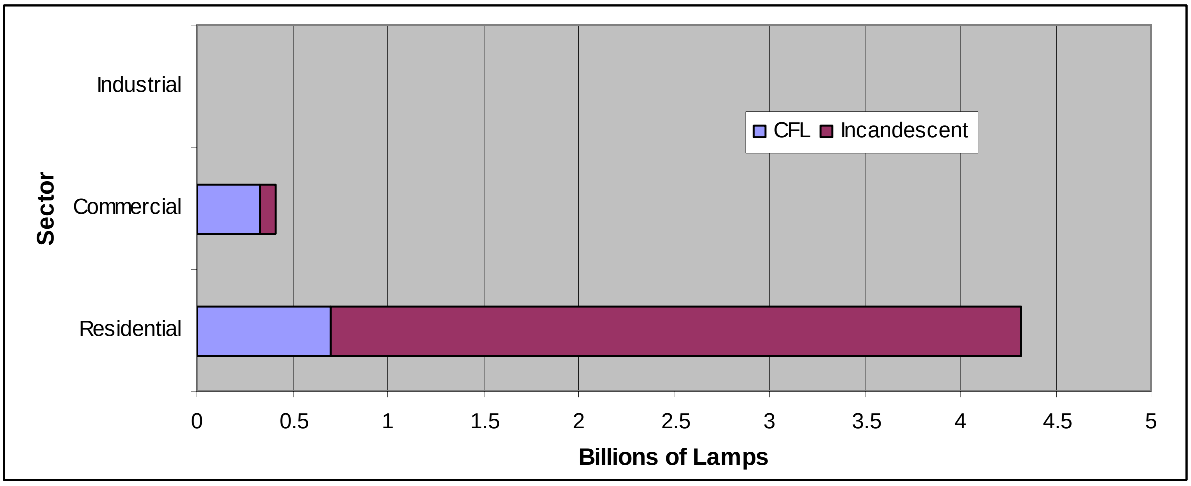

Figure 3: U.S. Medium Screw Base Socket Saturation - CFL and Incandescent by Sector

By replacing less-efficient incandescent lamps, the CFLs currently installed in the U.S save 16 billion kilowatt hours, US$1.8 billion in energy costs, and 11 million metric tons of CO_2 a year Over their lifespan, these CFLs will save the U.S. 186 billion kilowatt hours, $21 billion in energy costs, and 122 million metric tons of CO_2 emissions.[4]

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[3] Note: Previous versions of the model did not account for stored CFLs. The latest version of the model uses the installed value of 68% of total CFLs in inventory, from [12].

[4] Calculations based on an average of 49 W difference in connected load between the average incandescent and the average CFL that replaced it [5], 1.9 hours of use per day [5], $0.1109 per kWh [12], 1.54 lb of CO2 per kWh [13], and a lamp rated lifetime of 8000 hours [10].

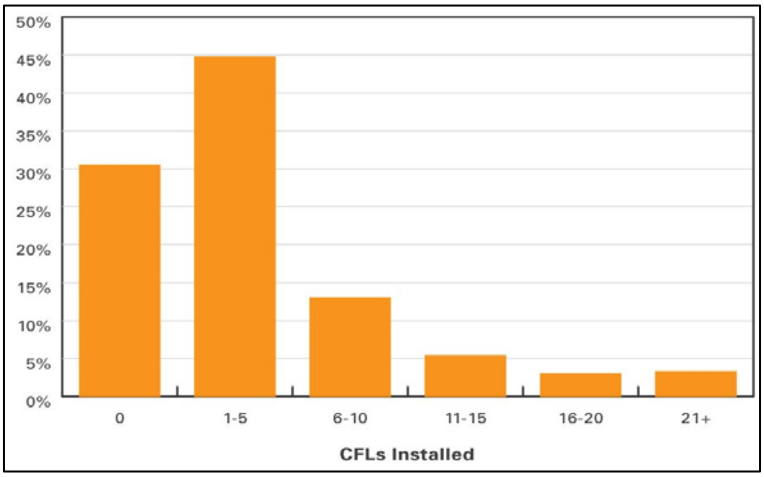


Figure 4. CFLs distribution across U.S. homes

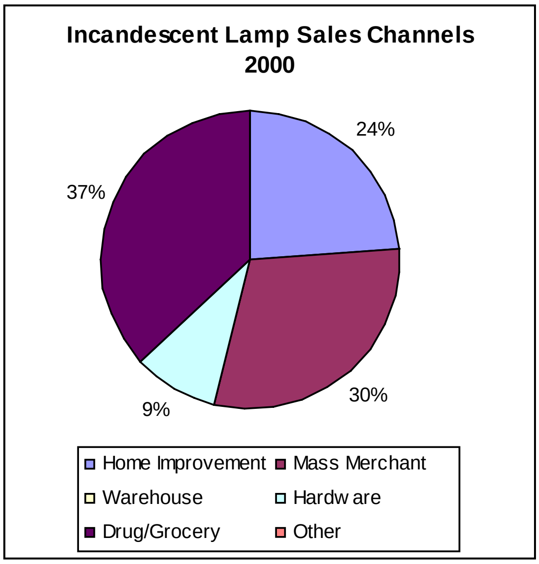
The distribution of CFLs across all U.S. homes is not uniform, but instead reflects the adoption patterns for most innovations in transition from the "early adoption" to the "early majority" stage of diffusion. [14] We developed our distribution based on the California Lighting and Appliance Saturation Study 2005. This distribution was adjusted to reflect the 12% saturation (4.52 CFLs average) calculated by our model. This distribution is shown in Figure 4.

Of particular note, 30% of U.S. households still have no CFLs. While 70% of households have at least one CFL, the majority (45% of all households, or 64% of CFL users) of these have five or fewer. Innovation diffusion theory predicts that households without CFLs are lower-income, have lower-education levels and lower-socio-economic status than households with CFLs. These characteristics strongly correlate with a low rate of adoption for innovations, and is supported by anecdotal information from U.S. energy efficiency programs. [14]

Sales Channels, Product Availability and Competition

Sales channels [11][15]

The primary sales channel for CFLs in the U.S. is the so-called "big-box" (very large) retailers. This includes home improvement stores (such as The Home Depot and Lowe's), mass merchants (such as Walmart), and warehouse stores (such as Costco and Sam's Club). In 2006, for example, such retailers accounted for 66% of all CFL sales in the U.S. Grocery stores and drug stores, which are the traditional channels for incandescent lamp sales, sell only a small share of CFLs. The reason for this difference has not been definitively determined, but generally, big box retailers have more available shelf space to display products; can purchase CFLs in larger volumes and at lower prices; and sell many goods that are more expensive than CFLs which makes CFLs seem relatively inexpensive in comparison.



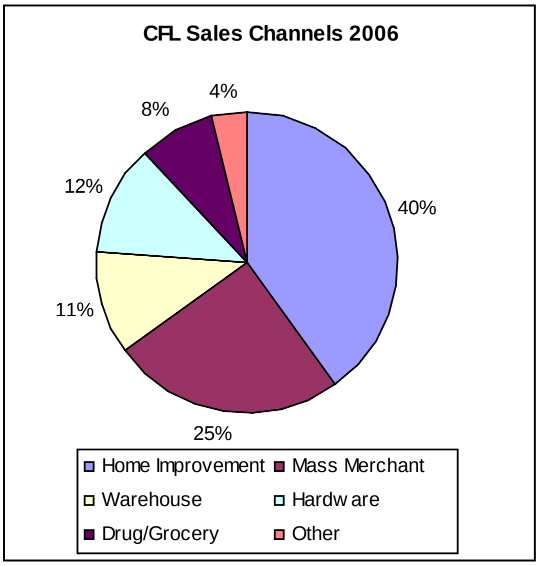


Figure 5: Incandescent Lamp Sales Channels

Figure 6: CFL Sales Channels 2006

Growth in product availability and competition

As the sales volume and revenue potential of CFLs has grown in the U.S. and worldwide, competition and product variety and availability have expanded. In 1999, five manufacturer partners offered 22 ENERGY STAR qualified CFL products to the new national ENERGY STAR for CFLs program. By the end of 2008, 93 manufacturers offered more than 3,340 ENERGY STAR qualified CFL products[5].[6] An extensive range of ENERGY STAR qualified CFL types are now available throughout the U.S. from bare spirals and tubular fluorescents to reflectors, A-shape, globe, dimmable, three-way, and candelabra options.

Role of Promotion by Energy Efficiency Program Sponsors

Twenty years of investment and active promotion of CFLs by U.S. electric utilities and other U.S. state and regional energy efficiency program sponsors (EEPS) have played an important role in developing the U.S. CFL market. These investments were originally driven by regulatory mandates and funded through a surcharge on electricity in a number of U.S. states. Regulatory mandates continue to drive U.S. CFL promotional spending, but more recently, rising concerns about energy supplies and concerns about climate change have led some electric utilities in U.S. states without complementary regulation to also pursue CFL promotions.

As EEPS savings objectives, and CFL sales volumes, have increased, CFL promotion program models have evolved. The programs began in the early 1990s by directly installing CFLs in the homes of low-income customers, and then progressed to discount mail-in coupons and free CFL giveaways. As demand began to grow, the programs transitioned to various kinds of discount coupons and finally to the wholesale subsidies which dominate EEPS program design today. Each step in this program design evolution allowed more CFLs to be promoted at a lower cost per CFL.

Energy efficiency program investment and return on investment in CFLs

Due to their relatively low purchase cost and high energy savings, CFLs are the largest single source of energy savings for almost all EEPS. For the longest running and most established programs (such as those in California and New England), CFLs provide more than 60% of annual energy savings. Over the last several years spending on CFL promotions has grown rapidly. In 2006 there were 24 CFL promotion programs in the U.S. and $50 million in dedicated funding; in 2008, there were 71 programs and $175 million in dedicated funding. [10] Economic stimulus funding earmarked for energy conservation under the American Recovery and Reinvestment Act of 2009 may lead to a manifold increase in CFL program spending and activity.

U.S. CFL promotional programs work

The data suggest that EEPS CFL promotions have increased CFL socket saturation. CFL saturation is higher in U.S. states and regions that have invested most heavily in CFL promotions including California, the Pacific Northwest, Wisconsin, and New England. For example, a national survey found that California socket saturation is an average of 4.6 CFLs per home, where the state has spent $150 million promoting CFLs in the past three years. In contrast the Southeastern U.S. has invested very little in CFL promotion and has an average socket saturation of only 3.0 CFLs per home. [1] The 1.6 additional lamps per home in California save an extra 660 million kWh and nearly $95 million per year in utility bills for citizens of that state.[6]

Discussion of possible impacts of EISA incandescent efficiency standard on CFL market

Standards for incandescent lamps contained in the Energy Independence and Security Act of 2007 (EISA) are likely to affect the lighting market over the next several years. It is important to note that unlike similar legislation in other countries, EISA will not “ban” current incandescent lamps in the U.S. EISA sets new efficiency requirements for incandescent lamps that currently available products cannot meet, but which new incandescent products should be able to meet. These standards are summarized in Table 1.

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[5] The number 3,340 refers to number of model numbers. The number of unique CFLs is smaller because the same CFL may be carried under different brands.

[6] Calculations based on an average of 49 W difference in connected load between the average incandescent and the average CFL that replaced it [5], 1.9 hours of use per day [5], $0.1421 per kWh [12], and total California households of 12,140,888 [16].

Table 1: EISA 2008 U.S. General Service Incandescent Lamp Standards

Tier 1

Rated Lumen Ranges	Maximum Wattage	Minimum Rated Life	Effective Date
1490-2600	72 W	1,000 hours	01,01,2012
1050-1489	53 W	1,000 hours	01,01,2013
750-1049	43 W	1,000 hours	01,01,2014
310-749	29 W	1,000 hours	01,01,2014

Tier 2

Products	Minimum Efficacy	Minimum Rated Life	Effective Date
All lamps	45 lpw	NA	2020

The format of the standard allows manufacturers some flexibility in responding. A simple interpretation of the limits is that today's 100W lamps will have to use no more than 72W starting in 2012, today's 75W lamps will have to use no more than 53W, and so on. However, the structure of the EISA legislation also allows these new incandescent lamps to comply by producing less light than current incandescent lamps. For example, a current 100W incandescent lamp usually produces about 1700 lumens. EISA allows the new 72W lamps to produce as few as 1490 lumens, at an efficiency level of 21 lumens/watt. EISA also contains exemptions for a range of specialty lamp types and low-wattage decorative style lamps.

When EISA became law, manufacturers initially responded with plans to bring new incandescent technologies to market which would comply with the new efficiency requirements. Philips Lighting, in fact, already offers a halogen infrared lamp on the U.S. market that meets the EISA standards. It remains unclear, however, whether these new products will find as wide acceptance as current incandescent lamps. The price of the Philips halogen IR lamp is currently more than the price of many CFLs. Of course, prices will drop as the number of manufacturers and the volumes of products increase. More recently industry statements regarding the development of new incandescent technologies have significantly diminished.7 Some historically dominant incandescent manufacturers may simply choose to eliminate general purpose incandescent lamps from their product lines.

The effect of EISA on the U.S. lighting market will likely be determined by shifts of sales volumes between existing incandescent product types, by the introduction of new, more efficient incandescent lamps, and the prices of all incandescent lamps relative to CFLs, EISA may drive the U.S. market towards greater CFL saturation, or it may create a new market for marginally more efficient incandescent lamps, at least until more aggressive requirements become effective.

Technical Status

The combined efforts of, lighting manufacturers, retailers, energy efficiency programs sponsors, and the U.S. Department of Energy's ENERGY STAR for CFL program have succeeded in moving CFLs from the margin to mainstream in the U.S., but just how well do these CFLs perform? Are they reliable enough to build consumer confidence as households fill more and more sockets? As EEPS programs expand, are they actually achieving the savings that CFL manufacturers claim? The following section explores the results of four years of testing of 121 models of CFLs by the Program for the Evaluation and Analysis of Residential Lighting, or PEARL. [17] Two of the authors sit on the board of PEARL8.

In the U.S., EEPS have savings targets, usually expressed in terms of life-time kilowatt hours saved for energy efficiency measures installed in each program year. EEPS usually estimate savings from CFLs using manufacturers' claims for product performance. Before the ENERGY STAR for CFLs program debuted in 1999, EEPS often developed and adopted their own technical criteria for CFLs,

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[7] See, for example, http://www.cleanbreak.ca/2008/11/26/ge-suspends-development-of-high-efficiency-incandescent/

[8] Granda and Reed

which differed across the country. ENERGY STAR provided a common, consistent standard for CFL performance that could be used by EEPS. In a departure from ENERGY STAR programs for appliances and other products, which focused solely on energy efficiency, the ENERGY STAR for CFLs program explicitly set minimum requirements for CFL operating performance and reliability. ENERGY STAR's planners recognized the importance of not only requiring that CFLs be energy efficient, but that they also meet customer expectations regarding lighting performance and reliability.

PEARL

By 2001, most U.S. EEPS were already using ENERGY STAR for CFLs as the minimum requirement for CFLs promoted by their programs. However, a group of EEPS, due to direct experience in the field and feedback from program participants, became concerned that ENERGY STAR qualification was not always indicative of higher CFL quality.

One particular area of concern was that ENERGY STAR gathered information on product performance once, often before a CFL entered the market, but did not monitor product quality over time. To qualify a product under ENERGY STAR, a manufacturer typically pays to test pre-production CFLs at an accredited lighting laboratory9. The laboratory provides the test results to the manufacturer and the manufacturer submits the results to ENERGY STAR. Pre-production CFLs may be more carefully manufactured than regular production products. Also, commercial relationships between manufacturers and laboratories create at least the potential for conflicts of interest and manipulation of test data by manufacturers.

With leadership from the Natural Resources Defense Council (an environmental non-governmental organization), a group of concerned EEPS created PEARL to test regular production CFLs over time, in a way that avoided potential bias and provided an independent source of CFL performance data. PEARL purchased CFLs at retailers and paid to have them tested them at an accredited laboratory. Manufacturers had no financial involvement with PEARL, and were not aware of their products being tested until they received the results.

PEARL has only tested a small percentage of ENERGY STAR qualified CFLs. The CFLs PEARL has tested were not randomly selected and cannot claim to be representative of all ENERGY STAR qualified CFLs. PEARL's sponsors nominated CFLs for each test cycle based on high sales volumes, customer complaints, or to look at new types of products. The CFLs tested by PEARL are most representative of the CFLs promoted by EEPS during 2004-2008

PEARL has tested all major types of CFLs sold in the U.S. market including bare tube models, covered or encapsulated models, reflector CFLs, and CFLs capable of multiple lighting levels (both 3-way and dimmable). CFLs tested came from 29 different brands10 including the "big three" international diversified lighting companies, as well as many smaller manufacturers. All but two of the CFL models tested were ENERGY STAR qualified and available for sale in North America at the time of testing.

Table 2: PEARL CFL Testing and ENERGY STAR Compliance

PEARL cycle	1	2	3	4	5	**6**	**7**	**8**	**9**
Date Complete	5,'01	1,'02	1,'03	12.'03	8,'04	**9,'05**	**12,'06**	**11,'07**	**8, '09**
Number of CFLs	13	18	20	20	18	**34**	**33**	**29**	**25**
Non-complying CFLs	NA	NA	NA	NA	NA	**7**	**7**	**8**	**TBD**

The history of PEARL CFL testing is shown in Table 2. The first four PEARL testing cycles supported the need for broader testing. In 2004 with the results of cycle 5, DOE started to disqualify or "delist" CFLs from ENERGY STAR based on PEARL results. With cycle 6, PEARL began to test CFLs in sufficient numbers, and across a sufficient range of criteria, to give a picture of general compliance with ENERGY STAR.

[9] National Institute of Standards and Technology National Voluntary Laboratory Accreditation Program

[10] The number of actual manufacturers may be lower because a single producer in China may serve as the original equipment manufacturer (OEM) supplier for more than one CFL brand in the U.S.

The following analysis contains data from PEARL cycles 6 – 9 for a total of 121 CFL models and over 1500 individual CFLs (for all tests). All 121 CFL models were tested for a range of ENERGY STAR technical criteria, including luminous efficacy (lumens/watt), and lumen maintenance (lumens at 1,000 hours of operation, and at 40% of average rated life divided by lumens at 100 hours of operation). PEARL did not perform complete life tests, but did collect data on CFL failures during aging for the lumen maintenance test at 40% of rated life.

Performance Relative to ENERGY STAR Performance Requirements

As also shown in Table 2, at least 20% of the CFL models tested in cycles 6 – 9 did not meet one or more of the ENERGY STAR performance requirements (results for cycle 9 are still pending as this paper is published). However, in every product category, for every CFL type, multiple brands had products that met the ENERGY STAR performance criteria.

CFL Performance Trend Analysis

In addition to compliance with ENERGY STAR, PEARL test results also provide some insight into the continued development of CFL technology for products sold in the U.S. over the last five years. The following tables show results for efficacy, lumen maintenance, and interim lamp-life measurements.

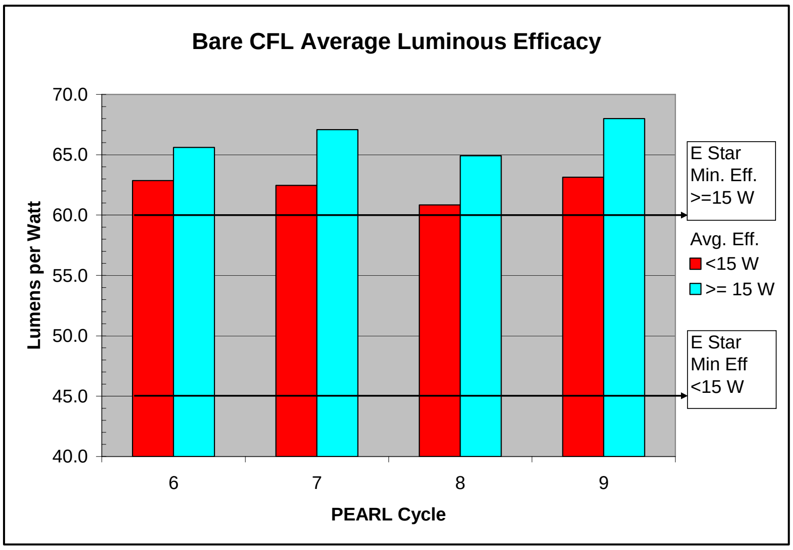

Figure 7: Luminous Efficacy by PEARL Cycle with ENERGY STAR requirements

As shown in Figure 7, the luminous efficacy of CFLs tested by PEARL did not show definite trending over the five years. All but four of the 121 CFLs tested met the relevant ENERGY STAR minimum efficacy requirements shown. As expected, higher wattage CFLs were more efficient, but as Figure 7 shows, the average efficiency of the CFLs in the less-than-15 watt category still exceeded the ENERGY STAR requirements for the 15 watt and greater category.

Covered and reflector CFLs are not shown in Figure 7 due to space constraints. While the efficacy of these types of CFLs was lower than for the bare CFLs, reflector and covered CFLs still easily met ENERGY STAR requirements.

Lumen Maintenance

The light output of most lamp technologies degrades over the lamp's operational life. All fluorescent lamps suffer lumen degradation and light output has been of particular concern with CFLs. In the past, ENERGY STAR and EEPS surveys have identified inadequate light output as a significant reason for negative customer attitudes about CFLs, but recent surveys have found broad satisfaction with light output with average scores of 8 on a scale of 10, among the 70% of households that own CFLs.[1][11]

PEARL testing shows that average lumen maintenance at 1000 hours of life was consistently above the ENERGY STAR requirement of 90% for bare CFLs across all four PEAR cycles. Average lumen maintenance for covered and reflector CFLs was not as impressive (Figure 8).

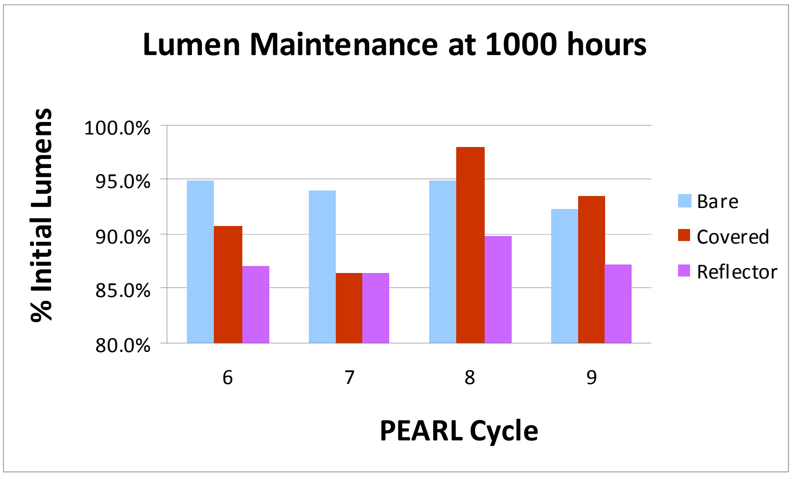

Figure 8: Lumen Maintenance by CFL Type and PEARL Cycle

Percent lumen maintenance at 1000 hours is calculated by dividing actual CFL lumen output after 1000 hours of operation by lumen output at 100 hours of operation. The light output from all types of fluorescent lamps tends to vary during an initial "burn in" period before stabilizing and then beginning to steadily degrade over the lamp's life. Lumen output at 100 hours of operation is generally assumed to be the stable, maximum lumen output of a CFL. Interestingly, PEARL found several CFLs that actually needed a longer burn in period in order to stabilize. For these lamps, lumen output actually rose between 100 and 1000 hours of life.

Lamp-Life Performance Variability

PEARL data on frequency of CFL failure during the first 40% of rated life offer a unique opportunity to evaluate the average rate of CFL failure during this period and how that rate varies by lamp-type and manufacturer. The results for variation by lamp-type primarily confirm what was already known, but variations among manufacturers are striking.

According to Illuminating Engineering Society (IES), average rated life is the length of time it takes for 50% of a sample of lamps to fail, while being switched continuously for 3 hours on, and 20 minutes off under constant temperature. PEARL does not officially test CFLs to ENERGY STAR's minimum average rated life requirement, but because the lumen maintenance test uses the same switching regime as the IES average rated life test, PEARL provides valid data on the frequency of lamp failure within the first 40% of average rated life.

For the lumen maintenance test in PEARL cycles 6 - 9, a sample of ten CFL were tested (five of each sample were tested base-up and five base-down, except for reflector CFLs where all ten of each samples were tested base-up). Data for the 40% of rated life lumen maintenance test were available for 1060 individual CFLs tested by PEARL at the time of publication, 83 or 7.8% of the CFLs had failed before 40% of rated life was reached[11].

Interim Lamp-Life by Manufacturer

As noted above, PEARL did not use random selection to choose CFLs for testing. Of the 121 models tested, 72% (76 models) came from only eight brands. For each of these frequently-tested brands, PEARL tested between 5 and 18 CFL models. This means that at least 50 individual CFLs from each frequently tested brand were subjected to the lumen maintenance test, and that the number of CFLs tested was great enough to give a good indication of the tendency of that brand to early failure.

CFLs from frequently-tested brands experienced 43 (or 5.7% of 760 CFLs tested) failures during the 40% of life lumen maintenance test The CFLs from the other, less-frequently tested brands, when considered in aggregate, had a failure rate of 13.3% during the 40% of rated life lumen maintenance.

The difference in early failure rates between the more and less frequently tested CFLs is perhaps not surprising, given that the more frequently tested brands were generally the larger, more established companies that might be expected to sell higher quality CFLs. However, not all frequently tested brands had low early failure rates.

[11] By the deadline for the submission of this paper, 15 of the 25 CFLs included in PEARL Cycle 9 had not completed the 40% of rated life lumen maintenance test. When these final data are received we expect the total count of failed CFLs across Cycles 6-9 may be higher than 83.

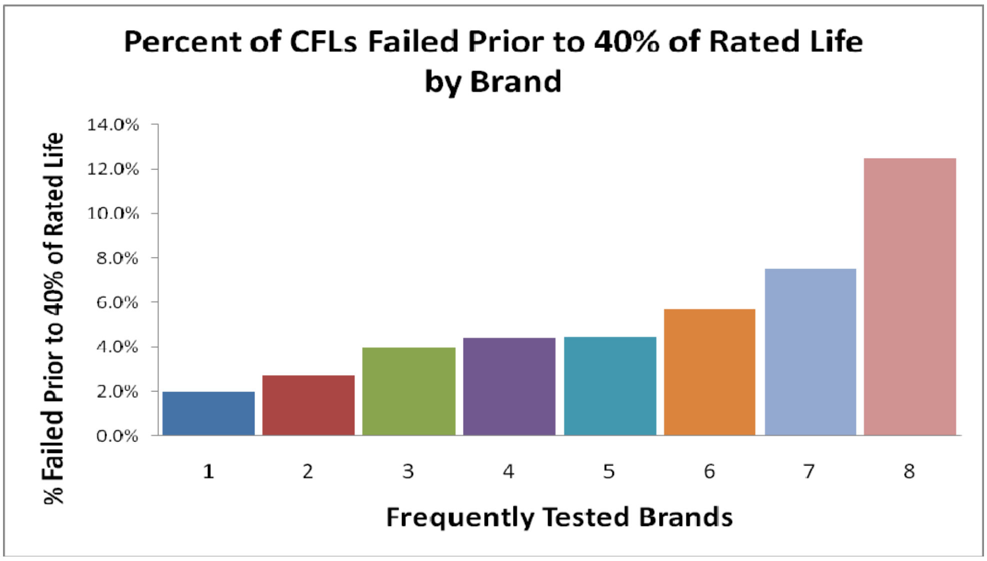

Figure 9: Early Failure for Frequently Tested CFL Brands

As shown in Figure 9, five of the frequently tested brands had a less than 5% failure rate in the first 40% of rated life. Two brands had slightly higher failure rates, and one brand had a 12.5% failure rate prior to 40% of rated life.

This variation is consistent with research performed by the National Lighting Product Information Program that also showed significantly different patterns to failures by brand. [18]

Conclusions and Recommendations

The U.S. market for CFLs is maturing from infancy to adolescence. U.S. consumers are generally satisfied with CFLs, However, tremendous energy savings potential remains as 30% of households still lack any CFLs, 45% have five or fewer and only a small proportion (13%) of households has more than ten. Given that the average U.S. home has 37 medium screw-base sockets [5], American residents and utilities have only tapped a small portion of potential savings CFLs could provide. At current sales levels most eligible sockets could be saturated with CFLs by 2018 and possibly sooner.

While CFL socket saturation is very likely to continue to grow in the U.S., the rate of this growth beyond 2012 is uncertain. As EISA performance requirements are phased in for the most popular wattages of incandescents (100, 75, and 60 watt in 2012, 2013, and 2014 respectively), CFL market share and saturation growth rates may increase, or CFLs may compete with a new generation of incandescent lamps. In the latter case, CFLs would still offer substantial savings potential.

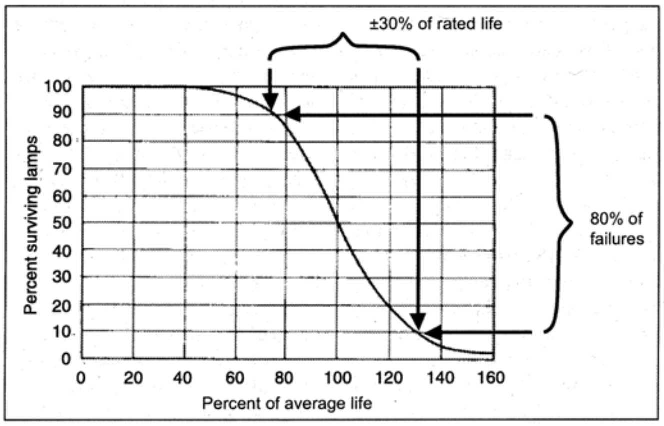

Figure 10: Idealized Lighting Product Failure Curve

Four out of five lamps purchased for use in U.S. homes are still incandescent suggesting that there may still be resistance to purchasing CFLs even among households that have CFLs. The still notable price premium over incandescent lamps may be a factor. CFL shipments to the U.S. declined in 2008, coincident with the economic recession. This drop in CFL shipments may understate consumers' price sensitivity for CFLs, given that EEPS provided CFLs subsidies of over US$150 million in 2008. Some EEPS are currently planning to reduce CFL subsidies because they consider the CFL markets, at least in their regions, to be "transformed".[12] We believe that there is a danger that CFL sales could further decline if EEPS subsidies are reduced in the near term.

The PEARL data suggest that the great majority of U.S. CFLs meet ENERGY STAR efficiency, lumen maintenance and interim life requirements. The interim life data showing failures at 40% of rated life is concerning because at least one major national CFL brand (with products frequently tested by PEARL), has sold CFLs with potentially high levels of failures prior to 40% of rated life.

The observed levels of failures prior to 40% of rated life for this brand is high compared to other CFL brands and high relative to fluorescent lamps in general. The Illuminating Engineering Society (IES) failure curve for traditional fluorescent lamps (Figure 10) [18] has less than 5% failures before 50% of average rated life.

The real danger of early failures is the potential impact on the public perceptions of CFLs. Long-life is one of the primary CFL attributes marketed by manufacturers, EEPS and ENERGY STAR. Customers are not told that for some CFLs that they may only experience an *average* longer life, It is also important to remember that PEARL testing occurred in a controlled environment. Typical residential conditions, like hot light fixtures and frequent switching, can reduce the life of even high quality CFLs. Many consumers fail to read the product packaging and install CFLs in inappropriate sockets. The U.S. media [20] has recently begun to target CFL early failure as an issue and negative impressions regarding CFLs could be created in consumers and pose a barrier to market transformation. The market stalling effects of low CFL reliability have been anecdotally observed in developing countries.

The time is ripe for a new focus by manufacturers, EEPS and ENERGY STAR on CFL quality and reliability. The most recent revision (version 4.0, fully effective July 1, 2009) to the ENERGY STAR technical requirements essentially incorporates the function of PEARL into ENERGY STAR. Starting later this year, ENERGY STAR will begin to test qualified CFLs in a new, independent testing program. This new program will cover many more CFLs (20% of all models every year) than PEARL was able to. The information provided by this new testing program will give DOE the ability to set new performance and reliability criteria to protect U.S. consumers, ensure energy savings and defend the integrity of the ENERGY STAR brand. EEPS can also play a role by focusing on CFL quality, in addition to price, in designing their subsidy programs, and by working closely with DOE to make sure that subsidies go to high quality CFLs.

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Really bright – the lighting campaign

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O.Ö. Energiesparverband

Abstract

The campaign "Really bright" ("Richtig hell") was carried out in 2007 by the O.Oe. Energiesparverband, the regional energy agency of Upper Austria on behalf of the regional government and aimed at promoting "good and efficient lighting". It started with the promotion of efficient lighting in "larger buildings" and was followed by activities targeting the domestic and the public sector.

A mix of measures and initiatives were carried out, ranging from promotion measures, training courses and competitions to pilot projects and lamp exchange initiatives.

Within the campaign "Really bright", more than 100,000 inefficient lamps were exchanged and more than 40 newspaper articles were placed [1]. The aim of the campaign was to achieve lasting change in investment and user behaviour patterns, and not single actions. Information and promotional activities are therefore being continued.

Background

The region of Upper Austria – located in the North of Austria with 1.4 mio inhabitants - has made a strong commitment to sustainable energy. By 2030, all electricity and space heating will come from renewable energy sources [2]. In order to achieve this, a step change in energy efficiency, especially efficiency of electricity use, is necessary. One priority area identified is lighting.

The regional campaign "Really bright" ("Richtig hell") was started in 2007 with the aim to promote "good and efficient lighting". Main target groups are households, businesses and public bodies.

The campaign was funded by the region of Upper Austria.

Approach

The activities were based on thorough market research activities including the founding and involvement of a stakeholder network.

Market research

A representative survey was carried out in the region (n≥500), with the aim to get more information on knowledge levels, attitudes and purchasing channels and habits.

The market research showed that the awareness on CFLs was very high, 65% of the households regarded the use of CFLs as very important. Surprisingly, 70% said that they use CFLs, 42% of them use even 3-5 lamps - possibly, social desirability was reflected more in the answers than the real situation in the Upper Austrian households.

In general, CFLs are chosen because they contribute to electricity saving and have a longer life time than incandescent bulbs. However, CFLs are considered to be very expensive. This is also the main reason not to use them.

In general, lamps are mainly bought at the individual retailers (28%) or the DIY-shops (24%) [3].

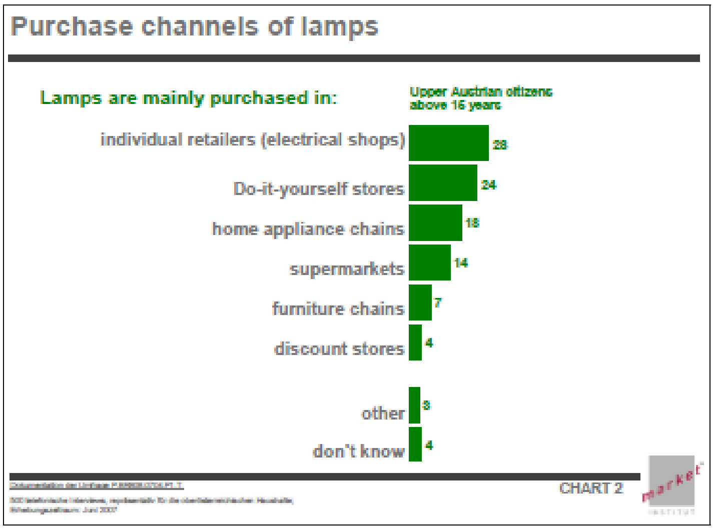

Table 1: Market research

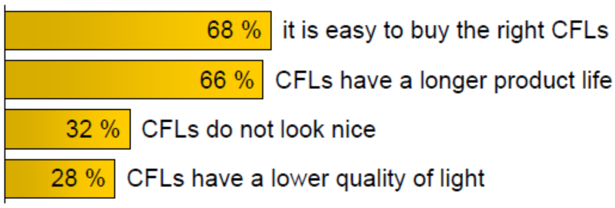

Table 2: Market research

The following main results were found:

- rather good general opinion in general but low specific knowledge
- confusion of halogen lamps and of CFLs
- a certain disparity between saying and doing was detected
- groups less likely to use CFLs are under 30ies, singles, persons living in rented apartments or in smaller homes
- generally, the interest in the topic was not very high

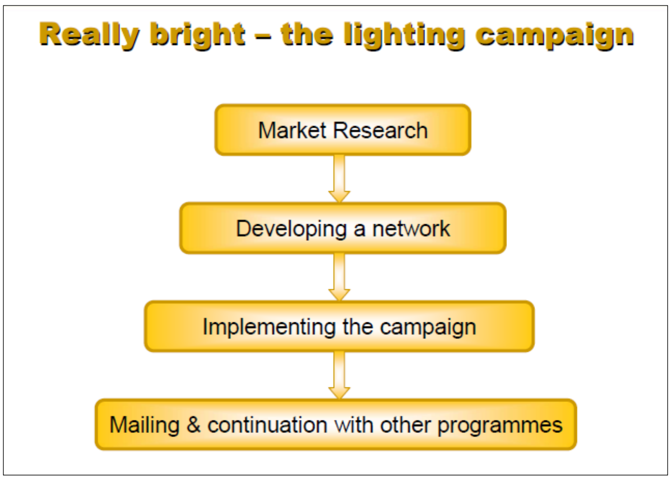

Table 3: The lighting campaign

For the campaign, the following conclusions were drawn:

- it is crucial to attract attention to the topic - many people are not that automatically interested!
- provide specific information on CFLs (how to recognise them, how to use them, which types exist...)
- try to create a long-term change in behaviour

Measures

A mix of measures was implemented, including among others:

- *Training:* a new training course for efficient lighting for tertiary sector buildings was developed and implemented and lighting included in existing training seminars. New training courses on the calculation of the energy performance indicator (energy performance certificate according to EPBD) for non-residential buildings also includes lighting aspects [5].
- *Networking:* at an early stage of the project, the O.Oe. Energiesparverband set up a network of experts and stakeholders. This included a preparatory round-table, the cooperation with 160 retailers in the lamp exchange programme, as well as Philips and Osram and the cooperation with numerous experts in events and training courses.
- *Energy advice on efficient lighting*: the regular advice service of O.Oe. Energiesparverband (15,000 advice sessions per year) was enlarged and a focus is also put on lighting issues. The advisers, which provide advice to businesses passed a special training.
- *Publications:* a number of publications for different target groups were developed, e.g. "Innovative lighting for service buildings", a folder on CFLs, "Really bright at home", "Efficient lighting for hotels and restaurants" [6]

- *Events:* a number of events were carried out. A regional conference (300 participants) informed about efficient lighting for non-residential buildings, a "Breakfast for Mayors" targeted municipalities and put a focus on office and street lighting. Finally, an international conference (334 participants) organized in the frame of the annual World Sustainable Energy Days brought this topic to an international audience.
- *Competitions:* competitions for municipalities ("Die hellste Gemeinde") and households
- *Website:* a new website (www.richtig-hell.at) was developed for the promotion of the campaign which is regularly updated as an information platform for different target groups. Additionally, a lighting hotline is answered by experts.

- *Legal measures:* in the cause of the implementation of the Directive on the energy performance of buildings, special attention was given to lighting and the promotion of new standards. [4]

Media cooperation

A media cooperation was entered, media activities included among others:

- TV spots and radio spots
- supplement to the largest daily newspaper (8-page, Friday, >130,000 copies)
- selected press advertisements

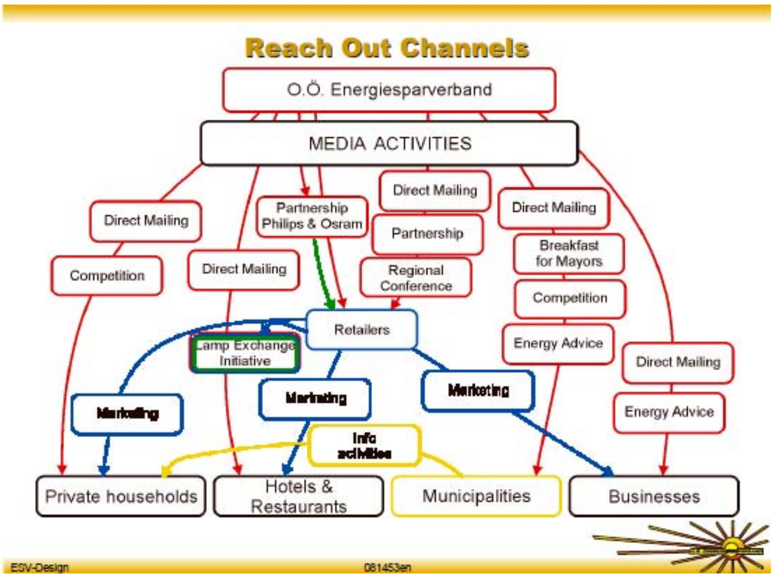

Table 4: Reach out channels [7]

Examplary measures and initiatives

Competition for households

Households that bought one or several CFLs within a period of several weeks, could win 1,000 €. The response was very high:

- 1591 participants
- purchase of 4821 lamps documented
- frequent use of lighting hotline

Pilot project: Lamp exchange initiative for companies (focus on hotels & restaurants)

In cooperation with Philips and Osram, for a period of 2 months, selected lamps could be bought at a reduced price. 165 retailers participated in the campaign and were listed as partners on the website.

Pilot project: Retrofitting of lighting in social housing buildings

Within this pilot project, retrofitting of lighting in staircases of social housing buildings of the housing association "EBS" were prepared and implemented. In cooperation with the housing association, one typical social housing building was selected, an energy audit carried out, the savings potential calculated and measures suggested and implemented. First results for retrofitted lighting in staircases were very encouraging:

- 52 % less electricity consumption
- increased lighting comfort
- annual reduction of electricity costs: 252 €

The measures were extended to buildings of the same type and recently four more building types were selected for advising and retrofitting.

Building of the regional parliament

600 lamps were exchanged in the historic building of the regional parliament. This pilot project demonstrated the importance of public authorities taking initiative for their own buildings and leading by example.

Results and conclusions

Within the campaign "Really bright", more than 100,000 inefficient lamps were exchanged and more than 40 newspaper articles were placed. The aim of the campaign was to achieve lasting change in investment and user behavior and not single actions. Information and promotional activities are therefore being continued, especially in the context of electricity saving campaigns.

For the domestic sector, the following conclusions can be drawn:

- Exchange of lamps is quite easy
- In principle, CFLs are well known and awareness is high
- However, CFLs are seen controversial and wrong information and prejudices hamper further market penetration. It is important to continue to communicate quality issues and different available types of CFLs.

For non-residential customers (including office and service buildings) the following conclusions can be drawn:

- Market development and levels of awareness are even lower than for domestic consumers. Energy efficient lighting is also more complicated than for the domestic sector (different technical solutions are possible, exchange of the whole lighting system is quite expensive…)
- EU Directives & their national/regional implementation are helpful (EuP, Energy Services, EPBD - European Buildings Directive), but increased information and training activities remain necessary. One single campaign without regular information and advice service has less long-term effects.
- Energy advice is the most successful tool because it supports people when they are really on the point of making an investment decision.
- It is not enough to offer financial incentives (e.g. cheaper lamps) without accompanying advice service.

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ENBW Lighting Expert - Showing the difference in lighting installations

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Abstract

The implementation of energy efficient lighting concepts demands for appropriate design and benchmarking tools. Architects, lighting designers as well as electricians need support in the design phase of new buildings as well as buildings in a retrofit process; for domestic and non-domestic lighting installations alike.

The conceptually new designed software *"ENBW Lighting Expert"* supports experts involved in theses processes with specifically designed workflows. These allow to rate lighting energy demands (net and primary energy) and C02 emissions by lighting use. For buildings under construction alternative solutions can be analyzed and optimized (e.g. lamp technology: halogen vs. compact fluorescent lamps or leds). For retrofits an estimation of the energy saving potentials can be obtained by setting the buildings status quo into relation to a new lighting installation (e.g. using luminares with a higher efficiency).

The tool can be applied to one-family dwellings up to larger apartment units with centralized facilities like parking garages, staircases etc. Especially for rating retrofits a check list is provided, which helps assessing existing installations in situ and which is for user convenience closely linked to the graphical user interface of the tool. The algorithms employed rely on the current European lighting standards. The tool's output is designed to support decision makers, showing them which lighting options are energetically most effective. Based on application examples the presentation will demonstrate the key features of the tool *"ENBW Lighting Expert"*.

1. Introduction

Emerging new lighting technologies and significant reductions in costs of lighting systems enable architects, designers as well as consumers to put into force energy efficient lighting concepts while simultaneously maintaining a high lighting quality. With respect to the primary energy demand of buildings, measures incorporating energy efficient lighting have a significant impact on the overall building energy demand due to the generally high primary energy factor for electricity (e.g. 2,7 in Germany).

The spread of efficient lighting technologies like compact fluorescent lamps for domestic use are accompanied by several legislative and standardization efforts. One action to name is the directive of the EU Commission to ban inefficient incandescent lamps in the next decade. The emerging energy efficient lamp technology of LED lamps is expected to economically breakthrough within the next years.

Aside the lighting techniques themselves, the implementation of energy efficient concepts demands for appropriate design and benchmarking tools. Architects, lighting designers as well as electricians need support in the design phase of new buildings as well as buildings in a retrofit process; for domestic and non-domestic lighting installations alike. Consumers need to be informed about the benefits, on a technical, economic and environmental scale.

The EnBW as one of the four mayor energy companies in Germany has now developed together with the Fraunhofer Institute of Building Physics the software *"ENBW Lighting Expert"* [1,2]. It supports experts involved in theses processes with specifically designed workflows. These allow to rate lighting energy demands (net and primary energy) and C02 emissions by lighting use. For buildings under construction alternative solutions can be analyzed and optimized (e.g. lamp technology: halogen vs. compact fluorescent lamps or LEDs). For retrofits an estimation of the energy saving potentials can be obtained by setting the buildings status quo into relation to a new lighting installation (e.g. using luminares with a higher efficiency).

In this paper the main features of the software tool are presented. An application example of the tool for a typical residential building with two shops attached is given.

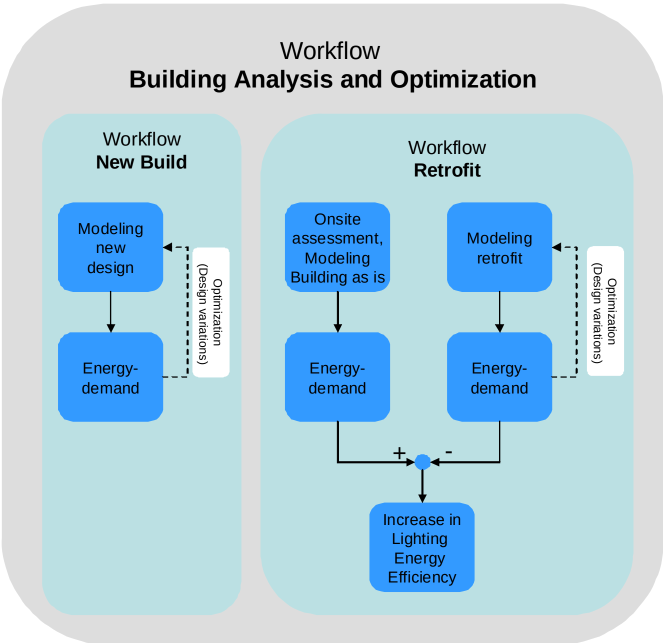

Figure 1: Workflows supported by the *“ENBW Lighting Expert”*.

2. Features of the *“ENBW Lighting Expert”*

The *“EnBW Lighting Expert”* offers the following features to rate the energetic behavior of lighting installations in residential as well as non-residential buildings:

- Workflows - specially matched to the design process - allow time-efficient analysis and optimization of lighting energy demand for new installations and retrofits as shown in figure 1.

- Fast and intuitive determination of the lighting energy distribution in buildings as depicted in figure 2.

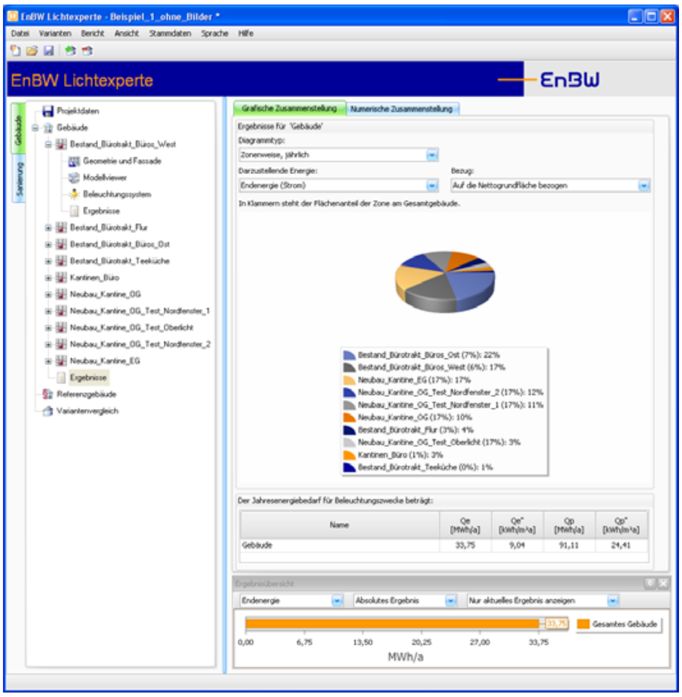

Figure 2: Overview on representation of calculation results. Exemplary comparison of relative contributions of different zones.

- Hereby supporting decisions, which incorporate the measures that are most effective.
- Check list for an on site building assessment, as depicted in figure 3 and 4 (left picture). The procedure allows fast quantitative and qualitative analysis of existing lighting installations, therefore providing reference levels for retrofit measures which can then be compared to new installations. The check list is matched to the input of the graphical user interface. Different procedures for residential and non-residential buildings are provided.

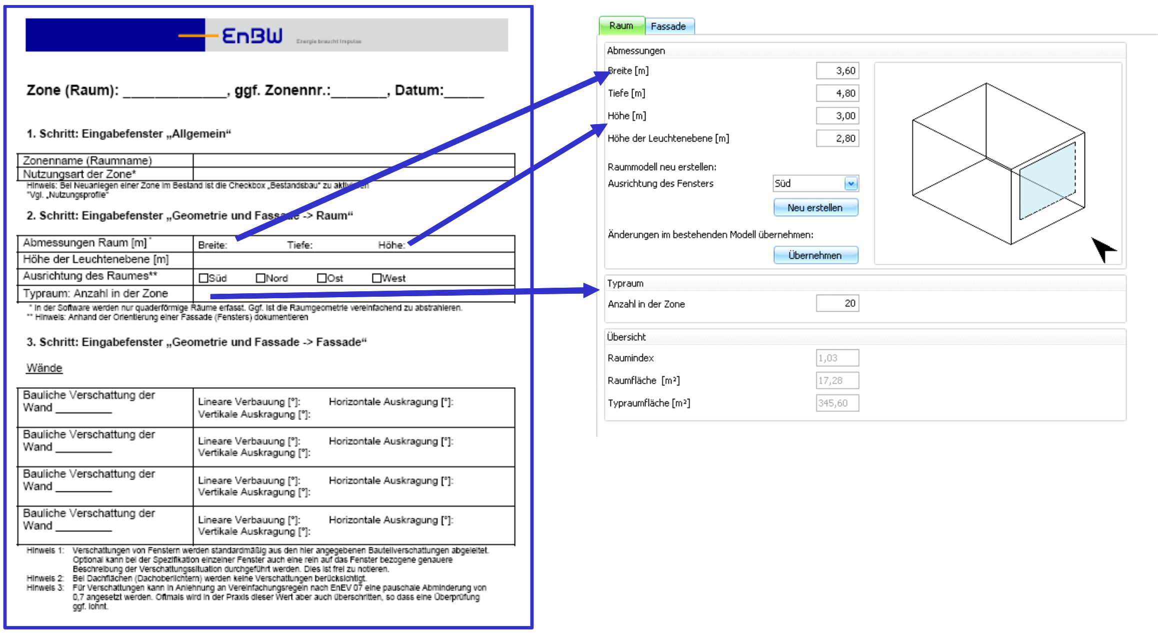

Figure 3: Check list for assessing existing lighting installations. Checklist is matched to the Graphical User Interface.

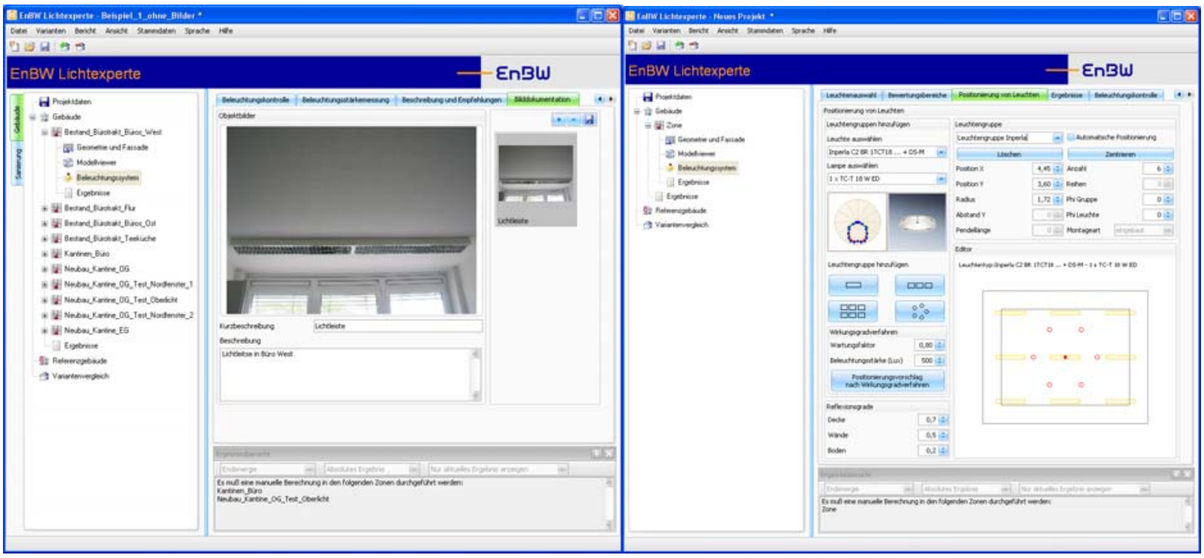

Figure 4: Assessment and documentation of an existing installation (left). Detailed design and layout of an artificial lighting systems (right).

- Therefore a simple way to obtain a reference baseline for retrofit of existing lighting systems is provided. Potentials of different alternative solutions can be shown. Also design errors in existing systems can be identified easily (e.g. less installed power in combination of not meeting the lighting requirements).

- Based on the latest standards. (DIN EN 12464, EN 15193, DIN V 18599) [3,4,5].

- User Profiles, representing statistical behavior in different task areas, e.g. living, offices, hall-ways, parking lots.

- Various evaluation criteria available like energy (final and primary) and CO_2.

- Advisor on lighting and lamp technology, with a database of typical lamps and lighting solutions especially for dwellings, including functionality to rate economic issues. Whole scale data base for non-residential lighting (lamps and luminaires).

- Easy to handle and intuitive application due to a logical structure, an extensive on demand help system, graphical aids, a hierarchal structure (fast access to quick estimates down to quite detailed evaluation and analysis methods). The tool provides a very much focused approach to evaluate the energetic impact of lighting, leaving aside overhead input that other programmes often request, as shown in figures 5 and 6.

- User support for the application of the programme and project evaluation available at the EnBW homepage (www.enbw.com).

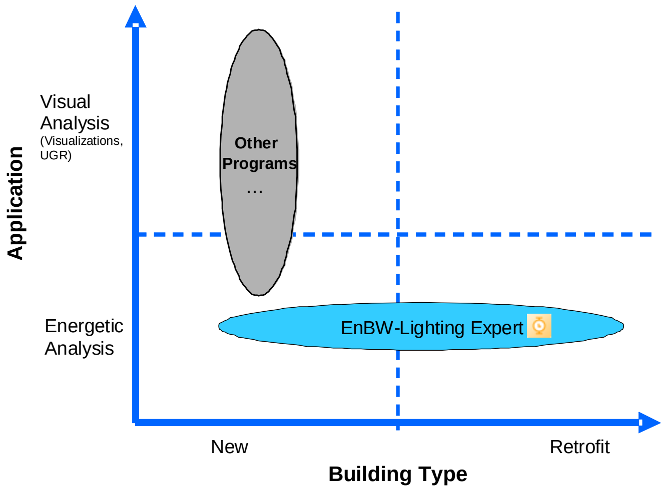

Figure 5: General strategic positioning of the software *“EnBW Lighting Expert”* with respect to other lighting software systems.

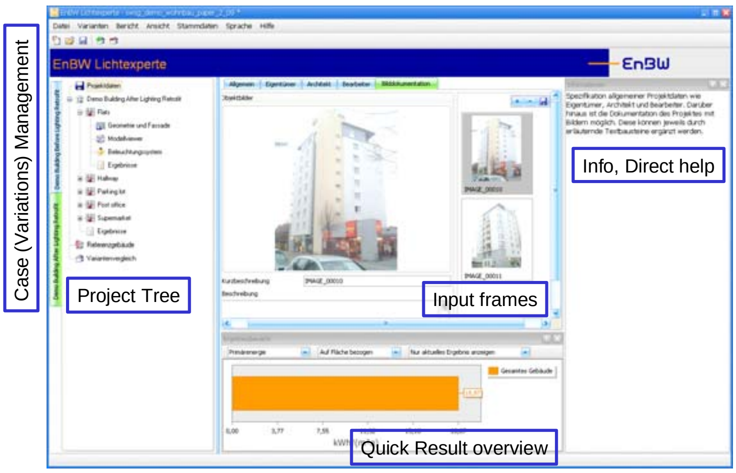

Figure 6: Architecture of Graphical User Interface.

3. Example

The example shows the impact of replacing elderly conventional lighting technology (lamps and ballasts) by state of the art energy efficient solutions. A representative building type in its current state is described. The considered retrofit measures are presented and are compared to the lighting energy demand before retrofit.

3.1 Building description

The example building, representing a quite common building typology in Germany, as depicted in figure 7, comprises 16 appartements, a parking garage, a post office and supermarket is analyzed and optimized.

Figure 7: Building type under investigation. It comprises apartments, a parking lot, a post office and a supermarket.

The overall net floor area is about 2200 m², with the 16 apartments accounting for over 50% of the surface area. Conventional lighting technology based on incandescent or halogen light is found in the apartments. The other parts of the building are lit by either compact or tubular fluorescent lamps with conventional ballasts. As depicted in figure 8 the overall net energy demand for lighting of the building is 9,65 kWh/m²a and 26,05 kWh/m²a primary energy (for the German electricity mix). Flats contribute with 8,06 kWh/m²a net (21,77 kWh/m²a primary energy). Assumptions about the user behavior (switching) are in accordance with [6]. In addition figure 8 shows the relative contributions of the different building zones.

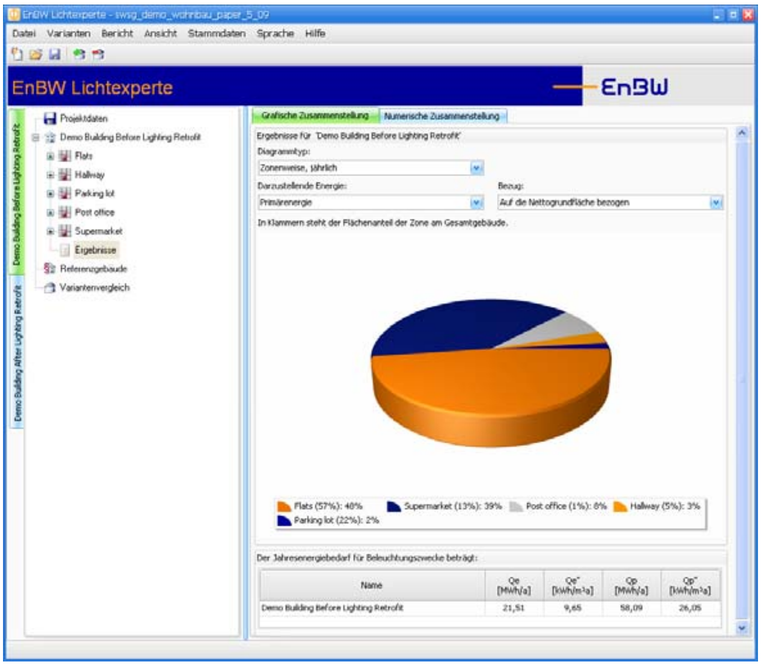

Figure 8: Representation of the overall lighting energy demand before retrofit for the building under investigation and the contribution of the different utilization zones.

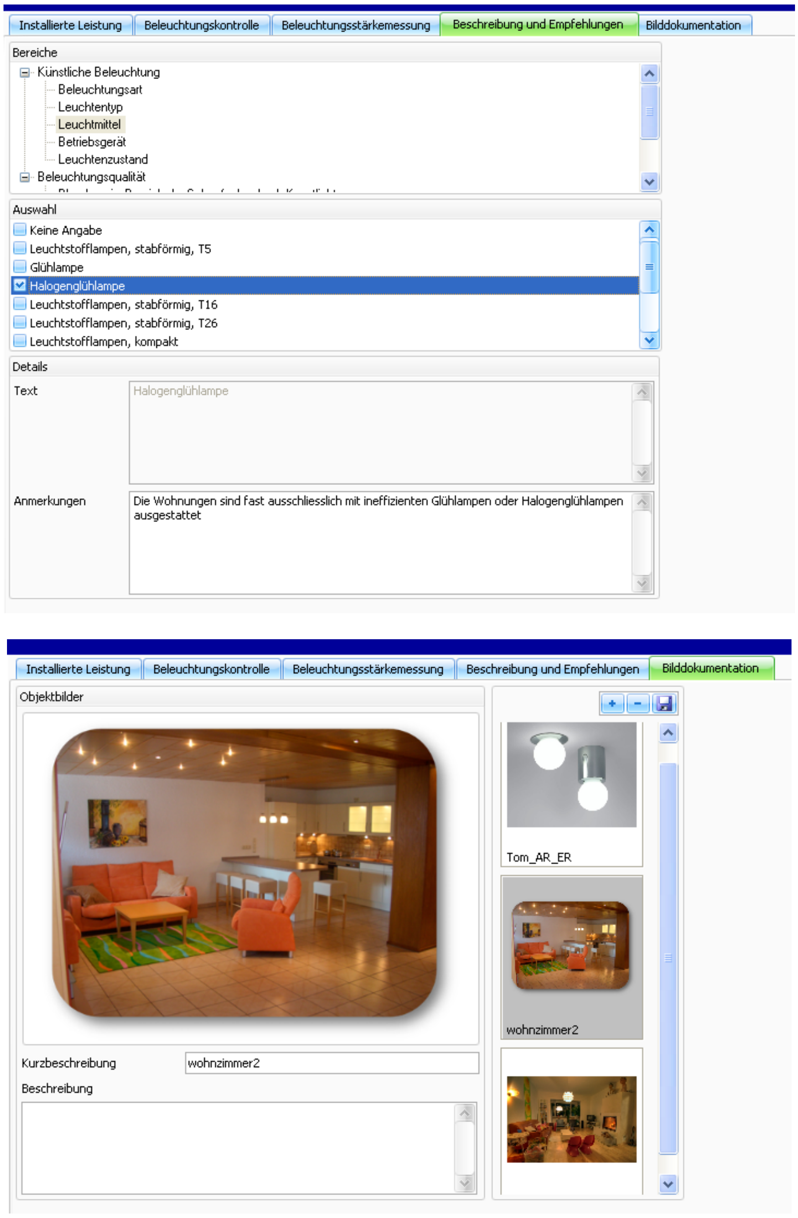

Figure 9: Exemplary documentation of the lighting system in a typical apartment. The *"EnBW Lighting Expert"* allows to document the status quo with text and pictures taken at on-site building assessments. The documentation can then be compiled into a report.

3.2 Retrofit of the lighting system

The lighting system is now assumed to be replaced by one with state of the art lamps and ballasts. Incandescent and halogen lamps are replaced by compact fluorescent lamps with electronic ballasts. Former fluorescent lamps with conventional ballasts are replaced by lamps with electronic ballasts. Lighting management systems like occupation detection in hall ways or daylight dependent dimming in some of the supermarket floor areas can be considered with the tool as well.

Figure 10 provides the results for the retrofit of the lighting system. Overall lighting net energy consumption could be reduced to 5,11 KWh/m²a (13,79 kWh/m² primary energy under German conditions). The relative contribution of the flats could be reduced significantly due to the exchange of inefficient incandescent lamps by fluorescent lamps.

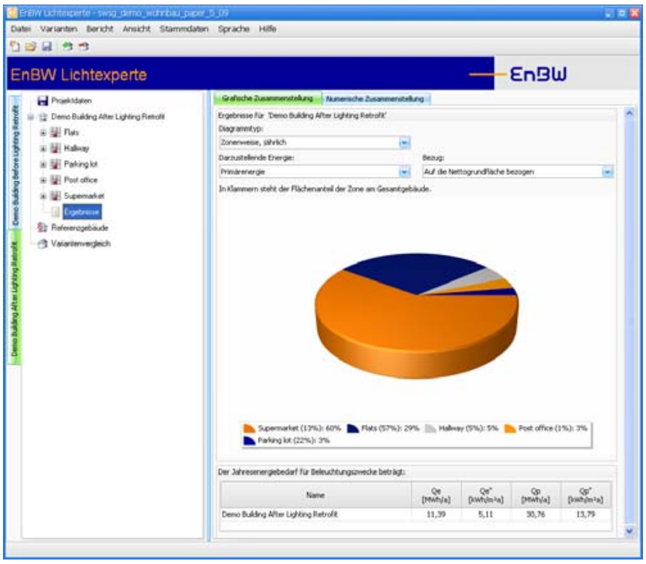

Figure 10: Representation of the overall lighting energy demand after retrofit for the building under investigation and the contribution of the different building zones.

3.3 Comparison of variations

The *"EnBW Lighting Expert"* now allows, as depicted in figure 11, to directly compare the different cases under investigation. The significant increase in lighting energy efficiency of the building (more than 50 %) can be directly deduced from the presented results.

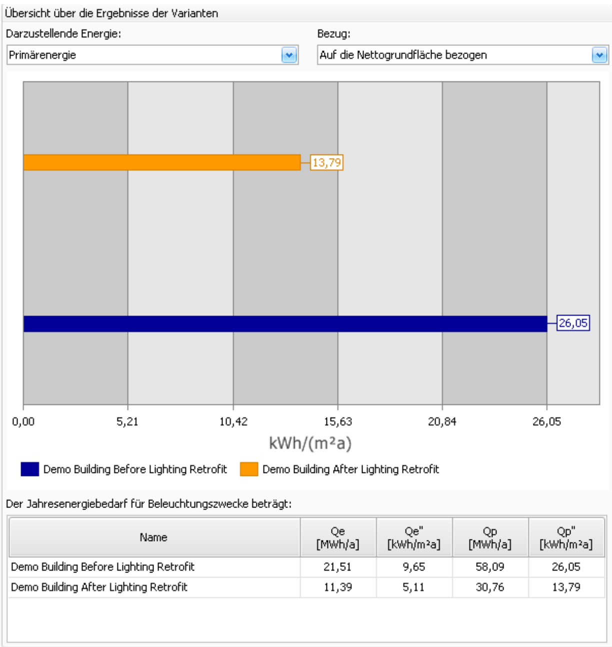

Figure 11: Comparison of different cases under investigation.

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ENERGY-SAVING EXPERIMENT IN MOSCOW RESIDENTIAL SECTOR

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Abstract

The advantage of the Compact Fluorescent Lamp (CFL) over incandescent lamps is a well-known fact for lighting engineering specialists: a compact luminescent lamp has a 5-7 times higher luminous efficiency and 8-12 times greater exploitation period than incandescent lamps. The greatest effect compact luminescent lamps use is evident in residential areas of the country. Incandescent lamps are the most popular source of light and more that 25% of energy is used for lighting in this sector.

Keywords : energy saving, compact fluorescent lamp (CFL), experiment in Moscow, lamp replacement

What is usually clear to the specialists is not always obvious for most of the customers, especially considering the high price of the CFL (10 times higher). This is why it is very important to show to the public the advantages of the CFL, People can understand based on their own experience how quickly the CFL expenses are repaid. An active energy meter could help achieve this.

A large experiment was undertaken in two high-rise buildings in South-Western administrative district (SWAD) of Moscow in winter 2008. This experiment was carried out by the group of companies "TOPSERVICE" and administrations councils "Konkovo" and "Yasenevo" with the support of the SWAD prefecture. The scientific and technical leadership was realized by Moscow Light House. Two high-rise buildings were chosen to make the experiment convincing: 25 story block of 138 flats equipped with electric ovens and 14 story block of 94 flats with gas-stoves. There were different electricity prices in these buildings (first building: 1 rate-1.66rub /kWh and 2 rate-0.42rub/ kWh; second building: 2.37 rub /kWh.

An important factor for the experiment was that the group of companies "TOPSERVICE" supplied tenants with free CFLs ("Cosmos" trademark). The Group of companies "TOPSERVICE" and community services specialists gave tenants guidance before replacing the lamps. All tenants were informed about the experiment in advance (special leaflets were published and distributed). These leaflets were also displayed on information boards around the buildings. Security service specialists and electricians questioned all tenants about the necessary quantity of CFL, lamp power, cap of a lamp, etc. and also informed tenants about the aims and stages of the experiment.

Not all tenants agreed to participate in this experiment for a number of reasons. As a result the incandescent lamps were substituted for CFLs in 78 flats with electric ovens and in 87 flats with gas-stoves (overall in 165 (71%) flats).

A total of 2872 incandescent lamps was substituted, with 100 (48 %) and 60 (52%) W power. It was interesting and unusual that tenants requested a wide range of CFL "Cosmos"- with a 9, 13, 20, 25 lamp power and E27, El 4 (44%) lamp cap (an average of 17,4 CFL per flat). During the 5 months of the experiment disabled CFLs were replaced. This was about 2% of all CFLs used in the experiment).

As a result of the experiment a reduction in installed power of 178 kW ws achieved. This provided energy savings of about 267 000 kWh with 1500 hours of lamp's working time in one year.

Energy saving in flats with electric ovens averaged 11% and 31% in flats with gas-stoves. At the same time the light level in most cases increased.

According to a survey, tenants were satisfied with the result of the experiment and they were ready to use CFL in future.

Calculations derived from experimental results show that refitting 70% of Moscow's homes with energy saving light bulbs (CFL) instead of existing incandescent lamp would cost 4.7 billion roubles, whilst achieving power reductions of 2600 MW and a decrease in energy consumption exceeding 2.5 billion kWh.

Spending less than 4% of Moscow's energy saving budget can achieve energy savings of a similar magnitude.

The effectiveness of such a project has been confirmed by the actions of British Gas, which delivered its 52 million UK customers a Christmas gift of four energy saving CFL bulbs. These bulbs are expected to provide annual energy bill savings of £18.50, saving enough energy overall to power 150.000 homes for a year, whilst dramatically cutting CO_2 emissions.

In our opinion, the results of the experiment in the South-Western administrative district of Moscow should be commented on in Moscow press and television. This experiment can be extended and put into practice in other districts of Moscow. Also it is very important to support this SWAD prefecture's initiative to introduce energy saving technologies and effective reduction in power consumption from the Moscow Government.

Lighting efficiency in dwellings: a case study

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Abstract

The use of energy efficient lighting in dwellings in combination with the preservation or the improvement of the visual comfort is a huge challenge. There is an important lack of knowledge and information in this field due to multiple factors: little or no energetic and photometric information about the residential products, uncertainty about the behaviour of the users, economic limitations … This paper presents a lighting renovation project in social apartments. The lighting systems were renovated in six similar apartments, at different level, in order to evaluate the lighting saving potential and the influence of the human behaviour on the lighting consumption. This paper presents the obtained average illuminances, luminances and installed powers for each cases. It shows that, if the choice of the lighting system is left to the inhabitant, inefficient systems are used and lighting comfort is seldom reached. Moreover, replacing incandescent lamps by high efficient compact fluorescent lamps (CFL) induces high energy savings but comfort level is hardly reached in that case. Luminaires manufacturers should work on the design of aesthetic and efficient luminaires and more technical information should be given on the luminaire packing. Finally, this paper shows that the human behaviour has a large influence on the lighting consumptions, particularly for inefficient lighting systems.

Introduction

The global warming and the decreasing of fossil fuel stock resources are two current major worldwide concerns. Lighting can represent from 5 % up to 20 % of the total electricity consumption of a household [1]. There is a large disparity in the efficacy of available lamps, which varies from 10 lm/W (incandescent bulbs) up to more than 90 lm/W (TL lamps). Moreover, studies show that low-efficient incandescent lamps are still widespread used in household [2]. For that reason, the European Commission decided to gradually prohibit the sale of low-efficient incandescent lamps [1]. In this context and in the context of the European Building Performance Directive, the Belgian Walloon government funded a research on the "study and decreasing of lighting consumptions in social housings", called the ECLOS project.

The project, realized in collaboration with the Walloon Social Houses society, was based on the renovation of electric lighting in six apartments, following three levels of complexity. The objectives were to evaluate the lighting energy saving potentials, to study the human comportment and to determine necessary future industrial innovations to encourage the use of high-efficiency lighting systems. The planned deliverables of the project are a guideline for the social housing agency and architects, a guideline for lighting manufacturers and a booklet for private individuals.

Lighting renovation

Selection of the dwellings

The lighting renovation was applied in some apartments of a large social houses complex, simultaneously to a complete renovation program; the buildings were thermally insulated, single glass windows were replaced by double low emissivity windows and interior and exterior finishes were all renewed. Every inhabitant moves from his apartment to another apartment located in the same complex but in another building.

Figure 1: view of the apartment buildings before (left) and after (right) renovation

The lighting was retrofit in six similar renovated apartments, coupled by two. Two other apartments were used as references cases. All of the eight apartments were monitored.

The renovations levels were the followings:

- Type 1: reference case - lighting system chosen by the inhabitants.
- Type 2: luminaires chosen by the inhabitants but replacement of the provided lamps by more efficient lamps.
- Type 3: installation of efficient luminaires and lamps, at the position fixed by the social housing society.
- Type 4: achievement of a high quality and efficient lighting systems, moving the light position if necessary.

Methodology

Criteria for the choice of lamps and luminaires

Cost aspects were considered in type 3 and type 4 renovations. For each of these interventions, one apartment was renovated with low cost residential lighting and the second was renovated with luminaires traditionally applied in the tertiary field (low cost industrial lighting) whose design could meet esthetic aspects expected in housings.

As there is no standard for residential lighting, minimal average illuminance values were fixed at, in general, 50 % of the values recommended in the European EN 12464-1 standard for a similar area [3].

The working plane position is only known in the kitchen. Its goal value was fixed to 500 lux. In order to maintain an acceptable uniformity in the remaining space, a goal value of 300 lux was set for the rest of the kitchen. In living rooms, the working plane depends on the furniture position, which was unknown when the calculation were done and which can change during the building life. The objective illuminance was thus fixed to 150 lux for the entire room, except for a perimeter of 0.5 m width along the walls. The average illuminance goal was set to 100 lux in bedrooms (taking into account a perimeter of 0.5 m) and 100 lux on the floor in circulation areas. The applied maintenance factor varied between 0.63 and 0.76 according to the lamp and luminaires types, following CIE 97 [4].

The traditional lighting system provided by the social housing agency in the renovated houses consists of one light point on the ceiling in bedrooms, two light points in living rooms (with separate supply) and three light points in kitchens (two on the ceiling and one 36W T8 lamp above the cooking plane). In bathrooms, one central ceiling light point (18W CFL downlight) and one 18W T8 lamp above each mirror are installed. One light point is placed in the entrance hall and two light points in the corridors.

Step 1 – Selection of interesting lamps and luminaires

The first step of the project was an extensive study of available lamps and luminaires. The studied characteristics were the start-up time, the color and color rendering, the shape and the bases for the lamps. For luminaires, the priority was to find aesthetic luminaires with fluorescent or compact fluorescent lamps, equipped with separate ballasts, electronic if possible. Lighting management systems easy to use in renovation were also studied.

Step 2 – Simulations

The choice of luminaires and lamps was based on DIALUX lighting simulations. The modeling of luminaires employed in the tertiary field was straightforward, as photometric data were available. For the low-cost residential lighting systems, the data did not exist and therefore files of similar tertiary luminaires were employed, not always with success.

Step 3 – Choice of luminaires with the inhabitants (type 3 and 4)

Based on lighting simulations, a selection of luminaires was proposed to the future inhabitants of type 3 and 4 apartments in order to offer them the final choice, according to their own aesthetic opinion.

Installed lighting systems

Tables 1 to 8 present the lighting views and data for the kitchen and living rooms in the eight monitored apartments. Bedrooms, bathrooms and halls were also studied and renovated but results are not presented here. Illuminances in apartments type 3 and 4 were measured directly after the lighting system installation, at night and without furniture in the rooms. Luminances and illuminances in apartments 1 and 2 were measured after about 10 months of occupancy, at night but with furniture in the rooms. The illuminance values given for the kitchen are the average working plane illuminance versus the average illuminance in the rest of the space. Luminance views were taken at night with a Canon EOS 40D digital camera calibrated and combined with the Photolux software [5]. All the views were taken with the same white balance in order to allow a color comparison between pictures but exposures time can differ from pictures to others. The UGR was calculated from luminance views shown in Tables 1 to 8, for two directions in the room, when possible. The fisheye center position was fixed at 1.2 m height. The obtained values are compared to a maximal acceptable value of 25 as imposed in EN 12464-1 for corridors in hotels and restaurants [3].

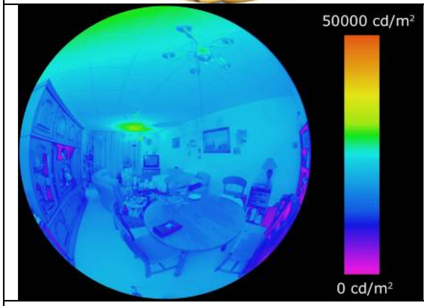
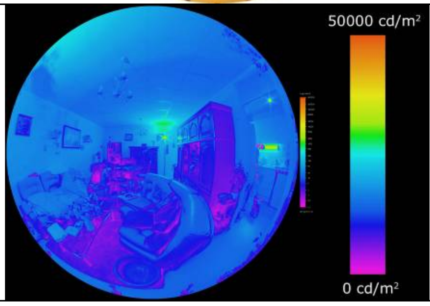
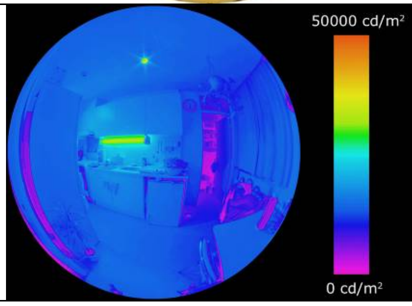
The following paragraphs describe the different lighting systems chosen by the inhabitant and/or the researchers, for kitchen and living rooms. The average illuminance (Eavg) and luminance (Lavg) are given, together with the UGR value for the view point and direction represented by the picture. For the kitchen, the first number is the working plane illuminance, followed by the average room illuminance.

Type 1 apartments

The type 1 apartments are references cases; the lighting systems were freely chosen and installed by the inhabitants.

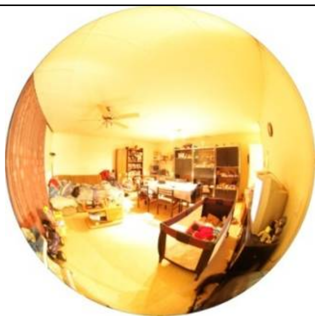
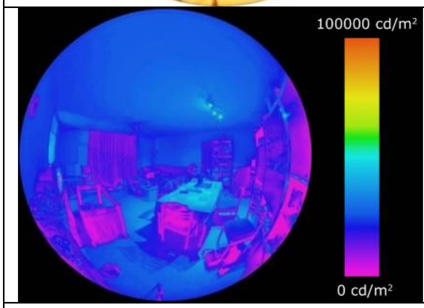
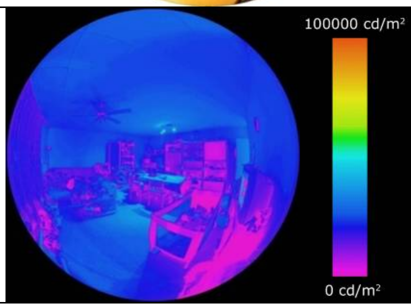
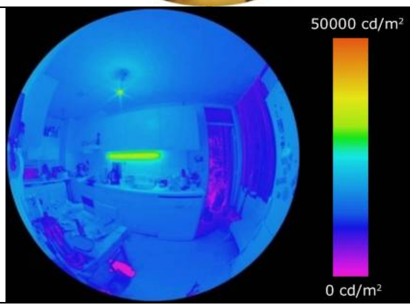
In apartment 1a (Table 1), the living room is lit by two chandeliers of five incandescent lamps each, seldom used, and two portable indirect halogen torchieres of 500 and 300 W usually used as general lighting. For that reason, pictures were taken with those lamps on. The low UGR value obtained for the first picture is due to the total indirect light while the high UGR value found in the second picture is due to the sloping of the upper part of the luminaire and the direct view of the high intensity halogen lamp. The goal illuminance value is reached. The kitchen is lit by an incandescent spotlight combined with a fluorescent tube above the sink. The goal values are not reached in the kitchen.

Table 1: Lighting data for apartment 1a (72.2 m^2); total installed power: 1592 W

		
		
UGR = 7.3 Eavg = 159 lx Lavg = 28 cd/m^2	UGR = 40.9 Lavg = 35 cd/m^2	UGR = 23.7 Eavg= 412/156 lx Lavg = 30 cd/m^2

In apartment 1b (Table 2), the living room is lit by four halogen spotlamps and the kitchen is lit by an incandescent lamp alone (no luminaire) combined with the fluorescent lamp above the sink. The illuminance values obtained in the living room are very low and far below the objective of 150 lux. UGR values obtained in the living room are low but the UGR obtained in the kitchen is very high, due to the direct view of the incandescent lamp filament (clear bulb).

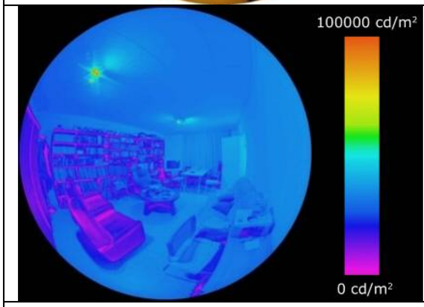
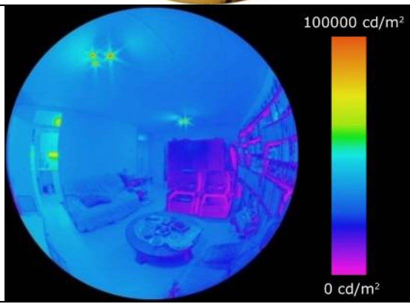
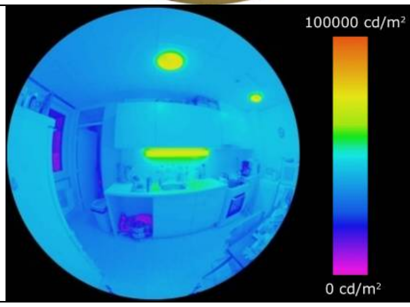
Table 2: Lighting data for apartment 1b (105.9 m^2); total installed power: 1176 W

		
		
UGR = 18.4 Eavg = 40 lx Lavg = 2.6 cd/m^2	UGR = 16.8 Lavg = 1.8 cd/m^2	UGR = 30.8 Eavg = 493/123 lx Lavg = 34 cd/m^2

Type 2 apartments

In type 2 apartments, the easiest re-lighting solution was applied; the lamps chosen by the inhabitants were replaced by low energy lamps, placed in the same luminaires.

Table 3: Lighting data for apartment 2a (74.3 m^2); total installed power: 293 W

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>UGR = 21.8
Eavg = 48.7
Lavg = 13.5 cd/m^2</td><td>UGR = 26.7

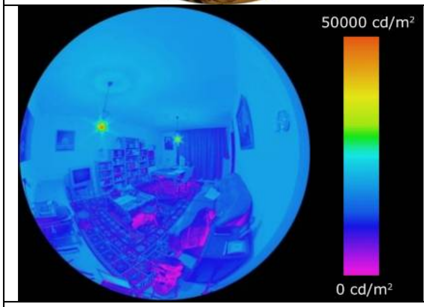
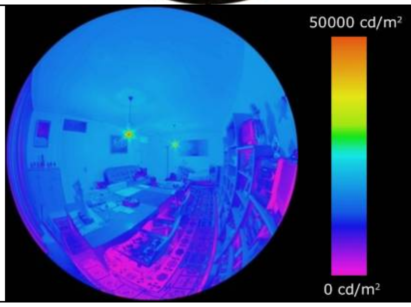
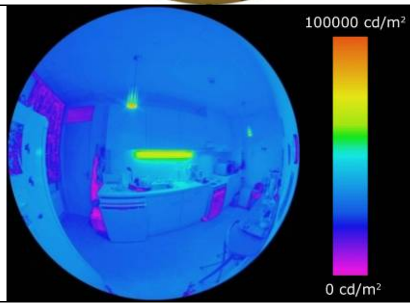
Lavg = 24.3 cd/m^2</td><td>UGR = 24.1
Eavg = 750/237 lx
Lavg = 78 cd/m^2</td></tr>
</table>

In apartment 2a (Table 3), the initial installed lighting power was about 300W in the living room and 120W in the kitchen. After replacement, the power was reduced to 60W and 82W, respectively, without loss of light flux.

In the living room, the six halogen spots were replaced by six compact fluorescent lamps of 11 W each. These lamps were the most powerful compact fluorescent spots available at that time. Measurements show that the obtained average illuminance in the living room is still very low and far below the goal value of 150 lx. In the kitchen, the working place illuminance is above 500 lux and the general illuminance is slightly below the goal value of 300 lx. The UGR can be higher than 25 in the living room, as the spot can be glaring if placed in the center of the vision field. The measured UGR in the kitchen is acceptable (below 25).

For apartment 2b (Table 4), lamps chosen by the inhabitant were compact fluorescent lamps (CFL), except for the hood lamps. However, some of the lamps were old generation CFL, with a long warm-up time and important color shift during the warm-up time. All the lamps were replaced by new CFL lamps. The living room power did not decrease but in the kitchen, installed power decreased from 114 W to 82 W. The achieved illuminance in the living room is far below the goal value. The illuminances in the kitchen are still below the goal value but the result is better than in the living room. The UGR in the living room is high as the lamps can be directly viewed by the occupant.

Table 4: Lighting data for apartment 2b (73 m^2); total installed power: 248 W

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>UGR = 28.6
Eavg = 57 lx
Lavg = 11.6 cd/m^2</td><td>UGR = 30.9

Lavg = 8.4 cd/m^2</td><td>UGR = 18.2
Eavg = 433/181 lx
Lavg = 47 cd/m^2</td></tr>
</table>

Type 3 Apartments

In type 3 apartments, low energy luminaires were installed at the position fixed by the social housing agency. Apartment 3a is equipped with low-cost domestic luminaires and apartment 3b with industrial and more expensive luminaires.

Table 5: Lighting data for apartment 3a (105.7 m^2); total installed power: 566 W

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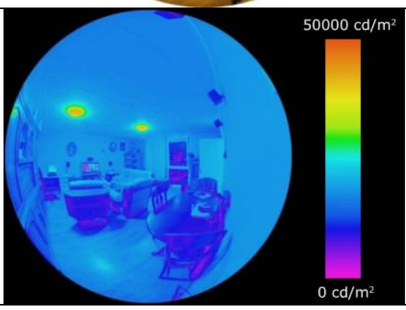
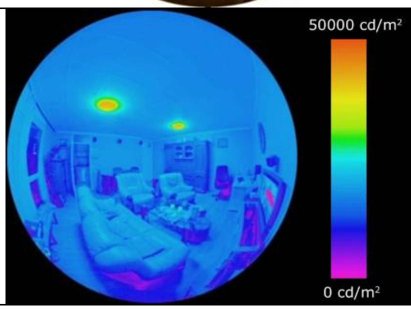
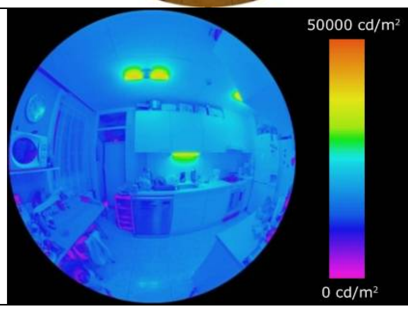
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>UGR = 22.6
Eavg = 223 lx
Lavg = 15.3 cd/m^2</td><td>UGR = 23.3

Lavg = 18.3 cd/m^2</td><td>UGR = 20.1
Eavg = 585 / 351 lx
Lavg = 46 cd/m^2</td></tr>
</table>

Apartment type 3a (Table 5) is equipped with low-cost luminaires, except in the living room, for which the inhabitant rejected the available domestic luminaires for aesthetic reasons. The living room is lit by two ceiling surface mounted luminaires of 40 W each, equipped with fluorescent tubes. The general kitchen lighting consists of two luminaires each equipped with two compact fluorescent lamps of 11 W. The working plane is lit by an 18 W TL wall surface mounted luminaire. The average illuminance values are all above the goal values. The UGR are acceptable as they are below 25.

Table 6: Lighting data for apartment 3b (76.1 m^2); total installed power: 429 W

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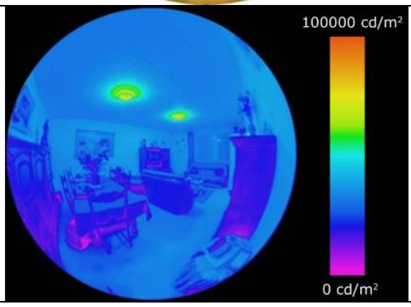
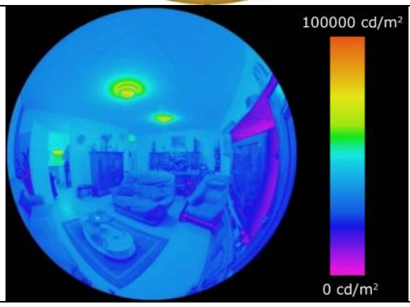
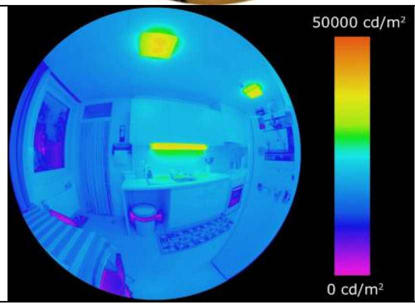
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>UGR = 21.1
Eavg = 176 lx
Lavg = 14.4 cd/m^2</td><td>UGR = 20.8

Eavg = 22.2 cd/m^2</td><td>UGR = 19.8
Eavg = = 1062/490 lx
Lavg = 83 cd/m^2</td></tr>
</table>

The living room of apartment 3b (Table 6) is lit by two ceiling surface mounted luminaires equipped with a 55 W fluorescent tube each. The kitchen lighting system consists of two 36 W ceiling surface mounted luminaires combined with a 28 W TL luminaire placed above the sink. The illuminance goal value of 150 lx is reached in the living room and in the kitchen, measured illuminance are far above the goal values (500 and 300 lx), mainly due to the application of a maintenance factors for the simulations (and the selection of the luminaires). The UGR values are below 21.1.

Type 4 Apartments

In type 4 apartments, the lighting and management systems were totally renovated, in order to show that it is possible to create an attractive luminous ambience without deteriorating the energy efficiency or the comfort.

In apartment 4a (Table 7), the living room is equipped with five recessed CFL downlight luminaires of 18 W each, combined with two 16 W wall mounted luminaires. The two systems can be switched on or off separately. The average illuminance is high and inhabitants report that they seldom use the two lighting system together. For that reason, the luminance views were taken for each system switch on, separately. In the kitchen the lighting system consists of a combination of indirect fluorescent lighting located above the kitchen cupboard and fluorescent direct lighting above the sink (under the cupboard). The illuminance obtained on the working place is too low as well as for the rest of the space. The main reason is probably because the luminaire fluxes and photometric curves were unavailable and had been evaluated by the researcher. The UGR value is just above 25 in the living room and a little higher in the kitchen.

Table 7: Lighting data for apartment 4a (87.4 m^2); Total installed power : 446 W

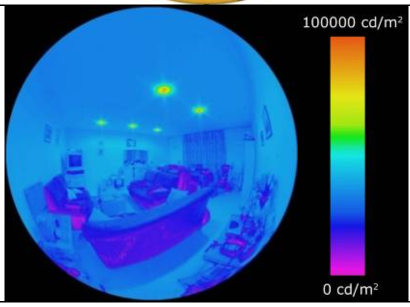
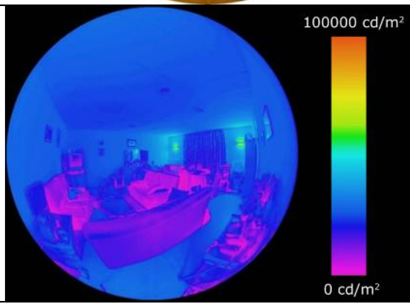
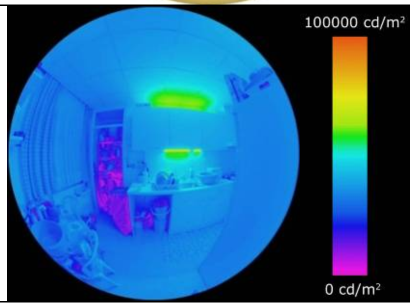
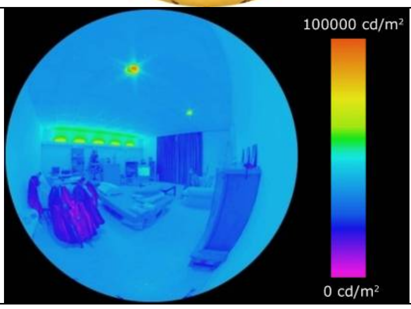
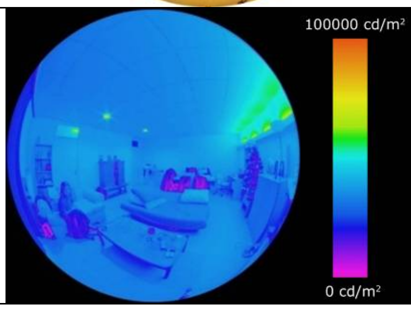
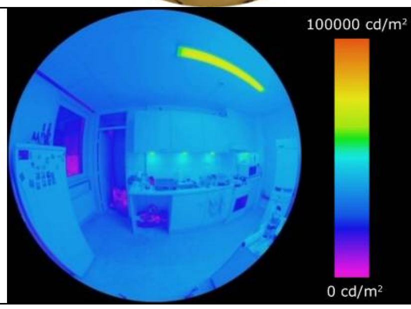
		
		
UGR = 25.3 Lavg = 20.1 cd/m^2	UGR = 14.2 Lavg = 2.7 cd/m^2	UGR = 28.5 Eavg = 312/153 lx Lavg = 27.7cd/m^2
Total Average illuminance (both systems on) = 254 lx		

Table 8: Lighting data for apartment 4b (87.4 m^2); total installed power : 429 W

		
		
UGR = Eavg = 186 lx Lavg = 29 cd/m^2	UGR = 17.1 Lavg = 18.7 cd/m^2	UGR = 17.3 Eavg = 806/412 lx Lavg = 74 cd/m^2

In apartment 4b (Table 8), the living room is lit by a combination of an indirect fluorescent lighting band and two CFL recessed downlight luminaires of 13 W each, having an asymmetric light distribution (wall washer). The obtained illuminances are above the goal value. In the kitchen, the working plane is lit by four flat CFL luminaires of 7 W each, mounted below the cupboard, combined with a fluorescent ceiling mounted luminaire of 35 W. The obtained illuminances are above the goal values and the UGR values are very low in both rooms.

Comparative analysis of the lighting systems

Figure 2a presents the total installed lighting power per square meter in the living room and in the kitchen. It shows that using CFL induces low installed power and thus possible high energy savings. For the renovation of type 3 and 4, the installed power is reduced by comparison to type 1 and increased by comparison to type 2. This comparison makes sense only when considering the energy savings but it does not take into account the luminous comfort. Indeed, the obtained illuminances are different. Thus, in order to evaluate the “energy efficacy” of the lighting system, it is interesting to study the electric lighting power per square meter and for an illuminance of 100 lux. This criterion is often used as reference in office buildings where a value below 2 W/m²/100 lux corresponds to an efficient system. This criterion of “efficiency” is plotted on figure 2b for the kitchen and living rooms.

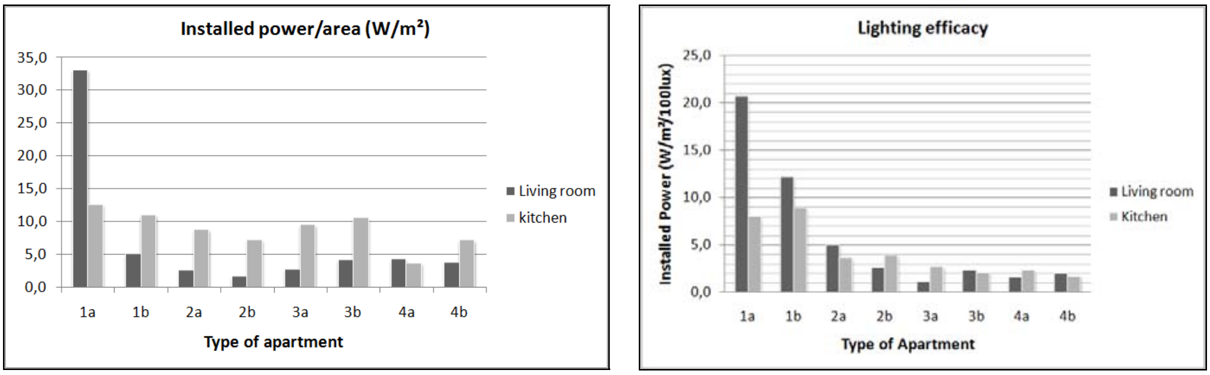


Figure 2: Installed lighting power (2a) and lighting efficacy (2b) in the eight apartments

Figure 2b shows that the more efficient solutions are type 3 and 4. It also shows that, while it is possible to go below 2 W/m²/100 lx in housing, a value of 2.5 W/m²/100 lx seems to be a more reasonable target value. It shows also that the lighting systems installed by the occupant are energy-greedy and that the replacement of commonly used lamps (mainly incandescent) by CFL induces high energy savings.

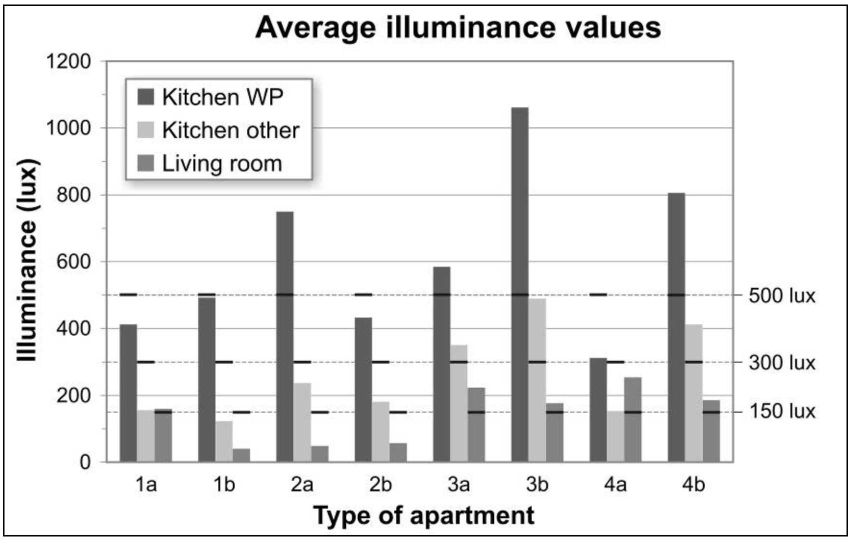


Figure 3: Measured average illuminance values

Figure 3 presents the measured illuminance values for both rooms in the four apartments. It shows that the goal values are seldom reached when the inhabitants chose the lighting system themselves. Figure 3 shows that the low-cost luminaires photometric curves were not very well evaluated, resulting in a too-low illuminance value in the kitchen. It also shows that the luminaire choice has an impact on the possible reached illuminance and that replacing incandescent lamps by CFL lamps does not guarantee the achievement of the goal values fixed in this project.

The comparison of obtained UGR values shows that they can be very high in housing (up to 40) and that it is possible to have high efficient lighting solution (types 3 and 4) without exceeding a value of 28. It seems reasonable to fix a target value of 25.

Satisfaction

Satisfaction of the inhabitants, evaluated through a questionnaire, was in general positive. People mainly use their lighting for functional reasons rather than for creating a specific lighting atmosphere. Criticisms mostly refer to the lighting management system. People regret that the general and local lighting cannot be switched on/off separately in the kitchen and in the bathroom. In the bathroom, it is also impossible to use the electric socket without switching on the light, which can result in a waste of lighting energy.

A luminaire having an integrated presence detector sensor was installed in one of the toilets but users are dissatisfied with the delay time. It appears that it is not evident for these persons to modify the setting by themselves, while it looks pretty easy according to the manufacturer instructions.

Concerning the lamps, inhabitant of apartment 1a claims that they do not use CFL because of their “bad” lighting quality but none of the persons having CFL in their apartments did complain.

Monitoring

In the eight apartments, a monitoring system registers the state (on or off) of each luminaire every minute. The total apartment electric consumption and the total lighting energy consumption are also measured by two independent electric meters.

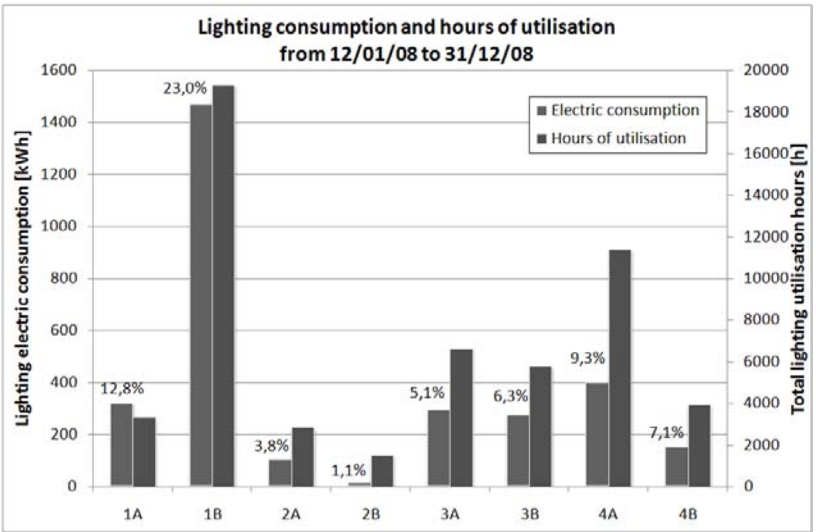


Figure 4: Lighting energy consumption and its part in the total electric consumption (in %)

These data (from 12 January 2008 to 31 December 2008), completed by the cumulative numbers of lighting hours, are plotted on Figure 4. Note that, the consumption of apartment 1a, equipped with portable lamps, was extrapolated from a 2 months local cumulative measurement (plug meter), taking into account the evolution of the lighting consumption in the dwelling through the year. Figure 4 shows that the differences in behavior are high. Occupants of apartment 1b switched on the light almost during the whole day (and even during night) while the occupant of apartment 2b almost never uses the light. The low consumption of type 2 apartments is due to their low use of lighting combined to the weak power of their lighting systems.

Discussion and advices for the lighting industrial sector

Saving possibilities

This study shows that replacing low efficient lamps by CFL induces high energy savings. However, it is difficult to reach correct illuminance values with domestic lighting systems traditionally equipped with incandescent lamps, without multiplying their numbers. Inhabitant should directly choose luminaires adapted to CFL or fluorescent tubes. However, the chosen illuminance criteria can be discussed.

Chosen Criteria

When comparing the goal illuminance to measured illuminance values in type 1 and 2 living rooms, it appears that the latter are, except in one case, three times lower. For the kitchen, the difference is lower because one of the lamps is a 36 W T8, provided by the social house society. In solution 3 and 4, people often used only one of the two lighting systems in the living room. So the following question appears: does inhabitant really need 150 lx in their living room and 300 lx in their kitchen? For UGR, the value of 25 seems to be reasonable but is only based on the EN 12464-1 standard and observations in eight apartments. For that reason, the following of the here-presented work will consist in a survey in dwellings. Luminance and illuminance will be measured and the distribution of lamp type will be studied. This work will also allow us to go deeper in the definition and the validation of a lighting efficiency criterion for domestic lighting.

Behavior

Human behavior has a large impact on lighting consumptions in housing. First of all, it is difficult to make people understand that some lamps consume much more energy than others and for example that some portable lamps like indirect halogen of 500 and 300 W should absolutely be given up. Moreover, the monitoring result shows that the switch on and off behavior has a huge impact on the lighting consumption. This impact is of course higher for low efficient lighting systems. One solution might be to educate and to increase the people's awareness about global warming and its environmental impact. But it is very hard and the results are doubtful. For that reason, regulation on the available lighting systems is very important and work on the design of aesthetic domestic lighting is necessary. In the future, it is planned to study accurately the human behavior in these dwellings and to try to correlate this comportment with daylight availabilities. The final objective is to extract and to model characteristic behaviors in order to implement them in electric lighting consumption prediction tools like Daysim or the Belgian single patch sky and sun simulator [6-7].

Material and packaging

For housing, the T5 circular lamps seems to be very interesting and lighting companies should work on the design of esthetic luminaires equipped with these lamps. It is also difficult to find domestic luminaires equipped with electronic ballasts, even in the "high efficiency luminaires" ranges. Industrial luminaires are in general of better quality, more robust and reliable. The lamps are masked in a better way, resulting in lower UGR.

On the other hand, few domestic luminaires offer efficient lighting and the information given to the customer is poor, not to say inexistent. Some luminaires were provided with very low-quality fluocompact lamps, resulting in 100 % lamp failure after about 1000 hours. The packaging of the lamps should inform the customer about the type of ballast, the lamp color temperature, etc. This is never the case. Some luminaires were provided with warm and cold color temperature lamps mixed together, resulting in poor luminous conditions.

It is also very difficult to find, for bathrooms, aesthetic efficient IP54 luminaires with a separate switch, even in the industrial luminaire variety and there are at the moment no efficient indirect luminaires that can replace indirect portable halogen torchieres.

Finally, lighting manufacturer should work on desk light and on domestic electrical appliances lighting, whose part in the total lighting power will increase if a major effort is made for the general lighting.

Acknowledgment

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The development trend of China's Green Lighting

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Abstract

The Chinese government's 11th 5 Year Plan includes ten specific Energy Saving Projects, of which one is the Green Lighting Project. The implementation of the Green Lighting Project involves the promulgation of new policies and measures such as financial subsidies for the promotion of high efficiency lighting products, and energy efficiency labeling. To support the implementation of the Green Lighting Project, China is preparing to revise national energy efficiency standards for fluorescent ballasts, double-capped fluorescent lamps and compact fluorescent lamps. New efficiency standards will be developed for solid-state lighting and incandescent lamps, as well as a lighting electricity-saver application technology standard.

This paper describes the content, implementation process and development schedule for China's Green Lighting Project and discusses the revision and development of product efficiency standards for Chinese lighting products. The paper also reviews the role of lighting product efficiency standards in China's Green Lighting Project.

1 China's Green Lighting Project

"Green" lighting uses energy efficient, environmentally friendly technology to give people the lighting service that they need. Green lighting applications choose lighting products that have high efficiency, long life, stable performance and safe operation while also making optimal use of sunlight for illumination. The objective of the Green Lighting Project is to plan and organize a series of activities around this approach.

With sponsorship from the United Nations Development Programme (UNDP) and the Global Environment Fund (GEF), the Green Lighting Project achieved some notable benefits during the ten years from 1996 to 2005. Achievements included encouraging Chinese lighting manufacturers to develop and produce high efficiency lighting, increase output of same, and to become more market-oriented. From 2002 to 2004 alone, the consumption of energy-efficient lighting products in China, such as CFLs, rose from 1.78 to 2.44 billion units annually. The consumption of all lighting products in China during this time rose 20.1% while electricity consumption of lighting grew by only 15.8%1. This result fully demonstrates the effectiveness of China's Green Lighting Project.

[1] Source: the final report of the 2nd phase for Green Light Project of China

Two important objectives for the Chinese government are meeting the Outline of the 11th 5 Year Plan for National Economic and Social Development, and reducing the energy intensivity of each unit of Chinese GDP by 20%. In acknowledgement of the critical role of green lighting in meeting these objectives, the Chinese government has made green lighting one of the ten top key energy-saving projects under the 11th 5 Year Plan. Under the plan, the path for development of China's Green Lighting Project is specified as follows:

Technological transformation of energy-saving lighting production. This transformation will improve quality, reduce costs and enhance domestic capability for self-reliance and innovation. China will develop new manufacturing technologies for energy-saving lighting including but not limited to: complete automation of self-ballasted compact fluorescent lamp (CFL) production; part automation of key CFL manufacturing steps such as air exhaustion, machine bridging and sealing; and transformation of automated production for linear, double-capped fluorescent lamps and metal halide lamps.

Popularization of energy-saving lighting products. China will popularize energy efficient lighting through market transformation approaches such as bulk purchases, DSM, Energy Performance Contracting, quality commitments, and financial subsidies. Energy-saving lighting will be installed in high-visibility applications including government offices, schools, hotels and restaurants, shopping malls, supermarkets, large-scale industrial and mining operations, hospitals, railway stations, urban landscape lighting projects, and urban residences.

Transformation of traffic signaling. China will organize and launch the use of LEDs by demonstrating traffic signaling and landscape lighting applications.

In government document, China Medium and Long Term Energy Conservation Plan, the following eight supportive measures to ensure successful implementation have been emphasized:

- Research and promote the further acceleration of the transformation to green lighting
- Improve and implement key energy efficiency standards for lighting products and establish the mechanism of market access. This would include revising the energy efficiency standards for ballasts for single-ended fluorescent lamps, high voltage sodium lamps and tube fluorescent lamps. In addition energy efficiency standards would be set for street lamps, grille lamps, halogen lamps and associated ballasts, LED lamps and magnetic induction lamps.
- Accelerate the government's ability to monitor market data for energy efficient lighting products including sales by product and by province, region and city.
- Strength the certification of energy efficient lighting products. The government should establish a quality commitment for energy efficient lighting products and choose a few products, such as CFLs and double-ended fluorescent lamps, to develop a pilot international certification.
- Study and implement an energy-efficiency labeling system for 2-3 kinds of lighting products
- Incorporate a design review of lighting system energy efficiency into the energy conservation review for new buildings prior to construction.

- Develop and establish a recycling system for lighting products. This would include implementing the Management Measures for Recycling Lighting Devices, the Design Standard for Recovering and Recycling Waste Fluorescent Lamps, the Technical Standard for Harmless Treatment of Waste Fluorescent Lamps. It would also include developing new standards for the proper disposal of waste electronic and induction ballasts, and of high-intensity discharge lamps.

- Increase government investment in publicity, and establish a government support mechanism to develop and disseminate information about energy efficient lighting.

In summary the key objectives of China's Green Lighting Project are to support the restructuring of the lighting industry, to upgrade the technical standards for lighting products, reinforce the Chinese government's oversight and supervision of the lighting market, and improve capacity to provide information and education about energy efficient lighting.

2. Development and Implementation of China's Green Lighting Project

China's Green Lighting Project has already achieved some success in promoting the development of Chinese energy efficiency standards and implementing lighting product energy efficiency certification and labeling and government procurement systems. As a result, the Chinese lighting industry are now enthusiastically developing and manufacturing energy efficient lighting products due to the expanded market demand. Recently, particular progress has been made in three areas.

2.1 Financial Subsidies for High-efficiency Lighting

In December 2007, the Chinese Government issued the Interim Regulations on Popularizing the Financial Subsidy in High-efficiency Lighting Products. These regulations established subsidies to support the replacement of existing incandescent lighting and other low-efficiency lighting products. Manufacturers compete to participate in the subsidy program and the winners sell qualifying products to end users at an agreed upon price that reflects the value of the subsidy. The subsidy is provided from the central government budget, and open and financial management makes the process transparent to all participants.

During the 11th 5 Year Plan the Chinese government plans to lower national electricity demand by 29 billion kilowatts by supporting the installation of 0.15 billion high-efficiency lighting products. This is tantamount to the capacity of six thermal power plants with an installed capacity of one million-kilowatt PWR., reducing coal use to the tune of 15 million tons, $CO2$ emissions by 29 million tons, and $SO2$ emissions by 0.29 million tons per year.

In April, 2008 the Chinese government launched a promotion for the first wave of 50 million high-efficiency lighting products. This was achieved through a government procurement programme. A tender was opened by the Chinese government with a uniform invitation to the lighting industry. To be successful, winning bidders were required to have excellent marketing and after-sale service systems to ensure the installation and use of the energy efficient lighting products. The products procured were required to comply with the relevant Chinese certification for energy saving products. The bid winners must provide large customers with quality commitments for not less than one year, and individual customers with a minimum two-year warranty. The bid winners must well their products at the agreed price that reflects the subsidy, and must also have the ability to recover and appropriately treat waste lighting products.

As a result of the tender, thirteen suppliers of high-efficiency lighting products were awarded the first wave of government procurement contracts. The products covered included both CFLs and double-ended fluorescent lamps at two different energy efficiency levels. The double-ended fluorescent lamps must be three tri-phosphor T8 and T5 models. This promotion received excellent support from local governments, some of which provided additional subsidies from local funds for qualifying products sold in their local markets. In these areas, energy efficient lighting products were offered to customers at low prices, or in some cases for free.

2.2 Energy Efficiency Labeling for Lighting Products

In January 2008, the Chinese government published2 the third list of products to be covered by the Chinese energy efficiency label. This list included CFLs and high voltage sodium lamps. According to the announcement, the management of energy efficiency labels would be implemented from June 1st, 2008 for both new lighting product categories, which was the first time that the system of energy efficiency product labels were applied to lighting in China. Meanwhile, China also promulgated Detailed Rules for the Implementation of Energy Efficiency Labels for CFLs, and Detailed Rules for the Implementation of Energy Efficiency Labels for High-voltage Sodium Fluorescent Lamps.

The detailed rule for CFLs applies to products with ignition and operation characteristics commonly intended for residential use and similar applications (AC voltage of 220 V, 50 Hz frequency), with screw or bayonet mount and nominal power between 5 – 60 W. The Rules are not intended for CFLs with lampshades". The detailed rules for sodium lamps applies to high-voltage sodium lamps with transparent glass shells with rated power of 50W, 70W, 100W, 250W, 400W and 1000W which are widely used for outdoor lighting.

The energy efficiency labels for these self-ballasted fluorescent and high voltage sodium lamps are in the "grade III" category. On the top of the label appears "CHINA ENERGY LABEL" in English. Under this heading appears:

- Manufacturer name (or abbreviation)
- Product model number
- Energy efficiency level
- Nominal power rating (W)
- Colour Temperature
- Initial efficacy (lm/W)
- Applicable energy efficiency standard number

[2] Announcement number 8, jointly issued by the State Development and Reform Commission, General Administration of Quality Supervision, Isnpection and Quarantine, and the Certification and Accreditation Administration of the People's Republic of China.

For purposes of the label, the “manufacturer” is the brand-owner and not necessarily the actual producer of the product in question. Manufacturers or importers can print the label themselves and are responsible for their quality and accuracy.

The Energy-efficiency Label Management Center has the responsibility for maintaining records of each labeled product. The Center publishes the label information on www.energylabel.gov.cn and regularly issues the label information relevant media. The Center also provides manufacturers and consumers with information on the energy efficiency of products, and immediately announces the results of any inspection or supervision activities. Any attempt to forge, abuse or otherwise falsely use the label can make a manufacturer subject to corrective action by the Center’s quality supervision department, including a fine of not less than 50,000 yuan or more than 100,000 yuan. For serious offenses, the offender’s manufacturing license shall be revoked by the Departments of Industry and Commerce.

Figure 1 Energy Efficiency Label for Auto-Ballasting Fluorescent Lamp

2.3 Gradually Eliminate the Incandescent Lamp

According to a report from the International Energy Agency, incandescent lamps are being gradually eliminated around the world. The report estimates that 38% of electricity consumption for lighting can be saved in two decades, and CO2 emissions lowered by 16.6 tons. Australia was the first country to develop a plan to eliminate incandescent lamps and the government will institute a ban no later than 2010. Subsequently, many countries have started down the path to eliminating incandescent lamps. A few Canadian Provinces and U.S. States are also pursuing incandescent lamp bans.

With the support of the United Nations Development Programme (UNDP) and the Global Environment Fund (GEF), the Chinese government is preparing the program “Eliminating Incandescent Lamps and Accelerating the Popularization of Energy Saving Lamps.” As its title suggests, China will eliminate the incandescent lamps through positive policies aimed at promoting the development of energy efficient lighting.

3 Development Trend for Lighting Product Energy Efficiency Standards

The research and establishment of national energy efficiency standards for lighting products is a key part of China's Green Lighting Project. China has already established energy efficiency standards that cover fluorescent lamps ballasts, double-ended and single-ended fluorescent lamps, CFLs, high pressure sodium lamps and ballasts, and metal-halide lamps and ballasts. These standards set the basic framework for energy efficient lighting definitions in China by establishing four technical indices:

- Current minimum performance for energy efficiency
- Future minimum performance for energy efficiency in the form of targets
- Evaluating values of energy conservation
- And grades of energy efficiency

The number of Chinese energy efficiency standards and the range of products covered by them compares favorably with other countries, but some of the standards have not been revised in some time and there are still some important product categories not covered by standards. This lack obstructs the implementation of energy conservation policies and measures for these products. In order to improve the consistency and coverage of energy conservation policies and measures for lighting, and to ensure the effective implementation of the Green Lighting Project, China is currently undertaking, or will undertake the revision of existing standards and the development of new ones.

3.1 Chinese Lighting Standards in Urgent Need of Revision

3.1.1 Fluorescence lamp ballast

Energy efficiency standard GB17896-1999 "Minimum Values for Energy Efficiency and Evaluating Values for Energy Conservation for Tubular Fluorescent Lamp Ballasts" has been in place for ten years, but has never been revised since being issued. This standard adopted the U.S. method for evaluating ballast efficiency, the Ballast Efficiency Factor (BEF). However, over the past decade electronic ballast technology has developed rapidly, and quality has improved greatly. During the period the European ballast test method has become widely acknowledged by the lighting industry. Therefore, the current ballast standard does not meet the requirements for current national policy needs both in terms of index and test method. A revision of this standard has been approved by the Standardization Administration of the PRC and associated work is underway.

3.1.2 Fluorescence lamp

Energy efficiency standard GB19043-2003 "Minimum Value of Energy Efficiency and Grades of Energy Efficiency for Common Lighting Double-end Fluorescent Lamps" and GM19044-2003 "Minimum Values of Energy Efficiency and Grades of Energy Efficiency for Common Lighting CFLs" have been inexistence for five years and both overdue for revisions. The target energy efficiency levels included in the 2003 standard for double-ended fluorescent lamps was included as the evaluating level in the 2005 energy efficiency standard for the same product category. Therefore, since August 1, 2005 the evaluating values of energy conservation have been the minimum allowable levels of energy efficiency in double-ended fluorescent products.

CFLs are the primary substitute for incandescent lamps, and international harmonization activities are active and seem to be making headway. The applicable scope of the performance standard for CFLs in China has been extended so the scope and technical index shall be extended accordingly.

Single-ended fluorescent lamps (or "pin-based" compact fluorescent lamps) are widely used to light residential, hospitality and retail buildings as a substitute for incandescent. No energy efficiency grade was provided in the former standard, therefore the standard will be extended to also include an index of grade for this product category as well.

3.1.3 Metal Halide Lamps and Ballasts

Metal Halide (MH) lamps can now achieve good colour rendering with luminous efficacies between 70 and 85 lm/W. This performance makes MH lamps (particularly low-power versions) ideal substitutes for incandescent lamps. Energy efficiency standards GB 20053-2006 "Minimum Values of Energy Efficiency and Grades of Energy Efficiency for Metal Halide Lamp Ballasts" and GB20054-2006 (the equivalent standard for MH lamps) have only been in place for two years. However, at the time these standards were formulated, only scandium and sodium series MH lamps were available on the market and therefore the scope of the standards is too narrow, applying only to products rated at 175 W and above. Revised performance standards that take into account product categories made possible by ceramic and rare-earth series MH lamps are in the works. The new standards will establish performance criteria for MH products down to 20W rated power. This should further help to popularize MH lighting and to eliminate incandescent.

3.2. Standards in Urgent Need of Formulation

3.2.1 Standard for Lighting Electricity-Saving Equipment

In many parts of China, the distribution voltage supplied by the mains is higher than the rated voltage of lamps, which results in large amounts of wasted energy for lighting. Chinese companies have developed a variety of lighting energy saving devices whose working principle is to lower the voltage supplied to lighting equipment. No energy efficiency standard exists for such voltage-limiting devices, and the energy efficiency benefit from their operation cannot be evaluated. Many manufacturers of voltage limiting devices have appealed that standards for this type of equipment be established as soon as possible, and they are currently in process.

3.2.3 LED Lamp Emergency Exit Lighting

Emergency exit lighting technology has evolved continuously from the original incandescent lamp, to fluorescent and now at last to LED with continuous improvements in energy efficiency. Currently, there is a mixed market for incandescent lamps, fluorescent lamps, and LED lamps as emergency exit lighting in China. Without an energy efficiency standard, the actual efficiency level of emergency exit lighting products cannot be evaluated. A standard for exit lighting is urgently needed to allow energy conservation policies and measures to be implemented accordingly.

3.2.4 Indoor Grille Lamp(fluorescent troffer fixtures)

The indoor grille lamp is ubiquitous in offices, schools, industries and public places. Its efficiency directly affects national electricity consumption for lighting. The number of grille lamps is increasing rapidly with urbanization and increasing demand for lighting. The development of an energy efficiency standard for grille lamps is an important part of the plan to meet energy conservation targets in the 11th 5 Year Plan, and will also help improve Chinese product competitiveness on the international market.

3.2.5 Street Lighting Fixture

Street lighting fixture is also expanding rapidly with urbanization and roadway construction in China. Because of typically long life times, it is important to optimize the efficiency of street lighting fixture when it is first installed, and the potential savings from efficient street lighting fixture are large. At present there is no standard for evaluating efficiency and both the quality and efficiency of street lighting fixture in China varies widely. Inefficient technologies are still used in some areas, causing significant wasted energy. The establishment of an energy efficiency standard for street lighting fixture will accelerate the elimination of low-efficiency products and promote the popularization and application of high-efficiency options.

At present the Standardization Administration of the PRC has approved the revision of the energy efficiency standard for grille lamps, and has listed the following items on the China “2008-2010 Resource Conservation and Comprehensive Utilization Standard Program”:

Development of an energy efficiency standard for emergency exit lighting

Development of an energy efficiency standard for street lighting fixture

Revision of the energy efficiency standard for single-end fluorescent lamps

Revision of the energy efficiency standard for double-ended fluorescent lamps, and

Revision of the energy efficiency standard for CFLs

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Off-Grid-Lighting solutions for least developed countries

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Abstract

About 1.6 billion people worldwide don't have access to an electrical grid and therefore depend on "fuel-based lighting". Nearly 80 billion liters of kerosene are burned every year only for lighting, resulting in emissions of about 200 million tons of CO_2. The related cost for kerosene of more than 40 billion Euro is comparable to the existing grid based lighting market.

So called "Energy Hubs" provide electrical power gained by sun light and filled into rechargeable batteries. These Hubs with their mobile electrical power distribution are the technical key for a sustainable solution bringing light to least developed countries.

The pilot project to test the principle idea was started in Kenya and Uganda in 2008.

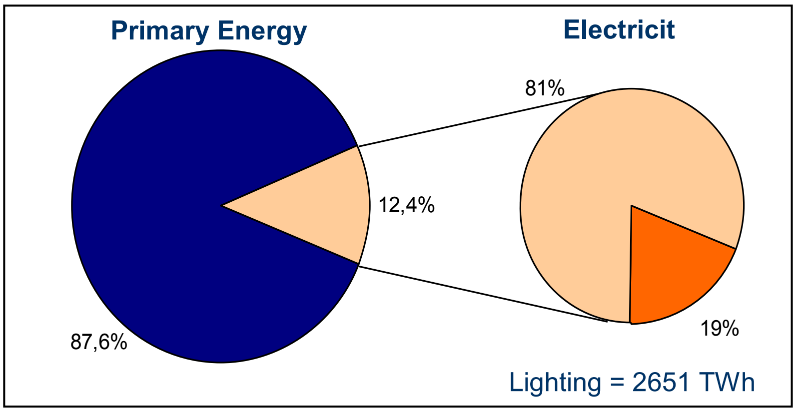
The concept of the OSRAM Energy Hubs represents both: A new business model adding profitable growth and a contribution to Social Responsibility and Sustainability of OSRAM and Siemens.

1 The starting point

OSRAM has made a worldwide commitment to adopt a sustainability philosophy – the "Global Care Program". This program governs all of our business practices, innovations and our code of conduct. The sustainability initiative is designed to drive positive results to the triple bottom line, addressing social, economic and environmental needs. OSRAM is a member of the UN Global Compact [1], and we actively support all ten principles. Recycling and the use of recycled material as well as the development and distribution of environmentally friendly technologies are key elements of our commitment.

1.1 Global impact of lighting

The IPCC climate report expected warming of 1,4°C to 5,6°C in this century [2]. Scientists agree that the leading cause of man-made global warming is the increased concentration of CO_2 in the atmosphere. The commitment of the EU is to reduce CO_2-emissions by 20% until 2020 in the scope of the 2005 Kyoto protocol (compared to 1990) [3].



Picture 1: Energy consumption for Lighting

Lighting accounts for 19% of the global electricity consumption, that is 2.4% of the worldwide primary energy consumption. 2651TWh were used for lighting in 2005, accounting for 1325 million tons of CO_2 [4].

Additionally, 190 million tons of CO_2 are emitted by the burning of kerosene for off-grid lighting. Huge potentials exist by using more efficient grid-based lighting, while intelligent alternatives for off-grid lighting could eliminate the need for kerosene here entirely.

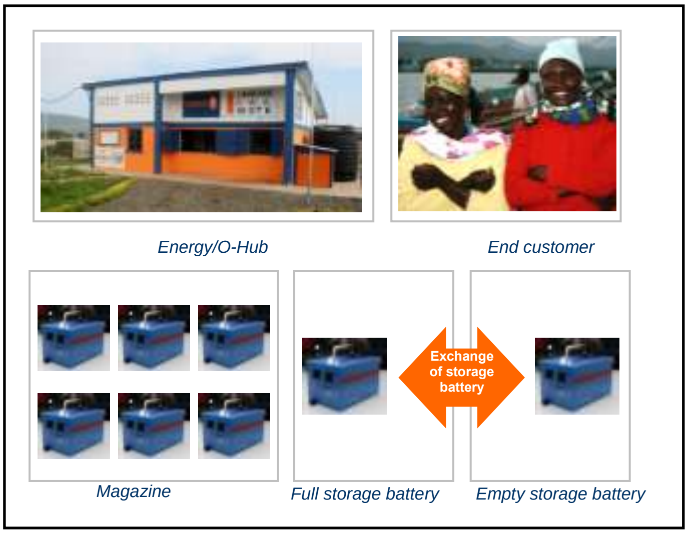
Possibly 70% of the kerosene based lighting could be changed to renewable solutions, which would result in an additional 130 million tons of CO_2. With innovation, energy-saving products and solutions, OSRAM contributes to mitigating climate change with strict compliance to the concept of the Triple Bottom Line (People, Planet, Profit) [5].

2 Developing the Market of Developing Countries: A new Business Model

1.6 billion people, or ¼ of the world's population, depend on "fuel-based lighting". These people account for a large share of kerosene consumption and CO_2 emission. The annual fuel consumption for lighting is about 77 billion liters of kerosene and the annual emission of carbon dioxide is about 190 million tons of CO_2. The present price for 77 billion litres of kerosene amounts approximately to 40 - 50 billion Euro [6].

Many off-grid solutions already exist, but they all fail to be successful on a large scale because providers do not think "beyond the product". An entrepreneurial and innovative concept including infrastructure, engineering and maintenance is necessary in order to overcome income and distribution constraints and thus to be viable and sustainable!

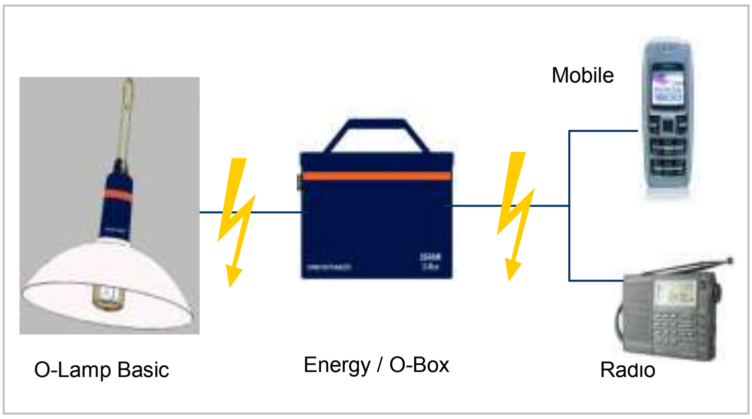
In creating a concept for OSRAM's Off-Grid project, it was necessary to identify why kerosene remains so popular for lighting purposes with inhabitants of regions where there is no power grid. Kerosene-based lighting is connected to miscellaneous problems and inconveniences for the users. Kerosene is increasingly expensive, dangerous, unhealthy, and has a poor light quality. But Kerosene has one crucial advantage: it can be bought in small portions and thus makes allowance for low and irregular incomes. Any Off-Grid solution that intends to replace fuel-based lighting must, therefore, take this into account and provide electricity small portions as well to meet customer needs.



Picture 2: Energy hub and Battery change system (OSRAM)

To address the above challenges OSRAM introduced the Energy Hub principle. In the Energy Hub empty batteries will be exchanged with charged. In this concept OSRAM not just sells light, but also becomes a generator and a supplier of energy in the form of energy boxes the so called O-Boxes.

Included with the O-Box is the O-Lamp Basic; and in addition it is possible to run a transistor radio and charge a mobile phone. All kind of mobile phones also can be directly recharged at the Energy-Hub.



Picture 3: Multiple use of the Energy Box (OSRAM)

OSRAM offers also the option of recharging additional products, such as lanterns with built-in batteries**.** A lantern allows the user operation of a 5W CFL lamp which provides approximately 12 hours of light, equivalent to 1 ½ litres of kerosene. Lanterns and O-lamps with LED are in preparation. These solutions will provide longer life and longer operation time up to 30h.

All broken batteries and fluorescent lamps are collected at the Energy-Hub and will be recycled or disposed according to regulations.

2.1 Water, an additional challenge that OSRAM can address in Developing Countries

2.4 billion people do not have satisfactory sanitation. 1.1 billion people currently use uncontrolled water sources (2/3 Asia, 1/3 Africa), and this will increase to 2.3 billion by 2015. 4,500 children die everyday due to the consequences of unsafe water and inadequate hygiene (>3 children every minute).189 Heads of States adopted the Millennium Development Goals to halve the number of these people in the timeframe from 2000 to 2015 [7, 8].

Presently all Energy-Hubs are equipped with a UV water purification unit capable of making 3 000 litres of drinking water per day. It is planned to equip further O-Hubs with membrane filter units capable of producing up to 10,000 litres of clean drinking water. Thus, drinking water will become an integral part of the Energy-Hub concept.

Picture 4: Every Hub also provides clean drinking water (OSRAM)

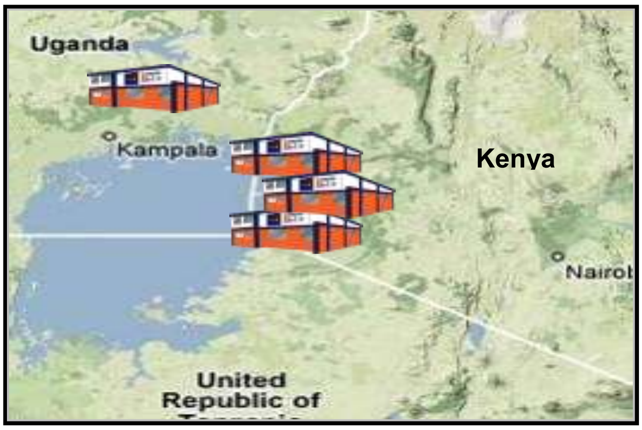
2.2 Microfinance

The microfinance aspect is also key for OSRAM's concept. The microfinance principle that was introduced by Muhammad Yunus [9] provides the poor and not creditworthy with small loans. The integration of microfinance into the Off-Grid project was to fulfill two important aspects. Firstly the idea to include existing structures of local communities, e.g. organizations of workers and secondly to make the necessary small deposit for the use of expensive Energy-Boxes or the purchase of other products affordable.

3 The East African Project

As part of the initial pilot phase a total of four Energy-Hubs have been inaugurated in East Africa These four have been constructed in areas that provide different conditions, in order to asses the product and system demands.

We currently have two local partners in the region, and a social & environmental advisory partnership with Global Nature Fund. The first Hub was officially launched on April 1, 2008. Two additional hubs are operating since October 2008, and a fourth was finalized by March 2009. The first three hubs are located in Kenya at Lake Victoria, the fourth in Uganda, near to Kampala.



Picture 5: Location of Energy Hubs (OSRAM)

In the course of the pilot project at Lake Victoria, the main focus is on fishermen as the target customer, since for them light is a means for work. Each fishing boat uses about 1,200 litres of kerosene each year. In total about 20 million litres of kerosene are used each year. A fisherman has to spend more than half of his income for kerosene! Every year about 50,000 tons of CO_2 are emitted!

Picture 6: Fishermen at work with O-Lamps (OSRAM)

The O-Lamp Basic also addresses the illumination in people's houses, providing a clean high quality light, eradicating the hazards associated with kerosene use. Furthermore at an approximately 30-40% reduction in costs vs. kerosene, the potential ability for poverty alleviation is available.

4 Conclusion and next steps

Today lighting innovations are happening all the time in industrial countries. Much more challenging is the approach how to bring clean, safe and reliable lighting in an economic manner to the poor of this planet.

The Off-Grid project of OSRAM is characterised by a holistic approach of "thinking beyond the product". It includes infrastructure and maintenance but also environmentally friendly products. The project is based on the commitment to develop a sustainable solution to support the livelihood of people and make "future light" affordable.

In this paper it isn't possible to refer to the various approaches in this field which exist all over the world. It also wouldn't be fair only to discuss some of it. Therefore only some general words: Several meaningful approaches failed because of missing responsible, maintenance and continuous improvement of the used technology to get more robust products and keep competitive also in future. Others are focused on certain regions because of limited resources and depend mainly on founding.

The difference of OSRAM's concept compared to many other solutions is that it is based on the triple bottom line – People, Planet, Profit – and therefore enabling the creation of a sustainable business. We think, only a running business with advantages for all involved parties can generate a sustainable system. Without making at least some profit it never will be possible to introduce solutions which will survive in the long term especially also not in developing and emerging countries

After proving the concept in more detail OSRAM plans to expand the pilot project to more regions in Africa and Asia. First results will be shown during the presentation at the EEDAL '09 conference.

5 Comment to the project

Achim Steiner, UN Under-Secretary General and UNEP Executive Director said [10]:

"The challenge of this generation is to deliver energy to the 1.6 billion without access to the Grid in a way that does not contribute to humanity's global environmental footprint including impact on the climate.

To do this we need innovative and creative solutions and partnerships that bring together governments, businesses and communities in common cause. There are many shinning examples of how we can fast forward tomorrow's economy today and in doing so put the world on course to more sane and sensible energy and development policies.

OSRAM's Off-Grid solution piloted in East Africa on and around Lake Victoria, is a case in point. The innovation is not only providing an economic benefit for fishermen but a underlining that small-scale solutions can be the fastest and most eco-friendly way of transforming the energy needs of local communities.

UNEP is delighted to be associated with this innovative solution which could be one among several blue-prints of achieving a wide range of important and laudable goals".

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Transforming the Market for Efficient Lighting, Russia

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Abstract

Lighting accounts for 14% of all electricity demand in Russia and consumes approximately 137 billion kWh year. The largest energy saving potential in lighting systems exists within Russia's industrial buildings, residential sector and public buildings. The total lighting energy savings potential in Russia is enormous: 56 TWh/annum which is equivalent to approx. 39 Mt CO_2 per annum, and this project aims to tap 60% of that potential.

While the energy saving potential in this sector is enormous, there is a number of barriers to energy efficiency investments and market transformation. Among those barriers are the absence of mandatory energy efficiency standards and labeling schemes for lighting equipment; regulatory constrains hampering investment inflow into public and residential sectors; lack of state support for technological innovations in lighting; non-competitive local industry; and profound lack of awareness among consumers. Supply is dominated by cheap and low quality equipment.

In order to address these barriers and support Russian Federation in the market transformation towards energy efficient lighting, a new initiative has been developed with the Global Environment Facility (GEF) and United Nations Development Programme (UNDP) in partnership with the Russian Government – the Ministry of Energy of the Russian Federation. The project is coordinated with a UNEP/UNDP/GEF initiative 'Global Market Transformation for Efficient Lighting'.

The objective of the GEF project is to transform the Russian market towards efficient lighting technologies and the phase-out of inefficient lighting, thereby reducing national GHG emissions. The project will focus on phasing out outdated technologies for residential, public and street lighting.

Existing Situation in the Russian Federation for lighting

In 2007, for an installed power for lighting of 64.5 TW, the national electricity use was 137.5 TWh per year, which corresponds to 14% of national electricity consumption. Furthermore, lighting is responsible for 97 billion tons of CO_2 emission per annum. Commercial and industrial buildings account for more than 50% of electric energy consumed by the systems of artificial lighting.

According to expert estimation in 2020 the global consumption for lighting in Russia will be in the order of 157,8TWh [1] which corresponds to a moderate increase of less than 2%. However, this scenario doesn't take into account the fact that in many cases actual illumination levels are very low (some times 2 times lower than recommended by international standards in factories, schools, hospitals etc. [1] and the fact the proportion of elder population will increase in the next years (an older population requires higher light levels). These remarks lead us to the unavoidable conclusion that if no action is undertaken the lighting demand in Russia will increase rapidly over the next years.

The following table gives some numerical values:

Group of lighting equipment	Established capacity, (GW)	Electric energy consumption, (GWh/year)
Industry and commercial buildings	28	85,000
Public, educational and state buildings	8	12,000
Street lighting	1,5	4,500
Residential sector (private sector)	15	20,000
Agricultural sector, including population.	5	16,000
Total	**57,5**	**137,500**

It should be noticed that:

- The part of light flux generated by low-efficiency incandescent lamps is 35%, in the Western countries it does not exceed 20%;
- In the residential sector the penetration rate of energy efficient light sources (CFLs) is very low compared to any other western country;
- In the tertiary sector the penetration of T5 technology is almost negligible (it is difficult to find T5 lamps in the Russian market). The T8 (and older T12) lamps used are still 1st or 2nd generation products, whereas in western countries 3rd and 4th generations are used;
- The level of power for lighting in public buildings is close to 7 W/m^2 per 100 lux in the working space when in U.S. and Europe this amount is about 2.5 W/m^2 per 100 lux;
- The generation of 1 Mlmh of light flux requires 36 kWh in Russia whereas this value is as low as 25-26 kWh in Western countries;
- Lighting control systems that are today widely used in western countries are almost absent from Russian market.

Contrary to the common opinion that electric energy tariffs are relatively low in Russia and do not stimulate energy efficiency the actual situation is changing. At present the cost of electric energy ranges from 7 to 10 Euro cents per 1kWh depending on the type of the consumer.

The real step to stimulate energy efficiency was the decision of the government to increase tariffs on energy resources. In particular, in May 2008 Federal Tariffs Service (FTS) approved marginal levels of the increase of energy tariffs for the year 2009. Overall in Russia the increase will come to 19%, as it was indicated in the forecast of social and economic development of the country. In the regions the increase will vary from 10% to 26%. It's planned that already in 2010 and 2011 the tariffs will increase (the growth of tariffs will be higher than inflation rate).

It should be noticed that initial connection to the power supply costs extra fees. In different regions the connection fee varies. The highest figure is in the Moscow region (about 1000 Euro per 1kW), in the Nizhniy Novgorod region it's about 250 Euro per 1kW.

Situation of the National Lighting Market

Supply of efficient lighting is currently limited in Russia. Although all technologies are available in principle, there is virtually no domestic production of the most efficient technologies and supply is inadequate if market demand increases to the levels envisaged with this project. Manufacturers have indicated an interest in supplying more efficient lighting if the project helps to create more demand.

At the present moment the total value of the lighting market, including import products, makes about US$ 2 billion per year, and most likely, the growth will continue.

It should be mentioned that unlike many industries lighting industry in Russia has withstood the critical test reforms. Domestic production covers about 50% of the whole demand for lighting products (light sources, fixtures, power sources, components etc). The greater part of local production is represented by inefficient old technologies like incandescent lamps, luminescent lamps of the first and second generation (T12, T8), electromagnetic ballasts etc.

The quality and efficiency of imported products do not comply with the best international standards either. High quality products for lighting systems are very expensive for Russian markets and more especially for individual end-users. Lack of technical and quality supervision of import commodities led to flooding of the domestic market with lighting products of dubious quality, coming from both legal imports and a large shadow market.

But there are some positive changes at the lighting market. For example, world leaders in electric lamps production are of course present in the Russian market (General Electric (USA), Osram (Germany), and Philips (NL)). Among them only Osram, which purchased the "Svet” plant in Smolensk in 2004, has its own Russian manufacturing capacity.

UNDP/GEF Lighting Project in Russia: Objectives and Outcomes

The UNDP/GEF project “Transforming the market for efficient lighting in Russia” is developed in the framework of a broader GEF/UNDP/EBRD/UNIDP Umbrella programme “Energy efficiency in Russia” endorsed by the Russian Government and the GEF Council. The project will be implemented in 2009-2014 with the financial support from the Global Environment facility (GEF), Russian government and private sector.

The objective of the UNDP/GEF project is to transform the Russian market towards efficient lighting and to phase-out inefficient lighting, thus contributing to the reduction of national GHG emissions. All lighting sectors will be addressed by the project: household, public and tertiary buildings and street lighting. Thus, the project will promote efficient lighting technologies and catalyse phasing-out of inefficient technologies (inefficient bulbs, fixtures and ballasts).

While it is not realistic to assume that a single project can transform the market of a large, complex country like Russia, the project will make sure that, at the federal level, instruments and policy frameworks are introduced to initiate and facilitate a market transformation; that suppliers of lighting equipment are supported in transforming their supply; and that markets are transformed in two major regions: Moscow and Nizhniy Novgorod, and for three major end-uses: homes (Moscow pilot), public buildings (Moscow pilot), and street lighting (Nizhny Novgorod pilot). On the top of this, the project will communicate the benefits of lighting energy efficiency programs nationwide. Throughout implementation, this project will work closely with the GEF/UNEP/UNDP Global Initiative for Phasing Out Inefficient Incandescent Lighting, the UNDP/GEF Russian Standards and Labelling program and with the energy efficiency programs of the Russian federal and regional governments.

The Russian Federation and regional governments have recognised, in recent years, the need for energy efficiency to combat rising energy demand and increases in GHG emissions. The project will capitalise on this development, bringing together all relevant parties, like governments, technical institutes, trade organisations, suppliers, retailers, distributors, and end-users of lighting equipment, utilities, NGOs, in one national efficient lighting platform. This platform will coordinate initiatives between parties; monitor the market and track results. Further, the platform will adopt quality and performance standards (including environmental performance) for efficient lighting, thus creating a clear definition of EE lighting that can be used to market products, promote EE lighting and procure efficient systems. This addresses the current lack of technical information on lighting - an important barrier for government, commercial and industrial markets - as well as the lack of a clear regulatory basis for the adoption and promotion of energy efficient lighting.

Whilst efficient lighting is not technically new, it has not yet been widely adopted in Russia. In this context, it is valuable to demonstrate the potential of new technologies. The City of Moscow and the

City and Region of Nizhny Novgorod have indicated their interest in taking a leading role in this project, implementing, at their cost, efficient technologies in their facilities and – building on this – inducing a market transformation in their regions.

In Moscow, the focus will be on public building lighting, starting with the retrofitting of health and educational buildings of the City of Moscow, with the goal of phasing-out outdated T12 fluorescent tube technology and traditional magnetic ballast. In Residential sector the increase of the CFL penetration will be also one of the project outcomes.

In Nizhny Novgorod, the focus will be on street lighting, with the goal of phasing-out obsolete technologies like mercury and incandescent lamps.

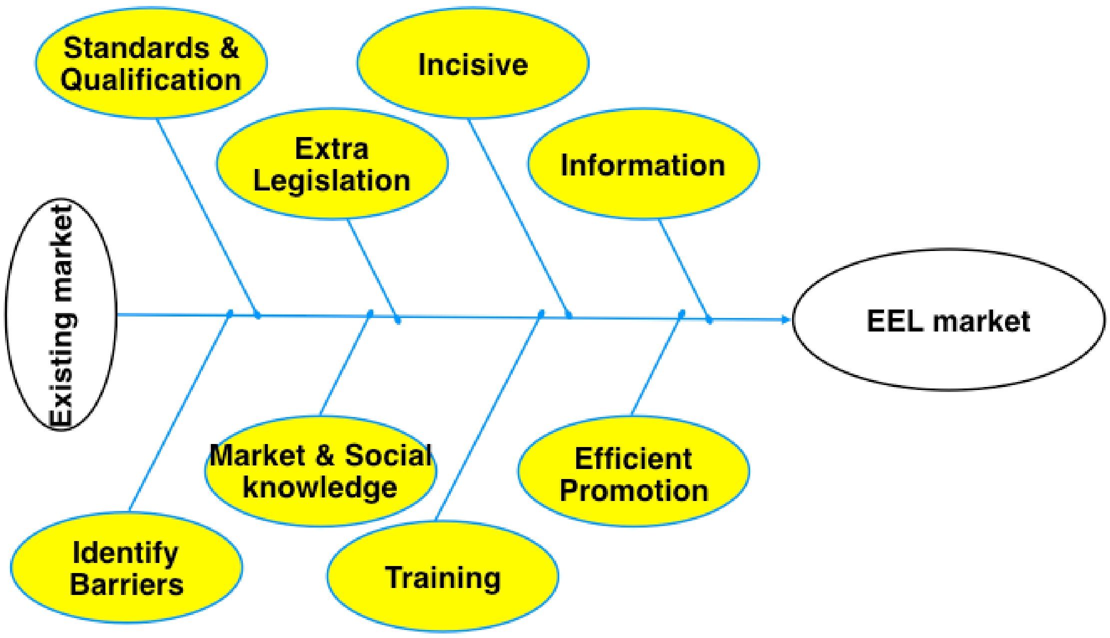
These actions will be accompanied, in both regions, by a marketing campaign for efficient residential lighting, to promote CFLs and other energy efficient technologies and phase-out traditional incandescent lamps.

The project will also collect and disseminate information about other, more specific lighting technologies, but its marketing efforts will focus primarily on the main technologies listed above, to maintain momentum and prevent a loss of focus when engaging in various smaller-scale lighting applications.

The main **project goals** are:

- Promoting efficient lighting technologies by means of mandatory state regulations (standards and norms);
- Transforming, step-by-step, the national market by phasing-out inefficient incandescent lamps and other inefficient lighting technologies (fixtures, ballasts and other)
- Stimulating national actors by means of research programs, and quality standards.
- Creating a reliable national qualification scheme for protecting the national market against low quality products by means of modernising national test laboratories and adoption of international norms.
- Promotion of efficient lighting technologies in Russia by means of attracting the world leaders of lighting industry.

To achieve this ambitious objective we need to effectively promote high quality energy efficient lighting systems (EEL) based on widely accessible arguments, training, socio-economic knowledge, standardization, inciting measures and extra legislation. The following "fishbone" graphics illustrate all the above issues.



The GEF project is designed to remove the following set of barriers:

- Low public awareness for energy saving linked to lighting
- Lack of strong legislation to support EEL
- Lack of awareness of lighting professional and the general public

- Low quality of existing products in the Russian market
- Low availability of high-quality products
- Barriers linked to finances

One important output of the project will be the creation of innovative methods to promote EEL systems. As examples of such actions we can list the following:

- Indentifying negative arguments that potential end-users may oppose to EEL systems, through surveys and questionnaires to individual users as well as to professionals, and collect "complaints".
- Elaborating EEL promotion, information and communication strategies for individual consumers. Mass media (TV, radio, national, regional and local press) will be targeted.
- As web impact in Russia is rapidly increasing, a web based "Energy Conservation Performance Catalogue" which focuses not only on energy efficiency, but also on quality of the equipment in conjunction with customer satisfaction should be created. This catalogue should also include a number of good practice examples that may convince end-users on the pertinence and necessity of use EELs.
- Increasing end-user awareness on energy consumption of lighting systems trough training and information.

It is of major importance also to provide raining and credible information on the new standards, and on the benefits of EEL to lighting specifiers (architects, engineers, municipal lighting specialists, etc). This will be achieved by:

- Developing new curricula for both initial and life-long training. Russia has today all necessary "grey-matter" disseminated across the country to various Universities and Institutes. Coordination is absolutely necessary.
- Setting-up a broad and open discussion of measures on raising energy efficiency of lighting installations. For that purpose existing specialized magazines like "Svetotekhnika" are planned to be utilized as well as events like INTERLIGHT Moscow, the International Trade Fair for Lighting, Light Technology & Intelligent Building Technology that take place every year. These international events can be explored to promote dialogue between important national and international stakeholders.
- Developing users-friendly tools that lighting specifiers can use for conceive EELs adapted to its application.

An important outcome from this GEF/UNDP project will propose establishing a highly skilled independent council consisting of leading professionals to control energy efficiency lighting and ecological compatibility of projects of lighting installations. This council should be placed under the auspices of the Ministry of Energy. The members of this council should include key persons representing federal authorities, industrial stakeholders and academic leaders. The main role of this Federal Energy Efficient Lighting Council (FEELC) will be to act as interface between market and governmental instances. The FEELC should discuss various issues concerning EEL market transformation and propose measures to be adopted by the legislative and normative national bodies. This FEELC could also propose, and then initiate and evaluate national research projects in the domain of EEL.

The project will operate closely with the GEF/UNEP/UNDP-initiative "Global Market Transformation for Efficient Lighting" and GEF/UNDP/EBRD/UNIDO Umbrella programme "Energy Efficiency in Russia". Initial contacts with the GEF/UNEP/UNDP Global Programme management have identified important synergies that both programmes – national and global - could effectively capitalize from. Through these synergies, the Russian project can take account of global strategies and interact with international industries, whilst the global project will learn from the practical implementation issues that emerge during the national project design stage, and take these into account.

A more detailed description of the UNDP/GEF project components is provided below:

Outcome 1. Improvement in the efficient lighting standards and policy framework

Work on development of standards and regulations of energy efficiency will be carried out based on existing normative statement on certification of products (lighting and electric equipment) and on statutory acts of branch standardization of energy consumption. The very first action in the frame of this GEF/UNDP project is to collect, critically compile and then transpose to Russian context international (and western national) standards and recommendations.

As example, SNiP (Construction Norms and Regulations), MGSN (Moscow City Construction Regulations), SanPiN (Sanitary Regulations and Standards) and other regulatory documents shall be revised as follows:

- Transpose in Russia the EU directive EC/98/11/EG dated 27.01.1998 for definition of energy efficiency and the associated measurement method proposed by DIN EN 50285:1999;
- Introducing maximum permissible specific capacities of lighting installations in individual premises and buildings at large as well as of external lighting installations depending on the type and purpose of the building;
- Introducing restrictions on the use of lighting fixtures and lamps with a low lighting efficiency depending on the rated illumination level, the annual operating time of the lighting installation and requirements to the quality of lighting. As a rule, lamps with light output of less than 50 lumen/w, the colour rendering index of less than 80, the service life of less than 4,000 hours, $\cos\varphi < 0.9$, and the payback period of more than 2.5 years shall not be used;
- Limiting the use of lamps with a large decrease of the light flux in order to ensure a possibility of a sharp reduction in the rated maintenance factor to lower the installed capacity of lighting installations.
- Forbidding the use of lighting fixtures with discharge lamps and an electromagnetic ballast with a high level of loss of energy, and establishing production of lighting fixtures with electronic ballasts with a loss of less than 10%;
- Introducing stringent requirements to the mode of operation of lighting installations (cleaning of lighting fixtures and replacement of lamps) to ensure an additional possibility of reducing the maintenance factor and improving the quality of lighting;
- Introducing stringent requirements to the quality of lighting fixtures not only from the viewpoint of safety of their use as is stipulated in the IEC documents but also with regard to the efficiency factor of lighting fixtures, the light output ratio of lamps, $\cos\varphi$, power consumption, and change of behaviour in the course of operation;
- Introducing mandatory use of automatic switch on and switch off in large lighting installations in case of sufficient natural lighting or depending on the presence or absence of people.

Certification of products is the procedure proving conformity of products with determined requirements such as safety, electromagnetic compatibility and other. Observance of standards, and assessment of the level of quality control of lighting fixtures by a limited number of highly specialized certification centres is a real necessity. Appropriate accredited organizations or committees fully independent from manufactures, suppliers and sellers will implement certification process. Today, several certification centres deal with lighting equipment certification, in Moscow, Saransk, Nizhniy Novgorod and other cities. Rosstandard accredits the majority of them. Because the testing equipment available is insufficient for performing tests in accordance with all normative documents in force, the centres are cooperating at performance of tests. In the frame of this GEF/UNDP project it is proposed to develop the program of upgrading key laboratories so that they may serve as main qualification authority in the future that can certify several testing laboratories disseminated all across the country. Once this step accomplished, the project can suggest to Federal Government to impose:

- Tight control of the quality of locally-manufactured EE-lamps (introduction of penalties for products of low quality can be desirable).
- Tight customs control of the availability of certificates on imported products obtained only at specialized certification centres as well as use of components (lamp holders, collector blocks, etc.) certified by the same laboratories, which certified the lighting fixtures.

Outcome 2. Support to the supply chain for EEL

One of the outputs envisages examining and assessing impact of various financing schemes like bill financing, ESCO financing, Carbon Certificates and DSM requirements is necessary Once the impact of various methods evaluated the FEELC will propose to institutional stakeholders some selected methods for implementation. The following list gives some examples:

- New federal legislation could be proposed that will oblige all public institutions switch to using CFL and FL T5 with electronic ballast within three to five years;
- A system of economic incentives for publicly funded organizations to improve their energy efficiency could be developed; low-interest bank credits with extended repayment periods could be allocated under state guarantees;
- In collaboration with lamp manufacturers and importers a number of CFLs could be provided free of charge annually from the fund of support to low-income families and pensioners over

65 years of age

As has been explained in the above sections the situation in national lighting industry is very discouraging at the moment. Imposing new quality standards and banning some types of inefficient lighting devices may have a strong negative impact on that industry that still employs more than 14,000 people (only for production of incandescent lamps). Any serious market transformation program cannot just bypass this problem and ignore its social impact. It is possible to strengthen the national industry by setting-up strong RTD projects for the development of new EEL products. One of the outputs is dealing with that issue. This type of action should be initiated and monitored by the FEELC but the funding should be independent from this GEF/UNDP project budget. However, in order to demonstrate the capacity of the national industry to evolve, the conception and validation of some high technology EEL products chains (for instance LEDs) can be cautioned and partially supported by this project and financed by national and private investments.

Outcomes 3 & 4 Demonstrating pilot activities

Given that a large part of Russians aren't really convinced that lighting is an important issue for energy economies, the most adapted method to transform their opinion is to clearly demonstrate the benefits. Under that hypothesis large scale demonstrations in both indoor and outdoor lighting applications are necessary. Previously, some small/medium-scale demonstrating activities have been undertaken in Russia and the result was strongly encouraging. In the frame of the GEF/UNDP project we propose the following major demonstrating activities:

Moscow city hospitals and schools: In Moscow region there is an energy-saving program "Energy savings in Moscow" for the period 2009-2011; According to this program it is scheduled to replace the existing systems by energy efficient lighting during 2009-2011 in 100 schools / hospitals. Targeting schools for this pilot should be considered as high impact promotion mechanism because children (the citizens of the future) who get the habite to live in high quality energy saving lighting environment will more probably reproduce the same behaviour later as consumers and decision makers. It should be noticed that school - college consume approximately 200 – 300 MWh/year of electricity and hospitals use 200-500 MWh/year (depending on the size in both cases). The lighting consumption in this type of buildings ranges between 40 and 60% of the global electricity use. The expected energy savings in the frame of that project is between 25 and 30%.

Moscow residential sector: A residential promotion campaign will be designed. This will be preceded with a monitoring in order to learn more about residential lighting energy use. The pilot will include 100-200 flats in several residential buildings. Usually one flat is equipped with 15 incandescent lamps (60 W), each flat consumes about 600-700 kWh per year. After replacement of 15 incandescent lamps by 15 CFLs (15W) each flat will consume 150-200 kWh per year, the energy savings potential ranges from 50% up to 75%. It should be noticed here, that an energy use monitoring would be implemented in the pilot: In 5-10 typical flats we'll install a special system that will allow monitoring energy consumption only for lighting. Consumer surveys will also be undertaken; their results will feed into the design of the CFL promotion. Particular attention may be paid to residential areas facing capacity constraints on their distribution system. Furthermore, an advertising campaign on CFL will be organized in Moscow. We plan that this activity will be done together with manufactures/distributors. In fact in collaboration with retailers we will create advertising materials to inform the customers about energy saving and advantages of CFLs. If the project is a success this approach will be applied in all residential districts of Moscow. We hope that this project will help population to trust energy saving technologies and the municipality will get additional electric capacity.

Street Lighting in Nizhniy Novgorod oblast: in Nizhniy Novgorod region there is a program for reconstructing street lighting for the period 2008-2012. The pilot includes the replacement of more than 20,000 lighting points with dimming capacities and centralised control. Within the frames of the program electrical network will be upgraded. It is expected to reduce actual installed power by 4 MW (that leads to 10-12 GWh saving per year). In addition the maintenance cost will be reduced by a factor of two and the quality of lighting will be greatly enhanced.

The UNDP/GEF project is open for cooperation with national and international partners. The project will be implemented in close partnership with the global industry players. It will provide technical, policy and financial assistance to the effective transformation of the national lighting market and contribute to the abatement of GHG emissions through improved energy efficiency.

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Be aware of CFLs: our experience in the implementation of the energy saving lamps' use.

Patrizia Pistochini

ENEA, Italian National Agency for New technology, Energy and the Environment

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Abstract

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 European Climate Change Programme (ECCP) was launched, identifying, with stakeholders, cost-effective actions that contribute to CO_2 emission reductions and identified the residential lighting as an important area. To achieve considerable savings in this sector, a coherent strategy is required to transform the lighting market. To ensure a sustainable growth and use of CFLs, the partners of the EuropeaN Efficient Residential Lighting INitiative (EnERLIn Project EIE Programme, SAVE) have developed valid promotional material and implemented coherent promotional campaigns to inform and train end-users in order to achieve a self-sustained CFLs use growth.

EnERLIn's objective is to provide criteria for a coordinated promotion campaign at European level that may lead to an increase of 50% of the number of CFLs per household in the participating countries.

The presentation provides an overview of the 14 partners' national initiatives concerning CFLs promotion campaigns accompanied with supporting measures to increase the CFLs in households.

The aim of the Enerlin Project

In the EnERLIn project, 14 partners collaborate, from different EU countries worked together during 3 years on the market transformation for Energy Efficient Residential Lighting. The consortium could quantify the importance of residential light in Europe (for energy consumption as well as for the market itself) and identified clearly barriers that impeach market transformation.

During that period, the consortium worked on CFL quality and CFL promotion. In that frame, the European CFL Quality Charter has been amended in order to take into account new requirements for CFLs in accordance with EcoProfile and EuP directives.

In order to discard barriers, the consortium designed several promotional campaign scenarios adapted to various targets (young or elder people, western or eastern countries, consumers or retailers etc.). Afterwards many original promotional materials have been produced and tested during several campaigns across regions and countries. Our executed campaigns validated the concept that we proposed at the beginning of the project: a successful promotion should rather target the right population than be a generic one. In parallel we prepared papers in general and specialized press releases addressing various targets (end-user as well as professionals), interviews, TV and radio broadcasts have been diffused is several countries. In addition, many training actions have been proposed, and widely new communication and information technologies like web, web TV, net-lessons and e-learning, were used for addressing the population at various levels. All in all, we estimated that more than two million people has been touched by EnERLIn actions during the 3-years project duration and this will continue in the next years thanks to agreements with national and international institutions that will maintain our web page and associated tools. A special mansion here are the efforts that EnERLIn consortium devoted to address young population, this has been done in collaborations with schools. This is a very important achievement because children are the "citizens of the future" and they will reproduce in the near future energy efficient behavior that they learn. EnERLIn campaigns critical evaluation showed clearly that population awareness can be increased to significant way by using well-designed promotional tools that address real barriers. As proof, in several countries a significant increase of CFL sales has been observed following EnERLIn campaigns.

Overall, we can consider that the EnERLIn project could demonstrate the possibility to overcome barriers that impeach market transformation provide that promotional tools are designed such way in order to address not only barriers but also the right segment of the population. Unitary - style campaigns addressing only barriers are not efficient. Furthermore, training actions are a very powerful tool for promotion, especially, when the target market is considered as highly conservative, which is the case of lighting. Young children should also be a privileged target because they will reproduce energy efficient behavior in the near future.

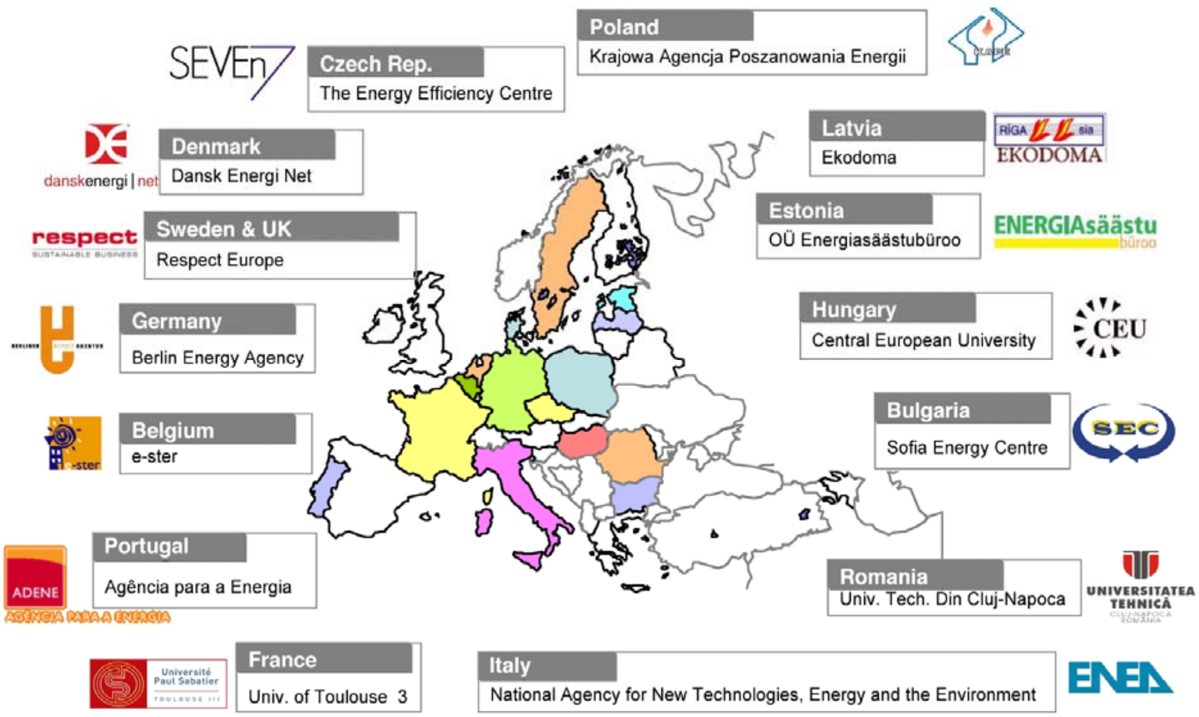

Figure1: The EnERLin consortium

The CFL- Market

In the European Union (EU27) the penetration of CFLs is 53%, number of CFLs is 2.71 on average, which is very still low.

- In Germany, the market share of CFL is approximately 18% and the sales volume of CFL doubled in 2007. The average number of CFL is 6.5 in the private households. 70 % of the households have at least one CFL.
- In Latvia a constant growth in sales of CFL is reported.
- In Estonia, the trend is showing that CFLs are in fashion, many producers are putting tied belts on CFLs and halogens Growth rate of CFLs is expected 10%. Most of them are used in industrial, municipal and office buildings. Only small percentages are used in residential sector. Importers are expected 30% increase.
- In Portugal a significant price difference can be seen between supermarkets and specialized stores. In 2007, the average number of lighting points is 6.9 but only 1.3 CFLs are present by

household and only 50% of houses are equipped with at least 1 CFL (please specify the year things are moving fast!).

- In Hungary CFLs are widely available at reasonable prices, in good quality and with a wide product spectrum. The penetration has grown to 78% in 2007. 78% of house holds used, or are using, at least one CFL. These house holds have on average 14 bulbs, 6 of them are CFLs.

- In Denmark, 2006 investigations showed that now only 16% of the population don't use CFLs while it has been around 30% for several years. The penetration has been growing more slowly the recent years from an average of 5 CFLs in 2000 to 6 CFLs/home in 2006. This is about 22% of the total stock of lighting sources in Danish households. It is found that it is important to use more costumer-oriented information such as description of bad and good quality. Sales are expected to grow with 13% till year 2010. The CFLs are primary sold by electricity companies, supermarkets, IKEA and Do-it-yourself shops.

- In Bulgaria, a CFL sale has increased the past years (2005-07). The market of CFLs in Bulgaria, according to the importers and sellers, has grown around 15%. The average number of CFLs per household is 0.6.

- In 2006 in Romania, the number of CFLs per household is around 2.8

Barriers for CFLs implementation

An important task in the frame of EnERLIn is to understand why end-user avoids (or dislikes) CFLs for the residential use. Analysis of possible barriers to implement CFLs has been carried out in order to understand the human mechanism regarding willingness and avoidance to implement CFL. Efficient information could wave-out some “barriers” like shape but then, consumers become more demanding on colour issues and quality. One of the major outputs of EnERLIn project is the establishment of reliable criteria for measuring the CFL quality. It is clear that in this domain more information in destination of the end-user is necessary.

The result showed that around 30% of the households do not want to have CFLs in their homes for various reasons:

Human Factor

Technical characteristics: end users do not appreciate CFL shapes, CFLs that often misfit to “design” luminaries and Colour temperature & rendering.

Device features: CFL dislikes rapid (or random) ON-OFF cycle and is incompatible with presence detectors, CFL power supply dislikes mains voltage fluctuations, Plug & Play CFLs aren't dimmable and need warm-up time

*Financial topics: many g*ood quality CFLs are still expensive, and many inexpensive CFLs aren't reliable. The return time on the consumers investment is short but not directly observable in a periodic electricity invoice

Environmental topics: The danger due to electromagnetic wave interactions with the human tissues. A formal document issued by the consortium demolishes that unjustified statement. The presence of mercury inside CFLs is in net decrease (in the order of 2 mg/lamp). EU RoHS allows a maximum of 5mg.

Quality

EnERLIn has collected and compiled existing national standards and any other official documents concerning CFL quality in National level. The objective is to observe the common points between countries and deviations from EU-standards (when existing).

One task of EnERLIn consortium is to contribute to the European Quality Charter revision; this is done in agreement with other international initiatives like ELI and International CFL Harmonization Initiative. It is clear that in addition to the Quality Charter it is necessary to provide a standard CFL test procedure.

The following factors have been proposed as basis for a set of CFL-quality indicators that we can divide into four sections: Energy conversion assessment, Lifetime assessment, Comfort assessment and compliance with other standards and regulations.

ENEA (IT) and UPS (FR) have carried out a CFL quality check and monitoring. The tests aimed to evaluate the ageing of CFL in a simulated real-use environment, and are based on EU standards and Quality Charter. Tests are performed on a number of CLFs (with most common power ratings and form different brands) under different environmental conditions (i.e. in climatic chambers).

In comparison with the original planning, different testing conditions and cycles sequences have been investigated, as during the project the progressive implementation of Directive 2005/32/EC (Ecodesign for End Using Products) has started.

Guidelines for promotional campaigns

The most important outcome from EnERLIn project is the design and testing of various CFL promotional campaigns. To achieve these objective several steps were necessary:

- Probe the end-users and retailers using specific questionnaires in order to be able to evaluate campaign impact.
- Elaborate various campaign scenarios adapted to different target populations.
- Create attractive promotional materials and tools.
- Collect results and analyse the impact for different campaign strategies.

Questionnaires are an easy way to gather information. This way has been chosen inside the EnERLIn project to collect information on CFLs in household environment from two different points of view: those who use CFLs (end-users; the demand side) and those who offer CFLs (manufacturers, retailers etc; the supply side)

Therefore, we can split the activity from now into two parts: questionnaire for the end-users and questionnaire for the manufacturers, retailers etc.

First, we believe that we can collect mostly qualitative information from questionnaires, rather then quantitative information. The questionnaires, if there are well designed could then provide very useful information on the following points:

- Segmentation of the market
- Knowing and using the object
- End-user behaviour knowledge: future purchase and influencing factors
- Experience and satisfaction of the user
- What are the preferred information sources

One important outcome from EnERLIn project is the creation of a document that includes various questionnaires for end-users and CFL-professionals. Partners develop the questionnaires in various languages for covering various situations. This global document is available in the project web page.

According to the questionnaire answers, the reasons that CFLs are not used in a larger manner are the followings:

The CFLs do not fit with the household lighting fixtures: many people responded at this question and they were not familiar with the fact that CFLs have evolved in new compact shapes and that are similar versions in design with respect to the classic incandescent lamp design.

They do not know the quality of CFLs: a promotion campaign to promote these lamps would be very useful to compensate this shortcoming.

They keep the CFLs in places where the electrical energy consumption is very low (closet, storage room): in places where the consumption is quite rare, people still use GSLs of low powers. Due to the very short period (below 30 minutes/day), when these lamps are used, the savings will be lower than those obtained in a regular room where the consumption is much higher. Beside this, the investment will be recovered in a longer period.

The name of the manufacturers: general speaking, everyone is familiar with the world manufacturers, but a considerable part of the products sold are "no name" products.

An interesting matter of the people that use CFLs is the opinion concerning the light of the colour, life cycle and even towards the price. Half of the interviewees are not aware of the fact that the saving allows the recovery in a year of the whole investment.

Again, it is important to realise a promoting campaign in order to better present and inform the end-users about the qualities and benefits of CFLs. The reasons why CFL are not used on a large scale are:

- CFLs qualities are not known: a continuous promotional campaign is needed;
- Lack of trust for no-name products: only main producers are known; CFLs need a certification to be reliable;
- People do not know the lifetime of CFLs (> 8000 hours); GSL lifetime around 1000 hours.

We estimate that the elder population is not informed about CFL (thinking the price is 3 or 4 times higher than it is actually in shops), and that is why they do not use them. However, for people staying at home most part of the day, power savings and costs could be very significant. People with high educational level know about CFLs use them. It is essential to continue the informational campaign about the advantages and benefits of using CFLs in the residential lighting.

The customer complains regarding the CFL use:

- Lifetime is not equivalent to what is reported on the packing (especially for lamps imported from China, Turkey and some lamps by Philips and Osram).
- The lamp power is not equivalent to the number of Watts written on the packing
- The equivalence of lumen output on the packing is not correct resulting in the customer complains about the lighting output is too low. .
- They have an unpleasant light, with fatigue effect on the eyes.

The national campaigns and contributions to the promotion of CFLs

The objectives of the **German** Campaign were the dissemination of efficient lighting systems in private households, public authorities and the tertiary sector. The partner Berliner Energieagentur (BE) did not only focused on final consumers but also on professional decision makers by approaching the lighting contracting as a promising instrument to promote efficient lighting.

The campaign "energy saving lighting" pursued the following targets:

- Improvement of the information and motivation about technologies and implementation strategies for efficient lighting for private users, decision makers of public authorities as well as companies in the service sector and industry.
- Overcoming of implementation barriers for the utilization of CFLs and lighting refurbishment.
- Support of marketing activities of lighting services companies due to their key role in lighting refurbishment.

The campaign improved the marketing activities of manufacturers and energy service companies (ESCOs).

The lamp database available on the web site offers the comparison of about 300 lamps from different manufacturers with regards to their technical characteristics and energy efficiency, both in German and English language. Guidelines for contracting of street and indoor lighting as well as templates for contracts are available on the website, too. There were registered more than 2000 accesses to download the offers.

A series of workshops about energy efficient lighting has been held in five regions in Germany in cooperation with regional partners. The target group of the series were public authorities. The direct addressing of target groups was complemented by initial consultations to topics such as financing, funding, and technical implementation. The consultations focussed on the implementation of good practice examples.

Good-practice examples are currently little-known and the campaign has improved the communication of such to a high extend. Private consumers are interested in information about the quality of CFLs, affection by switching and colour rending.

In connection to the workshops and the awarding of GreenLight Partnerships the following publications were made: 8 press release of the Berlin Energy Agency; 11 media responses to GreenLight awarding and workshops; 31 articles on the internet and 1 TV contribution

The campaign was sponsored by the Federal Ministry for the Environment, Nuon Stadtlicht and Eurolux Ag which contributed with funds for workshop-series and database. It involved local energy agencies (partners of the workshops), steering committees: European Lamp Company, Federal Ministry for the Environment, Senate of Berlin, CO2-online GmbH, Energy service companies, German Electrical and Electronic Manufacturers' Association.

The participants of the campaign reported their appreciation of Best Practice, workshops, CFL Data Base and considered it important for the energy efficiency in lighting systems.

The Berliner Energieagentur is planning several activities in efficient lighting promotion with the focus on industrial lighting and workshop series for public lighting together with the German Electrical and Electronic Manufacturers' Association.

Latvia carried out a CFL promotion campaign “More light for less money” in the municipality of Jelgava. The main promotional activities concerned:

- Drawing, comics and energy saving calculations competitions for school pupils.
- Information days for Secondary schools.
- Informative stands in Point Of Sale (POS) and workshop for POS people.
- Distribution of booklets for inhabitants of Jelgava.
- Information about campaign in mass media.

Campaigns in schools involved 605 pupils, distributing posters and booklets completed with important information about efficient lighting and CFLs and what to do with the end of life bulbs.

During the campaign, not only the pupils have been informed about energy efficient lightening, but also there teachers and other people that came to the schools. And one of the best ways to change people behaviour and think environmental friendly is to start with children because they are open to new information and can also affect their parents' opinion.

10 shops from Jelgava decided to participate in the campaign and put in the shops informative stands with booklets about energy efficient lightening and energy efficient lamps with action prices.

Most of these shops are located in the suburban area of Jelgava and are more enlightened for building people. The other shops were located in the centre of Jelgava and they were more pointed to electronically staffs.

In all shops have been installed campaign stands and posters in visible places, so that potential buyer could easily find the places where to find necessary information about energy efficient lightening.

The problem was that many of the Point Of Sale sellers were not interested in the active participation the campaign explaining people about energy efficient lightening and motivating them to tray out energy efficient bulbs. But yet the people bought more energy efficient bulbs during the two campaign weeks than usual.

For the campaign on the streets about 20 000 leaflets have been prepared and distributed by campaign endorsers with the campaign T-shirts.

During the distribution also explanation to people about the aim of the campaign and about energy efficient lamps were given. Poster and booklet were distributed.

During the campaign two kinds of workshops have been organized: one for point of sale and students and another for enterprises and schools of Jelgava.

For the first workshop the agenda was developed to explain what is energy efficient lightening and the benefits of using CFL and how to convince customers to buy energy efficient bulbs with the involvement of Osram and Philips. The company “Ekogaisma” Ltd. explained about the disposal of end of life lamps. From each Point Of Sale there was at least one person who participated in the workshop.

The second workshop was held for enterprises in Jelgava to inform them about the possibilities to get financial benefits from energy efficient lightening, thinking environmentally friendly giving the accent to industrial energy efficient lightening and explaining the positive experience changing incandesces bulbs to energy efficient ones.

To reach a wider audience about the campaign information about CFL and energy efficient lightening campaign “More light for less money” the Mass media such as Newspapers, Radio, TV broadcast and home page of the Municipality were involved. The campaign involved Philips Latvia, Osram, Ekogaisma and Plaza which sponsored with free CFLs and reduced prices.

A campaign-closing event was organized including the award of winning pupils that participated in the competitions and a summary of all activities that carried out during the campaign.

The positive results of the campaign impact to citizens, shows that such campaigns are needed and can be implemented in other municipalities.

Italy promoted two main different campaigns.

The first was dedicated to a face-to-face promotion of the CFLs and organized in occasion of the School Day held in Italy on the 23rd of March 2008, where ENEA, the JRC of Ispra and Teaching Regional Direction collaborated. Over 1100 children from 25 Italian schools visited the JRC-Ispra site. The young guests in the age between 9 and 18 and each of their schools were given the opportunity to choose the laboratories, installations and presentations they wanted to see. More than 250 students coming from secondary schools and higher education, divided in 6 groups attended the Laboratories of ENEA.

The questionnaire was prior sent to the teachers in order to make the students fill them out before the visit. More than 150 students handed them back and received a free CFL, bought from Sylvania at a special price and the booklet “Energy saving with lighting” edited by ENEA.

The evaluation of the questionnaire reported that the total lamps installed are in average 20.5 out of which 4.1 are CFLs and most of them are installed outdoors. The majority of the families were satisfied with CFLs’ light intensity and lifetime, 44% with CFL light colour.

Many appreciations on CFLs considered the importance of the energy saving and good light. Negative comments were addressed to the too cold light. Users would appreciate the improvement of energy saving, colour and intensity of light and lower prices.

The second one was a web campaign. In the 1996, ENEA developed an e-learning platform (http://odl.casaccia.enea.it) thanks to a National ADAPT project funded by the FSE (European Social funding). ENEA contacted the 1500 ENEA e-Learn platform users by an e-mailing service.

The CFL campaign was addressed to several categories (students, teachers, citizens, decision makers) at national level as single users and as members of Universities, schools and training organization.

The most important rate of our users (59.7%) are employees, public and private managers. The range of age of our users is between 20 and 70 and the 69% of them are between 26 and 40.

The questionnaire, the third one, friendlier oriented, was realized. This module has been used as final version in order to contribute to the promotion of the use of CFLs providing necessary information to pursue the right “energy strategy” inside the houses. It consists in an introductory section that the end-user can read or not and a set of answers regarding his profile, then questions regarding lighting in general and in his house, CFLs and his comments / opinions about their use.

The ENERLIN Italian campaign was completed with a relevant promotional strategy on the Internet, infect, several invitations to fill in the questionnaire was published on the web page of ENEA and on several web sites referring to Local Energy Agency, Professionals Association, Schools, web newspapers. The web campaign involved 388 users coming from all over Italy.

With respect to the education level, 62% of the users had a University Degree, 34% came from high school. Of them 69% were engaged in technical field.

The total lamps installed are in average 24.7 out of which 14 are CFLs and most of them are installed in the dinning room and outdoors

In conclusion final users reported that slow switching time is an “inconvenience”, accepted in name of environmental and economical benefits; in order to compensate the slows witching time, more CFLs lamps are ignited together. A change of habits was indicated: Lights are always switched “ON” for at least 5 minutes and they are switched OFF only when nobody will reasonably use the room anymore. Users are willing to install CFLs into refrigerators, but unable to find CFLs with suitable size. A latest question: “Incandescent lamps are the past. CFLs are the present. Are LED lamps the future?”

The most successful element of the SIC-UDA PMI campaign was due to the network of ENEA users and contacts, built up thanks to the large number of projects in which ENEA is involved. Another very important and successful element was the recognized international role of ENEA in the energy field, so that each ENEA initiative is perceived from end-users as useful and important. A weak element of Italian campaign was the lack of sponsors in the energy field.

Poland prepared and produced a wide promotion campaign around schools. A training day was organized for 600 teachers giving them the set of the materials (DVD film, Guidebook for students, Guidebook for teachers, poster). Over 20 thousand students received the information regarding CFL usage at home, climate changes and GHG emissions. Afterwards, a CFL Promotion campaign „Effective lighting", was prepared in five schools for two education levels: a secondary school and a higher education.

The module "Efficient lighting" has been defined as evaluation object. The assessment of the "Efficient lighting" module and its functioning at the EnERLin project has been received as the aim of the evaluation. The procedures used to collect the information are Interviews with the teachers and students, Observation of the activities carried out at the chosen schools and questionnaires completed by the teachers together with students using the module "Efficient lighting".

Energy efficient lighting problems are interesting for students but not well known so far. The project realization has not only educational value but school society integration feature too. Teachers and students have assessed the concept of the module "Efficient lighting" and its utility in the educational process with high importance.

Approximately 100 000 final users attended the CFL campaign. The campaign was successfully as defined in general education program base. It was not so easy to discover financing way to continue the campaign around whole country. It would be helpful to emphasize on promotional campaigns (media, street happenings, school training, press articles, leaflets and posters) and subsidy of CFLs in the future.

In **Sweden,** Respect has made a priority to bring the main partners together to create a platform for a successful implementation CFL campaign in Sweden and coordination with international partners.

The design of a campaign for Swedish market together with the Swedish Energy Agency was based on standards for CFLs. A platform for standardization guidelines was prepared for the implementation of a strong network with the distributors of CFLs.

A promotion and standard leaflet was designed, based on a Danish leaflet and printed in 25 000 pieces and later up to 150 000 pieces). The leaflets were distributed through the market partners as IKEA and other retailers. A follow-up meeting was held, with the purpose to establish a standard market group with members from all main retailers.

The partner started a campaign for schools involving also households and retailers. Meeting with key market players as Osram and IKEA has strengthened the message. Developed campaign activities within their business market campaigning and prepared them for further actions with other partners.

The brochure titled "Energy efficient and good residential lighting", guides the readers to successfully illuminate their homes "function by function" and "room by room". In 2008 this brochure was disseminated to 900 000 clients of the largest Swedish utility Vattenfall.

Furthermore, Fortum another large Swedish utility disseminated the brochure to 850 000 of its clients. Amongst the housing societies HSB through its 3900 housing society members disseminated the brochure to over 200 000 of its condominium owners.

A huge effort focusing on engagement of strategic partners lead to contribute with information and activities based on the CFL Campaign material. More than 30 meetings have been organized with partners and organizations have played an important role in the EnERLIn project.

A project, initiated through the Swedish Energy Agency, with participation from Swedish Association of Municipal Housing Companies (SABO) and leading lighting vendors in Sweden developed and disseminated LED based lighting in residential stairwell applications.

The Road to Copenhagen has played an important role in spreading the message from the EnERLIn project. The website was viewed by 2722 visitors coming from 77 countries. The conference "Road to Copenhagen" held in Brussels reached also more than 150 decisions makers.

Danish Energy Association stated that they were not able to carry out an information campaign but they have calculated six possible scenarios stating that scenario analysis is a very important tool to get at clear picture of what is reachable in the future CFL market. These scenarios have been developed in order to assess the maximum energy efficiency potential for lighting in Denmark including the maximum number of CFL that can be installed in Danish households. Further more, the Danish Partner has started a process for Energy savings project including technical development of new applications.

The experience shows recommended assessment methodologies for electricity companies working with information campaign activities aiming to increase the penetration of CFL into the market and addressing it to the end-users.

The 10 **Bulgarian** Campaigns organized by Sofia Energy Centre were called “quality” and addressed to citizens, decision makers, installers, other professionals and sellers.

In Bulgaria, the end-users inquiry was executed through random telephone calls. The number of people contacted was about 500, from them 200 replied. The main conclusions are:

- 74%, i.e. % of the population do not have a single CFL;
- The average number of lighting points in a household is 14;
- The average number of CFLs for a household that has such is 2.5 lamps;
- To the question “Do you know anything about CFLs” 60% of the questioned people responded “Yes” and 40% responded “No”’
- 80% are not satisfied with the CFLs. The main reason for the dissatisfaction of the customers are:
  - The low-quality CFLs on the Bulgarian market.
  - The investment is very big.
  - The energy saved from CFLs can hardly be noticed in the total energy bill.

The second inquiry was addressed to the importers, retailers, architects and designers. Of all the questionnaires handed out, 20 returned filled in. The following results from the inquiry should be underlined:

- The ordinary incandescent lamps have the biggest share on the market. Second come the halogen lamps, and third – CFLs.
- To the question “To what an extent do the existing luminaries for incandescent lamps prevent their change with CFLs?” 21% replied to a large extent, 43% think that this is not of such a great importance and 36% that this is not a big deal.
- In recent years, mainly the Chinese manufactured lamps were sold because of their low price. Their bad reputation, however, decreased people’s interest towards CFLs. At present, the interest towards quality European lamps is growing.

The CFL campaign was addressed to about 2.5 million of final users through leaflets, TV broadcasts and newspapers. The Bulgarian partner involved the ENERLIN Consortium, the National Committee on Illumination and CEZ Electro Bulgaria. The participants reported that they feel confident in saving energy and money due to CFLs but the residential efficient lighting must not be based on CFLs. A successful element of their activities was the increased market of CFLs by 15%, a weak element the higher price of CFLs. In the future, they are planning to phase –out Incandescent Lamps.

The **Czech** CFL Campaign was realized in two specialized shops on the light sources and lamps, with high expertise and assistance availability.

The agreement was that questionnaires were given to clients and shop visitors interested in light sources and/or lamps ensuring a good return rate of the papers.

The target group was educated consumers, often professionals, who visit these shops. However, they also include general public.

The questions in the questionnaire are based on the general project level, but updated to the Czech conditions, in terms of their relevance. The survey was undertaken in the period of January – April 2007. Up to now, 2000 copies of papers have been distributed and some 400 have returned.

The campaign involved over 4 million of final users at national level. Philips Lighting Cz, Osram Cz, Ekolomp and South Bohemian Regional Energy Agency were involved. Philips, Osram, Ekolamp and the Ministry of Industry and Trade sponsored the initiative co-financing the production of promotional materials (leaflets and info packs). On the web, promotion of the good quality of CFLs was made. Eight types of leaflets were printed and distributed, over 50 articles were published and TV and Radio involved.

The inquiry showed that some two thirds of the survey participants do have at least one CFL at home. From those households, which have at least one CFL at home, they have on average 3 pieces of CFLs installed. On the other hand, in a typical household the number of light points is 15, so there is a definite potential for at least some more CFLs to be installed.

Regarding the qualitative aspects of the CFL usage, only one third of respondents feel that they have sufficient information on the CFL quality aspects. Some 66% think that the shape of lamps and luminaries prohibit the wider usage of CFLs.

A majority of the respondents agrees that CFLs reach the declared lifetime (70%), and that the higher purchasing price is appropriate (62%). Of the respondents, 65% do like the colour of light of the CFL bulbs and 40% consider the energy efficiency to be as high as declared.

A successful element of the campaign was the high outreach and the interests shown by the media and the public. The campaign will be continuing in the future.

The technical University of Cluj Napoca was partner of two programs, namely EnERLIn and CREFEN, targeted to the energy efficiency in residential buildings lighting. Subcontractors were involved in the survey and the dissemination of the activities.

The Promotional campaign organized in **Romania** was addressed to end-users, dealers, architects and electric and lighting installations designers.

Special attention was dedicated to the young generation and the over 50's. For the young generation, in order to improve their energy efficiency thinking, and for the over 50's, to give a solution to the problem of the energy bill (instead of living in dark) to switch to CFLs and to have a brighter environment (witch has proved to be excellent for health) and also a reduced electricity cost).

They distributed promotional offer through the House of Retired People which can give a certain discount of 10% for new CFLs sold to customers.

Romania promoted in the university frame an information program for students from the Technical University involved in the scheduled design activity during their study were supported to use CFLs in their projects.

Also, special attention was given to the promoters of new projects, mainly for residential buildings, Architects and Electric-Lighting Installations Designers. Thanks to their positions to educate the professionals and to improve their knowledge to promote the CFLs use in residential buildings.

The questionnaires for end-users were designed in such a manner that half part remained to the people as an information support on the EnERLIn programme, the parameters and advantages of the CFLs use. The main difficulties in the campaign was to persuade people to answer the questionnaires

In 7 CFL campaigns, 892 final users were involved. The diffusion was 50% local, 17% regional and 33% national. Furthermore an average number of CFLs per household is 2.8.

It has been seen that CFLs are mostly known by end users who live in urban areas and those who have higher education. They have replaced the normal lamps with CFLs especially in the places where the lamps are mostly used.

In rural areas, especially in the villages that are very far away from the city, there is a lack of information concerning the quality of CFLs which leads to not using them.

Two seminars were organized to promote the CFLs Knowledge and many CDs offered to architects and designer. Papers of the project were submitted at several international conferences, national symposiums and other scientific events. Some presentations were made in media, informing on the CFLs use in local newspaper and TV media.

According to the questionnaire answers, the reasons that CFLs are not used in a larger manner are because the CFLs do not fit with the lighting fixtures in the house; end-users do not know the quality of CFLs and keep the GSLs in places where the electrical energy consumption is very low (closet, storage room): in places where the consumption is quite rare, people still use GSLs of low powers. More than 70% agree that the decision to buy an appliance should be based on energy efficiency class as well.

The name of the manufacturers is everyone familiar but still there are “no name” products that are sold on the market. CFL needs a certification to be reliable. People do not know the durability of CFLs the pay-back time.

We estimate that elder population is not informed about CFL (they think the price is 3 or 4 times higher than it is actually in shops), and that is why they do not use them. On the other hand, they are the ones who stay at home most part of the day and for them power savings and costs could be very significant. People with high education know about CFL and use them.

A national Promoting Campaign by media is essential to promote the advantages and benefits of using CFL in residential lighting. The Partner is planning to perform a national informative campaign on a very official manner at governmental or Energy board levels.

The **Hungarian** partner carried out a national wide survey to examine the use, the attitudes, behaviour, knowledge of and experiences with CFLs of the consumers. The pilot campaign was organized in 3 different kinds of units of the retail market. Shop assistants were trained, a simple message chosen. Campaign material was placed at the entrance and at the shelves. In case the customer bought a CFL and filled in the questionnaire, he would get a free CFL. The campaign lasted 3 weeks.

In the shop of the GE Lighting Tungsram, the campaign was successful; customers were conscious and looking for good quality goods and invested in CFLs. In department stores, shop assistants were generally too busy. The only feasible action to promote environmentally friendly technologies was to “hide” the traditional incandescent lamps in low, backside shelves. In hypermarkets, the campaign was a complete failure. Shop assistants did not collaborate with the promotion of CFLs distributing leaflets and information as it was considered as a kind of extra activities.

The inquiry showed that the main reason for buying CFLs is the reduction of energy consumption. It should be noticed that 60% of the people are expecting more reliable information about CFL benefits. 93% of the people who asked for information found it useful and of high quality.

In **Portugal**, in the framework Energy Efficiency Plan (PNAEE), the partner ADENE had a strong involvement in a specific programme (“Casa Mais”) that aims to promote efficient lighting in the residential sector, namely the replacement of 5 million GLS lamps by CFLs.

In this context, a wide dissemination of information material was planned. This included, in 2009, the distribution of almost 300,000 copies of the brochure “A Luz certa em sua casa” that was produced under Enerlin project.

The programme “Casa Mais” has two actions: “Families” and “Schools”. The first one started in September 2008 and ended in December 2008, and until October about 900,000 lamps were distributed to homeowners. The action “Schools” is scheduled for the first semester of 2009 and it is expected to involve 500,000 students of 2nd and 3rd grades. During the action one (1) GLS lamp will be replaced by three (3) energy saving lamps.

In Portugal, meetings have being organised for students belonging to the schools that participated and are winners of a contest named “Rock in Rio – Escola Solar”. This initiative had the collaboration of ADENE, including its promotion. The meetings included a lecture on efficient residential lighting and distribution of a package (leaflet “A Luz Certa em sua casa”, questionnaire about equipment and behaviour, as well as a “gift” energy saving lamp).

Finally, five meetings were organised with students of 2nd and 3rd grades of North and Center regions of Portugal. The initiative involved from 6 schools (about 200 students)

Dissemination activities

Dissemination activities are part of EnERLIn consortium duties. The objective is to reach as many people as possible.

The activities consisted in the creation of multifunctional web page (portal) as well as other activities like organization of meetings, challenges, press conferences, radio and TV broadcasts, publication of articles in general and specialized press. The presence of two menus, one horizontal on the top with the different media used for the promotion of the CFL lamps, that is: e-learning, downloadable documents, multimedia, useful links, general information and news; the other menu is vertical and is more related to the project itself that is it contains: the description of the project, the partners involved, support services, registration area. The search of “ENERLIN” on the internet will results in 1.550 hits.

The e-learning section includes net-seminars and e-learning courses in lighting, the CFLs calculation, the software RENA, “Energy saving in housing”.

The documentation section contains a Minimum Data Set of the uploaded documents that has been studied in order to ensure the traceability of the documents in a very easy way.

National initiatives have been developed by the partners in their own web in order to allow the CFL customer to make the right choice by using the results of the information of the Project.

Most of the partners have realized information web-pages to disseminate general and scientific information on the issue of efficient lighting and their own contributions to the aim of the project. Italy in particular published three “News” on the ENEA WEB TV on its web site.

In addition to the above-sited searchable database, EnERLIn created an additional portal that lists more than 50 good-practice examples.

The EnERLIn consortium has organized four major international and national level events. At regional level we point out 2 regional workshops organized by SEC in Bulgaria “a Panel on Efficient Residential Lighting” and by ENEA for the President of the Architects coming from the Province of Lodi in Lombardy Region “the activities carried out by ENEA on energy efficiency policies and renewable energies”.

Another way to disseminate the activities is competition. Latvia organized a drawing-comics competition and a calculation lottery for different aged pupils. In Romania a competition for the best promotional poster was organised.

Press and Media advertisement have been used to promote the Project.

In particular the German partner distributed three pages in a national newspaper with the motto “planting a tree today and save the climate in 50 years - or save the climate now and switch to a CFL”. Additionally, the reader got a discount for a CFL and a picture of the person installing a CFL was shown in the newspaper

In Latvia the EnERLIn campaign was widely advertised in local and national mass media by newspaper and homepage of radio and TV broadcast.

In Poland, 3 promotional articles in different magazines were published about the CFLs

In Bulgaria and Romania interviews were taken and broadcasted by the team of TV.

In Czech Republic over 50 articles (with over 4 million readers) have been written and published in a number of widely distributed media, newspapers and magazines.

In order to design a broader presentation of the EnERLIn project to decision makers in Europe and integration in the Road To Copenhagen project was proposed.

Road to Copenhagen project involved both business representatives as Osram and parliamentarians in all 27 European members state (GLOBE). www.roadtocopenhagen.org

EnERLIn project is registered since June 2007 as partner to the Sustainable Energy Europe 2005-2008 Campaign.

Some info about the common dissemination action & publications carried out by the Consortium are: one chapter in a book, 7 general press releases & interviews, 5 communications in specialized conferences, 8 paper in peer-review scientific journals, 38 papers on the project, 9 participation in national and international events and fairs, 14 general presentation concerning ENERLIN objectives and 5 on-line publications on the project.

Conclusions

Artificial light generation is a fundamental need for human being. This seems to be a very general lesson, however it has a very strait forward incidence to all Energy Efficient Lighting schemes that can be proposed for implementation:

- End-users are very conservative and reluctant to new lighting solutions especially when they don't satisfy some aspects related to quality of life. Energy saving due to light is considered as important by population but they come second to quality of life and comfort. This implies that, especially in Residential sector that any EEL project for market transformation has to take into account the holistic view of quality of life otherwise the campaign it condemned to fail.

- End-users are very keen on CFL Quality. Low quality devices "pollute" the market and seriously impede the increase of market penetration of that energy efficient technology. By the new eco-design requirements, a systematic CFL quality control is imposed on EU level following a well-defined unique testing protocol and associated with readable and compulsory labelling.

- There is a significant lack of knowledge and data on the penetration and the trends in use of various lighting technologies in households. This is especially valid in Eastern European countries, therefore it is difficult to clearly articulate what we would like to achieve with a campaign and whom exactly we could target in order to increase efficient light sources penetration. Monitoring and evaluation (pre and after) is necessary in management of successful campaigns.

Finally, the success of the execution of the EnERLIn project can be summarised with some key figures such as 23 CFL promotion campaigns in ten European Countries. Those campaigns touched more than 25 million of EU27 inhabitants, about 5% of the total EU population [3].

On the EnERLIn web site, 6 different types of net seminars are downloadable, 2 e-learning courses are given, 2 software programs are available: a CFLs calculator and RENA a simulator of energy saving in households, and one database[4] has been created.

References

[1] EnERLIn Consortium. *Campaign Results & Impact Evaluation*, 2009.

[2] EnERLIn Consortium. *Public Report,* 2009, www.enerlin.enea.it

[3] EUROSTAT, http://epp.eurostat.ec.europa.eu/

[4] High Quality CFL Data Base, http://www.homespeed.org/German/ratgeber_licht_englisch/Version0.1/seite1.php?portal_id=enerlin

Tubular daylight guidance systems - Energy Saving Potential in Residential Buildings in Romania

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Abstract

Traditional vertical window can provide adequate daylight within about six meters of the window. Daylight levels decrease asymptotically with distance from the window so that a disproportionate amount of daylight/solar gain must be introduced into the front of the room to achieve small increases in daylight at the back. A number of systems exist to redirect daylight into areas of buildings that cannot be lit by conventional glazing. One major generic group is known as 'beam daylight' - redirects sunlight by adding reflective or refracting elements to conventional windows. The second major group is known as 'tubular daylight guidance systems (TDGS)'. These consist of a light transport section with, at the outer end, some device for collecting natural light and, at the inner end, a means of distribution of light within the interior.

TDGS daylight guidance systems are linear devices that channel daylight into the core of a building. The nature of the systems and the factors influencing the costs and various benefits that contribute value are identified. Lighting systems in residential buildings, lit by electric lighting and daylight guidance, were surveyed. Data on the physical characteristics of the systems, lighting conditions achieved, and user views were collected. The results formed the input to a cost and value analysis which permitted the economic limits of the systems to be evaluated. Some evaluations were made about the energy savings and the environmental benefits.

1. Introduction

Why is daylight not always a primary consideration in building design? There seems to be some common barriers, throughout the world, that hinder appropriate integration of the daylighting aspects: lack of knowledge on the performance of daylighting systems and lighting control strategies; lack of appropriate and user friendly daylighting design tools; lack of evidence of the advantages of daylighting [1].

The architectural volumes are evaluated by shades and light, either natural or artificial. Le Corbusier said about architecture that it is "the learned play, correct and magnificent of the volumes reunited under light". The underground spaces (metro, commercial galleries, passages) are architectural expressed in a theatrical manner, with the artistic effects realised by the artificial light of projectors, by the dynamics of environment, by the esthetical effects.

Windows – through which daylight is introduced to the interior, where the light is modified and controlled, and from which the views out beyond the building are obtained – are at the heart of the matter. There is a correlation between solutions to the control of sunlight for thermal reasons and for those of glare – cutting out sunlight from different directions to avoid overheating in summer will reduce glare for the interior – but it should be borne in mind that the reduction of glare may not by itself provide a solution to the provision of thermal comfort.

The natural environment aspects, the unique qualities of daylighting make their introduction into buildings as relevant as when there was no viable alternative in artificial sources:

1. *Change and Variety* – the direction of the light, which provides modelling to the interior, the nature of sun and sky;

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[1] F. POP - Architectural Lighting, *Daylighting and Artificial Lighting, Some Thoughts Concerning Trends and Costs*, Technical University Cluj-Napoca, Lighting Engineering Center

2. *Color and View* - the contact with the exterior beyond, such as a view through the window, an experience of the weather and the world outside, the natural colour associated with daylight which imparts reality to the interior;

3. *Modelling and orientation, Sunlight effect* - the mood created by the variation of light, from day to day, and time to time as affected by the weather and seasons, the dynamics of lighting.

The avoidance of glare is a maximum priority for most architectural programmes, particularly those with fixed work positions, and 'add-ons' after the building is complete, such as internal shading devices, are not the solution. Much can be done by external shading or high-tech glass; what is important is that glare avoidance is an integral part of design strategy being planned for and executed at the design stage of the building. On certain elevations the window may require protection from solar radiation, either through the selection of the glass used or by external shading, or both. The use of internal shading is less efficient for thermal control, but is more easily managed. When used, external shading becomes a structural element and is both visually and structurally important: visually it has an impact on the external appearance of the building and structurally it must withstand all the external pressures applied to it.

The average Daylight Factor gives a measure of the overall level of daylight in a room. With a 5% average DF the room will have a well daylight appearance, whilst a 2% average DF may require supplementary artificial light in work spaces for much of the time. However a 2% average DF is very adequate in a domestic situation.

A difference in the perception of spaciousness occurs when penetration of the boundaries are windows, doorways, or other openings in the spatial envelope, providing mental engagement for the eye by connecting the space of the observer with outside activities. Ne'eman and Hopkinson (1970) found that the main determinant for people's preference for window openings was the amount of visual information provided by the outside view. Keighley (1973) stated that the most frequently preferred opening was a central, horizontally shaped window that provides a view to the skyline, and that the preferred window opening is a large horizontal aperture, that occupied 25% to 30% of the wall into which the window was cut.

2. Daylighting systems

Daylighting systems can be classified[2], after their main function as systems with shading and systems without shading.

Two types of daylighting systems with shading are discussed: systems that rely primarily on diffuse skylight and reject direct sunlight, and systems that use primarily direct sunlight, sending it onto the ceiling or to locations above eye height.

Shading systems are designed for solar shading as well as daylighting; they may address other daylighting issues as well, such as protection from glare and redirection of direct or diffuse daylight. The use of conventional solar shading systems, such as pull-down shades, often significantly reduces the admission of daylight to a room. To increase daylight while providing shading, advanced systems have been developed that both protect the area near the window from direct sunlight and send direct and/or diffuse daylight into the interior of the room.

Daylighting systems without shading are designed primarily to redirect daylight to areas away from a window or skylight opening. They may or may not block direct sunlight. These systems can be broken down into four categories:

- Diffuse light-guiding systems redirect daylight from specific areas of the sky vault to the interior of the room. Under overcast sky conditions, the area around the sky zenith is much brighter than the area close to the horizon. For sites with tall external obstructions (typical in dense urban environments), the upper portion of the sky may be the only source of daylight. Light-guiding systems can improve daylight utilization in these situations

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[2] IEA. *Daylight in Buildings.* International Energy Agency. Berkeley, California, 2000

- Direct light-guiding systems send direct sunlight to the interior of the room without the secondary effects of glare and overheating
- Light-scattering or diffusing systems are used in skylit or toplit apertures to produce even daylight distribution. If these systems are used in vertical window apertures, serious glare will result
- Light transport systems collect and transport sunlight over long distances to the core of a building via fiber-optics or light pipes

Some systems can fulfil multiple functions and are therefore in more than one category. Light shelves, for instance, redirect both diffuse skylight and beam sunlight[3].

3. Tubular daylight guidance systems (TDGS)

Traditional vertical window can provide adequate daylight within about six meters of the window. Daylight levels decrease asymptotically with distance from the window so that a disproportionate amount of daylight/solar gain must be introduced into the front of the room to achieve small increases in daylight at the back. While this can increase energy savings over a larger room area by offsetting electric lighting energy, the corresponding increase in cooling due to solar heat gain, and/or heating due to structural heat loss, can negate these savings. The use of glazed areas on other parts of the building envelope including atriums, skylights and roof monitors may light some areas remote from windows but these are of limited use in lighting deep core areas [1].

The estimated lighting level was simulated with Dialux 4.6 Software for a room (6*12 m) situated in Bucharest. The room has the windows orientation NE on the 6 m wall. In Figure 3.1 it can be seen the limited amount of daylight inside a 12 m deep room. The same figure illustrates the lighting level when there are used fluorescent 36 W lamps.

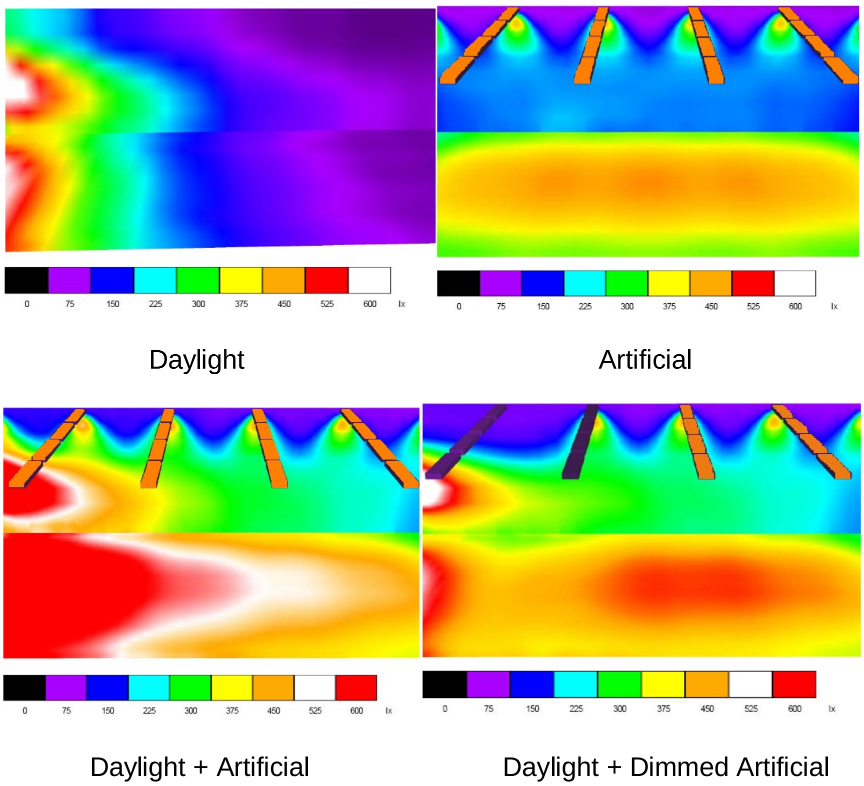

Figure 3.1 Lighting levels for a room (l=6 m, L=12 m, windows on the left side NE, simulation for a building situated in Bucharest, summer time)

A number of systems exist to redirect daylight into areas of buildings that cannot be lit by conventional glazing. One major generic group is known as 'beam daylighting' - redirects sunlight by adding

[3] Ticleanu C. *Modern Daylighting Techniques*, International Conference Light & Lighting 2002, Bucharest, November 2002.

reflective or refracting elements to conventional windows. The second major group is known as 'tubular daylight guidance systems TDGS'.

TDGS consist of a light transport section with, at the outer end, some device for collecting natural light and, at the inner end, a means of distribution of light within the interior – Figure 3.3. Collectors may be mechanical devices that actively direct daylight (usually sunlight), or be passive devices that accept sunlight and skylight from part or whole sky hemisphere, and may be located at roof level gathering light from the zenith sky or on the building façade. Zenith openings capture light from the brightest sky region but may cause glare or overheating due to direct solar penetration. Orientation is a major determinant of collection efficacy in façade mounted collectors. The transport element is usually a tube lined with highly reflective silvered or prismatic material and may contain lenses or other devices to redirect the light. Light is distributed in an interior by emitters which differ little from conventional luminaires. Light transport is the feature that sets tubular guidance systems apart from other daylight redirection methods. The principal function of transport elements is to deliver light from the collector to the point of exit but some may additionally act as emitters. Recently considerable research effort has been directed at transport systems, a major factor being the availability of new low cost light redirection materials. Usually there are four different transport methods, namely, beam/lens systems, hollow mirrored pipes, hollow prismatic pipes, and solid core systems.

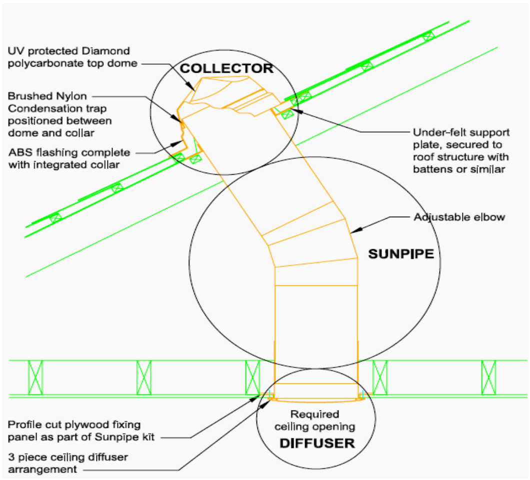

Figure 3.3 Tubular daylight guidance system with passive collector [4]

The light pipe, lined with highly reflective material, is used to guide sunlight and daylight into occupied spaces (Figure 3.3). Highly reflective materials include anodised aluminium and coated plastic film such as Silverlux, which have reflectance greater than 95%. Commercial light pipe are available from a number of manufacturers, in straight and bend sections for on-site assembly and installation. They allow the light pipe to go through complex roof spaces to reach rooms that are not easily accessible to skylights. A light pipe is normally fitted with a clear top dome which removes harmful UV radiation and prevents the ingression of rain water and dust. A diffuser fitted to the bottom of the light pipe ensures that light is distributed around the room it illuminates. Compared to skylight or windows, the light pipe transmits less solar heat on to the illuminated surfaces. This is particularly valuable in summer for preventing inhabitable hot spots in a building. In winter, a light collector (e.g., a sun-scoop) could be mounted above the top opening to allow significantly more sunlight from low angles to be collected [5].

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[4] Monodraught Ltd official web site, *Sunpipe Technical*.

[5] Shao L, Riffat S B, Hicks W AND Yohannes I. *A Study of Performance of Light Pipes Under Cloudy and Sunny Conditions in the UK.* Institute of Building Technology, University of Nottingham. Proc. of Right Light 4 (Copenhagen, Denmark, 19-21 Nov 1997). ISBN87-87071-73-8.

4. Case of study (passive TDGS – installed in Cluj-Napoca)

The experimental set up is shown schematically in Figure 4.1. A light pipe produced by the Velux Company was mounted inside a 4.2*3.5 m room on the first floor of the building. The house is part of a duplex situated in Cluj-Napoca. The cylindrical light pipe has a length of 2 m and a diameter of 430 mm. A highly reflective film is laminated, using adhesives, to the interior surface which has a minimum reflectivity of 95%. The top of the pipe was sealed with a clear anti-yellowing acrylic plate. A pearl white diffuser was fitted to the lower opening of the light pipe for even light distribution within the room.

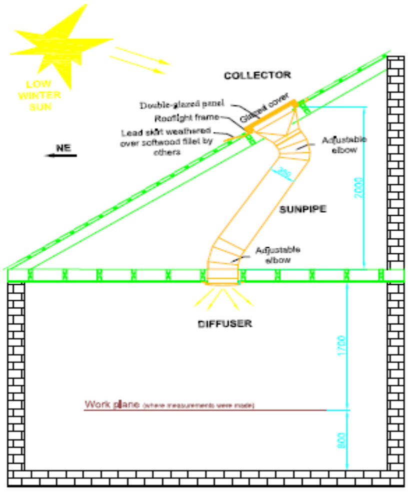

Figure 4.1 TDGS set-up for a pitched slate roof faceing NE

The owners of the house guide themselves in choosing the right device for their application using the technical support of Velux Company. The calculation were made using Velux Lux Software. The results provided by the software are shown in Figure 4.2.

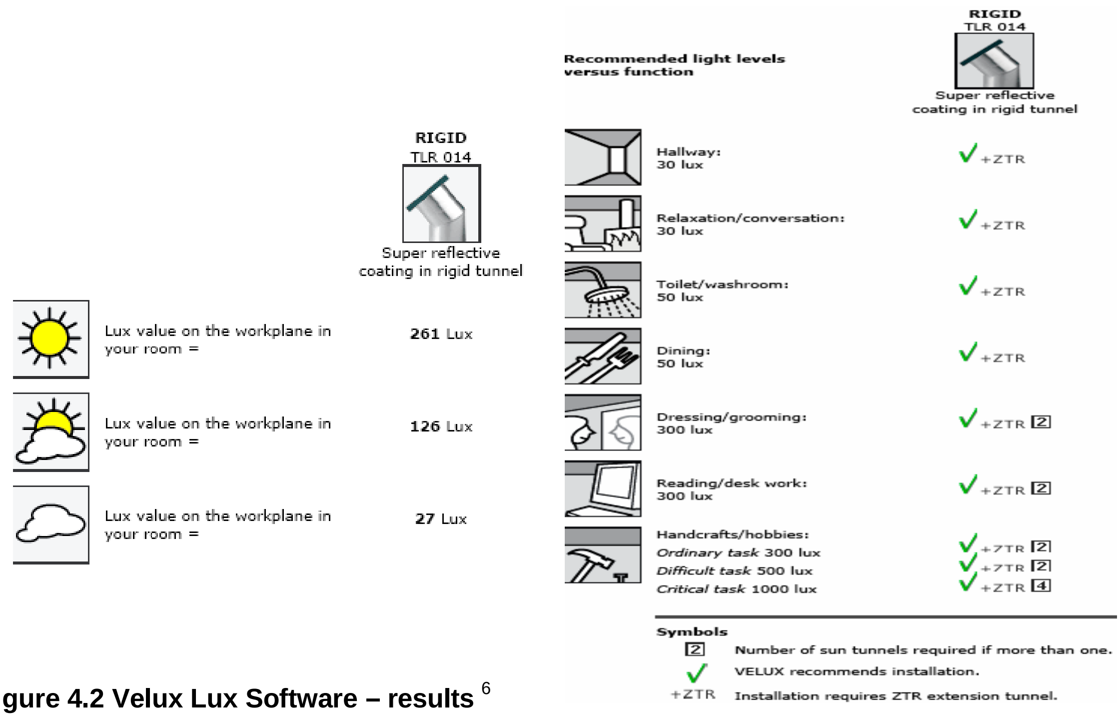

Figure 4.2 Velux Lux Software – results [6]

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[6] VELUX România S.R.L. official web site, Velux lux calculator

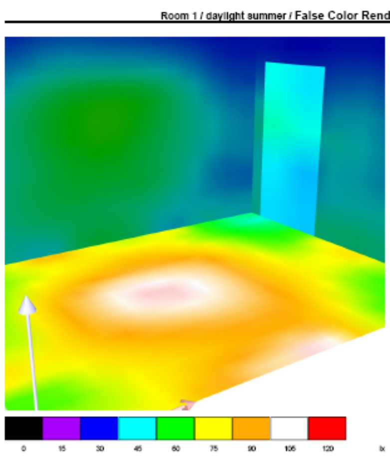
Illuminance measurement was carried out using a standard light meter which had a range of 0.05-100,000 lux. The meter was based on a photovoltaic cell which has a spectral response similar to that of a standard human eye thus avoids the need for correction for various types of light sources.

Illuminance of the sun on the open field, and that within the working plane inside the room were obtained using two separate photocells. The readings were recorded manually and cares were taken to ensure that there was no passing clouds or other significant changes of lighting condition between reading the two cells. The photocell within the room was normally placed in the centre, at a 0.8 m distance above the floor where the working plane is assumed to be. Measurements were carried out in three different days in the winter time. As shown in Table 4.1, the readings made in the first day are not conclusive because of the ice covering the collector.

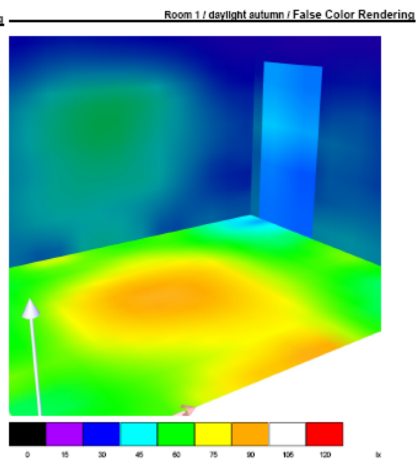
Table 4.1 Light pipe performance under cloudy and mix conditions

Date	Hour	Work plane illuminance	External illuminance	Internal / External Ratio	Comments	Average work plane illuminance
		lx	lx	%		lx
29.12.08	8:35	7,5	1.200	0,63	 The collector was covered in ice	19,18
	9:00	10,0	2.300	0,43		
	9:22	14,0	2.900	0,48		
	9:46	19,0	4.500	0,42		
	10:00	20,0	5.000	0,40		
	10:17	22,5	5.500	0,41		
	10:30	22,5	5.500	0,41		
	11:00	27,0	8.000	0,34		
	11:30	30,0	8.300	0,36		
	12:00	25,0	7.500	0,33		
	12:40	23,0	6.500	0,35		
	13:50	21,0	5.150	0,41		
	14:50	20,0	5.000	0,40		
	15:50	7,0	1.150	0,61		
04.02.09	13:13	135,0	24.000	0,56		64,75
	13:33	85,0	10.000	0,85		
	13:50	60,0	4.400	1,36		
	14:15	34,0	3.200	1,06		
	14:30	40,0	3.600	1,11		
	15:00	69,0	5.000	1,38		
	15:20	55,0	4.500	1,22		
	15:40	40,0	3.500	1,14		
06.02.09	10:59	100,0	11.400	0,88		112,25
	11:15	88,0	7.500	1,17		
	11:20	92,0	19.000	0,48		
	11:39	98,0	20.000	0,49		
	12:02	120,0	26.000	0,46		
	12:10	130,0	28.000	0,46		
	12:38	140,0	18.000	0,78		
	13:23	130,0	12.000	1,08		

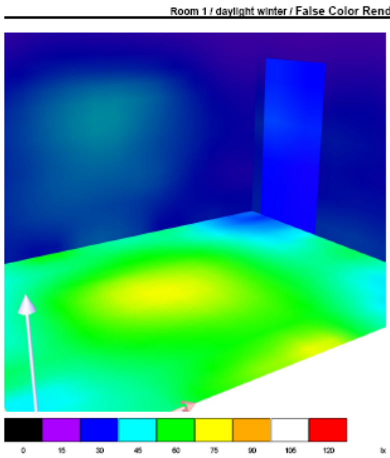
Some simulations were made for the same room using the Dialux Software. There were taken into consideration the four seasons, the 12:00 hour of 15 of January, April, July and October, plus the exact latitude and longitude of the building. The TDGS was assimilated with a roof light but the direct sun light was not taken into consideration for the calculation. Also the roof peek shadow was not considered for the simulation. Opposite to the measurements results, Figure 4.3 shows the lighting levels on the room floor.



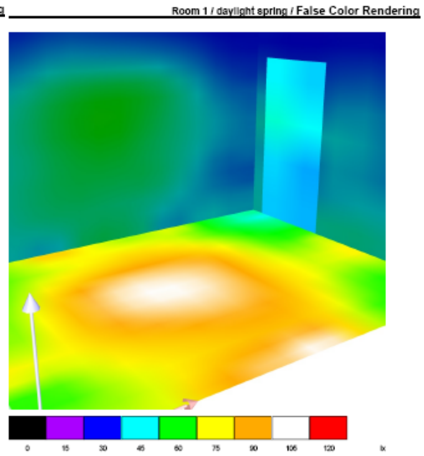
Summer



Autumn



Winter



Spring

Figure 4.3 Dialux simulations – results

A brief payback analysis uses the Workbook for GreenLight profitability calculations. The comparison is made between systems which respond to the customer's visual needs. The estimations are for the same room where the TDGS system was installed. It is taken into consideration a 100 W GLS system, 20 W CFL system, and one 430 mm TDGS system. The daily burning time is about 6 hours, referring to the non-working population, and the estimated system lifetime is considered at 25 years (equal with the TDGS lifetime). Figure 4.4 shows the profitability calculations results.

6. Profitability			
Type of comparison		**CFL vs. GLS**	**TDGS vs. GLS**
Undiscounted economics			
Payback Time	Year	0.1	7.7
	Month	1.6	92.5
Savings per year	kWh / year	166	219
	Euro / year	17	22
	Ton of CO2 / year	0.1	0.1

Figure 4.4 Workbook for GreenLight profitability calculations – GLS/CFL/TDGS

5. Lux outputs of a passive TDGS

The amount of light produced by a passive TDGS is quite variable, depending on sky conditions, whether it is cloudy or sunny, the time of day, the time of year, the length of the system, and the external conditions, whether there are trees, higher surrounding buildings. The following chart, therefore is offered by manufacturers as guidance only as to a reasonable guide as to the maximum amount of light that is likely to be produced by a passive TDGS on a typical flat roof application with a standard length (usually 600 mm) of sunpipe, under steady state conditions.

For vertical systems, on smaller sizes a total maximum length of 8 m is recommended, but on larger sizes up to 20 m in length can be used. There is a 12% reduction of light for each 45° bend used and there is a 6% reduction in light transmission for every meter of sunpipe. 30° & 45° adjustable elbows can be used with all sunpipe applications to direct daylight to where it is required[4]. For the horizontal systems it is recommended the installation of the collector on the south facade of the building and a maximum sunpipe length up to 4 m.

The amount of light produced will also vary depending whether it is measured immediately below the diffuser, at floor level or at a midpoint (usually the work plane, about 0.8 m from the floor). For the following charts, we have based the output that would be measured at a point of 1.5 m below the diffuser level, that is at desk level of a typical room with a floor to ceiling height of 2.4 m.

The light levels given are those that can be measured immediately below the diffuser at desk level and whereas the spread and distribution of natural light is extremely good, the light levels measured say 2 m away will be somewhat less.

Next there are provided some Monodraught Ltd's data. They have produced tables below showing three sets of values. The first table at 105 klux externally as the maximum value of light that could be expected in the UK under midday Summer conditions. The second table is probably the most typical being under Summer conditions, but under an overcast sky of 45 klux and is probably typical for a period of time from say, March through to October. The third table is for 20 klux externally, which is a typical Winter condition, under an overcast sky. All the Figures given are taking account of the new Super Silver sunpipe material – Table 5.1 [4].

Table 5.1 Passive TDGS – lux outputs [4]

Diameter	Full Summer Sun (105klux)		Overcast Summer (45klux)		Overcast Winter (20klux)		Area Lit (to a normal daylight level)
	Lux Value	Lumen output of systems	Lux Value	Lumen output of systems	Lux Value	Lumen output of systems	
230mm (9")	360	2160	170	1045	65	370	7.5 sq.m (approx 80sq.ft)
300mm (12")	760	4460	330	1940	130	760	14 sq.m (approx 150sq.ft)
450mm (18")	1820	10770	750	4410	300	1768	22 sq.m (approx 230sq.ft)
530mm (21")	2530	14995	1050	6265	430	2550	40 sq.m (approx 430sq.ft)
750mm (30")	4350	25568	1975	11620	900	5300	50 sq.m (approx 530sq.ft)
Other SunPipe sizes available with hemispherical top domes							
900mm (35")	7700	45300	3850	24650	1425	8390	60 sq.m (approx 650sq.ft)
1000mm (40")	13630	80180	7505	43380	2250	13050	70 sq.m (approx 750sq.ft)

Note: A 100w light bulb generates approximately 1000 lumens or 170lux.

The most remarkable feature of TDGS is the amount of intensified light it can deliver. The light will vary depending of the time of year but can be expressed as an equivalent to electric lighting, as shown in Figure 5.1 – research conducted by the University of Nottingham.

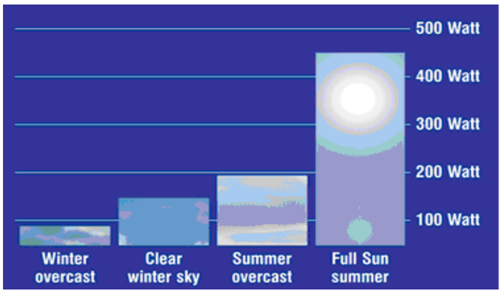


Figure 5.1 The output of a 300mm diameter passive TDGS to a flat room application [4].

6. Energy-saving attributes of passive TDGS

Compared to other daylighting technologies, TDGS have some certain advantageous considering the next points[7]:

1. *Virtually no summer heat gain.* In the summer, traditional daylighting technologies let in a lot of the suns' heat, causing an increase in air-conditioning energy consumption that far outweighs any electric lighting energy savings.

[7] U.S. ENVIRONMENTAL PROTECTION AGENCY. *Global worming*

2. *Virtually no winter heat-loss*. In the winter, warmed air rises, gets cooled by horizontal or vertical glazing, then sinks to be reheated. Again, traditional daylighting technologies waste far more heating energy than they save in electric lighting energy.

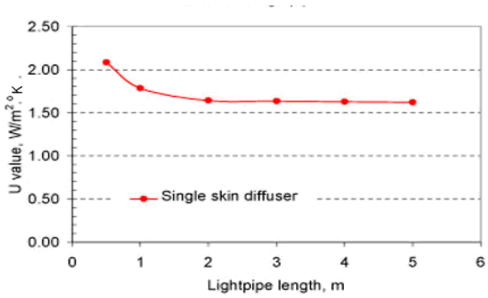


Figure 6.1 U-value of TDGS [4].

3. *Minimal invasion of the thermal envelope.* Traditional daylighting technologies require the removal of 10 times more roof (or wall) insulation than a TDGS. Whether it's a wall of vertical windows that allows daylight to reflect off a white wall for indirect lighting (a clearstory), or skylights that just let the sun shine in through the roof, the insulation sacrifice is tremendous. A common residential skylight measures 75 X 150 cm which is over 1.1 square meters in area. A TDGS – 330 mm diameter is less than 0.085 sq. m. in area, yet it brightens up a greater area of the room than does the skylight. In this case, and as a general rule, installation of a skylight requires the removal of 11 times as much roof insulation as the installation of a TDGS – 330 mm diameter.

4. *Lights Up Entire Rooms*. Ceiling diffuser spreads nature's light evenly throughout the entire room. No "spot-light" effect like traditional skylights.

5. *Easy to Install.* Installs between joists and rafters (or trusses). No framing, no drywall, no taping, no mudding, & no finishing. Average installation time is 2-4 hours.

6. *Maintenance Free*. TDGS uses only highest quality components for longevity and performance. As with any light fixture, dome may require occasional cleaning.

7. *Doesn't Leak.* Exclusive Industrial Grade Flashing & Storm Collar, Hurricane Rated.

8. *Reduce Disposal of Heavy Metals and Hazardous Waste.* Along with lower re-lamping frequency comes a reduction in the disposal of heavy metals and hazardous waste products (e.g. mercury and phosphorous), materials found in fluorescent and certain HID lamps.

9. *Pays For Itself.* Energy Savings (reduce electric-lighting energy requirements), virtually no impact on cooling & heating and longer life for lighting bulbs used only at night. (Lamps that required replacement after 1 or 2 years will now last 4 to 5 years).

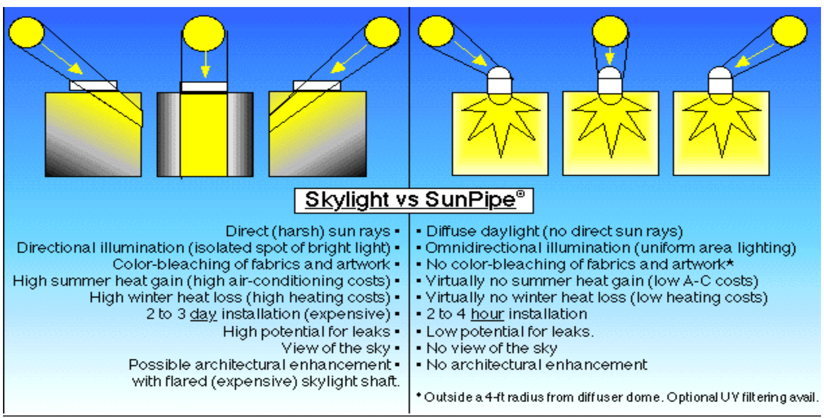


Figure 6.2 Skylight vs passive TDGS [7].

A comparison of TDGS and the standard skylight is shown in Figure 6.2. Most of the skylights implemented today use diffuse glazing. This should eliminate the main skylight disadvantages related to directional illumination. When integrated into the architectural building designs, standard skylights have proven to be a very economic way of bringing larger amounts of daylight into a building. Traditional skylights are usually at the end of a long shaft, they do not provide much light for a room unless the sun happens to be shining directly through the glass. TDGS is designed to collect even low-angle light and redirect it to the diffuser, which sends light to all corners of a room.

7. TDGS energy saving potential in residential buildings in Romania

One major disadvantage of the TDGS is that it can provide natural light only during the day. Relevant for the energy saving potential of the TDGS in the residential sector there is the non-working population, the end users that need light during the day – Figure 7.1.

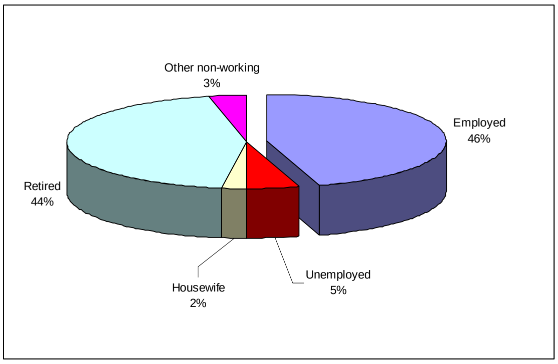


Figure 7.1 Dwellings distribution by occupation of family head, Romania [8]

The last official numbers provided by the Romanian National Institute of Statistics for the year 2002, shows a total number of over 7.3 millions dwellings for the Romanian residential sector. The Figures presented in Table 7.1 denote the large number of households owned by non-working family heads (approximately 4 millions). Dividing this number with the national average of dwellings per building we can assume a total of 2.35 millions buildings with dwellings having non-working family head.

Table 7.1 Number of dwellings distributed after the family head occupation, Romania [9]

Dwellings by occupation of family head	
Employed	3,308,442
Unemployed	347,180
Housewife	166,524
Retired	3,243,073
Other non-working	250,672
Total dwellings, non-working	4,007,449
Total dwellings	7,315,891
Average number of dwellings per building	1.7
Total buildings with dwellings having non-working family head	**2,357,323**

Scientists estimates electric lighting savings for the residential sector taking into consideration a non-working residential couple who spend a considerable amount of time at home with a 300 mm diameter passive TDGS installed (usually in the kitchen/hallway/bathroom). The system typically replaces the burning of 200 to 500 Watts of electric lights for 3 to 7 hours per day. For this example we'll assume a 300 Watt savings for 5 hrs. per day, only 5 days per week. This leads to electric savings for a TDGS 300 mm diameter of about 390 kWh per year.

If we consider that in each 2.35 millions buildings with dwellings having non-working family head, at least one TDGS 300 mm diameter is suitable to be installed and taking into account the previous electrical savings example, we can assume total energy savings for residential lighting in Romania of

[8] Data provided by INS – Romanian National Institute of Statistics, 2002.

about 916 500 MWh per year. Additionally savings can be assumed for the total number of residential buildings during the weekends (total number of residential buildings - 4.38 millions [9] * 300 Watt savings for 5 hrs. per day, only 2 days in the weekend leads to additional total electricity savings of 630 000 MWh per year). The previous predictions examples show electricity savings for the residential sector in Romania by installing in each building a TDGS 300 mm diameter of about 1.5 million MWh per year. Even a greater saving potential should be available for the commercial sector where usually the main activity take place during the day.

8. Conclusions

"Personal responsibility," says Miller, "means doing things the right way and not causing the release of unnecessary pollutants into our eco system." The typical passive TDGS costs $400 to $600 installed and will prevent over 3 tons of CO_2 from entering our air over the next 10 years. All this, while providing healthy, natural interior illumination, far superior to any electric light in both colour and intensity. It just makes good common sense to implement such technology [9].

Daylighting systems require a specific conception, very close related to the geographic context where they are built, to environment (natural and artificial obstructions), to imposed levels of visual comfort and to climate.

The development of new materials with better performance in light reflection and transmission has lead to various solutions of energy efficient lighting systems able to grow potential for future applications.

Any technical and economical analysis of these systems must take into account both energy efficiency, and visual comfort conditions for the lighted spaces. For example, these solutions present outstanding possibilities to improve visual comfort in underground spaces, which are energy efficient due to low thermal losses.

Perspectives offered by these solutions of integrated lighting systems lead to a higher visual comfort and to new possibilities of space utilization.

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Labelling & Standards

Progress towards Managing Residential Electricity Demand: Impacts of Standards and Labeling for Refrigerators and Air Conditioners in India.

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Abstract

The development of Energy Efficiency Standards and Labeling (EES&L) began in earnest in India in 2001 with the Energy Conservation Act and the establishment of the Indian Bureau of Energy Efficiency (BEE). The first main residential appliance to be targeted was refrigerators, soon to be followed by room air conditioners. Both of these appliances are of critical importance to India's residential electricity demand. About 15% of Indian households own a refrigerator, and sales total about 4 million per year, but are growing. At the same time, the Indian refrigerator market has seen a strong trend towards larger and more consumptive frost-free units. Room air conditioners in India have traditionally been sold to commercial sector customers, but an increasing number are going to the residential sector. Room air conditioner sales growth in India peaked in the last few years at 20% per year.

In this paper, we perform an engineering-based analysis using data specific to Indian appliances. We evaluate costs and benefits to residential and commercial sector consumers from increased equipment costs and utility bill savings. The analysis finds that, while the BEE scheme presents net benefits to consumers, there remain opportunities for efficiency improvement that would optimize consumer benefits, according to Life Cycle Cost analysis.

Due to the large and growing market for refrigerators and air conditioners in India, we forecast large impacts from the standards and labeling program as scheduled. By 2030, this program, if fully implemented would reduce Indian residential electricity consumption by 55 TWh. Overall savings through 2030 totals 385 TWh. Finally, while efficiency levels have been set for several years for refrigerators, labels and MEPS for these products remain voluntary. We therefore consider the negative impact of this delay of implementation to energy and financial savings achievable by 2030.

Introduction

The Indian Bureau of Energy Efficiency (BEE) finalized its first set of efficiency standards and labels for frost-free refrigerators in 2006. These regulations were soon followed after with the publication of levels for direct-cool refrigerators and air conditioners. Both the refrigerator and air conditioner program introduce Minimum Efficiency Performance Standards (MEPS) and comparative labels simultaneously, with levels for one to five stars. Also, both define several successive program phases of increasing stringency. This paper performs an analysis of the likely impacts of both schemes, and consists of three components:

- Cost effectiveness to consumers of efficiency technologies relative to current baseline.
- Impacts on the current market from efficiency regulations.
- National energy impacts.

The analysis relies on detailed and up-to-date technical data made available by BEE and industry representatives. Technical parameters were used in conjunction with knowledge about air conditioner use patterns in the residential and commercial sectors, and prevailing marginal electricity prices, in order to give an estimate of per-unit financial impacts. The overall impact of the program is evaluated by combining unit savings with market forecasts in order to yield national impacts.

The analysis begins with the rating plans drafted by BEE, along with an evaluation of the market baseline according to test data submitted by manufacturers. MEPS, label rating levels, and baseline efficiencies are then presented. Baseline efficiencies are used to estimate the fraction of models likely to remain on the market at each phase of the program, and the impact on market-weighted efficiency levels. A Life-Cycle Cost (LCC) calculation is used to evaluate the impacts of the program at the unit level, thus providing some insight into the appropriateness of the levels chosen, and additional opportunities for further ratcheting. In addition to LCC, we also calculate payback periods, cost of conserved energy (CCE), and return on investment (ROI).

Finally, we calculate national impacts. This is an extension of unit level estimates in the two previous sections. Extrapolation to the national level depends on a forecast of equipment purchases (shipments. The scenario corresponding to the BEE plan is combined with shipments through a stock accounting model in order to forecast refrigerator and air conditioner energy consumption in each scenario, and associated electricity.

BEE Draft Standards

BEE's published document announcing the first set of efficiency standards for appliances and other energy-consuming equipment described the philosophy of review and update in the following way:

> *"Instead of setting a very tough standard and rating plan at the onset of the program, a phased approach is being adopted, wherein the rating plan will be upgraded every two years till an internationally benchmarked energy efficiency level is achieved." (Source: BEE)*

The original BEE plan called for implementation of refrigerator standards in 2006, with subsequent updates in 2008, 2010 and 2012. Air conditioner ratings were announced in 2007, with updates scheduled for 2008 and 2010. Each successive update will ratchet the entire scheme up one star rating (two-star units become one-star, three-stars become two, etc.) However, the labeling program was made mandatory only in 2008, thus presumably delaying the updates. The original ratings are shown in Table 1.

Table 1 – Star Ratings for Refrigerators and Air Conditioners

Star Rating	Direct Cool Refrigerators		Frost-Free Refrigerators		Air Conditioners (Window and Split)	
	Consumption (kWh/yr) = *k* * *AV* + *c*				EER	
	k	*c*	*k*	*c*		
Unit	kWh/yr/ℓ	kWh/yr	kWh/yr/ℓ	kWh/yr	W/W	Btu/hr/W
*	0.645	541	0.8716	759	2.3	7.8
**	0.516	432	0.6973	607	2.5	8.5
***	0.413	346	0.5578	486	2.7	9.2
****	0.33	277	0.4463	389	2.9	9.9
*****	0.264	221	0.357	311	3.1	10.6

Refrigerator consumption levels are given by the following formula:

$$\text{Consumption (kWh/yr)} = k * AV + c$$

In this equation, *AV* is the adjusted volume, which is the storage volume of the fresh food compartment plus the storage volume of the freezer compartment multiplied by a constant, which is set at 1.31 for direct cool models, and 1.42 for frost free models. The consumption equation consists of a constant term *c*, and an additional term k, which is multiplied by volume in order to allow for higher consumption for larger units. Air conditioner efficiency is defined in terms of Energy Efficiency Rating (EER), which quantifies cooling energy output divided by electricity energy input. The lowest allowable rating is the one star level. Models not meeting the minimum Energy Efficiency Rating (EER) for this level will be prohibited for sale on the market. Thus, the one star level amounts to a minimum efficiency performance standard (MEPS).

Current Market and Impact of Standards

As part of the regulation development process, a sample of no-frost refrigerators was tested according to the mandated Bureau of Indian Standards (BIS) procedure. No data were available for direct cool refrigerators. However, a sample of models with market share and wattage characteristics were available from an earlier phase of the standards-setting process [1]. Energy consumption was inferred from wattage according to the method used in a report drafted in support of BEE's standards development [2][1]. The results of the market study for frost-free refrigerators and air conditioners is shown in Figure 1.

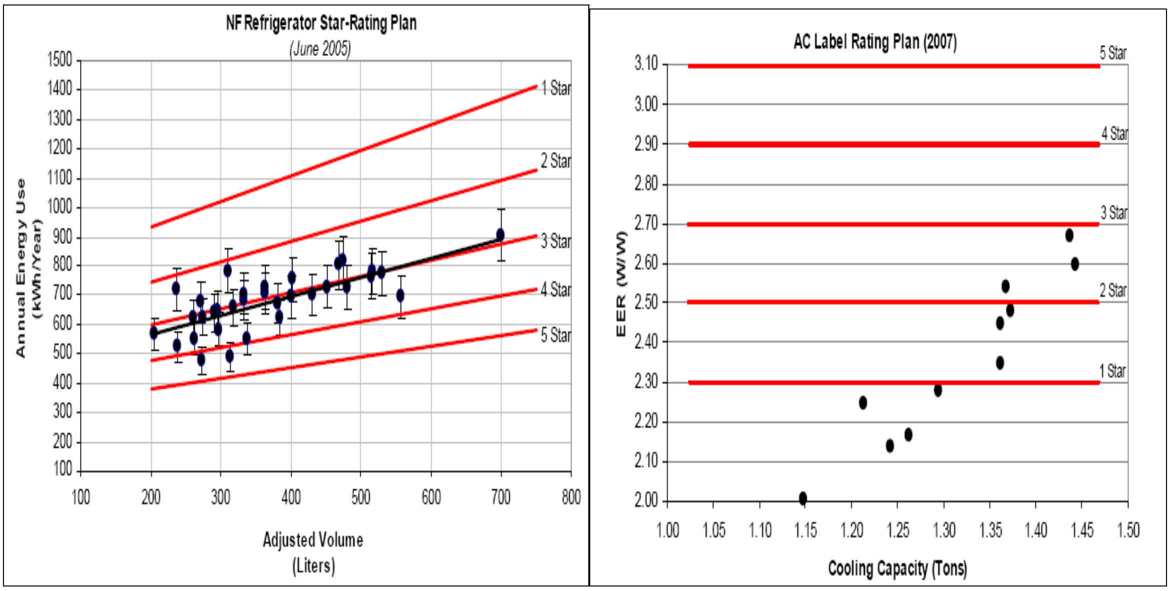

Figure 1 – Frost Free Refrigerator and Air Conditioner Test Data and Rating Plan

Source: BEE

The results of the test data shows that all of the frost-free refrigerators pass the minimum one-star level, and most fall into the two or three-star category. By contrast, only 6 of the 11 air conditioner models tested will be permitted for sale. Of these, 3 will be rated one star, and three will be rated with two stars. After two updates, where the current three-star level will become the minimum, most of the current frost-free refrigerator models and all of the air conditioners will be prohibited for sale. Therefore, with moderate ratcheting, and assuming that the models tested are representative of the market as a whole, the MEPS and ratings plan are quite stringent. On the other hand, the estimate of energy consumption for direct cool refrigerators in combination with their adjusted volume indicates that ratings for this product class are less stringent, with 51% of models meeting the four-star requirement, and no models rated less than three stars.

Cost Effectiveness

It is important to evaluate the cost effectiveness of efficiency measures for both labeling and standards programs, particularly if these are mandatory, as they are in India. In the case of a labeling program, energy efficiency becomes a marketing tool as an attractive selling point to consumers. The attractiveness of buying energy efficient equipment may be offset somewhat, however, by higher retail prices on these models. In the case of MEPS, cost-benefit analysis is even more critical, since in this case the regulation imposes real costs on the consumer, and generally implementing agencies are reluctant to impose onerous costs. On the other hand, MEPS can generally be engineered such that they provide a net benefit to consumers, and a cost-benefit analysis allows for design of regulations that maximize financial benefits, or maximize energy savings to the nation. In this section, we

[1] By comparing wattage values to available test data, the report concluded that on average, baseline direct-cool refrigerator compressors cycle 38% of the time.

evaluate the cost-effectiveness of a variety of efficiency design options from the consumer viewpoint, and compare them to the MEPS levels set by BEE. In addition, the cost-benefit analysis gives some indication of gains likely to be made by the labeling component, and the construction of alternative efficiency scenarios. The methodologies we use to characterize cost-effectiveness are:

- *Life Cycle Cost* – LCC calculates the net incremental cost over the life of the appliance, including increased equipment (first) cost, and lifetime operation cost savings, which are discounted according to the year from purchase they are accrued.
- *Payback Period* – The number of years after which cumulative operating cost savings exceed incremental equipment cost.
- *Cost of Conserved Energy* – The incremental first cost paid divided by discounted energy savings over the life of the appliance. Cost effectiveness is evaluated by comparing the CCE with prevailing electricity prices.

In order to estimate cost effectiveness, the relationship between equipment prices and efficiency must be known. The most reliable way to generate a *price-efficiency curve* is by considering specific design options known to increase efficiency by certain amount, and their associated costs. The cost of efficiency can be estimated in terms of material costs to manufacturers, which can then be scaled by the appropriate markups in order to estimate retail prices.

Unit Energy Consumption and Retail Price

There are two main product classes for residential refrigerators in India: single-door direct cool (manual defrost) and two-door frost-free. Traditionally, direct cool units have dominated the market, but frost-free units are gaining ground. According to a recent survey of Indian refrigerator manufacturers [1], direct-cool units claim 82% percent of the market, with 18% held by frost-free. While sales of refrigerators are currently growing at about 6% per year, one source indicates, that frost-free sector is growing at 20% per year, indicating a strong market trend towards this product class [3]. The parameters necessary to assess the cost effectiveness of improved refrigerator efficiency are taken from an engineering analysis [4], which evaluated the characteristics of a baseline refrigerator model and utilized a simulation software package in order to determine efficiency benefits. This analysis used cost estimates for a 165 liter one-door refrigerator reported by Indian refrigerator manufacturers. This unit is fairly representative of the direct-cool market in India, as most (66%) direct-cool models sold are in the 165-175 liter range [1]. According to the methodology of [2], we determined that the baseline refrigerator uses an average of 0.98 kWh per day, or 359 kWh per year. Frost-free models are more than twice as energy intensive. According to a sample of models tested by manufacturers, the average consumption of a frost-free model is roughly 2.4 kWh/day, or 876 kWh per year. We proceed by applying the cost efficiency results to direct cool models, and then extrapolating these results to the no-frost class, although we realize that it neglects efficiency options related to the defrosting function.

In order to estimate incremental prices of higher-efficiency models, we scale the percentage manufacturer incremental costs according to an estimate of baseline retail price, taken from a survey of a comparison-shopping website in India (www.compareindia.com)[2]. The average of a sample of 17 models between 165 and 175 liters is $184 at current exchange rates (45.45 Rs/$). For frost-free models, the baseline is around 220 liters, with about half of sales for units within the 220 to 250 liter range. A sample of 18 models from the same retail source yields an average price of $311 for frost-free units between 220-235 liters.

Engineering data for window air conditioners was provided to BEE, and shared with LBNL researchers as part of the development of a techno-economic analysis, which was presented to the Air Conditioner Technical Committee in May of 2006. Data were provided only for window units. We assume that incremental retail prices and the cost-efficiency relationship given for window units also hold for split systems. This assumption is a rough approximation which may not reflect the actual cost-

[2] Price data are from a sampling of retail outlets, and therefore we judge them to be competitive and potentially more representative of actual prices paid than manufacturers' suggested retail prices.

efficiency relationship for split units. As noted earlier in section 2.1, although window units currently account for about 60% of the Indian room AC market[3], the market is quickly transitioning to split units. As a result, costs for window units, which may be reflective of split unit costs today, may no longer be representative of split unit costs in the future as manufacturers put more of their attention on the design and production of split units. Thus, although the efficiency options being considered for window units are similar to what would be applied to split units, their cost implications for split units could significantly change due to manufacturing efficiencies gained by increasing split unit product volumes.

Air conditioner data specify the typical configuration of units currently on the market, that is, the baseline design (Design Option 0). The baseline efficiency is estimated to be around 2.3 EER. As discussed in the previous section, about half of the units tested perform better than this level, and half are below. Each successive design option added to the baseline configuration has the effect of raising the efficiency. In addition, inclusion of these features increases manufacturer costs for materials, labor, and retooling.

Traditionally, commercial firms have been the dominant purchasers of air conditioners in India, but this situation is changing. In 2002-2003, RAMA estimates that half of the air conditioners sold in India were purchased for use in homes, and this fraction rose gradually to 58% by 2006. Because of the significant difference in use patterns and electricity rates between commercial and residential users, we evaluate cost effectiveness separately for each user type. Unit Energy Consumption (UEC) is calculated by estimating the number of hours per day and per month that the business or household operates each air conditioner. Investigations by RAMA indicate the following use patterns:

<u>Commercial Use</u> - *9 months/yr × 25 days/month × 8 hours/day = 1800 hours/yr.*

<u>Residential Use</u> - *6 months/yr × 30 days/month × 8 hours/day = 1440 hours/yr*

The hours of use can be combined with the power consumption of a typical air conditioner in order to arrive at energy consumption. The capacity rating of air conditioners is based on being operated at full power. We assume that the consumer operates the air conditioner at 75% of full capacity on average, and apply a scaling factor of 0.75. A 1.5T unit typically operates at 2kW full power[4]. Therefore, UEC is given by

$$2kW \times 0.75 \times Hours,$$

which yields 2700 kWh per year for commercial users, and 2160 kWh per year for residential users.

Marginal Electricity Prices and Discount Rates

Residential electricity rates are much lower than commercial rates in India. Residential electricity rates are subsidized to a large degree (but to a much lesser degree than agricultural rates), and consumers pay low rates on average. Rates collected by most State Electricity Boards in India, however, have a residential tariff schedule that charges significantly higher rates for usage above a certain baseline. The impact of higher electricity efficiency will be to reduce consumption in the highest block. Therefore, the relevant consumer electricity savings is calculated according to this *marginal* price. Marginal prices were calculated by LBNL for a previous study using SEB tariff rates that covered most of India, and found to be $0.059/kWh for residential customers and about $0.083/kWh for commercial customers [5].

Consumers value immediate savings more than future savings. The time value of money is typically accounted for by discounting future savings using a discount rate. There is limited data on which to base consumer discount rates in India. The rate currently used by utilities for their investment in demand-side efficiency programs is 10%. We assume that rates used for other sectors will be somewhat higher, with residential consumers discounting deferred savings by the largest factor. We

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[3] Source: Indian Refrigerator and Air Conditioner Manufacturers Association (RAMA)

[4] A 2000W unit with baseline EER of 2.29 has a cooling capacity of 4580 W/h, which is typical of the tested sample of 1.5 T units.

therefore assume a discount rate of 15% for residential consumers and a slightly lower rate of 12% for commercial consumers.

Life Cycle Cost, Payback Period and Cost of Conserved Energy

Given estimates of retail price, UEC, marginal electricity prices and discount rates, calculation of cost-benefit estimators is straightforward. The first of these is a Life Cycle Cost (LCC) calculation. LCC is given by

$$LCC = P + \sum_{n=1}^{L} \frac{OC}{(1+DR)^n}$$

In this equation, *P* is the appliance retail purchase price, *OC* is the annual operating cost (refrigerator or air conditioning utility bill), and *DR* is the discount rate. The sum runs over the life of the appliance, which we assume to be 15 years for both products. Simple payback period, in years is given by the incremental cost ΔP between two options, divided by the annual operating costs savings ΔOC.

Finally, the cost of conserved energy (*CCE*) is also a useful indicator of the value of the investment into efficiency. Cost of conserved energy is given by

$$CCE = \frac{P}{\sum_{n=1}^{L} \frac{\Delta E}{(1+DR)^n}}$$

In this formula, retail price *P* appears in the numerator, where the denominator is energy savings ΔE over the life of the appliance, discounted in each year after purchase. *CCE* can be compared to electricity prices in order to judge cost-effectiveness.

Table 2 Cost-Effectiveness of Direct Cool Refrigerators

Design	**UEC**		**Equipment Price**	**Elec. Bill**	**Payback Period**	**LCC**	**ΔLCC**	**CCE**
	kWh/day	kWh/yr	$US	$US	Years	$US		$US/kWh
0	0.98	359	$184	$21.31	0.00	$308	$0.00	$0.000
1	0.94	341	$186	$20.24	2.24	$305	-$3.84	$0.023
2	0.76	276	$191	$16.39	1.46	$287	-$21.54	$0.015
3	0.54	196	$203	$11.64	1.96	$271	-$37.58	$0.020
4	0.52	190	$207	$11.29	2.33	$273	-$35.20	$0.024
5	0.49	179	$216	$10.61	2.99	$278	-$30.52	$0.030

For all of the design option combinations shown in Table 2, payback to the consumer relative to the baseline is less than three years, and all of them lower the LCC. Design option 3 has the lowest LCC. We estimate a discounted net savings of about $38 over the life of the appliance for this option. For the design options analyzed, CCE ranges from 1.5 to 3.0 cents per kWh, well below the relevant electricity price. Using the parameters in Table 1, a five-star 165 liter refrigerator with no freezer should consume less than 264 kWh/per year. Therefore, the analysis concludes that efficiency options are cost-effective well beyond the levels set by the labeling scheme.

Table 3 Cost-Effectiveness of Frost-Free Refrigerators

Design	UEC		Equipment Price	Elec. Bill	Payback Period	LCC	ΔLCC	CCE
	kWh/day	kWh/yr	$US	$US	Years	$US		
0	2.40	876	$311	$51.94	0.00	$615	$0.00	0
1	2.28	832	$315	$49.35	1.56	$603	-$11.15	0.01578
2	1.85	674	$323	$39.97	1.01	$557	-$57.89	0.01027
3	1.31	479	$343	$28.38	1.36	$509	-$105.78	0.01378
4	1.27	464	$350	$27.53	1.62	$511	-$103.29	0.01639
5	1.20	436	$365	$25.88	2.07	$516	-$98.35	0.02104

For frost-free units, we assume that incremental equipment costs and energy savings will scale with the direct-cool analysis. The estimated discounted savings for design option 3 is about $106 over the life of the appliance. For the design options analyzed, CCE ranges from 1.0 to 2.1 cents per kWh. From the testing sample, the average frost-free refrigerator is found to have an adjusted volume of 319 liters. For such an appliance, Design 5 corresponds to a four-star refrigerator in the BEE scheme

Cost effectiveness parameters are shown for various air conditioner design options for residential customers in Table 4, and for commercial customers in Table 8. Life Cycle Cost is about twice as high for commercial customers because of the higher electricity rates, higher hours of operation, and a lower discount rate. The lifetime costs for these consumers is over $2,000. First cost only accounts for a sixth of LCC for these users, while it's about a third of residential user LCC.

Table 4 Cost-Effectiveness of Energy Efficiency – Residential Customers

Design	EER	UEC	Equip. Price	Elec. Bill	Payback Period	Life-Cycle Cost Total	Life-Cycle Cost Change	CCE
	W/W	kWh/yr	$US	$US	Years	$US		$US/kWh
0	2.3	2160	$377	$128	-	$1,150	-	-
1	2.4	2038	$400	$121	3.2	$1,130	-$20	$0.033
2	2.6	1872	$414	$111	2.1	$1,084	-$66	$0.022
3	2.7	1831	$428	$109	2.5	$1,083	-$67	$0.027
4	2.8	1755	$451	$104	3.0	$1,079	-$71	$0.031
5	2.9	1685	$553	$100	6.1	$1,156	$7	$0.064
6	3.3	1504	$743	$89	9.1	$1,281	$132	$0.096

Table 5 Cost-Effectiveness of Energy Efficiency – Commercial Customers

Design	EER	UEC	Equip. Price	Elec. Bill	Payback Period	Life-Cycle Cost Total	Life-Cycle Cost Change	CCE
	W/W	kWh/yr	$US	$US	Years	$US		$US/kWh
0	2.3	2700	$377	$288	-	$2,399	-	-
1	2.4	2547	$400	$271	1.4	$2,308	-$91	$0.023
2	2.6	2340	$414	$249	0.9	$2,167	-$232	$0.015
3	2.7	2289	$428	$244	1.1	$2,142	-$257	$0.018
4	2.8	2194	$451	$234	1.3	$2,094	-$305	$0.021
5	2.9	2106	$553	$224	2.7	$2,131	-$268	$0.044
6	3.3	1880	$743	$200	4.1	$2,151	-$248	$0.066

Design option 4 gives the minimum LCC for both consumer categories, and therefore is the most cost-effective option according to this metric. Using a 2.8 EER product instead of a 2.3 EER model saves commercial consumers about $300 and residential consumers $70. It is important to note that in the commercial user case, LCC of design options 5 and 6 (2.9 and 3.3 EER) are also cost-effective and thus provide savings over the life of the appliance. This is not true, however, in the residential case, where the high price of these models would cause LCC to exceed that of the base case, although at the 2.9 EER level the difference is somewhat marginal. This means that all of the star ratings are cost-effective to consumers, except for the five-star category for the case of residential consumers. It is important to note, however, that currently there are no such units on the market, and over time manufacturers may learn how to produce these products at a lower price. More importantly, electricity tariff reform is a constant and pressing issue in India where residential (and agricultural) consumer tariffs do not currently cover the price of production. It is likely, therefore, that five-star air conditioners will become cost-effective to households in the near future.

The calculation of simple payback yields similar results to the LCC analysis. Payback is almost always less than 3 years for commercial consumers. For residential consumers, payback is between 2.1 and 3.2 years for the first four design options. For the most efficient two options, it is 6 years and 9 years. The discount rate for residential consumers used in the LCC analysis means that this is too long to wait for a return on investment for these users. For commercial consumers, CCE is always less than the marginal electricity price, and it is less for residential consumers for all but the two highest efficiency options.

National Energy Savings

The cost-benefit analysis described in the previous section is a critical element of policy development and evaluation, because it assesses the appropriateness of efficiency targets in terms of impacts on individual consumers. It can also help identify additional opportunities for improvement. Ultimately, however, the goal of any efficiency program is to reduce growth in energy consumption and associated emissions of greenhouse gases and other pollutants at the national level. National energy impacts are evaluated by combining the market average efficiency improvement scenarios with projections of shipments. It takes into account the rate at which new, higher efficiency products will enter the stock by use of a retirement and replacement model.

Market Efficiency Impacts

Energy savings in the appliance market due to an efficiency program depends on the response of the market as a whole. This behavior is impossible to predict with certainty, but conclusions drawn from the current distribution of products is indicative, if not precise. Some market transformation can be attributed to MEPS only, especially as minimum levels are updated. As Figure 1 indicates, the frost-free refrigerator market will be relatively unaffected by MEPS, until the current three-star level becomes mandatory. For direct cool refrigerators, removal of a significant percentage of models from the market would require that the four-star level become mandatory. The impact of MEPS is likely to be more significant for air conditioners about half the models do not pass the current one-star level, and none can be qualified as three-star or above. In developing the S&L scenario, we assume that the labeling scheme become mandatory in 2009, and levels of both products are ratcheted by one star level every two years, in 2011, 2013 and 2015.

The transformation of the market is likely to be greater than that suggested by MEPS alone, for two reasons. First, manufactures implementing efficiency technologies may find that it is cost-effective and in their interest to go beyond the minimum required by the standards. More important, however, is the impact of the labeling program. As mandatory enforcement comes into effect, all models will be rated with at least one star. The goal of the labeling program, however, is precisely to encourage manufacturers to market a significant number of models at the three or four star level.

In the case of refrigerators, we assume that the effect of the labeling program will be such that the average refrigerator efficiency will be 10% higher than it would be in the MEPS Only case. This corresponds to the situation where every model that remains after standards imposed also moves up a ‘half star’ in ratings. Equivalently, this level of efficiency would be achieved if half of the remaining models sold were a full star level higher than they would be in the absence of a labeling program.

For air conditioners, we also assume that efficiency levels for some models go beyond the requirement of MEPS. In 2009, we assume that the market will be divided evenly into one-, two- and three-star models, with the two and three star models just meeting the efficiency requirement of 2.5 and 2.7 EER respectively. In 2011, the one star models are eliminated. In this year, and 2012, we assume that the market is composed of 33% 2.5 EER (two-star), 33% 2.7 EER (three-star) and 33% at 2.8 EER (the minimum LCC level). Finally, in 2013 and beyond, the 2.5 EER will be eliminated. We then assume that the market will be divided evenly between models of 2.7 and 2.8 EER.

Market Forecast

Currently, about 4 million refrigerators are sold in India each year. Although the market does contain a component due to replacements of old refrigerators, growth is dominated by the entrance of households to the expanding middle class. Total sales of refrigerators in the years 1997-2002 was taken from a recent report [6]. For 2003-2008, we relied on an estimate of sales provided by Euromonitor [3], a marketing research firm. These two sources combined indicate a ten-year average growth rate of 5.9% per year. We assume that this rate of total sales will continue throughout the forecast period. We assume that the market share of frost-free refrigerator will increase from the current rate of 18% to 30% by 2030.

The new and increasing residential customer base for air conditioners has caused dramatic growth in the industry in recent years at rates of more than 20% per annum, according to RAMA. Growth peaked in 2003-2004 at 25%, and has since come down a bit, to 20%. The residential portion of the market grew from 50% to 58% percent over the data period. Sales in 2003-2004 totaled about a million units according to RAMA, and reached 1.5 million by 2005-2006. While we believe the RAMA data to be accurate, a long term forecast based on recent years is difficult. The Indian economy is expected to grow rapidly over the next few decades, but it is hard to be sure whether the current extremely high rates will continue. Therefore, we take the conservative approach and assume that sales will continue to grow, albeit at a more moderate level. Specifically, we assume a 15% growth rate over the next few years, to 2010, after which we forecast that it will stabilize at 10% per annum. The fraction of window shipments is estimated at 60% by RAMA, and is assumed to persist throughout the forecast.

We assume that the fraction of air conditioners which are sold to residential customers will continue to increase throughout the forecast period, at a rate of 2.5% per year, or somewhat lower than the growth rate over the last few years. According to this assumption, the residential market share will reach 64% by 2010, and 82% by 2020.

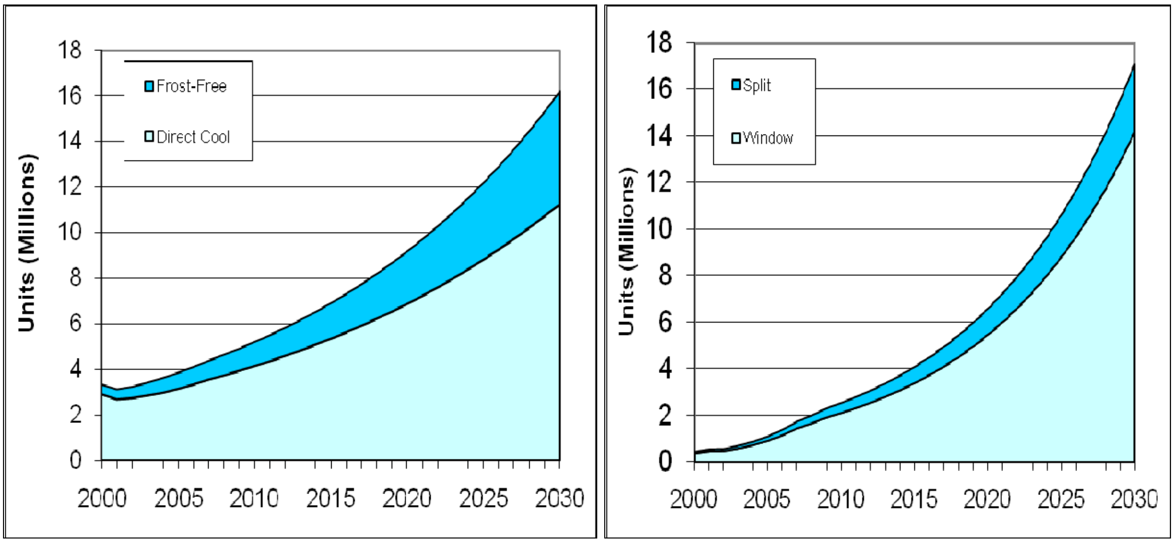

Figure 2 Refrigerator and Air Conditioner Shipments 2000-2050

National Energy Consumption

When regulations take effect and are stepped up, the average efficiency of products sold increases, but products installed before the new rules become effective are not affected. The number of affected and unaffected stock in each year is tracked by a lifetime accounting model that considers the lifetime of the products and when old inefficient products are replaced with new more efficient ones. Shipments figures allow for an estimate of the total stock of appliances when combined with a retirement function. The retirement function we use is a simplistic one: we assume that the mean life of a refrigerator or air conditioner in India is 15 years, and that units are retired and replaced with an equal probability between the 10th and 20th years after installation[5]. Energy savings is provided by calculating the total energy of the stock in the regulations scenario and comparing it to the *base case*, or 'business-as-usual' scenario. The total energy consumption (*NEC*) of the national stock of products in year *y* is given by:

$$NEC(y) = \sum_{age} Stock(y, age) \times UEC(y - age)$$

where the *UEC* of each cohort is determined according to the year of purchase *(y-age)*. For refrigerators, the UEC is estimated from the scenario description above, and UEC is calculated using the UEC for each star category, weighted by the market share of each. For air conditioners *UEC* is given for each scenario according to the following relationship:

$$UEC'(y) = UEC_{Base}\ (y) \times EER(y)_{Base}/EER(y)'$$

The *UEC* in the base case is assumed to remain constant in time for each type of consumer, but decrease overall due to the growth in the fraction of air conditioners used in homes. The results of the NEC for each scenario are shown in Figure 3.

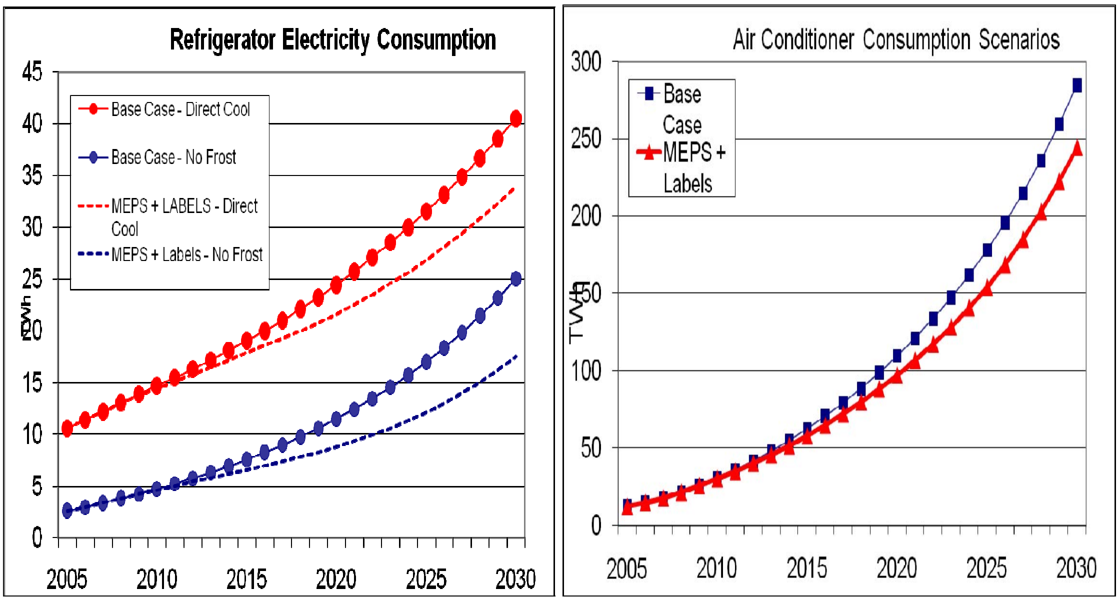

Figure 3 –Air Conditioner Electricity Consumption Scenarios

Several important features can be noticed in Figure 3. First, currently, the consumption of direct cool refrigerators is about three times as high as that of no-frost units since, although these refrigerators use less energy per unit, they dominate the market. As the forecast proceeds, the energy consumption of both products rises fairly rapidly, driven largely by new households entering the refrigerator market. Because the market share of no-frost refrigerators is growing, the energy consumption is growing more rapidly. By 2030, the consumption of surviving direct cool units is larger, but only by about 60%. Overall, in the base case, electricity consumption from Indian refrigerators will increase significantly, with a four-fold increase for direct cool and nearly a tenfold increase for no-frost. Total electricity consumption for refrigerators is estimated at 13.2 TWh currently, but is projected to be 65.5 TWh by 2030.

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[5] This is an approximate assumption, since repairs that significantly extend the lifetime of room air conditioners are common in India. The efficiency of extended-life units is expected to degrade. This is likely to affect baseline as well as high efficiency units, however. Therefore, while we acknowledge this point as having an impact on total consumption, we do not consider it has having a significant effect on net savings.

For air conditioner, the most obvious feature is the dramatic growth in consumption that is expected to occur between 2005 and 2030. This growth arises from a simple extrapolation of current sales, and the assumption that sales growth will continue at relatively high rates, although much lower than current rates of 20% per year. By 2020 most of the market will consist of units sold after the implementation of the MEPS and labeling program. Table 9 summarizes electricity consumption and savings results. The results show significant savings in percentage terms for both appliances by 2020, and even more so in 2030. Percentage savings are higher for refrigerators, because refrigerators generally afford more improvement at lower cost (from straightforward insulation measures). In absolute terms, however, by 2030 electricity savings from air conditioners are many times larger than that from refrigerator, due to the high consumption and rapid growth of this appliance. In order to better put these savings in context, we note that the total savings of 18 TWh in 2020 corresponds to 1.4% of total national electricity demand in that year, according to a recent report [7].

Table 6 – Electricity Consumption and Savings Results 2020 and 2030

Annual Savings	**Refrigerators**		**Air Conditioners**		**Total**	
In Year	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
	TWh		TWh		TWh	
Base Case Demand (TWh)	36	66	110	285	146	351
Policy Case Demand (TWh)	30	51	97	245	128	296
Annual Savings (TWh)	6	14	12	41	18	55
Annual Savings (Percent)	15%	22%	11%	14%	12%	16%
Cumulative Savings from 2009	15	64	58	321	73	385

Conclusions

This paper has considered the impacts of standard and labeling programs for refrigerators and air conditioners recently implemented in India. These appliances are both major consumers of electricity in India, with rapidly growing markets. The growth in air conditioner sales is particularly impressive. We can confidently conclude that the scheme as formulated by BEE is likely to be quite effective, and will save a significant percentage of electricity used by these end uses by 2020 and 2030, when virtually all of the stock will have been installed under the standards regime. Having said this, it is clear that there is room for increased stringency. First of all, the refrigerator standards set seem to have concentrated on frost-free units, and appear to be somewhat lax for direct cool units. Even though frost-free models are increasing in market share, and are much more energy intensive, our analysis finds that direct cool refrigerators will dominate electricity demand, because of their traditional dominance of the market (which may persist for some time due to their low price).

Improvement of efficiency of refrigerators and air conditioners in India is likely to be quite cost effective to Indian consumers. Our analysis finds that adoption of even the highest efficiency levels lower the life-cycle cost relative to the current baseline. This result holds for air conditioners as well, except for the very highest efficiency levels, and only for residential consumers, with the assumption that there is no increase in residential marginal electricity prices, which is unlikely. The cost-effectiveness analysis finds that in general, there is room to even further increase efficiency through the standards and labeling program. Updates in the scheme beyond those already announced by BEE are of course likely, and we hope that the Indian government would consider significantly increasing efficiency levels beyond those identified in the current scheme.

Finally, we note that an analysis such as the one we have conducted here makes a significant assumption about the effectiveness of the program, namely that updates will be issued on time, that compliance with the program will be good, and that a significant enough effort will be placed on publicity and education campaigns (including retailer training) to ensure a strong response to labels by consumers. We have already seen a delay in the program becoming mandatory, effectively resulting in several years in delay of impacts, in which time millions of appliances were sold. We can be optimistic about effective implementation, but not inattentive. Given a relatively robust technical bases for Indian standards, whether or not the predicted savings are achieved will depend on political will, support for BEEs mission at the highest levels of the Indian government, as well as support from the international community of energy experts.

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CECED encourages fair competition among all appliance manufacturers

Gerhard Fuchs

CECED, European Committee of Domestic Equipment Manufacturers

CECED[1], the European household appliance manufacturer's association, has started a new Bilateral Verification Procedure to ensure smooth and fair competition among appliance manufacturers subject to the European Directive on Energy Labelling.

The Bilateral Verification Procedure, which became operational in September 2008, is based on the principle that its signatories are aware of the legal obligation with regards energy labelling regulations and standards and deems it important to carry out necessary tests to ensure to consumers that the information given on the label is accurate. According to the rules of the Bilateral Verification Procedure, signatories can check the correctness of the energy label declaration to accelerate clarification and correction of any alleged inaccurate energy labelling.
In case a challenge is started based on an assumed incorrect energy label declaration, the appliance in question will be checked and tested by a laboratory which is agreed upon and trusted by both parties. The procedure calls for completing a challenge in nine weeks. It is intended to create a benchmark on how market surveillance could be enhanced by proactive participation of involved economic stakeholders.

Participants do not want to take the responsibility of Member States in enforcing compliance with the energy label but they want to be part of information sharing and discussion. The Bilateral Verification Procedure is a clear cut procedure that can quickly solve conflict issues about energy efficiency and performance declarations thus ensuring fair competition within our association and promoting fair competition toward the outside.

All CECED direct members producing appliances subjected to the Energy Label Directive have already subscribed to the agreement. The Bilateral Verification Procedure is now open to any manufacturer or importer interested in reinforcing mutual trust within the industry community. [1]

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1 CECED represents the household appliance industry in Europe. Its member companies are Arçelik, Ariston Thermo Group, BSH Bosch und Siemens Hausgeräte GmbH, Candy Group, De'Longhi, Electrolux AB, Fagor Group, Gorenje, Liebherr Hausgërate, Indesit Company, Miele, Philips D.A.P., Saeco, SEB and Whirlpool Europe. CECED's member associations cover the following countries: Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CECED encourages fair competition among all appliance manufacturers

Responsibilities

Three parties are addressed by the EU Framework Directive on Energy Labelling (92/75/EEC) [2]:

- dealers,
- suppliers,
- EU Member States.

“Dealers” are obliged to attach the energy label to the appliances whenever they are displayed in showrooms. In addition, an information fiche has to be provided to potential customers and structured information has to be provided if offered via internet. The level of information detail is listed in the relevant Energy Label Directive for all concerned products.

“Suppliers” (i.e. manufacturers, their representatives in the European Union and importers or, in general: persons putting appliances on the Community market) have to supply the energy label with their appliances and have to inform consumers and the distribution chain about the relevant product characteristics. As set out in Article 3.3 suppliers “shall be responsible for the accuracy of the labels and fiches that they supply.”

“Member States” shall ensure that energy labelling is properly applied in their territory. In Article 8 it states that Member States “shall neither prohibit nor restrict the placing on the market of [the] household appliances” when provisions are satisfactorily applied. And “unless they have evidence to the contrary, Member States shall deem labels and fiches to comply with the provisions…”. But “when they have reasons to suspect it is not correct” then they “may require suppliers to furnish evidence” by means of information and test reports. The authority will then check the delivered documentation and decide about the next possible steps of investigation.

Measurement procedure and tolerance levels

Each year manufacturers conduct hundreds of measurements related to their own energy label declarations and those of competitors. They have excellent laboratory equipment and knowledge in performing tests. Additionally, manufacturers are often contracting external laboratories for testing mainly because of capacity reasons.
The EU energy label is based on the principle of self-declaration which gives the manufacturer full responsibility for the declared values. In order to verify and substantiate the declared values, manufacturers may decide to perform measurements in their own laboratory or to contract an external unit. The number of appliances used for this testing can be decided by the manufacturer, depending on the desired statistical robustness the manufacturer wants as the basis of his declaration. In order to ensure a declaration that can withstand challenges, manufacturers have to take into consideration measurement variations between the laboratories (lab-to-lab variations). Additionally, as no measurement is perfectly accurate, tolerance levels have to be considered in two ways: production tolerances and measurement tolerances. All these parameters turn the decision process of the appropriate energy label values into a very complex matter.

The measurement procedure itself and the tolerance levels are defined in the harmonized EN product standards as listed in the Official Journal of the European Union. [3]

For example, a tolerance level of 15% is valid for the measurement of the first model with respect to energy consumption of a washing machine. If the test result of that first model is higher than the declared value plus the said tolerance level of 15%, then another three models have to be tested. The average measurement result of those models must be lower than the declared value plus 10% in order to be compliant.

It is very important to note that once a declaration is made for certain types of appliances the manufacturer has to ensure the long term stability of this declaration. As production conditions in the factories may change over time it is up to the manufacturer to keep the appliances’ energy label values at a fixed level and in line with the declared values over a long period of time. This implies a great number of tests at high costs.

“Accuracy of the labels” and market surveillance

Enforcement of European labeling is a task of market surveillance authorities of Member States. In some countries, such activities are performed dynamically and information on tests and actions are published on the Internet. In other countries, Member States authorities are less active. This situation leaves a gap to be filled for manufacturers looking for a faster correction of energy label infringements as product lifetime in catalogues and certainly on the internet is usually shorter than the entire verification process.

Solving the issue bilaterally

CECED has developed an internal verification procedure which can be applied by manufacturers voluntarily. Within this procedure the participants acknowledge the significance of Energy Labelling as it is crucial that consumers have confidence in the information given by the Energy Labeling of all available appliances. Manufacturers wish to:

- compliance checks on a fair basis,
- accelerate the clarification process and
- correct proven inaccurate energy label declarations.

It is essential that within this voluntary procedure the participants are fully aware of the legal obligations. They have to carry out the necessary tests and make the declarations fully in line with the applicable regulation and standards.

The CECED procedure became operational on 15 September 2008. According to the rules of the procedure signatories can check and challenge the claims of fellow participants in order to ensure compliance. It is intended to accelerate the clarification by solving the issue bilaterally. Based on the test result delivered by an independent laboratory agreed upon by the concerned parties, a final decision is carried out. Manufacturers have to correct the labeling if proven wrong.

How CECED Bilateral Verification Procedure works

The Bilateral Verification Procedure is a stepwise process which leads to the conclusion that either the challenged declaration was correct or wrong. During the whole process decisions are taken in a transparent way and must be agreed upon by both parties. The complete verification process should not take longer than nine weeks. With respect to this it is essential to have a good involvement of external laboratories from the very beginning of each procedure started.
The Bilateral Verification Procedure consists of the following steps:

1. Opening of the procedure

   The manufacturer who suspects the correctness of the declared value directly informs the concerned manufacturer.

2. Settlement

   The technical experts of both parties immediately start the work. They will check the available data together and will try to find an agreement. If it is agreed that the label declaration is wrong the process stops, but remedy actions have to be applied.

3. Selection of a testing laboratory

   If there is no agreement between the challenging and challenged party, a laboratory able to perform the test within a predefined timeframe has to be selected.

4. Test

   The test is carried out. Interrested participants can attend this phase.

5. Test result

   The laboratory informs the manufacturers about test results.

6. Consequences

In case of a wrong declaration the manufacturer has to correct the label data and inform his business partners.

It is essential that a fixed time frame is given for each of the steps. The total time should not exceed nine weeks. The "looser" of the procedure has to pay the cost for testing the appliances. The cost is depending on the number of appliances tested but typically in the range of several thousand Euros.

Concluding remark

The Bilateral Verification Procedure is a tool to encourage fair competition among all appliance manufacturers.
Industry's intention is to be part of information sharing and discussion and CECED is convinced that the experience gathered with the procedure is very valuable. Experience gathered in the process should be taken into account when specifying new market surveillance instruments. CECED believes that with this procedure fair competition among all manufacturers can be encouraged.
CECED is participating in the "ATLETE" market surveillance project of the EU-Commission and will share the experience gathered by the "Bilateral Verification Procedure" within this project. [4]

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UK Government Standards Process for Energy-using Products

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Abstract

In the most recent statement of UK Energy Policy, the Energy White Paper 2007 (EWP), the UK Government made a new commitment: to annually publish forward-looking Government standards for the energy performance of energy using products.

These will set out the Government's view of how product performance will need to improve over the next 10-20 years in order to meet national climate change and sustainable development objectives, and offer a unique opportunity to consult with a wide range of stakeholders about the evidence base informing government decisions, targets for product policies and a package of policies that the government expects will enable the UK to meet its climate change targets. This detailed policy analysis work is unique in Europe, and provides many valuable lessons for all involved.

The Government standards documents are based on the UK Market Transformation Programme (MTP) evidence base. MTP, which support UK Government on energy using products, currently employs about 30 experts, working on 20-30 energy-using products (domestic and non-domestic). The MTP evidence base includes information about ownership and sales of the main energy-using products, relevant technologies and efficiency trends and other aspects, such as usage factors and is reviewed and updated annually.

The paper will describe the Governments standards process and indicate how this process could transfer to the development of policies at the EU level, for example for the EuP Directive.

Goals of the Government Standards Process

As part of its commitments in May 2007's Energy White Paper (EWP), the UK Government, via its Market Transformation Programme (MTP), is obliged to "publish a series of consultation papers setting out [its] analysis of how the performance of energy-using products will need to improve over the next 10-20 years, including proposals for product standards and targets to phase out the least efficient products.... These will be updated annually."

Equally important as the formal obligation is that the Government standards offer a unique opportunity to involve a wide range of stakeholders in the preparation of product policy and to consult with this wide community about the evidence base informing government decisions, targets for product policies and a package of policies that the Government thinks will help the UK meet its climate change targets as defined in the EWP. This paper sets out the approach for the preparation and publication of Government standards documents for energy-using products in 2009.

The Government standards documents are based on the MTP evidence base. This evidence base includes information about ownership and sales of the main energy-using products, relevant technologies and efficiency trends and other aspects, such as usage factors. This evidence base is reviewed and information updated on an annual basis. The guiding principle for the UK Government standards process is the premise that consultations need to happen on the evidence that the Government plans to use in its upcoming policy decisions.

The first papers setting out the standards were published from December 2007, for last year's consultation process. A three month public consultation period followed. The final standards (http://www.mtprog.com/cms/whitepaper/), revised in light of consultation responses, were published in July 2008. The process of producing, presenting and consulting on the standards is being revised and refined to make the documents more accessible to stakeholders and useful to policy makers in 2009.

In 2009, MTP added information about important, previously uncovered aspects such as cost differentials for more energy efficient products. MTP also learned that its evidence base, while valid overall, had some gaps in areas that were not thought to be important previously, and some products also had gaps in their evidence. This needed redressing, as there is no value in publishing consultation documents if the Government already knows that the evidence on which these documents are based is not the evidence it plans to use going forward.

The presentation of the evidence has also been improved to make it easy for a wide stakeholder community to review the information the Government will use to decide on product policy. The Government standards document in 2009 consists of a single, cross-cutting overview focusing on key elements of the product policy preparation process, with summary product-specific information in an annex. Further information about the underlying evidence has been published on-line (www.mtprog.com) in briefing notes – each setting out the key factors for a product area.

2009 Government Standards Process

This section outlines the organization, approach and contents of the Government standards documents prepared in 2009 by MTP on behalf of the UK Government. As of June 2009, the documents prepared have entered a consultation phase until September 2009, whereupon MTP will update the documents based on stakeholder feedback.

Approach

The approach taken by the teams of experts for the preparation of the Government standards documents is as follows:

1. **Reviewing & upgrading evidence base, including cost data**
   The first task for the technical expert teams was to review existing MTP evidence, including modeling inputs and assumptions, and to expand the evidence base where needed to increase robustness. Specific topics in this expansion were the addition of cost data to the evidence base and models, and extension of the cut-off point for impacts beyond 2020 (to 2030). As part of this review, MTP models were updated to reflect new evidence as well as the evidence available last year but not included then in the final version of the documents.

   This task was conducted by technical expert teams, guided by product analysts.

2. **Preparing clear overviews on the evidence base (Briefing notes)**
   Once evidence was reviewed and upgraded, it was reported in briefing notes that provide stakeholders and the public with accessible information about the evidence used for the government standards and consequent government decisions regarding product policy. Templates were developed, which required that technical experts provided an overview of their information and assumptions, fully referenced, and in a common structure (between product groups).

   Briefing notes presenting evidence for public consultation will be cleaned-up versions of internal evidence reports; templates will be essentially similar.

   This task was conducted by technical expert teams, guided by product analysts.

3. **Analysing policy options including specification of target levels for policies**
   Based on collected evidence, technical experts assessed various policy options. This included the current key product policies (standards and labels) as well as other policies (Building regulations, CERT, etc). Where possible, the analysis included an analysis of likely product requirements for each relevant policy, with associated costs and benefits on the level of single products, and variations such as more or less stringent requirements.

This task was conducted by technical expert teams, guided by product analysts.

4. **Prepare policy package & assess impacts: costs, benefits, CO_2**
The analysis of policy options led to the development of a package of policies, which are a coherent set of identified policies that, combined, deliver UK energy-using products targets. The policy package was modeled to assess its overall energy, cost and CO_2 impacts.

   Modeling of overall impacts required several assumptions regarding aspects like population growth, CO_2 intensity and costs of energy. These aspects were harmonised with Defra & DECC / BERR data. MTP briefing notes specifying MTP-specific assumptions for these factors were updated or withdrawn.

   This task was conducted by technical expert teams and product analysts jointly, with support from MTP's modelling team and LC leads.

5. **Draft public consultation document**
With the evidence presented in briefing notes and models updated, a single consultation document was prepared. The content of this document is described in a separate section.

   This task was conducted by product analysts, supported by technical expert teams, MTP's modeling team and LC leads.

6. **Publish consultation documents & supporting evidence (briefing notes, models)**
Once documents were drafted and cleared by LC leads and SEUP, they went through a consultation with other Government departments and Defra's internal sign-off process. The consultation document was published on ________. Briefing notes have been placed online for public review; it is to be decided whether this will happen as soon as documents are ready or only when the consultation document is published.

   This task was conducted by SEUP, supported by product analysts and LC leads.

7. **Consultation phase**
The consultation phase will take place from June - September 2009. Outreach to specific stakeholder groups is planned to encourage participation of (especially) non-industry groups in the process. Specific tools like workshops explaining the policy preparation process and training in the use of MTP evidence may be made available for these stakeholders.

   During the consultation phase, MTP will be available to respond to questions by stakeholders requesting a clarification of the documents and the underlying evidence.

   This task will be conducted by product analysts and LC leads, supported by SEUP.

8. **Update documents and publish final policy briefs**
Following the consultation, responses must be analysed and a decision taken whether the evidence base, policy package and/or consultation document needs updating. The updated version of the documents, accompanied by a response to comments, must then be published, following the same sign-off procedure as for the consultation document.

   This task will be conducted by product analysts, LC leads and SEUP jointly.

Contents of the Documents

Primarily Cross-Cutting Overview

The primary consultation document, also known as the cross-cutting document, discusses the role of product policy in the context of the wider energy saving commitments. Using the latest projections, it explains where the largest savings are expected, and where more effort will be required both to 2020, and beyond. Suggested future priorities for Government in this area are also discussed.

The main scenario for the cross-cutting document is the policy scenario, describing the package of policies with which the government could achieve its targets. The policy scenario is based on a reference scenario, the latter setting out what would happen without new policies. Further, a baseline scenario will be added which describes the EWP or Climate Change Programme targets, for comparison with the new policy scenario. Finally, a fourth scenario will set a reference point for maximum savings.

Four scenarios:

- Baseline: pegged to EWP or Climate Change Programme target, updated for counterfactuals such as new information about installed stock and product usage.
- Reference scenario: takes account of underlying trends in markets and technologies and the estimated/implicit impacts of historical and current policy measures
- Policy scenario (including cost differential with reference): describes the package of policies with which the government can achieve its targets, over and above existing measures
- Best available technology (to be replaced by Least Life Cycle Cost after 2009)

The contents of the cross-cutting document are presented below:

1. Summary: The first part of the consultation document is a summary of the key issues. This is a one-page summary for high-level decision makers, accompanied by a somewhat longer summary (management report) providing a fuller overview over the evidence, if desired.
2. Context: A second section describes the position of energy-using products policy in the overall climate change policy mix, describing why the area is important and how its impacts compare to overall policy goals.
3. Coverage: The next section describes the products covered in the report, with brief descriptions of their policy implications, and those not covered, with a rationale for both.
4. Policy scenarios: Following this, a section describing the main policies is added, with an overview of the policies included in policy packages per product group.
5. The next cross-cutting overview describes progress against targets, which could be the EWP target or the Climate Change Programme / Bill (to be decided). In this section, overall impacts realised are tracked against planned ones, to justify the existence of the programme and show its contribution to climate change policy goals.
6. Long-term policy gap: The last cross-cutting section looks at longer-term targets, especially in view of the new long-term climate change targets being proposed. Since this target will require much further-reaching energy savings than currently projected, a forward-looking analysis is needed that looks at the policies that could potentially contribute to those far-reaching targets.

Annex Product-Specific Information

The cross-cutting document is supported by 9 annexes, covering the key background and performance standards for the specific product groups. Annexes contain product-specific details, highlighting key aspects of product areas in brief overviews (four page max per product area, but preferably shorter). The overview sets out:

1. Brief summary (1/2 page max)
2. Scope
3. Main trends in product ownership / usage / sales / technology / efficiency / costs
4. Key assumptions
5. Policy options considered for the product area: EuP / EL / …. (with timeline)
6. Policy scenario: description / rationale / impacts (costs, benefits, CO2)

Government Standards Briefing Notes

Further detail on product area assumptions, policies and scenarios are provided separately in a series of Government Standards Briefing Notes (GSBNs), available on the MTP website. GSBNs were prepared in sets of four documents for each product defined by MTP. The four documents are as follows:

1. Key Inputs – This document provide details and reference sources of the underlying data in the model, along with the key assumptions used in the model.

2. Reference Scenario – This document projects what is likely to happen to energy consumption of each product if no new policies are implemented. All agreed and formally signed-off policies are included in the reference scenario.

3. Policy Scenario – This document projects what is likely to happen if a defined set of new product-specific and related cross-cutting policies were implemented. The policies in the policy scenario have not yet been agreed or funded but represent those policies which are expected to be introduced as well as likely future revisions to existing policies and, in some cases, novel policy options.

4. Best Available Technology Scenario – This document projects what is likely to happen if the best available technologies on the (current and future) market were bought or installed from now on. The best available technologies are defined as the most efficient, or lowest energy consuming technologies available on the market, or those which are close to market.

Organisation

The preparation of the government standards documents requires the involvement of various teams of experts. Key experts involved are:

Product analysts

Product analysts lead the development of the documents on a day-to-day basis. They coordinate the detailed analyses of products with technical expert teams, taking the lead on policy options, review and edit outputs of these teams, draft the core consultation document and coordinate with SEUP.

Technical expert teams

Technical expert teams conduct the detailed analysis of product areas, reviewing and upgrading evidence, editing modelling inputs and analysing policy options for the various products.

MTP modelling team

MTP modellers prepare the models used to analyse the impacts of policy packages and run the final analysis of these impacts. They also support, with model runs, discussion with SEUP about an optimal policy package.

Experts from the MTP management team supervise the work of product analysts and technical expert teams, and guide the preparation and assessment of policy packages and the final consultation document. Defra's Sustainable Energy-Using Products unit oversees the preparation of the documents, review and approve these, consult with Other Government Departments and prepare the sign-off and publication of documents. Selected external experts will challenge and scrutinise policy packages.

Lessons Learnt with the Government Standards Consultation Process

Last year's consultation process, which was the first-ever for this policy area, has provided valuable experiences – about aspects that worked well, as well as points for improvement. No formal evaluation was conducted, but discussions among the team and with stakeholders have led to a number of lessons for future consultations:

- Different stakeholder groups require a different type of information, at different levels of detail, to be in a good position to effectively respond to a consultation document. Some stakeholders require detailed information about the products involved, others are more interested in the environmental or societal impacts of products and product policy. Consultation documents need to facilitate this, and be able to provide various levels of detail to the stakeholders that need these.

- Information is easier to understand if it refers to common metrics. Market shares in various product classes and energy demand over time are common ways of describing product efficiency, making it easier for non-technical stakeholders to grasp key messages quicker and more effectively.

- Information needs to be presented in a compact format. Although product policy is based on detailed analyses (of technologies, product performance, efficiencies, costs, etc), it is essential to keep the overall volume of consultation documents manageable – as no stakeholder is capable of reading and commenting on hundreds of pages of detailed information.

- Present information in a context, so that less-involved stakeholder understand what product policy contributes to the overall mix of climate change policies, which policy mechanisms are used and how much energy and carbon emission savings are expected from each product area. This enables a stakeholder to form an informed opinion of the relevance of each individual product policy, to facilitate better responses to and more stakeholder involvement in a consultation process.

These lessons have been taking into in the current round of consultation documents, and are expected to improve stakeholder engagement, especially from less experienced ones and those that focus more on consumer or environmental impacts of products, rather than their technology.

Potential Use for Developing Policies at the EU Level

The experience gained with the Government Standards consultation process in the UK provides some valuable lessons for Europe:

- An established evidence based, structured in a standard way across products and maintained regardless of whether a policy decision needs to be taken soon or not, is a very valuable resource for informing stakeholders and the public about the evidence that led to policy initiatives, and for prioritising regulations for one product over another.

- Developing such an evidence for the EU would allow the European Commission and Member States to assess, on an ongoing basis, which policies would be needed most urgently, and allow stakeholders to review this and provide better-informed opinions about it.

- It would also create a tool for tracking progress achieved with energy-using products policies in a systematic way, and highlighting the potential for future improvements of products, driven by regulations, market forces and/or consumer expectations.

- A European evidence base would allow for a much better comparison of national initiatives with those at the European level, and via this route, also a better comparison of initiatives between Member States. The use of common metrics and agreed ways of assessing the expected impacts of policies would enable a better-informed debate about policy priorities and to assess which policies have delivered on energy savings and CO_2 emission reduction.

- Finally, the act of drafting consultation documents requires that policy makers think, in a structured way, about the policies that can be used to initiate market transformation for energy-using products and how much each of these can contribute. This internal process helps policy makers to focus their attention on those products and policies where their efforts are most needed, and thus in maximising the impacts of their work.

Overall, there are many good reasons for developing a European-wide evidence base and a consultation process about the evidence and policy options available for energy-using products. The UK experience in this process can be helpful in setting this up, taking into account that a consultation process needs to be tailored to the needs of the audience, and that differences between Europe as a whole and the UK need to be taken into account.

Energy labeling in White Goods Worldwide

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Abstract

This paper gives an overview on various Energy Efficiency Labeling schemes for Major Domestic Appliances in countries, where GfK runs retail audits, i.e. measures the retail sell-out to final consumers and has currently energy label information per product available. Evidence given, impact on market demand and prices can be analysed. If not stated otherwise, the source of information is proprietary GfK Retail and Technology research findings.

Global Warming and Energy Efficiency

Global Overview on CO_2 emission[1]

The Klimaschutz-Index (Climate Protection Index) 2009 published by the NGO German Watch shows that the 10 major CO_2 emitters account for two thirds of emissions but only 50% of the global population (see fig.1). The USA account for a far over-proportional 20% of CO_2 emission with only 4,6% of the global population. China has closed up to the US in terms of CO_2 emission, but has also a 20% population share. Russia accounts for almost 6% of CO_2 caused by 2% of the global population. India has overtaken Japan and ranks #4 with 4,5% of CO_2 and 17% of global population. The relative emission per capita in India is of course still much lower than in Japan. Japan comes in as #5 with more than 4% of emissions and 2% of population followed by Germany with 3 and 1,3% respectively. Next are Canada, Great Britain, South Korea and Italy with each less than 2% of global emissions.

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[1] www.germanwatch.org, Klimaschutz-Index 2009, page 13

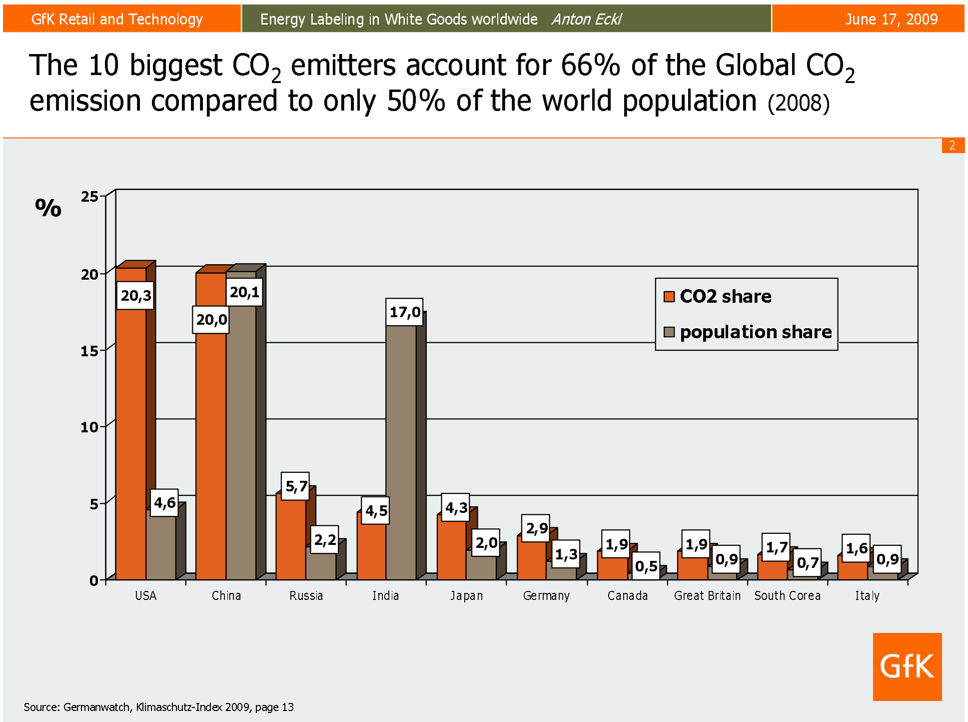

Figure 1: Global CO_2 emission and population share compared

Figure source: www.germanwatch.org, Klimaschutz-Index 2009, page 13

Energy Efficiency – The Way to keep Global Warming in Check?

According to Fatih Birol, chief economist of the International Energy Agency, energy efficiency must play a major role when it comes to reducing CO_2 as planned until 2030. Energy efficiency will have to contribute 54% compared to 14% through improved CO_2 capturing in carbon power plants or 9% through an increased usage of nuclear fuels.[2] According to Claude Turmes, member of the EU parliament, energy efficiency is even more important than the increased use of renewable energies to meet the CO_2 targets.[3]

Household Energy Consumption

Although the household energy consumption pattern is an important information to outline energy efficiency strategies for home use, comprehensive information is somewhat hard to find. For this paper I refer to a statistic provided by the Status Report 2006 on Electricity Consumption in the enlarged European Union (see fig. 2).

Almost one third of household electricity consumption can be accounted to Major Domestic Appliances such as Washing Machines and Cooling/Refrigerators in EU-15. The latter take the lion's share of 50% of White Goods consumption together with freezers as both usually run 24 hours a day and are present in each and every household. Hence the replacing of inefficient cold appliances has the highest impact on overall energy savings.

2 DIE ZEIT, February 12 2009, page 20, Fritz Vorholz: Irrelevante Debatte

[3] European Union Sustainable Energy Week 2009, Panel Discussion February 10 2009

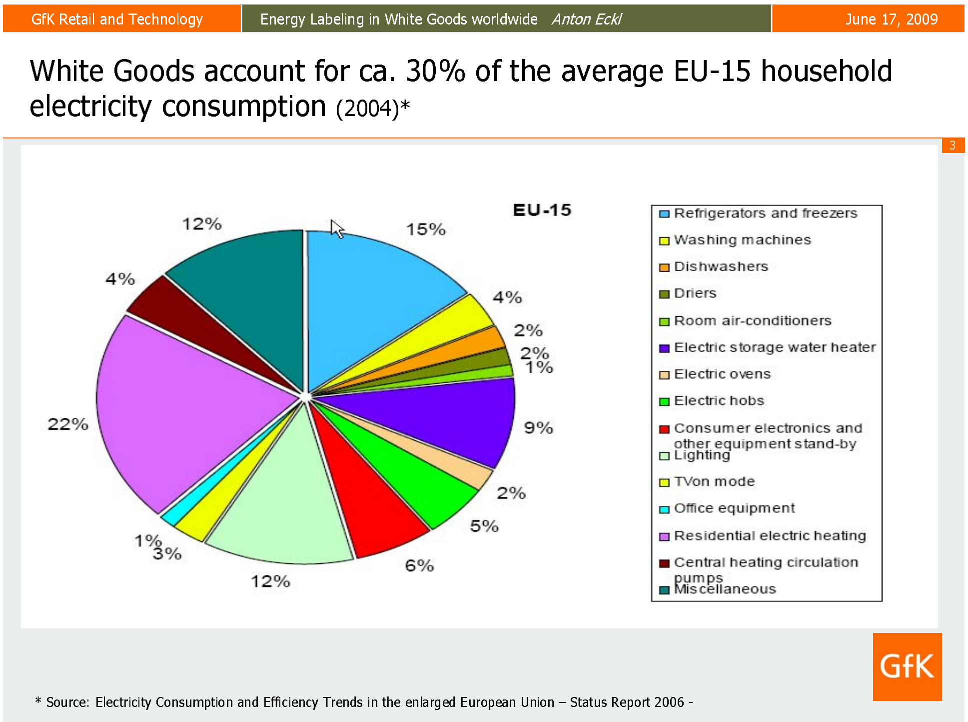

Figure 2: Household energy consumption pattern

Figure source: Paolo Bertoldi/Bogdan Atanasiu, Electricity Consumption and Efficiency Trends in the enlarged European Union – Status Report 2006, EUR 22753 EN

Characteristics and dynamics in the market for energy-efficient appliances

Energy Efficiency and the consumer purchasing process

How relevant is energy efficiency in relation to other purchasing criteria? Consumers rank ‘energy efficiency’ 2nd most important after ‘price’ in highly industrialized Japan and after ‘quality’ in the developing country Brazil according to an international retailer survey conducted by GfK in 2008 (see fig. 3). In Europe ‘energy efficiency’ ranks only #3 behind ‘price’ and ‘quality’ of the product. Within Europe we see clear country patterns. ‘Energy efficiency’ ranks #1 together with ‘quality’ in Germany whereas it ranks only #4 in the UK. These findings coincide with the sales success of highly energy-efficient products in Germany and the UK.

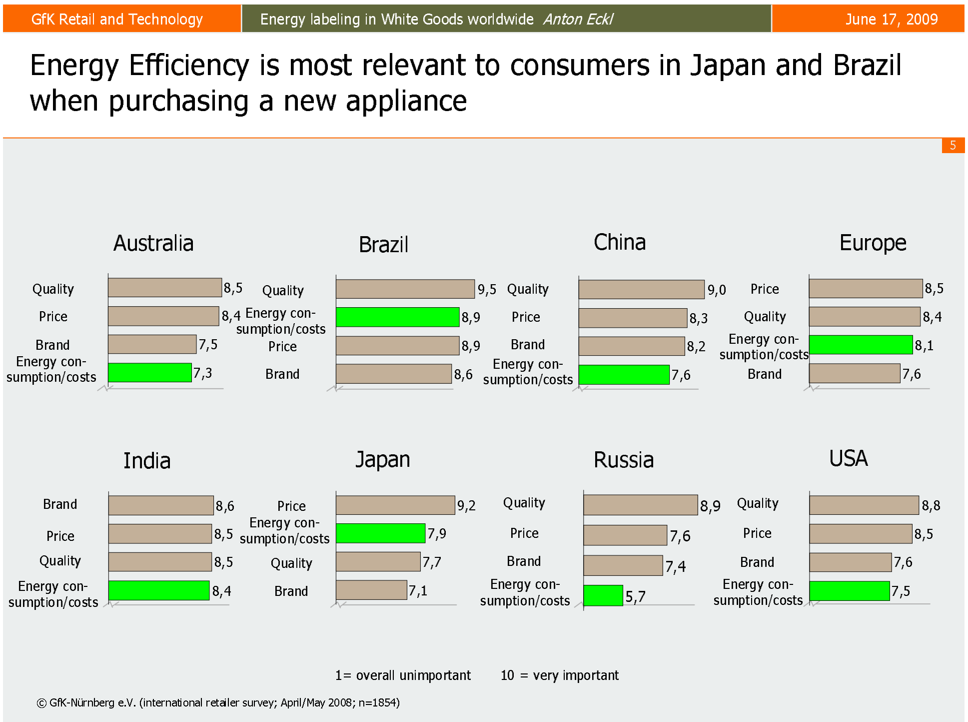

Figure 3: Relevance of Energy Efficiency in the consumer purchasing process

Figure source: GfK Nürnberg e.V. – Global View of Retailers on Energy Efficiency Labels – April/May 2008

Mid-term impact of better Energy Efficiency on the sold assortment's average consumption

The average consumption index reflects very well the efforts of the industry to offer more and more efficient appliances and the willingness of the European consumers to buy them. This index fell from 2003 to 2008 from 100 to 91 (dishwashers) respectively 85 (freezers) (see fig. 4). In other words: the average appliance sold in 2008 uses up to 15% less energy compared to 2003. Improved energy efficiency overcompensated the parallel trends towards the more convenient but also more energy-consuming Nofrost technology as well as the trend towards bigger appliances in general. Only in washing machines we see a reversal of the consumption index starting in 2008 because of the growing demand for bigger drum sizes across Europe.

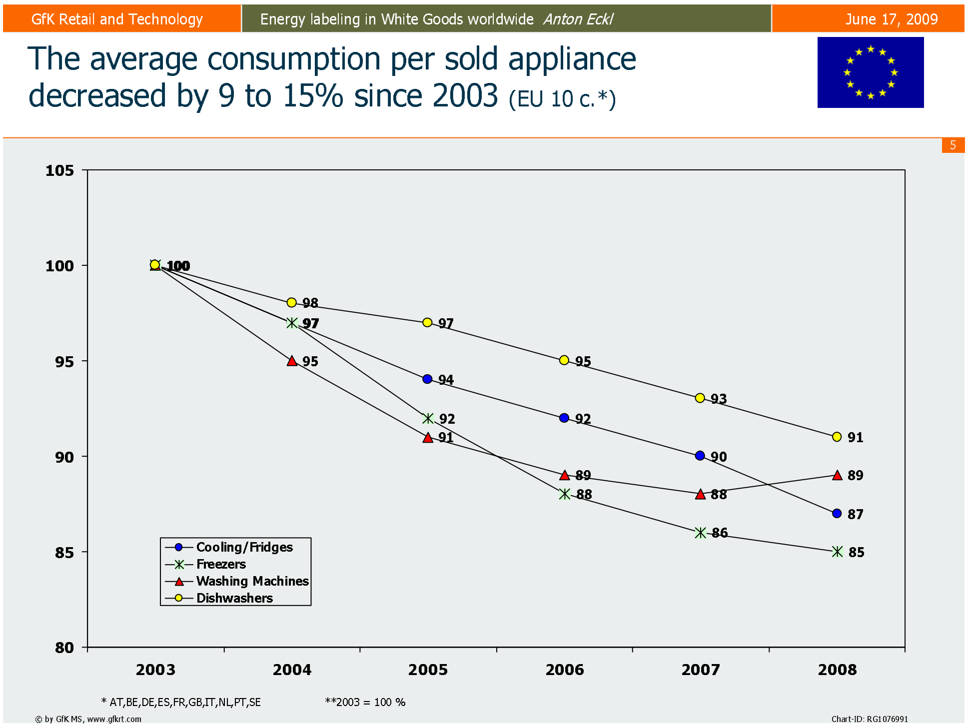

Figure 4: Sales-weighted average energy consumption index

Capacity-adjusted (consumption per kg loading capacity) we still see a strong decrease of the consumption index by -20 points over the last 5 years (see fig. 5). Yet the consumers' washing behavior has a major impact as to which line (fig.4 or fig. 5) represents the more realistic scenario for the in-use energy consumption of washing machines: Are the bigger drums really used to the full loading capacity leading to a reduction in the number of wash cycles or not?

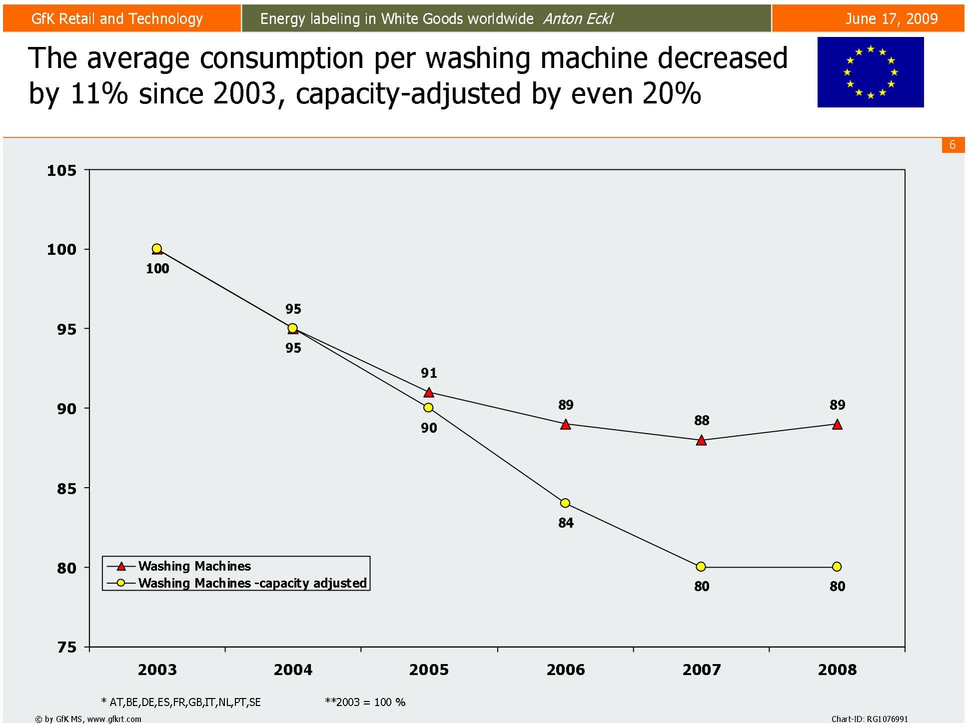

Figure 5: Sales-weighted energy consumption index for washing machines (average vs. capacity-adjusted)

Supply and Demand for energy-efficient appliances compared

Not only the demand-side is important to spur a development towards better efficiency. The supply of the right assortment in width and depth of products is equally important. The offer of A+ and A++ appliances in Germany is unrivalled (see fig. 6). More than 1.600 different high-efficiency appliances are available nowadays compared to only 450 in 2004. Along with the extended offer we see an ever increasing sales share of those appliances. The same is true for freezers, where the market is much tighter in terms of assortment, but the success of A+ and A++ with a sales share of 55% even more impressive.

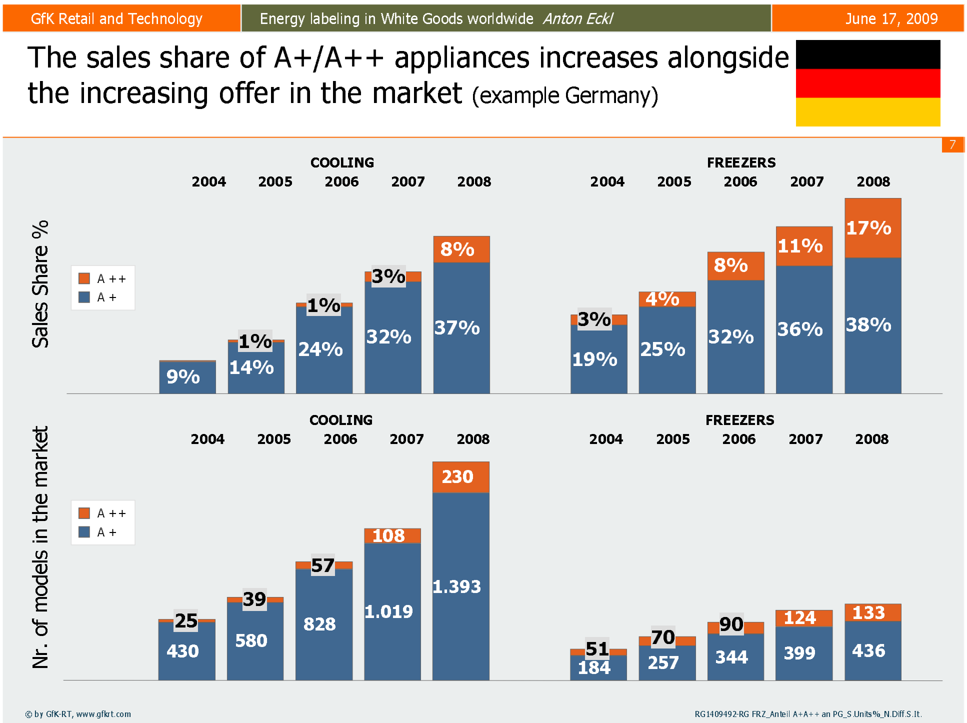

Figure 6: Development of supply (number of models) and demand (sales share) for A+ and A++ cold appliances (example Germany)

Long-term Price Development Study

With the increasing offer of highly efficient appliances prices tend to come down as well. When looking at the homogeneous segment of static Bottom Freezers we can state that the price premium of A++ appliances came down from 39% in 2003 to 29% in 2008 (see fig. 7). Usually those appliances come with additional features like Stainless Steel Doors, Digital Displays, Fresh Zones etc. contributing to the price premium as well.

The price of A appliances came down even stronger than in the case of A++ turning this segment into mere commodity.

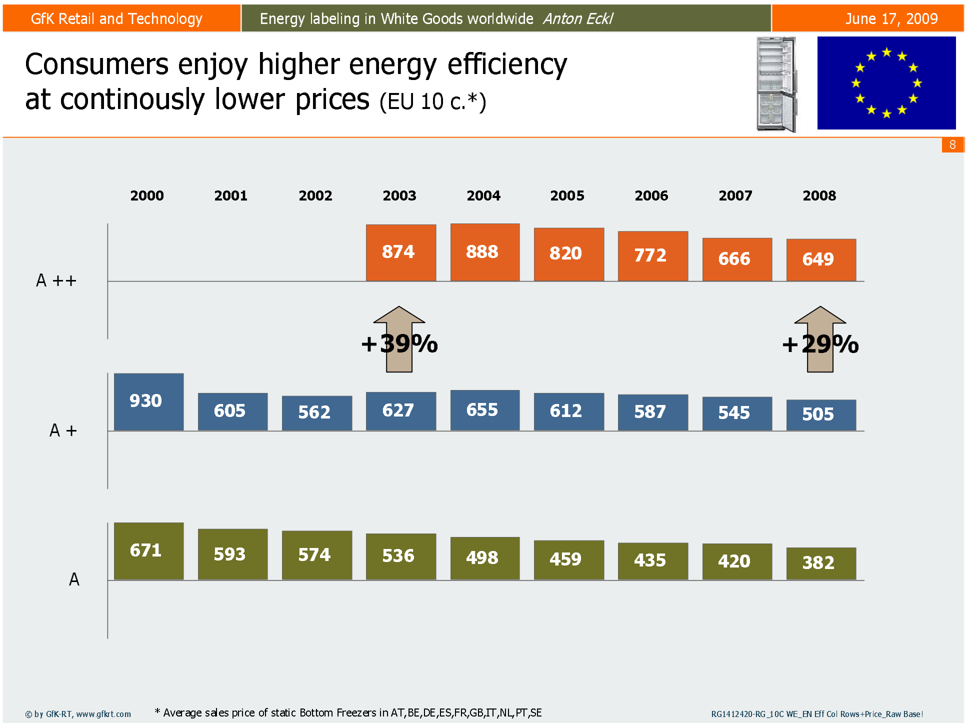

Figure 7: Price development of different energy efficiency classes for static Bottom Freezers in Europe (EU 10 c.)

Energy labeling programs in major markets outside Europe

The following chapter refers to selected countries with energy labeling schemes where GfK Retail and Technology runs retail audits.

Australia

The Energy Star Rating was first introduced in the states of New South Wales and Victoria in 1986. It is compulsory for washing machines, tumble dryers, dishwashers, cooling/refrigerators and freezers as well as air conditioners. After its revision in 2000 it classifies appliances from 1 (bad) to 6 (good) allowing for intermediate 0.5 steps.

8 years after the revision the label can still be considered future-proof as only very few appliances sold are rated 5 or better (see fig. 8). In tumble dryers the best rating is only at 2, but those are usually cheap products used in the rare case of a rainy day in Australia. Hence it would not make sense for consumers to invest more in a more efficient appliance.

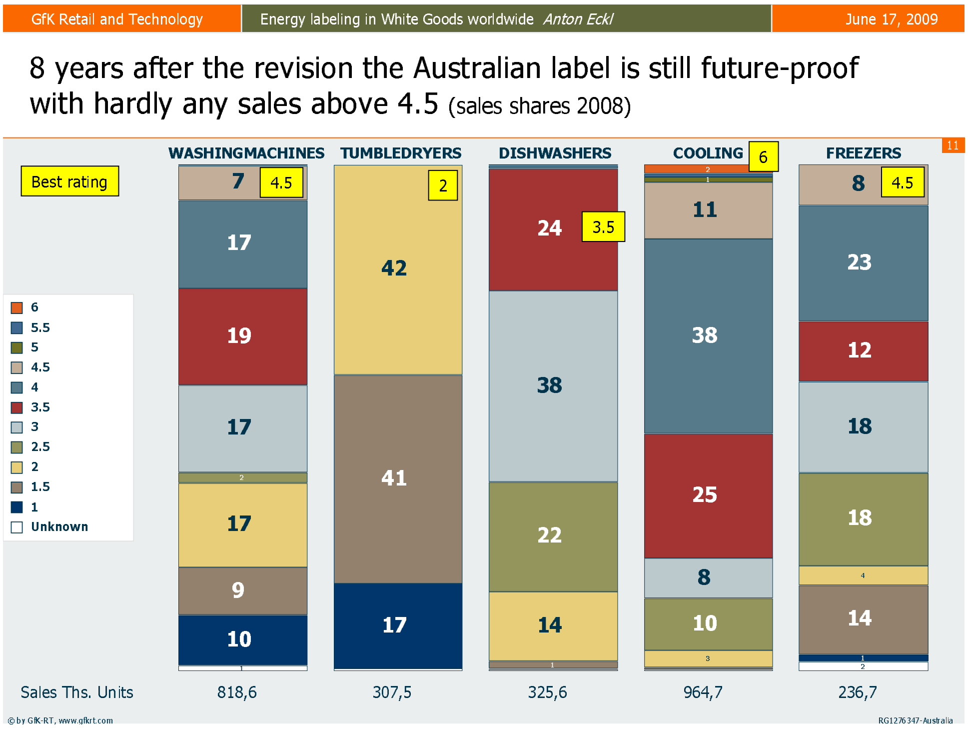

Figure 8: Sales structure by Energy Star Rating for Major Domestic Appliances in Australia 2008

Japan

The Japanese Top Runner approach was introduced in 2003 and due for revision already in 2006, when 2010 was set as the new Standard Target Year (TY) . It is compulsory for cooling/refrigerators and freezers, cookers/ovens as well as air conditioners. The label discriminates appliances by the Target Year, when all appliances must comply with the defined efficiency standard, the respective achievement rate in percent of the targeted efficiency standard and the number of stars (1-5) related to the achievement rate (5 stars are granted for an achievement rate of over 100%).

This system can be perceived as both effective as well as quite complicated as a GfK survey amongst Japanese retailers shows. Consumers there are perceived as not understanding the concept. This rating finds Japan at the very end of an international comparison (see fig. 9).

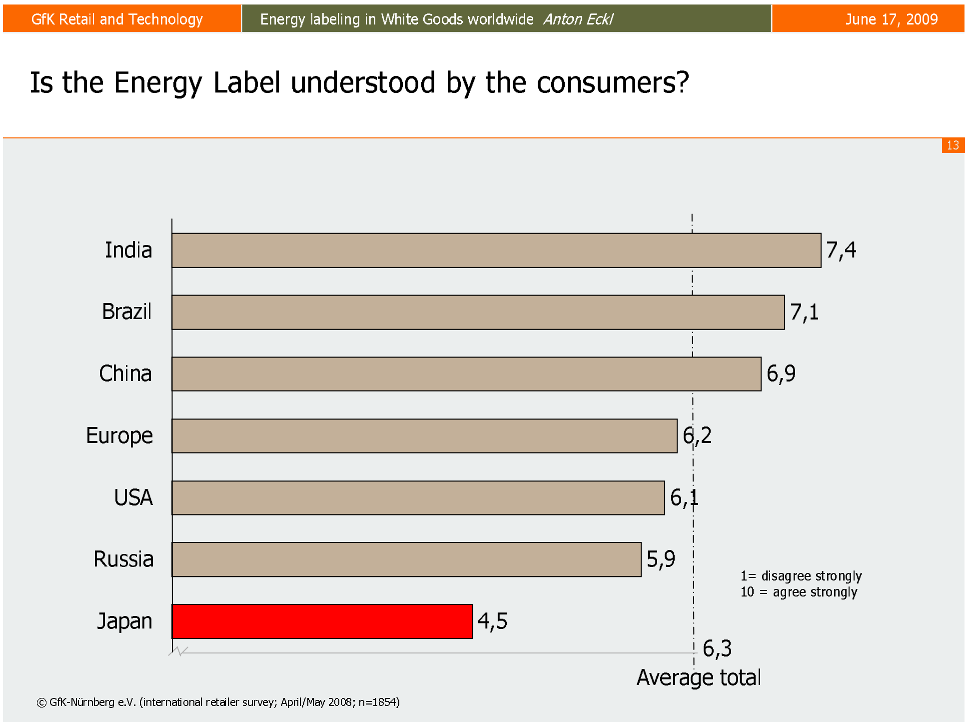

Figure 9: Retailer judgement of the ease of understanding of the respective country's labeling system for consumers April/May 2008

Nevertheless it spurs the driving forces for innovation in the market as it provides more efficient appliances in a short period of time. Standard Target Year 2010 was introduced as late as October 2006 determining that by 2010 no appliances underperforming this defined efficiency standard will be allowed for sale anymore. In the 12 months ending April 2008 86% (<=100% achievement rate) of the sold TY 2010 appliances was underperforming the standard whereas only one year later 52% (>100% achievement rate) were already outperforming the 2010 target standard (see fig. 10).

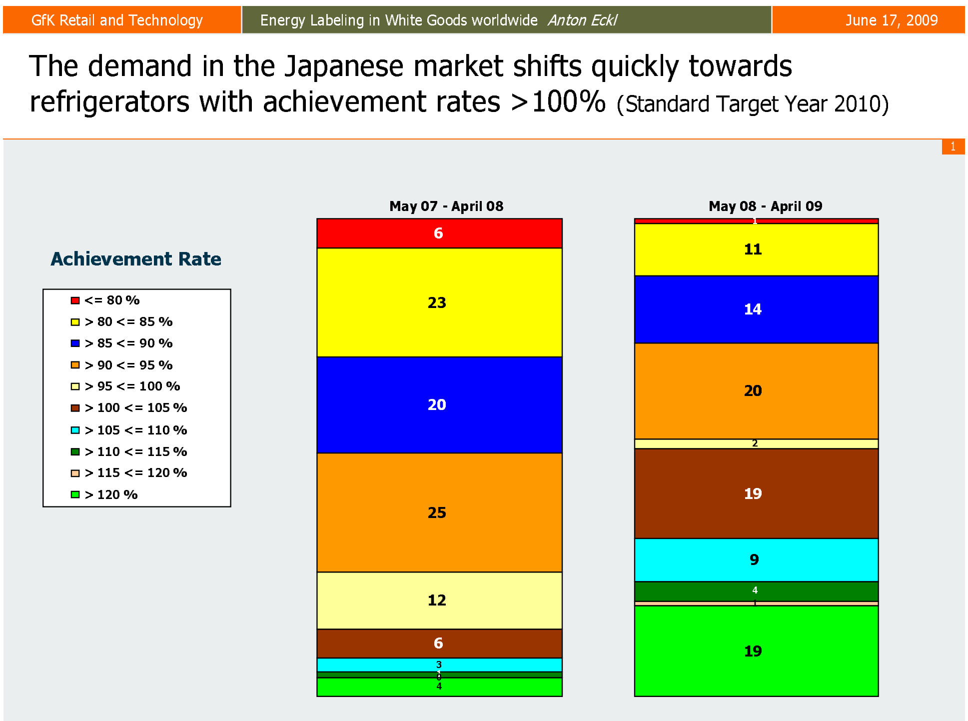

Figure 10: Sales structure for refrigerators by Achievement Rate (Standard Target Year 2010)

In the same time period the trend towards larger appliances (>400 liter net capacity) continues. (see fig. 11 right) Albeit this trend we see a strong decrease in share of appliances consuming more than 600 kWh per year (see fig. 11 left), which proves that the Top Runner Approach is delivering the desired results also in absolute terms.

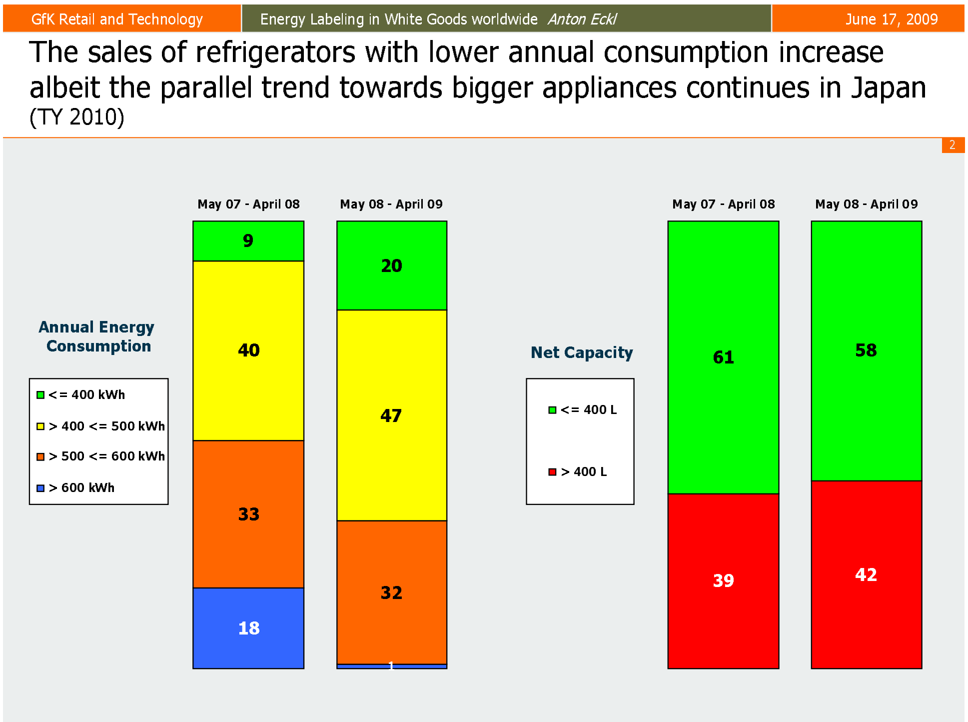

Figure 11: Sales structure for refrigerators by Annual Energy Consumption and Net Capacity (Standard Target Year 2010)

China

The Chinese Energy Label was introduced in 2005 for refrigerators, washing machines as well as air conditioners. It has some similarities to the EU-label, but is working with a 1 (good) -5 (bad) scale.

Class 1 is already prevalent in Cooling/refrigerators, but still a minor category for washing machines (see fig. 12).

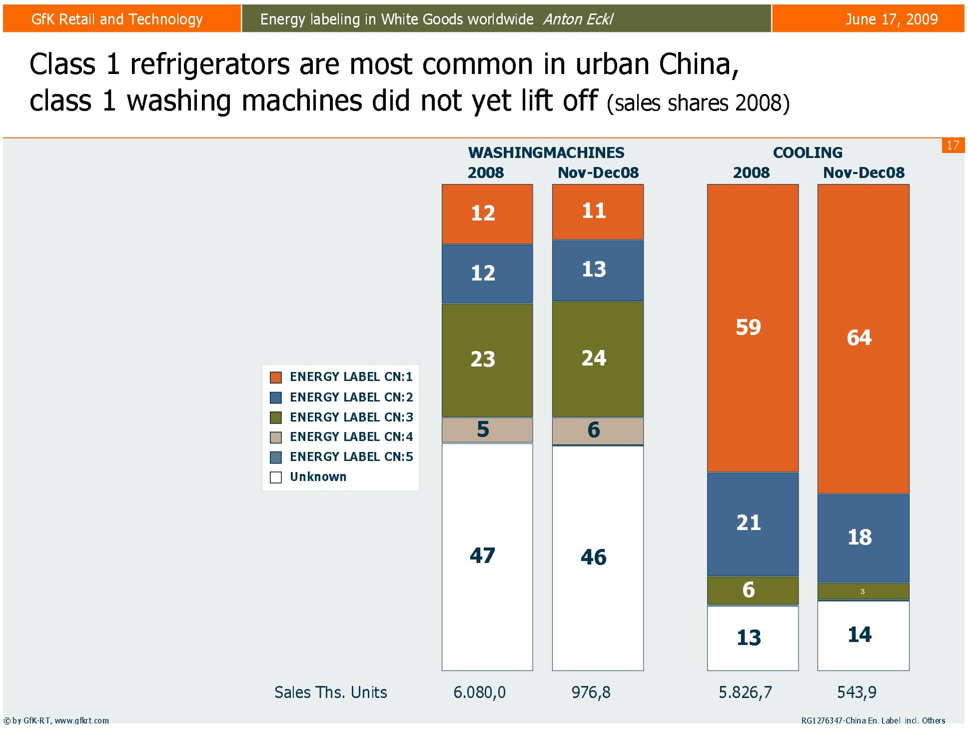

Figure 12: Sales structure by China Energy label 2008

One explanation can be found in the price premium for Class 1 washing machines, which is almost 100% over a Class 2 product, whereas the surcharge for a Class 1 refrigerator is only +13% (see fig. 13).

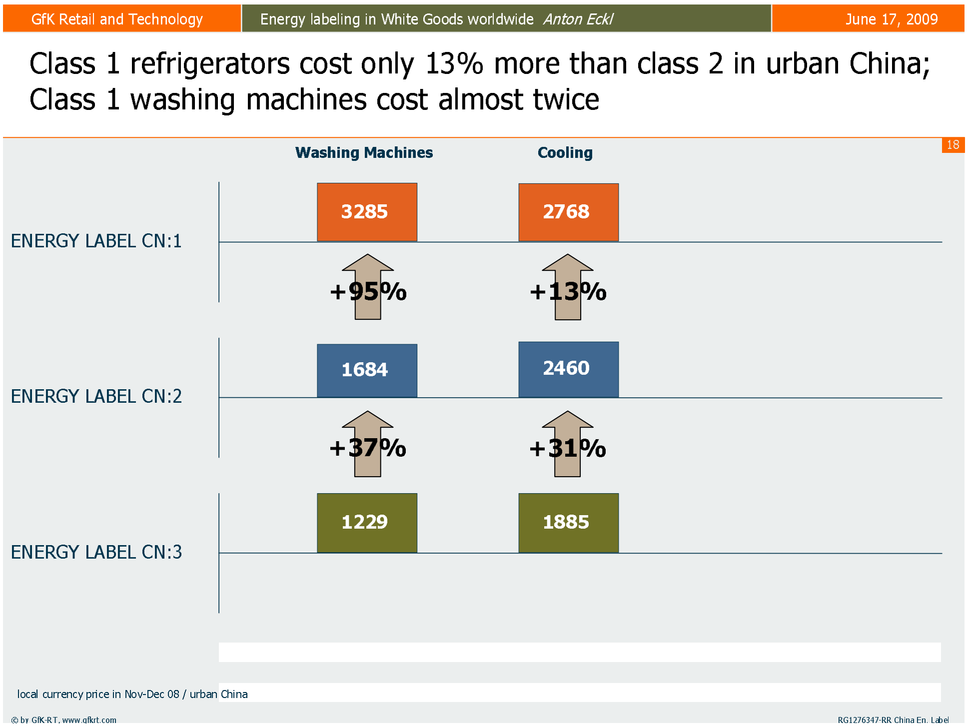

Figure 13: Average Sales Price for Washing Machines and Cooling/Refrigerators by China Energy Label Nov-Dec 2008

In the European style Drum Type machines sub-segment however the share of Class 1 products is already 54%, whereas the share in the most common Asian style Single Tubs is only at 4% and not existing on the cheap and very basic Twin Tubs (see fig. 14). These three categories clearly discriminate not only by Energy label, but also by price with Drum Type at 3.800 Yuan, more than twice the price of a single tub and more than 5 times the price of Twin Tubs.

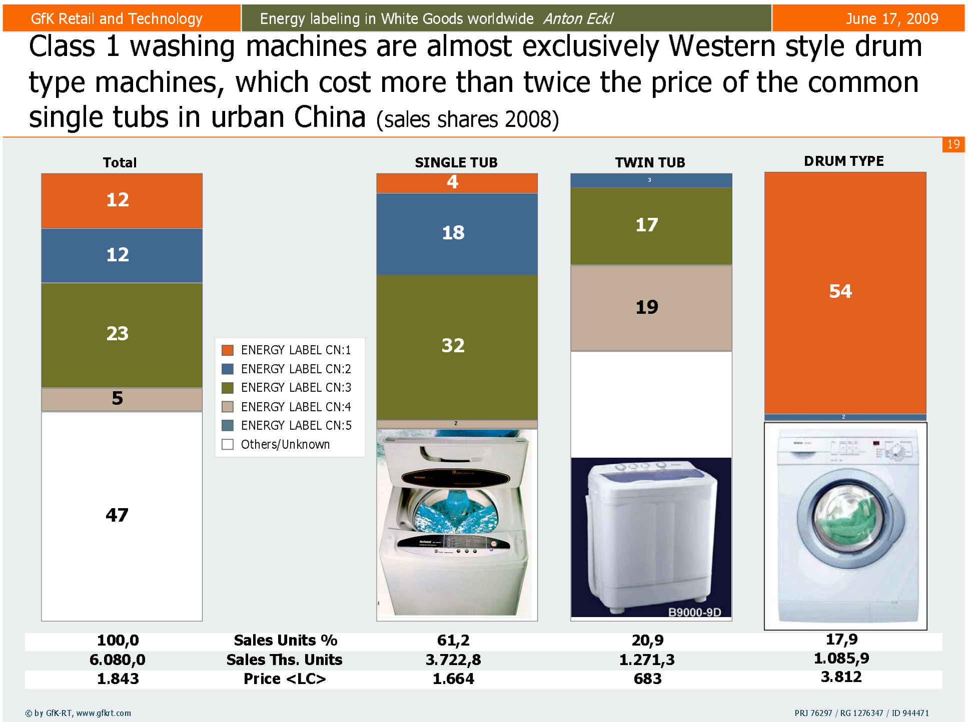

Figure 14: Sales Structure for Washing Machine Types by China Energy Label 2008

Brazil

The Brazilian Procel Label was introduced in 1993 together with a local adaption of the EU-label. It is compulsory for washing machines, cooling/refrigerators and freezers, cookers/ovens as well as air conditioners.

Brazilian retailers rate it very effective in selling more energy-efficient appliances with a 9,1 on a 1-10 scale being the best rating across all countries analysed in the international GfK retailer survey (see fig. 15).

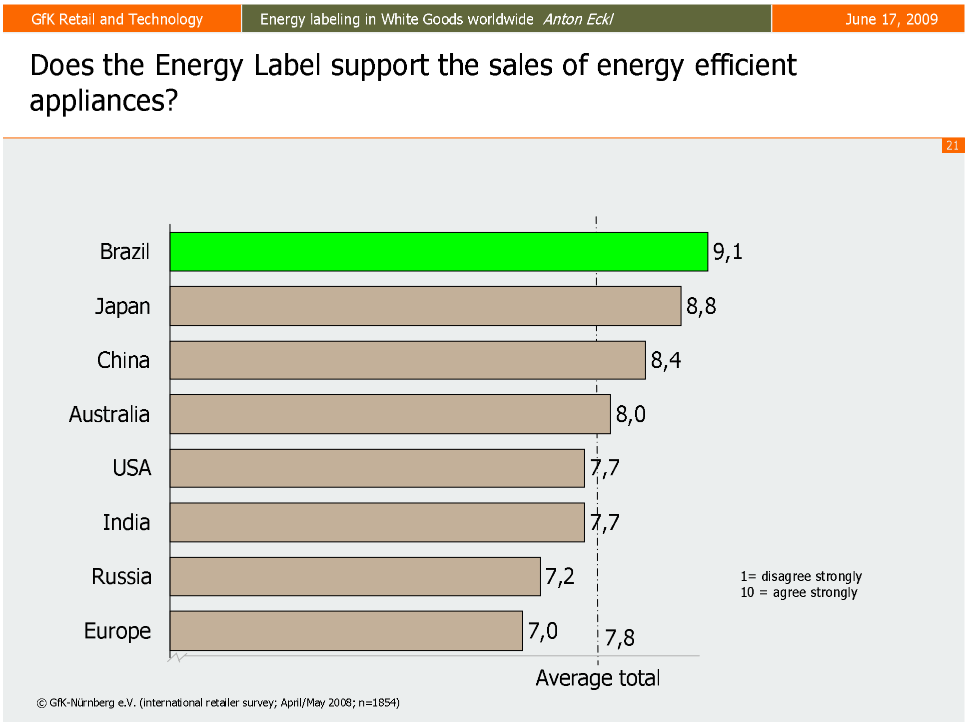

Figure 15: Retailer judgment on the effectiveness of the Energy label in supporting the sales of energy-efficient appliances April/May 2008

Industry is supplying an increasing number of A-labeled products supporting the already high level of 70% of sales for A-labeled products, which is still increasing incrementally until today. In early 2009 183 such products were on offer compared to 158 one year before, which represents a 16% increase year on year (see fig. 16).

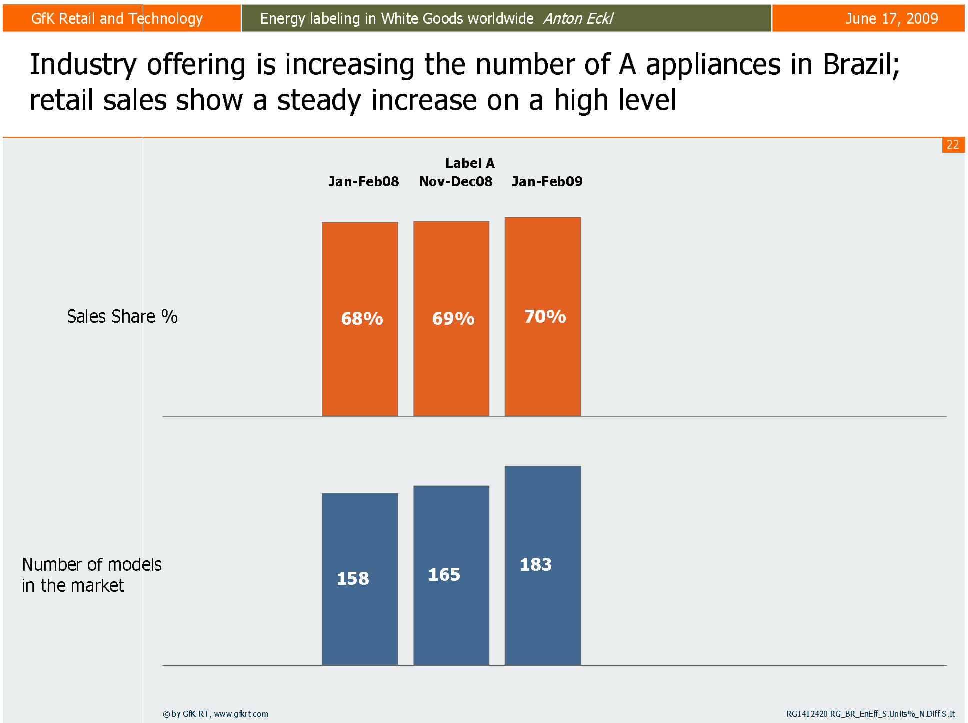

Figure 16: Development of supply (number of models) and demand (sales share) for energy-efficient appliances in Brazil Jan-Feb 2009

Chile

Chile followed with a similar labeling scheme in July 2007, but only for cooling/refrigerators and freezers.

Although the industry offer in Chile is rather high for A-labeled fridges (41% of all fridges), the consumer off-take is rather limited with 24% of all sales (see fig. 17 right). One explanation could be found in the rather preventive price premium of +56% for A-products compared to B. The Brazilian price premium is only at +11% (see fig. 17 left).

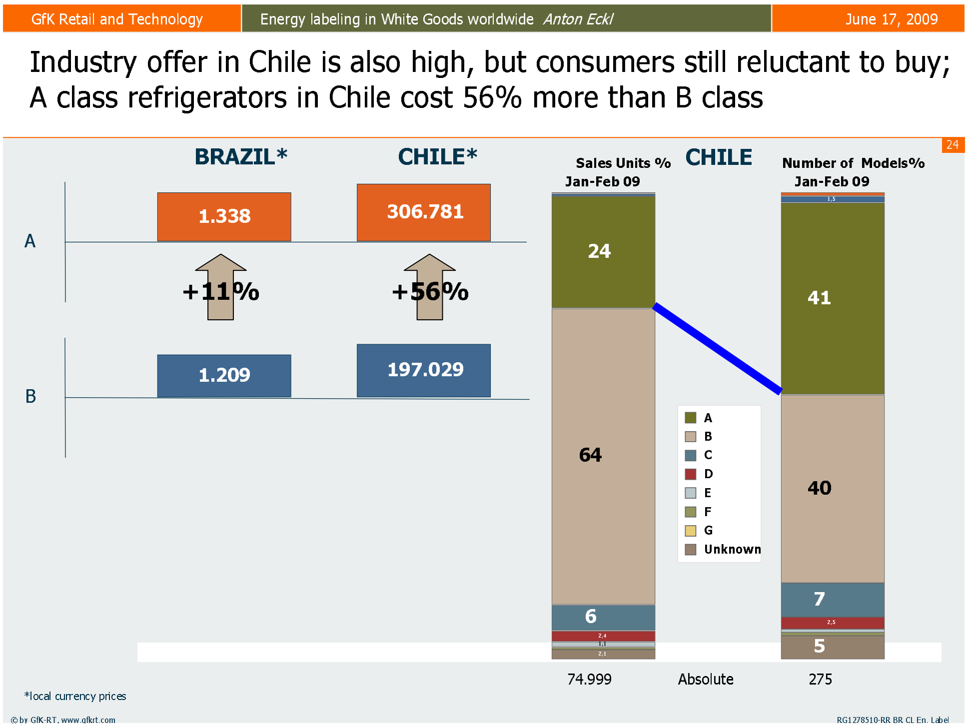

Figure 17: Supply (number of models) and demand (sales share) by Energy Label in Chile compared for Jan-Feb 2009; Price comparison with Brazil by Energy Label

As the Chile label is rather young (2007) compared to the Brazilian one (1993) it might be expected that the downward trend for prices will continue bringing the price premium further down. With now 34% it is down by 6 points in a year's time, but still very significant as the example for the most common Top Freezers shows (see fig. 18).

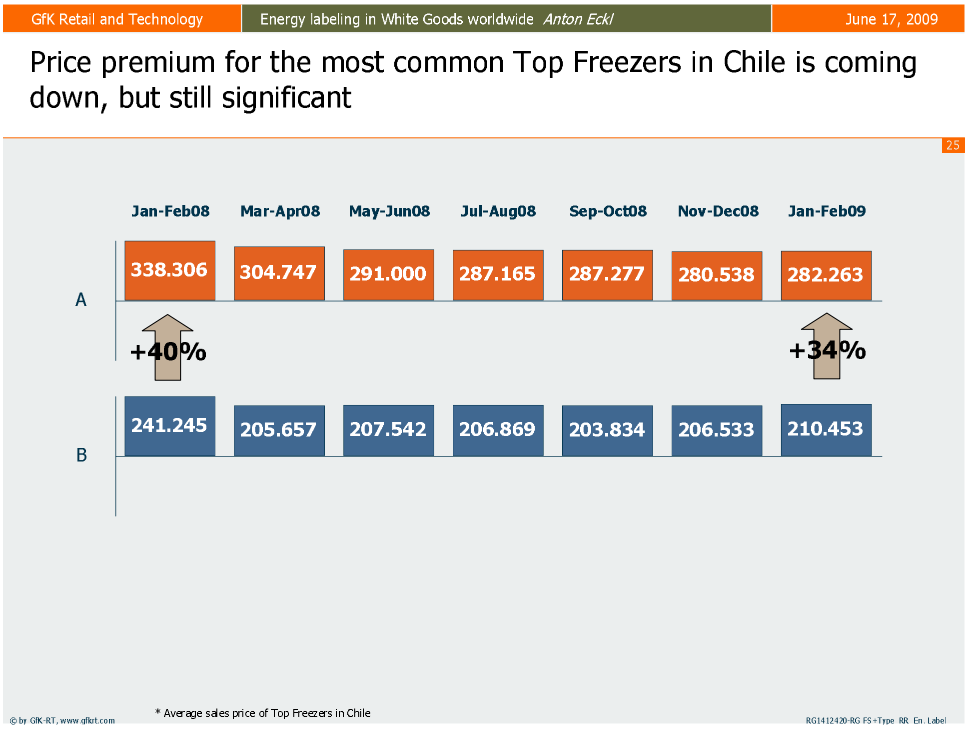

Figure 18: Price development of different energy efficiency classes for Top Freezers in Chile

Recommendations from international retailers

Based on the international GfK retailer survey 3 main areas of activities can be identified in order to further accelerate the transformation process towards more efficient appliances and harvest the desired energy savings (see fig. 19).

1) The development of more energy-efficient appliances is highly recommended by and large in all surveyed countries.

2) Financial incentives for the purchase of energy-efficient appliances are on top of the recommendation list in Europe and the US. GfK case studies on the Spanish ‘Plan Renove’ (since 2006) as well as the Italian tax-back subsidy system (since 2007) system have proven the effectiveness of such incentive schemes.

3) Producers are asked to provide cheaper energy-saving appliances mainly by the retailers in Europe, Japan as well as Brazil.

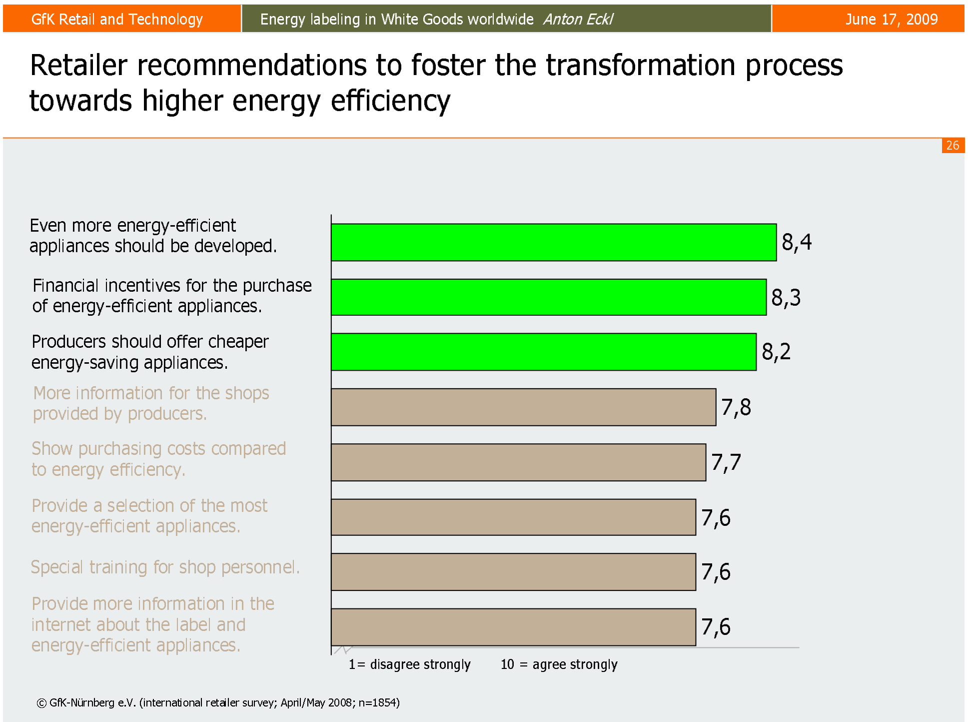

Figure 19: Retailer recommendations for more energy efficiency

Nevertheless the retailers themselves must contribute their fair share when it comes to promoting energy-efficient appliances. For example, even in Germany 55% of all cooling/refrigerators and 45% of all freezers sold are still only A or worse (see fig. 6 / difference between 100% and A+/A++ share). Retailers can position themselves as more eco-friendly against their fellow competitors by offering the most efficient appliances on the shelf and consulting potential customers towards those products.

Outlook for 2009:

The good news for stakeholders from politics, industry and retail alike is that the trend towards energy-efficient appliances is still robust against the omnipresent global crisis as the example for Europe impressively proves (see fig. 20). The same trend is by and large true for all the countries GfK retail audit data is available for.

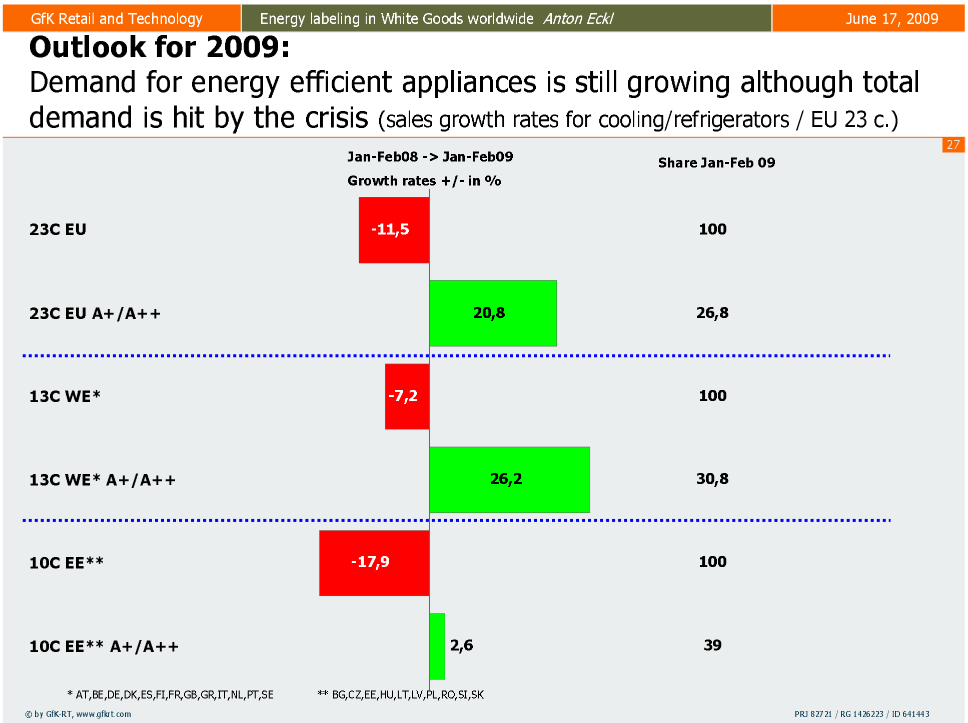

Figure 20: Regional breakdown of demand for total cooling/refrigerators vs. energy-efficient appliances compared (Europe 23 c.) Jan-Feb 2009

Summary

The issue of energy efficiency has a high relevance as White Goods account for approximately 1/3 of household electricity consumption (EU-15). It is most important to Japanese as well as Brazilian consumers according to the international GfK retailer survey. In Europe it is already considered more a hygiene factor as energy efficiency has already a longstanding and successful history. On the other side the EU energy label is due for revision as almost all washing machines and dishwashers are classified A and hence no differentiation is given anymore.

The ideal label has to be future-proof. Evidence shows that the Australian label still is in line with this request as only few appliances reach top energy star ratings 8 years after the label's revision in 2000.

The ideal label should be easily understood by the consumers, which is confirmed for most labels around the globe. Only the rather complex Top Runner approach from Japan falls short on this request.

Thirdly, the ideal label must speed up the transformation process towards a more energy-conscious purchasing behavior. This is on the other side very much fulfilled by the Japanese approach as the GfK retail audit analysis proves.

Energy-efficient appliances must be widely available at affordable prices in order to reach the desired energy savings.

Last but not least it cannot be stressed enough, that the sales of energy-efficient products are rather immune to the current crisis conditions and still show a significantly better performance than the market average.

References

[1] www.germanwatch.org, Klimaschutz-Index 2009, page 13

[2] DIE ZEIT, February 12 2009, page 20, Fritz Vorholz: Irrelevante Debatte

[3] European Union Sustainable Energy Week 2009, Panel Discussion February 10 2009

[4] Paolo Bertoldi/Bogdan Atanasiu, *Electricity Consumption and Efficiency Trends in the enlarged European Union – Status Report 2006*, EUR 22753 EN

All other information is based on proprietary GfK Retail and Technology research findings.

Opportunities for Energy Standards and Labels in CIS countries

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Abstract

A review of energy standards and labels for appliances, lighting, vehicles and other equipment highlighted that virtually no standards and labels exist in the Commonwealth of Independent States CIS countries. The review, conducted in 2008 for the Energy Charter Working Group on Energy Efficiency and Environmental Aspects, focuses on the countries that are signatories to the Energy Charter Treaty and its Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA) and it identifies steps that could support introduction of energy efficient standards & labels (EE S&L) programs in Energy Charter countries where they don't yet exist, principally CIS countries. However, the analysis and proposals are generally relevant to countries considering EE S&L as part of their policy mix.

Data collected for the report includes information on what kinds of products are covered by standards and labels in different countries; the definition of performance levels and test procedures, including the capabilities of testing facilities and the use of international test standards; evolution of performance levels over time; enforcement of labelling and standards; and the role of EE S&L in making consumers more aware of the importance of energy efficiency. Various sources of information were used, including a questionnaire for the countries involved and United Nations Development Program (UNDP) country offices, international databases (http://www.apec-esis.org/) and other data sources and consultations with international experts.

Based on the finding that currently no energy efficiency labels and standards are in existence in most of the CIS countries, a framework for supporting the implementation of EE S&L in CIS countries was developed. Adopting such standards and labels, and the underlying international test procedures, would lead to significant energy savings in the countries involved; harmonize S&L for many products across the region as well as with Europe and give a boost to the regional market for energy efficient products.

Background

EE S&L are key mechanisms to promote energy efficiency, especially in relation to household appliances, lighting products, industrial motors, automobiles and other mass-produced consumer and commercial energy-using equipment. They can also play an important role in making consumers aware of the importance of energy efficiency.

A study of the existing EE S&L policies in the countries that are signatories to the Energy Charter Treaty [1] and its Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA) has

[1] The Energy Charter Treaty and the Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects were signed in December 1994 and entered into legal force in April 1998. To date, the Treaty has been signed or acceded to by fifty-one states, the European Community and Euratom (the total number of its members is therefore fifty-three). The Treaty was developed on the basis of the 1991 Energy Charter. Whereas the latter document was drawn up as a declaration of political intent to promote energy cooperation, the Energy Charter Treaty is a legally-binding multilateral instrument. The fundamental aim of the Energy Charter Treaty is to strengthen the rule of law on energy issues, by creating a level playing field of rules to be observed by all participating governments, thereby mitigating risks associated with energy-related investment and trade.

been conducted in 2008 for the Energy Charter Working Group on Energy Efficiency and Environmental Aspects. Within the review, different approaches used for EE S&L in Energy Charter countries were identified, and their policy, legislation and implementation aspects described. The effectiveness of these approaches in improving energy efficiency in the countries was assessed, comparing this to approaches of other countries and regions, and recommendations for improved policy development and implementation in Energy Charter countries were given.

The aim of the study was to:

- Identify approaches used for EE S&L in Energy Charter countries, including policy, legislation and implementation;

- Assess the effectiveness of these approaches in improving energy efficiency in these countries, including in comparison with the approaches of other countries or regions, and suggest how this information could be used to improve policy development and implementation in Energy Charter countries;

- Suggest areas where international cooperation on standards and labelling could improve implementation and/or reduce costs, including linkages with other international or regional initiatives;

- Based on the above, make suggestions on possible future activities to improve the use of EE S&L to improve energy efficiency, with a focus on Energy Charter countries that currently do not have EES&L programs, particularly CIS countries.

In order to analyse the approaches used for EE S&L, data were collected on:

- The choice of products covered by standards and labelling;
- Definition and verification of performance levels, including the capabilities of testing facilities and relationship with international standards;
- Evolution of performance levels over time;
- Enforcement of labelling and standards;
- Metrics of performance for labels and standards (e.g. cost effectiveness, energy, emissions) and choice of information to be provided on labels;
- Relationship of EE S&L with local manufacturing and imports and economic impacts, including economic benefits of energy savings;
- The role of EE S&L in making consumers more aware of the importance of energy efficiency and steps they can take to limit energy use.

Geographically, the study includes all Energy Charter countries, but specifically considers the use of EE S&L in the Energy Charter countries that are economies in transition in Eastern Europe and Asia. Data collection included the circulation of a questionnaire among the members of the PEEREA working group, the circulation of the same questionnaire among experts and UNDP country offices via the assistance of UNDP, accessing international databases and other data sources and the consultation of international experts.

Data collection via international sources (and in particular the APEC-ESIS / CLASP database) has resulted in a reasonably complete overview of EE S&L in the OECD economies. Further information provided by UNDP has resulted in a good overview of the situation in the Russian Federation, Turkey and Romania. Information about the CIS-countries, however, is extremely scarce (with the exception of the Russian Federation). The only questionnaires, for Armenia, Georgia and Uzbekistan, were received via UNDP; these informed that EE S&L are virtually non-existent in these countries. This view is confirmed by (the lack of) information about existing EE S&L in international databases.

Given that the available information points to a lack of EE S&L in the focus countries for this study, further the study concentrates on the key role of and possibilities for EE S&L, how countries could benefit from each other's experiences and how international cooperation could facilitate next steps in the introduction of EE S&L.

The case of EE S&L

Energy efficiency standards and labels are sets of procedures and regulations that, respectively, prescribe the minimum energy performance of manufactured products and the informative labels on these indicating products' energy performance. They are meant to help the market recognize energy efficiency and act on it.

Standards and labels work best as part of a holistic market transformation strategy. Standards ensure that the worst performing products are removed from the market, while labels encourage consumers to purchase increasingly more efficient products. These can be further supported by direct incentives to support the introduction of leading-edge products through R&D support, subsidies, procurement, etc. However, standards and labels are fundamentally different in that labels support consumer choice in the market and provide manufacturers with benchmarks for product performance, while standards limit the choices available to manufacturers and consumers. A key decision facing policy makers is the appropriate mix between these and other measures. This will be influenced by factors including domestic market sizes, manufacturing capacities, economic conditions, energy costs, and international developments.

The effectiveness of standards and labels, and of product policy in general, relies on the unambiguous classification of product groups and of product energy performance classes. The product energy performance classification can be verified by a specific verification procedure, often including a test according to a specified test procedure. Such S&L specific procedures, however, rely also on general market surveillance for aspects as the unambiguous identification of product types, and the enforcement of product bans (by standards) and reliable labels. If that is not available in a country, product policies are likely to fail.

Well-designed and implemented S&L programmes compare favourably to other governmental energy policies and main advantages of S&L programmes include:

- They have a potential for very large energy savings;
- They are extremely effective mechanisms for delivering energy savings, reductions in greenhouse gas emissions as well as significant financial gains to consumers and society;
- They require change in the behaviour of a manageable number of manufacturers rather than the total consuming public;
- They create a level playing field, treating all manufacturers, distributors and retailers equally and allow governments to impose performance requirements instead of prescribing specific technologies;
- They are enacted internationally, increasingly harmonised between major trade blocks and part of a global approach; and
- The resulting energy savings are comparatively assured and can be readily and easily verified.

Lessons learnt in Economies in Transition

Individual countries have different experiences with implementation of EE S&L programmes. Various information collected on previous studies and projects by the study authors have been used to develop Case Studies of four Energy Charter Countries – the Russian Federation, Turkey, Romania and Australia, which are at different stages of implementation, have differences in approach and different economic and social contexts. But there are lessons for all countries already implementing or considering EE S&L programmes. Key lessons emerging from the studies in Economies in Transition are summarised below.

1. **Regulations only deliver when these are properly mandated and well implemented.**

   Russia: MEPS for a wide range of appliances have existed for a long time in Russia, and a framework for energy efficiency labelling was introduced in 1999. Both MEPS and labels, however, have not been really implemented so far, and the impact of these S&L is marginal. The voluntary status of the standards, lack of specific requirements for labels and lack of proper mandate to a government institute to actually implement requirements are contributing factors to this lack of impact.

Turkey: Procedures and budgets for compliance checking are needed. Turkey has adopted the EU energy labels for appliances and has assigned a government institute for its implementation. There are, however, no provisions for checking the compliance with the energy labelling regulations, and insufficient human and financial resources have been made available for these activities.

Romania: Proper mandates and procedures bring results. During its EU Accession process, Romania, for the first time, introduced EE S&L. It also established an institutional framework for their introduction. In recent years, the government agency in charge of this has developed comprehensive retailer compliance checking procedures. The importance of effective compliance checking is demonstrated by the significant decrease in non-compliance of shops: non-compliance started at 64 % in 2004, dropped to 39% in 2006 and dropped further to 18% in 2007.

2. **Access to testing laboratories is essential**.

Russia: The ability to test products needs to exist. There is one big testing facility in Russia that can test for the EU performance standards for washing machines. Further testing capacities are needed to make EE S&L a success in Russia, as well as test standards for other products preferably in line with international test procedures.

Romania: The market asks for compliance checking of products. Despite its success in improving the compliance of retailers with EE S&L, Romania has not yet succeeded in setting up the necessary procedures for checking the energy performance characteristics of products. Lack of access to testing facilities is one of the reasons for this omission. Major manufacturers present in Romania have insisted that the government should check energy performance declarations.

3. **Leading market parties ask for well-implemented EE S&L.**

Turkey: Leading manufacturers ask for the proper introduction of EE S&L. Leading Turkish manufacturers have recognised that they would benefit from the introduction of well-implemented EE S&L, and have offered their support to the Government for this. Properly implemented, well-enforced standards and labels would allow them to benefit from their investments in improving the energy performance of their products on the domestic market.

Romania: The market asks for compliance checking of products (see above)

4. **Manufacturers can benefit from introducing EE S&L.**

Russia: Introducing EE S&L can help local manufacturers. Local manufacturers currently lack any incentive to improve the energy performance of their products. The competition, imports and local production by subsidiaries of major European manufacturers, has innovated to meet the requirements of other major markets (particularly the EU). This has put local manufacturers at a disadvantage, and the introduction of EE S&L, especially when combined with training or technical support to manufacturers, could help them catch up with the competition.

Turkey: Not all manufacturers are similar. Turkish manufacturers are among the world-leading producers of high-quality products, exporting most of their best products to Europe. Turkey, however, is also hosting the production of low-quality energy using equipment that is exported to other parts of the world and sold domestically. Specific activities may be needed to support those small manufacturers to improve their production towards more efficient appliances.

5. **Energy efficiency standards and labels deliver.**

Romania: EE S&L deliver. A comparison of sales trends for refrigerators and washing machines, from 2003 to 2007 by energy class, demonstrates that consumers are gradually purchasing more and more energy efficiency appliances. The sales of A+ refrigerators has grown from 3.1 % in 2004 to 28.7 % by mid-2007 and the sales of A-class products have grown from 33.5% in 2003 to 62.6% in 2007.

Russia: The market needs time to adjust to EE S&L. The Russian market is still far behind EU markets (including new member states) in the energy performance of products. Due to the lack of standards and labels, Russian consumers cannot select products based on their energy performance. The price difference between average and better energy performing appliances is also quite substantial, which could indicate that the better products are still considered to be premium products (at a premium price).

Overview of S&L in Energy Charter Countries

EE S&L in OECD countries part of ETC

Energy efficiency standards and labels are common for the main energy-using products in most OECD economies, including those in the Energy Charter.

The EU labelling scheme (framework directive 92/75/EEC and its implementing directives) and MEPS cover the main household appliances and some other products and are implemented in the 27 EU Member States, Iceland, Norway, Switzerland, Liechtenstein, Croatia, Turkey and Macedonia. In addition to the mandatory labelling some countries have introduced voluntary labelling for certain types of products. The European Commission has negotiated voluntary agreements with the European Federation of Domestic Appliance Manufacturers (CECED), the European Association of Consumer Electronics Manufacturers (EACEM) and other manufacturers to improve the energy efficiency performance of washing machines, dishwashers, TVs, audio equipment, motors and water heaters. The European Union is currently in the process of developing and implementing minimum energy performance standards (MEPS) for a wide range of household, commercial and some industrial products (under a framework Eco-design directive) and a revision and extension of its energy-labelling scheme. [1]

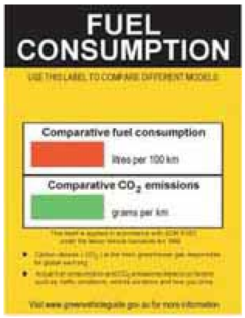
Australia has an elaborate S&L programme, and has set standards and introduced labels for a wide range of household, commercial and some industrial products. Standards and labels have been upgraded over the years: If standards and labels are successful, as in Australia, then most models on the market will tend to be classified at the efficient end of the label, which will mean the label becomes less useful to consumers and the supply chain. To achieve a better spread of energy efficient products a re-grading of the scale is required. This has happened in Australia on a few occasions. To facilitate the first change they set up a steering committee consisting of selected government, industry and consumer representatives to oversee initial studies and prepare the ground for work on the label transition process. An evaluation of the Australian experience shows that this process happened relatively smoothly. Further details are included in the case report on Australia. [2]

Japan does not have MEPS; instead it operates the Top Runner standards program. This program aims to dramatically improve energy efficiency of appliances by setting target values based on the current highest efficiency level of each type of product instead of the current average efficiency level. Manufacturers and importers have to ensure the average (sales weighted) efficiency of all shipped appliances meet this standard by a specified date (the target year). The program allows for improvement over time, making manufacturers constantly increase the efficiency of appliances. In addition a voluntary labelling scheme has been initiated in 2000 to indicate compliance with the set criteria. The Top Runner standards are voluntary as there is no minimum level, however the program itself is mandatory for all manufacturers and importers. [3]

Standards and Labels for Cars

Standards and labels are used for appliances and equipment, but also for cars and even buildings. Labels for cars are not as well known as those for household appliances, but the same principles apply as cars are also mass-manufactured products for which the fuel demand determines a huge share of their life-cycle cost. It is also difficult for a buyer to assess the energy performance (fuel efficiency) of a car unless these are equipped with reliable and comparable information about that, in other words an energy label.

Many Energy Charter countries have introduced energy labels for cars in recent years, although there is, unfortunately, not much harmonisation in their approaches yet. Some examples:



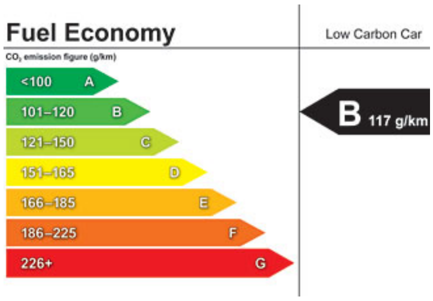
- Australia: A Fuel consumption label was introduced to promote consumer demand for vehicles with good fuel efficiency. All vehicles up to 3,500 kg must carry an energy label on their front windscreen when offered for sale. The label indicates the fuel consumption in litres per 100 km and the CO_2 emission per km.

- European Union: The European Union has introduced legislation that enables Member States to introduce car energy labels. Various EU countries have introduced (national versions of) an energy label. The European Commission has negotiated an agreement with car manufacturers about their voluntary compliance to CO_2 emission limits for cars. This agreement is now being replaced by a (mandatory) standard.

- Japan: Japan introduced, as part of its Top Runner programme, fuel economy standards for vehicles. The standard covers petrol, diesel and LPG passenger cars and busses and requires that the fuel economy of these vehicles must improve by 7 to 22% between 1995 / 2004 and 2010 / 2015 (percentage and target year dependent on the category).

- Switzerland: Switzerland introduced energy labels for cars, indicating fuel consumption (litres per 100 kilometres), CO_2 emissions (grams per km), and relative consumption expressed by category (A to G).

- United Kingdom: The UK introduced an energy label for cars indicating their CO_2 emission (grams per km), in numbers and on an A-G scale, to facilitate consumer choices for lower carbon emitting cars. The label also indicates the estimated fuel cost for travelling 12,000 miles and the Vehicle tax per year. It was introduced voluntarily by the cars industry under auspices of the Low Vehicle Carbon Partnership.



- Standards and labels for cars are also in place in countries outside the Energy Charter, for example in the USA (CAFE standard for cars and energy label) and Canada (EnerGuide fuel consumption label).

EE S&L in CIS countries

The Russian Federation has adopted a number of technical standards in the period 1983 – 1999, which became voluntary after the introduction of the Federal law on technical regulation in 2002. In the year 1999 a standard GOST P 51388-99 “Provision of Information for consumers about energy efficiency of products for household application” was developed, setting the framework for a energy efficiency labelling scheme broadly harmonised with the European one and to be implemented across a wide range of products. Due to its voluntary status, the absence of specific requirements for the energy classes for different products and lack of an implementing government institution, the technical standard has not been put into practice up to now. Armenia has also developed a national standard based on GOST P 51388-99, which has the same low application. [4]

No energy efficiency labels and standards currently seem to exist in other CIS countries. Information about EE S&L is extremely scarce, which signals that, even if S&L have been introduced, these are not well-known in the countries. There are no apparent reasons for the lack of EE S&L in the other CIS countries, or for the change from mandatory to voluntary standards in Russia. Questionnaires circulated for this report did point to a lack of knowledge of the potential of standards and labels, and also a lack of consideration of EE S&L as a policy tool. It is assumed that the unfamiliarity with standards and labels, and with product policy in general, is an important reason for their lacking in most CIS countries.

Potential Savings with EE S&L in CIS countries

International reference information suggests that EE S&L can lead to huge potential savings in CIS countries. In the absence of detailed information about the current market for appliance, equipment and cars and the products in use, it is impossible to provide sound projections for these potential savings.

Reference information, however, provides some guidance about the savings that could be possible if CIS countries would implement similar EE S&L programmes as currently in place in other Energy Charter countries. Savings achieved or projected in other countries are:

- Efficiency gains of 20 to 50% on most major appliances, representing well over half of all residential and commercial electricity demand [unpublished expert estimates, based on various preparatory studies for and evaluations of EE S&L];
- In the UK, the introduction of EE S&L for refrigerators and freezers alone is projected to deliver savings of approximately 3.5 TWh of electricity per year by 2020, equal to a 2% reduction in the residential electricity demand. During this period, purchase prices for these products also dropped notably [9];
- Very significant savings have been reported in Australia [5] and the USA [6] – for Australia, these indicatively amount to 6-7% of all electricity demand; for the USA, savings are estimated to amount to $ 100 billion by 2020;
- Calculations by LBNL indicate that Pakistan could save 20% of its projected national energy demand over a period of 25 years [7];
- Calculations by UNDP for a planned EE S&L project in Russia indicate potential savings of 30-35 TWh/year, equivalent to approximately 6% of all electricity demand.

Based on this, it would be reasonable to assume that CIS countries could save some 6% of all electricity demand by means of implementing effective EE S&L programmes for appliances and equipment, and further savings if the programmes would extend to heating equipment and cars. This savings percentage has been applied to the current (typically 2007) electricity demand in some CIS countries [8], in terms of electricity demand and monetary savings[2]:

Country	Indicative projections of EE S&L savings	
	Annual electricity savings	Annual monetary savings
Armenia	250 GWh	$ 25 million
Azerbaijan	1100 GWh	$ 110 million
Belarus	1,700 GWh	$ 170 million
Georgia	370 GWh	$ 37 million
Kazakhstan	2,200 GWh	$ 220 million
Kyrgyzstan	560 GWh	$ 56 million
Moldova	300 GWh	$ 30 million
Mongolia	160 GWh	$ 16 million
Russian Federation	33,000 GWh	$ 3,300 million
Tajikistan	880 GWh	$ 88 million
Turkmenistan	380 GWh	$ 38 million

[2] For this indicative projection, an energy price of $ 0.10/kWh was applied.

Ukraine	7,400 GWh	$ 740 million
Uzbekistan	2,400 GWh	$ 240 million

Possible Framework to Support the Implementation of EE S&L in CIS Countries

A possible framework to support implementation of EE S&L in CIS countries is by linking regional activities to national initiatives, by means of the inclusion of national practitioners in the training and information exchange activities, and via activities in the participating countries directly targeting government policy decision makers. The proposed framework consists of three main components:

- The development of a regional standards and labels strategy and the adoption of harmonized appliance and equipment standards and labels in the Europe and CIS region, or parts thereof, the development of testing capacities and the regional mutual acceptance of test results, and information of regional suppliers of the opportunities provided by harmonized procedures and requirements;

- Enhancing the capacity of national experts to develop and implement energy efficiency standards and labels through a training program, better access to the latest international information, exchange of information and experiences between countries and technical support during the design and initiation of national plans and as second opinion during their implementation;

- Creating awareness of national policy decision makers about the benefits of and requirements for appliance and equipment energy efficiency programmes, to stimulate their adoption and the mobilizing of resources for national activities on the development or improvement of energy efficiency standards and labels and compliance enforcement.

CIS countries will benefit from the proposed regional approach in several ways:

- By investigating the opportunities to adopt already developed of other countries in the region standards, labels and test procedures, countries can benefit from the analysis and development work already done, and reduce their need to invest significant resources in the development of national standards and labels.
- By harmonizing their test procedures and appliance and equipment energy efficiency requirements with their main trade partners, they can benefit from product improvements already developed for other markets;
- The same mechanism allows product manufacturers, established in the country, to take increased advantage of their investments in more energy efficient products, as they can sell these as easily, a recognized energy-efficient product, in other countries that have adopted the same procedures and requirements;

The suggested framework outline would facilitate the countries in cooperatively establishing a regional S&L strategy for the Europe and CIS countries, or parts thereof, including the selection of appropriate test procedures and product energy efficiency requirements for the countries involved. Mutual recognition of test results should be arranged, to allow for products once tested to be marketed as such in all countries in the region. As a last step, the suppliers of appliances and equipment should be informed of this, and be stimulated to make use of these procedures for the production and marketing of energy efficient appliances and equipment.

Various organisations, including International Energy Agency (IEA), Energy Charter, European Commission (EC) and different equipment manufacturers associations can assist CIS countries in the regional harmonization of energy efficiency standards and labels, by supporting the adoption of good-quality S&L developed in one country, by more countries in the region. Obvious candidates for such an approach are the energy labels and MEPS in place and in development in the EU, for those CIS countries that trade mainly with the EU. Further, the new UNDP/GEF S&L initiatives in the Russian Federation could provide a focal point for regional harmonisation. Adopting such standards and labels, and the underlying international test procedures, would harmonize S&L for many products across the region as well as with Europe, give a boost to the regional market for energy efficient products and lead to significant energy savings in the countries involved.

Taking into account the experiences of previous appliance standards and labelling development projects in the Europe & CIS region, any proposed actions should be built on a holistic approach trying to address the main policy, strategic, technical, modelling, and market issues related to developing, adopting, implementing, maintaining and enforcing energy efficiency standards and labels. Experience in Energy Charter and other countries revealed that there often is a need for specific support, including the training of experts, mobilization of national technical experts, and improvement of the regional markets for energy efficient products.

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Review on Chinese Energy Efficiency Standards and Energy Label System

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Abstract

In China today, coal is still the major energy resource. Finding the balance between high speed economic development and energy conservation is becoming a great challenge. To solve the problem, alongside enhancing the proportion of renewable energy in the energy supply mix, decreasing energy consumption and removing energy-intensive technologies, improving energy efficiency is another important key. As a major policy tool, energy efficiency standards are drawing more and more attention. This paper will introduce the development of energy efficiency standardization in China through two routes, Energy Efficiency Standards (EES) and Energy Label (EL) System.

Key words: Energy Efficiency; Standards; Energy Label System; China

At present, in line with the development of the world economy, energy demand of different countries is increasing rapidly. A preliminary estimation indicates the total global energy demand in 2020 will be 14200 Mtoe, 14% of which will be energy demand in China (2030 Mtoe). The proportion of energy demand in different regions or countries is shown in Figure 1. [1]

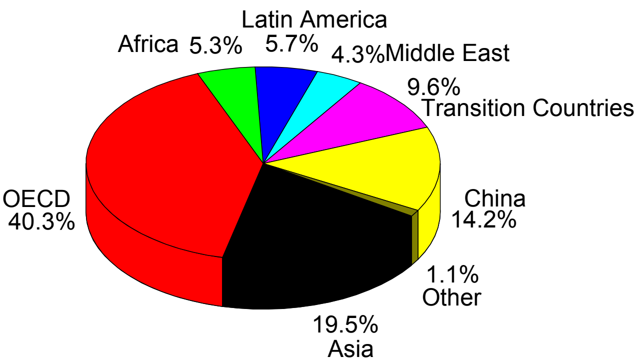


Fig.1 Energy demand forecast up to 2020

Due to a high proportion of industry (representing over 40% of GDP), with low value and low efficiency products, in 2001 China's GDP energy intensity was 829 toe/10^6 USD, about 3.2 times the world average level and 4.3 times the OECD level. Unit energy consumption for the most energy intensive products was over 20%-50% more than that of developed countries. By 2020, China's GDP will be redoubled with energy consumption doubling from 2001 to 2020. Finding the balance between the high speed economic development and energy conservation is becoming a great challenge.

For future energy development, Chinese government works on the following key principles: adjusting industrial structure; optimizing product variety; improving energy efficiency; building an energy conserving society; guaranteeing energy supply safety based on efficient and environment friendly technology; promoting the development and application of alternative fuel technologies; etc. As a key policy tool, standardization of energy efficiency is drawing more and more attention. This paper will briefly introduce the development of energy efficiency in China through two important routes, namely, Energy Efficiency Standards (EES) and Energy Label (EL) System.

The Chinese government pays great attention to energy standards. In 2008, the Standardization Administration of China (SAC), together with National Development and Reform Committee (NDRC), Ministry of Industry and Information Technology (MIIT), Ministry of Housing and Urban-Rural Development (MHURD), Ministry of Land and Resources (MLR) and other 11 ministries or government departments, promulgated the “2008-2010 Development Plan of Standardization on Resource Comprehensive Utilization”, in which energy conservation standards are the most important issue and will be treated as the major task over the coming years. In fact, China has already done a lot of work on energy standards, there are now more than 150 national standards on energy efficiency and conservation, including: fundamental standards, like standards on the calculation of energy savings estimates and comprehensive energy consumption etc.; standard methods for the monitoring of key industrial energy using equipment; standards on the economic operation of key industrial energy using equipment; standards on the rational use of energy for enterprises; energy auditing standards; standards on the metrics and statistics of energy; mandatory energy efficiency standards for end-use products and other standards on energy conservation management. [2]

As a critical part of energy conservation standards, energy efficiency standards (EES) are considered as one part of a broader effort to overhaul the nation's fuel and electricity, which can lay a foundation for promoting energy saving techniques and keeping sustainable growth. Normally the content of EES includes the following indices: 1) limited values of energy efficiency (limited values of electric power consumption), which define the minimum performance standard; specifying the criteria for energy conservation product certification; 2) energy efficiency grades, which are the basis of the index for energy efficiency labels; 3) target levels of energy efficiency, which benchmark the future market entrance levels; 4) test methods, which provide the basis on which the energy efficiency index is calculated. [3]

China started to develop energy efficiency standards since 1987. Till the end of 2008, there are together 36 EES in force. The product categories and products covered are shown in Table 1.

Table 1: China EES product list

Product categories	*Products*
household appliance 10	household refrigerator, room air conditioners, TV, household electric washing machine, domestic gas water heater, electric fan, electric cooker, electrical storage water heater, household induction cooker, variable speed room air conditioner
lighting equipment 8	double-capped fluorescent lamp, single-ended fluorescent lamp, integrated-ballast fluorescent lamp, tube-shaped fluorescent lamp, high-pressure sodium vapour lamp, ballast of high-pressure sodium vapour lamp, metal-halide lamp, ballast of metal-halide lamp
commercial equipment 3	water chiller, unitary air conditioner, multi-connected air-conditioning unit
industrial equipment 6	small and medium three-phase asynchronous motor, pump, transformer, compressor, air conditioner contactor, ventilator
electronic equipment 3	AC-DC/AC-AC external power supply, computer monitor, copy machine
Vehicle 4	passenger car, light-duty commercial car, tricar, low-speed truck

According to “2006 China Energy Statistical Yearbook”, the distribution of energy in the major energy-using sectors is shown in Figure 2. Following above sectors, the distribution of the EES could be analysed as Figure 3.

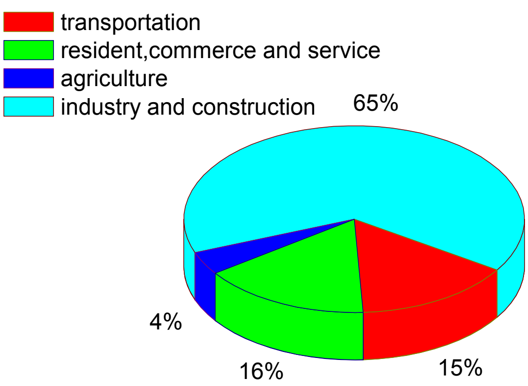


Fig.2 The distribution of Energy in 2006 [4]

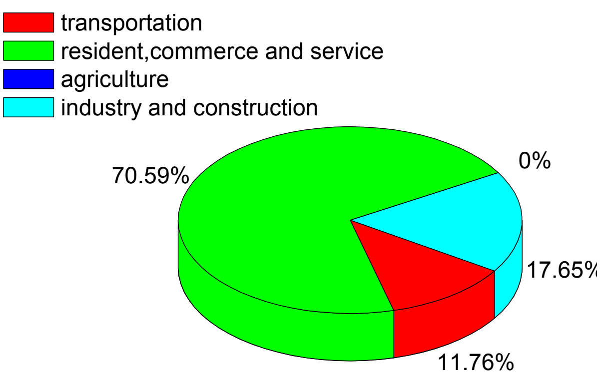


Fig.3 The distribution of EES in 2008

It is clear to see that the development of EES now is imbalance. Because of its large ratio of energy consumption, more EES should be developed in the industrial and constructional sector in the future.

Besides of the development of EES, how to effecitvely implement the standards is another important issue. The framework for the implementation of the mandatory EES in China is shown as in Figure 4. Different measures corresponding to the different EES indexes will be chosen for the implementation. The minimum performance standards for energy efficiency are set, eliminating high energy consuming products from the market; the energy efficiency grades are displayed in energy efficiency label system, which will be discussed later; and the energy efficiency grades are also used in the voluntary certification identifying energy conservation products. [5]

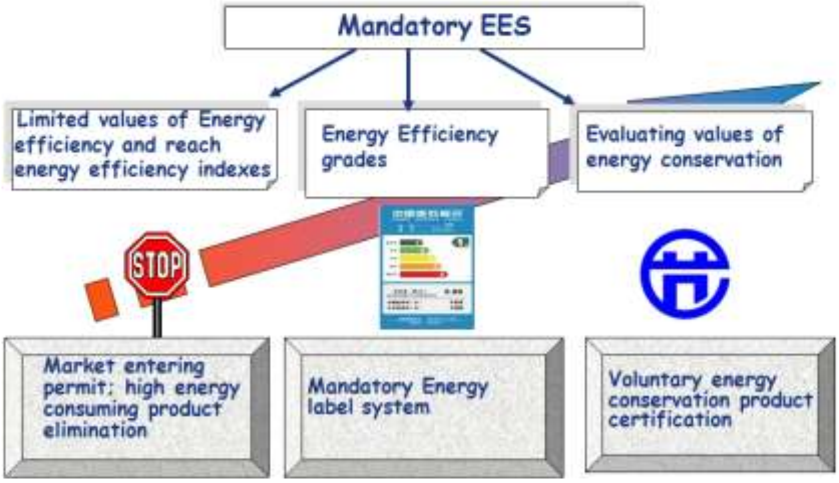


Fig.4 The framework for the implementation of EES

Energy Labelling (EL) is a key product policy tool and the Chinese EL System was established in 2004. The basic label pattern is shown in Figure 5.

Fig. 5 Basic label patterns and contents of China EL

The top part of the label states the name of the manufacturer, or the owner of the brand, followed by the specification and mode of the product, according to the relevant national product performance standards. The most important part of the label is in the middle, which shows the energy efficiency grade of the product: the higher the energy efficiency, the lower the energy consumption of the product. The energy consumption index and major energy performance index are shown at the bottom of the label, and these indices are determined using different technical specifications defined in the related EES. At the very bottom of the label the current version of the relevant EES is specified.

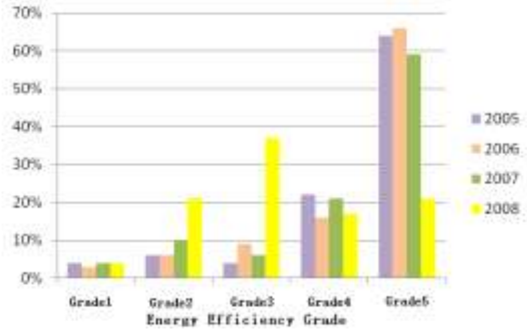
The Chinese EL system is implemented as a mandatory regulation and is managed by a number of organizations including NDRC; General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ); Certification and Accreditation Administration (CNCA) and relevant local organizations. The parties required to comply with the EL system are manufacturers and importers. There are two ways in which the EL information must be presented, namely, attaching energy efficiency labels to an obvious part of the product or on the product packaging and secondly, including the energy efficiency grade in the product instructions. The implementation mode of EL system is using manufacturer/importer self-declaration, product registration together with market monitoring. There are four unified requirements for EL system in China, namely, unified product catalogue, unified EES, unified implementation regulations, and unified label pattern and specification. Finally, the implementation organization for EL system is China National Institute of Standardization (CNIS).

There are together 15 kinds of products and equipments at the end of 2008 covered by the EL system in China, as shown in Table 2.

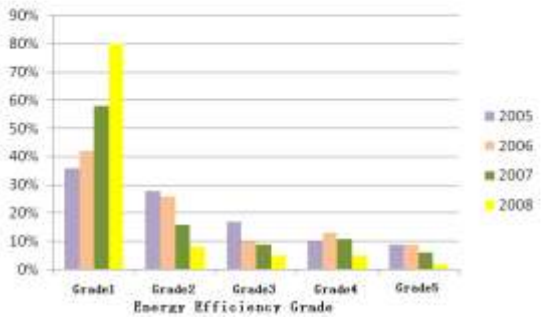
Table 2: China EL system product list

Product categories	*Products*
household appliance	household refrigerators, room air conditioners, household electric washing machine, domestic gas water heater, electrical storage water heater, household induction cooker, variable speed room air conditioner
lighting equipment	integrated-ballast fluorescent lamp, high-pressure sodium vapour lamp,
commercial equipment	water chiller, unitary air conditioner, multi-connected air-condition unit
industrial equipment	small and medium three-phase asynchronous motor
electronic equipment	computer monitor, copy machine

Four years after the implementation of the EL system in China, the energy efficiency of domestic appliances and lighting equipment has improved significantly. On the basis of preliminary statistics, total amount of saving energy is about 30 Mtoc. It is shown in Figure 6 that comparing with 2005, in 2008 the energy efficiency level of room air conditionors increases above 6%, the the market share of energy saving air conditionors increased from less than 1% to 5%. However, due to the higher cost of the high energy efficiency air conditionors, the market share of top-grade energy efficiency product is still low. In order to promote the high efficiency air conditionor market, Chinese government is planing to enforce government allowance program in 2009. And the energy efficiency level of household refrigerators increases 5%, at present the the market share of energy saving household refrigerators is above 80%. [6]



(a)



(b)

Fig.6 The product energy efficiency level changes from 2005 to 2008
(a) Room air conditioners; (b) Refrigiators

Because the Chinese government puts a great emphasis on energy efficiency standardization and its implementation, the EES and EL system related work is progressing rapidly. It is planned to expand the EES scheme to microwave ovens, printers, industrial boilers, commercial refrigerated display cabinets, set-top box, etc. By 2010, there will be over 50 products covered by the EES, and over 25 products covered by the EL system.

However, because of the large categories and amounts of various products in China, the harmonized energy efficiency measurement is becoming a problem. This will directly influence the reliability of the tested energy efficiency level. In another hand, it is always a problem in China for implementation and supervision of energy conservation program, including energy efficiency standards and energy labeling system due to the large border and different economic developing level. So in addition to enlarge the EES and EL covered product categories, one should pay more attention to the implementation and supervision of the published EESs and EL systems recurring to the foreign countries good experience.

Meanwhile, due to the high-speed development of the EES and EL systems, China is now ready to become more involved in the international harmonization of energy efficiency standards. China is keen to share its experience, and work on issues such as harmonization of energy efficiency test procedures for energy-using products and equipment; encouraging more countries to implement an EL system and find possible solutions for the harmonization of energy efficiency grades across different countries; sharing experiences of the system among the developing countries; introducing new energy-saving techniques and methods via implementation of ISO standards, and so on.

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Standards and labels for promoting energy efficiency in Russia

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Abstract

A UNDP/GEF project is being developed in the Russian Federation, to facilitate market transformation towards more energy efficient building equipment and appliances through introduction of energy efficiency standards and labeling. Since early 2000 Russia's economy was experiencing strong economic growth accompanied by rising income levels and living standards. Consequently, continuous raise in power demand has been observed stemming, inter alia, from a strong increase in new purchases and use of electric appliances in residential, public and tertiary sectors' buildings. The power demand in those sectors has grown continuously: from 174 TWh in 1990 to 213 TWh in 2004 (equivalent to 170MtCO2/year). This demand primarily comes from the use of electricity for home appliances (refrigerators and washing machines), lighting systems and building equipment (e.g. water pumps). Although energy efficiency has been named, by the President and the Government, as one of the 8 key priorities for the future development in Russia, there are still gaps in the existing legislation in the area of energy efficiency of electricity consuming products. The proposed UNDP/GEF project will be the first large-scale intervention of this type in Russia to design and implement energy efficiency standards and labels.

The new project to be implemented over the coming five years is a partnership of the Russian Government – Federal Agency for Science and Innovations of the Russian Federation, the United Nations Development Programme and Global Environment Facility. The strategy of the proposed

project is to address the existing policy, institutional, information, market and technological barriers that hamper the widespread introduction of energy efficiency standards and labeling. The goal of the initiative is to reduce electricity consumption and related CO_2 emissions in residential, commercial and tertiary sector buildings in Russia.

Background

Over the last years the *Federal Agency for Science and Innovation of the Russian Federation* has been supporting research and analysis to promote introduction of energy efficiency standards and labels in Russia. This work has been carried out in the framework of the Federal Program *Research and Developments in Priority Fields of the Russian Science and Technology for 2007-2012* aiming to explore potential impact of energy efficiency standards and labels on energy consumption in Russia. The activities have been carried out by the autonomous non-commercial association *RUSDEM-Energoeffect* and *OOO TERMEK*. The preliminary analysis carried out so far shows that Russia can achieve a considerable reduction in fuel and energy consumption and, as a result, reduction of Greenhouse Gases emissions through adoption of energy efficiency standards and labels.

In view of the above, the *Federal Agency for Science and Innovation of the Russian Federation* and the *United Nations Development Programme in Russia* (UNDP) have jointly initiated development of a new project with the Global Environment Facility (GEF) on "*Standards and Labels for Promoting Energy Efficiency in Russia".* The project is implemented in the framework of a broader GEF Umbrella Programme "Energy efficiency in Russia" led by UNDP in partnership with EBRD and UNIDO.

Russian energy sector

Russia ranks third in the world (6,5%) as to the volume of primary energy production after the USA (22,8%) and China (13,6%). Whereas the energy intensity of Russia's economy is twice as high as the world average, 2,3 times higher than in the USA, 3 times higher than that of the western Europe and Japan.

High energy intensity of Russian economy results in incremental GHG emissions and fossil fuel consumption. Besides the natural and climatic factors, the high energy intensity is driven by:

- relatively low (until recently) cost of energy resources;
- structure of the economy with a large share of power-intensive industries (60% of the overall industrial sector);
- Large share of outdated equipment and technologies.

The need to increase competitiveness of the Russian economy calls for significant improvements in energy efficiency in all fields of energy production and consumption. Existing energy saving potential in Russia comes to 360-430 million tons of oil equivalent or about 40-45% of the current energy consumption, including:

Fuel-Energy Complex: 33%;
Construction industry: 32%;
Housing and utilities sector: 26%[1].

Over the period of 2006-2008 the national economy demonstrated a steady growth at 6-8% annually. The current global crisis, without doubt, has not bypassed the Russian economy. Economic development indicators have shown changes already in the last quarter of the 2008. Some of the indicators related to energy consumption and potential introduction of energy efficiency standards and labeling are presented in Table 1.

Table 1. Russian Federation economic indicators (state statistics)

Indicators	Year 2008 vs. year 2007, %	December 2008 vs. December 2007 г.
Index of electrical household appliances production	103,6	76,8

[1] "Energy strategy of the Russian Federation for the period ending 2020", (2003).

(refrigerators and freezers)		
Construction volumes	114.5	99,7
Real monetary incomes	105,0	93,8

National energy strategy envisages a steady growth of domestic energy tariffs towards the level of world energy prices (table 2). An accelerated growth of electric energy tariffs is envisaged in the coming three years. It is projected to achieve a twofold increase of the electrical energy cost by 2011 compared to 2007.

Table 2. Increase in electrical energy tariffs (%)

	Year 2008 vs. year 2007	Year 2009 vs. year 2008.	Year 2010 vs. year 2009	Year 2011 vs. year 2010	Year 2011 vs. year 2007
For industry	116,7	126	122	118	211,7
For population	114	125	125	125	222,7

*- average across Russian regions

A considerable number of the Russian regions incur power resources shortages. In various regions a connection charge is being introduced, applied to new consumers of the power utilities; this factor becomes another incentive for greater efforts in energy saving and increased energy efficiency.

The downturns of the present financial and economic crisis require additional and more proactive measures in pursuing energy conservation policy. Energy efficiency improvement in all sectors is proclaimed among the country's top priorities stated by the President and Government of the Russian Federation. The recent resolution of the President calls for 40% reduction in the Russia's GDP energy intensity by 2020. The Project intends to facilitate achievement of the national energy strategy goals and addressing reduction in GDP energy intensity, and consequently in GHG emissions.

Status quo in appliance energy efficiency in Russia

Legal and institutional background: Some attempts were made to implement energy efficiency standards and labels in Russia in the previous years. Technical standard (GOST) P 51565-2000 for "Energy conservation. Household electrical refrigeration appliances" introduced the concepts of energy efficiency, energy efficiency classes (A-G classes). It also stated the time-limit for phasing out production of equipment with "G" class by 2002 and equipment with "F" energy efficiency class by 2004. It defined the energy efficiency label form specifying energy efficiency class. It was based on general energy efficiency standards and was targeted for implementation of European energy efficiency labeling scheme. This standard however lost its mandatory nature when a Federal Law "On Technical Regulation" has been passed. Energy efficiency standards and labels have not been developed in the Russian Federation in the subsequent years.

In the existing regulatory environment the relevance of the project focused on energy efficiency labeling and standardization has markedly increased. In the end of 2008 the Russian State Duma approved in the first reading the draft Law "On Energy Conservation and Energy Efficiency Improvement" providing a framework for state regulation in the field of energy efficiency of Russian economy. Effective enforcement of this law will require developing and piloting a large number of regulatory instruments at the federal and regional levels as well as a proactive awareness and promotion work with the population and industries.

Appliance market: The diagram hereinafter presents an energy use structure of the typical Russian household. As it is shown on the diagram the most significant share in the energy use structure goes to refrigerators - 32,8 %; lightning systems accounts for 26,9% and washing machines - 7,0%.

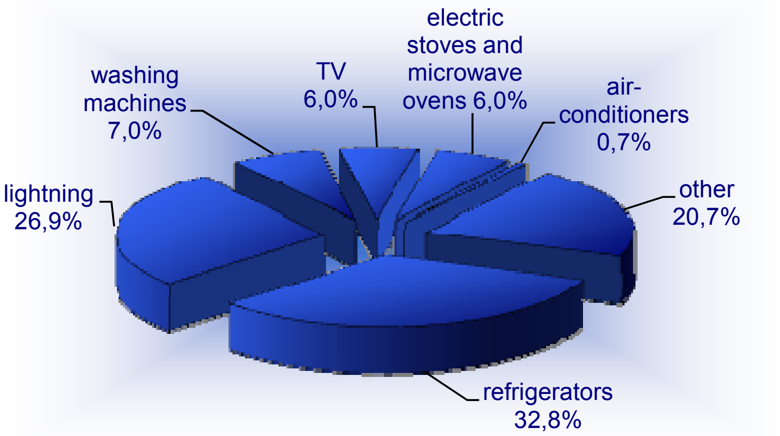

Diagram 1. Energy use structure of a Russian household

As to the technical equipment in the buildings the high energy-consuming items are pumps, ventilator units, refrigerating machines, air-conditioning and lightning systems. Information on dynamics of the refrigerators and washing machines markets is presented in tables 3 and 4.

Table 3. EE dynamics of refrigerators market

EE class	Share of the refrigerators sold, %					
	2004			2007		
	Russia	Western Europe	Central Europe	Russia	Western Europe	Central Europe
A++	0	0,2	0	0,1	0,6	0,1
A+	1,8	65,5	65,2	4,5	18,5	23,6
A	34,8	55,2	55,2	44,7	67,1	64,5
B	39,3	30,4	30,4	37,9	11,2	10,4
Others	24,1	8,2	8,2	13,0	2,4	1,1

Table 4. EE dynamics of washing machines market

EE class	Share, %			
	2004		2007	
	Russia	Central Europe	Russia	Central Europe
A+	7,3	10,6	17,6	39,1
A	79,7	72,3	77,1	57,6
B	8,2	9,7	2,9	2,1
C	2,3	6,0	1,3	1,2
Others	1,5	1,5	1,1	-

Data presented in the tables one more time favor the fact that countries of Central and Western Europe represent sizable markets of energy efficient equipment. This naturally affects their GDPs energy intensity. Energy efficiency standards and labels, no doubt, play a key role in this process.

Even though the Government of Russia qualified energy efficiency among Top Eight Factors for Russian economy there were no legal and normative documents developed since then to establish regulatory tools and incentives for improved energy efficiency in the energy consumption and appliances. Inefficient electric appliances are prevailing in all the segments of the market. Share of the inefficient products twice as much as a European average. Market research showed that electric appliances of F-D efficiency class (according to the classification adopted in EU) account for 55% of the new equipment sales. As a result household electric appliances in Russia use much more electrical energy on average than those in developed countries. A refrigerator in Russia uses on average 607 kW h/y versus to 364 kW h/y in EU. It is consumers' sluggish demand for energy efficient equipment due to poor awareness and lack of reliable information rather than a scarcity of manufacturers' engineering capabilities, which should be listed among the main reasons of this phenomenon. Nevertheless, the reduction of electricity subsidies in the residential sector as well as the tariffs growth provided economic incentives for reducing energy consumption and pursuing energy saving initiatives in the long-term.

Major commercial consumers are very much aware of the electricity saving benefits but they do not have an access to the information on the available supply. They are not familiar also with existing green procurement models

Energy efficiency potential: Development and introduction of energy efficiency standards and labels, as has been substantiated by the international experience, is appeared to be one of the least cost solutions to significantly reduce energy consumption. Estimates on possible reduction of electric energy demand and mitigation of emissions of greenhouse gases is presented in the tables below.

Table 5. Energy consumption and energy saving indexes of technical equipment in buildings

No	Types of equipment	Energy consumption, mln. kW*h/y	Import share, %	Average level of energy efficiency according to EU scale	Energy saving potential, mln. kW*h/y	CO_2 emissions reduction potential, mln.t/year
1	Water pumps	12800	50-55	C-D	3000-4000	2000-3000
2	Industrial air-conditioning and ventilation units	2900	60-65	C-D	600-800	400-600
3	Refrigeration machines of the central air-conditioning systems	850	85-90	D-E	250-300	180-200
4	Electric warm air curtains	2100	90-95	B-C	200-300	140-200

Table 6. Energy consumption and energy saving indexes of household electric appliances

No	Types of equipment	Energy consumption, mln. kW*h/y	Import content, %	Average level of energy efficiency according to EU scale	Energy saving potential, mln. kW*h/y	CO_2 emissions reduction potential, mln.t/year
1	Refrigerators, freezers	31600	36	C-D	2528-3160	1690-2117
2	Washing machines	7300	68	D-E	365-400	244,5-268

Domestic appliances aggregated energy use makes 96 billion kW*h/year. It is expected that electrical appliances market will show an increase by 10-15% per year, it will result in an increase of greenhouse gases emissions by 7-11 $MTCO_2$/year or 30 $MTCO_2$ in aggregate by 2010.

Next steps: Development and introduction of Standards and Labels for promoting Energy Efficiency

The UNDP/GEF project Objective is to reduce GHG emissions by facilitating the market transformation towards more energy efficient building equipment and appliances through introduction of energy efficiency standards and labeling

According to the world-wide experience the adoption of energy efficiency standards and labels represents an unparalleled means to substantially reduce energy demand and mitigate greenhouse gases emissions at relatively low costs on the part of the state as well as on the part of the private sector

The Project will promote and introduce standards and green procurement models for the major commercial marketers. The Project will also provide environment for efficient testing, monitoring and verification processes. This will be done to assess whether the country's newly shaped system is substantially responsive to the standards and labeling requirements. Eventually the activities involving domestic equipment producers would be carried out in the Project framework to provide support in the identification, development and sales of products that feature higher energy efficiency and are consistent with more strict standards. The proposed GEF Project strategy is to reduce institutional, information, market and technological barriers limiting the introduction of energy efficiency standards and labeling in Russia.

On the basis of the international experience in applying energy efficiency labeling the following elements have been identified:

(i) obligatory nature of labeling for energy consuming equipment and goods;
(ii) administrative restrictions on manufacturing and sales of products that are less efficient than required;
(iii) limitation of imports of inefficient equipment;
(iv) promotion and awareness to highlight the economic advantages of the energy efficient equipment in operation and its environmental friendliness.

Energy efficiency labeling would make a very efficient tool to provide implementation of the energy saving program in construction, public buildings maintenance (schools, hospitals and policlinics, sport facilities, administrative institutions and etc.), and in public procurement. These are the sectors suitable to arrange well-balanced combination of voluntary- and directive-based instruments for promoting energy efficient technologies. It is expected that engaging such sectors as household consumers and commercial entities into the energy saving process through energy labeling will be a long-term prospect. We should focus on informational campaign in this case. Contacts with the interested companies will be established and partners' relationships will be arranged within the framework of the Project aiming to demonstrate advantages of energy efficient procurement schemes.

The events planned will be tightly linked to the ongoing activities piloted in some of the Russian regions, for example, within the *Program of Energy Saving for the City of Moscow*. Targeted information and marketing events will be conducted in the selected areas for the targeted audience comprising manufacturers, distributors and public institutions.

Activities planned by the UNDP/GEF Project

The project envisages achievement of the following Outcomes:

Outcome 1: National legal and regulatory environment and institutional capacities are built to facilitate introduction and wide-spread application of energy efficiency S&L scheme

Although energy efficiency has been named, by the President and the Government, as one of the eight priorities for the future development in Russia, there is yet no existing legislation in the area of energy efficiency of electricity consuming products. The Federal Law on Technical Regulations doesn't provide for mandatory energy efficiency standards and labeling and provides weak incentives for the development of effective voluntary schemes. Morever, there is no official government ministry or agency which is delegated to develop legislation, propose programs and implement policy actions in this area. The project will approach this key barrier by building an enabling environment at the national level towards more effective federal policies and legislation, including institutional setting. It will also lay down and propose requirements for the introduction of energy efficiency standards and labels (EE S&L) for key electrical household appliances and technical building equipment.

The project will strengthen the capacity of policy makers to allow for efficient design and implementation of national energy efficiency and EE S&L policy, legislation, and programs. Taking into consideration the long periods required to promulgate or amend laws, the project will work along two parallel lines: (i) capacity building and promotion of EE and EE S&L legislation, regulation and programmes, EE standards and labels on the federal level, (ii) the implementation of a comprehensive, voluntary EE S&L programme - fully in line with the requirements developed at the federal level - in the selected pilot region Moscow. This voluntary EE S&L programme will include consumer, manufacturer, and retailer outreach programs, procurement standards and models, incentive schemes and monitoring and evaluation the impact of appliance energy efficiency programs. Due to the involvement of supply-chain stakeholders, the voluntary program will also promote market transformation in other urban centres throughout the Russian Federation.

It is not realistic to establish a compulsory system of the energy efficiency standards and labels without introduction of amendments in the normative–legislative base now in force. It is suggested that on the first stage energy efficiency labeling standards should be voluntary rather than mandatory. Accumulation of experience and involvement of a considerable number of domestic manufacturers would permit in future qualifying energy efficiency and labeling standards as compulsory ones.

Outcome 2: National S&L schemes for selected power-consuming products are designed and proposed, verification and enforcement capacity for their implementation developed based on international best practices.

The project will develop proposals for national S&L schemes for the priority products identified by the market analysis carried out in the PPG stage (see table 8) that will deliver the largest and most cost-effective energy savings in each of the targeted groups of equipment. For each selected product, the necessary elements of a full energy efficiency standardsand and labeling programme (test procedures and infrastructure, certification schemes, energy labels and MEPS) will be developed, complemented by procurement models and voluntary agreements with manufacturers and supply-chain actors. In parallel, the required verification procedures will be developed.

Table 8. Energy intensity of equipment

Equipment by groups	***Annual amount of energy use, millions of kW*h/year***
Industrial equipment for use in buildings	
Water pumps	12,800
Industrial air-conditioning and ventilation unit	2,900
Refrigeration machines of the central air-conditioning systems	850
Household equipment[2]	
Refrigerators and freezers	31,600
Washing machines	7,300

The observations made during the preparatory phase show that EU energy label is recognisable in the country so it is likely that the most suitable and cost effective solution for household appliances will be to link the Russian scheme to the EU one. For technical building equipment the best scheme will be selected after a detailed analysis of international antecedents. In this respect, a partnership will be established with “Rostest-Moscow”, one of the largest testing centers in Europe with over 500 items of machinery, electronic devices, etc. All its laboratories conduct tests of equipment for further safety and quality certification. The quality of their work has also been recognized by the leading international organizations, expert centres and testing laboratories and consumer associations. Their certificates are accepted and recognized in all member countries of the “System of international electrotechnical commission for verification of tests and certifications of electric equipment”.

[2] Lightning sources will be covered by a separate Lightning Equipment Energy Efficiency Project

The project will also make sure that the relevant government entities understand this importance and plan adequate human and financial resources for the process of S&L preparation and implementation. Other major stakeholders in the process will be manufacturers of both household and commercial equipment (incl. EU manufacturers that have set up production facilities in Russia, local producers) and the main importers of electrical equipment.

Outcome 3: Strengthened capacity of the local manufacturers to produce appliances complying with the new EE standards.

Manufacturers and other suppliers of appliances and equipment play a crucial role in transforming the market for energy efficiency products. Firstly, without adequate supply, markets for more efficienct products cannot be developed. Secondly, suppliers should see it as their interest to deliver more efficient technologies to (industrial, commercial and/or residential) customers, for example via an increased profit margin on better performing products. This also applies to the rest of the supply chain (including distributors, wholesalers and dealers or retailers). Thirdly, suppliers have, via their marketing efforts, a huge impact on customer perceptions of products, and can thus provide an important support or barrier for market transformation, depending on their position concerning energy efficiency improvements.

This project will work with domestic manufacturers and other suppliers (importers, assemblers, supply chain partners) to increase their capacities to deliver an adequate supply of good-quality energy efficient products. It will provide technical support to manufacturers about product and production technologies used internationally for more efficient appliances and equipment, provide technical expertise (mainly via national technical institutes and/or universities, and international expertise where needed) to examine production facilities and suggest improvements, and assist in the preparation of business plans for the production and marketing (or import of components, assembly and marketing) of more efficient appliances. This will ensure that domestic production capacities for efficient appliances and equipment can be increased, to meet the growing demand for efficient products that will result from the implementation of this project.

Further, to maintain profitability of investments and to ensure the buy-in of the supply chain into the marketing of efficient products, the project will closely cooperate with domestic manufacturers and other supply chain partners in the implementation of the other components of this project, particularly on the structure of the regulatory framework, both on federal and local level (making sure that there is an even balance of obligations on each party), the timing of measures (to allow for a reasonable return on investment within normal product cycles), the threshold values and definitions of standards (to prevent an undue discrimination against local or foreign technology), marketing efforts (to create a multiplier of project / government and supply chain marketing efforts) and with demonstrations (same).

Outcome 4: Increased consumers', producers' and retailers' awareness and improved marketing of appliance energy efficiency standards and labels.

The majority of the home appliances sold in the country have low energy efficiency – only about 20% percent of newly sold appliances on the market would belong to the A+ or A++ energy class according to the EU scheme (in comparison to about 80% in Western Europe). The reason for this is not the lack of technical capacities of manufacturers to produce efficient equipment, but mainly the low consumer demand for such products due to low awareness, lack of or inadequate information delivered to them and the high cost of high efficiency equipment. With the gradual reduction of the domestic energy subsidies, however, the household energy tariffs and bills have been increasing, creating incentives to look for savings and this trend will continue.

The project will develop and deliver to consumers targeted information about appliance energy efficiency characteristics, costs and benefits of energy efficient products and easy-to-use comparison tools, including an internet-based information clearinghouse. The project will also work closely with manufacturers of industrial equipment, large retailer chains and local utilities to assure that all stakeholder groups understand the meaning of the energy label and how they can deliver proper information and arguments to recommend high efficient products to customers.

Outcome 5: Pilot implementation of standards and labels

Based on the preliminary assessment, the project will confirm the choice of the priority products and regions (provinces) for piloting S&L schemes. The city of Moscow has been selected as a pilot region. The choice of Moscow for piloting implementation of S&L is due to the presence of leading retailers' networks and the opportunity to assess the impact of project campaign on different types of consumers (different income level). Also, Moscow is the largest and most advanced market to promote EE appliances (6 mln out of 56 mln households in Russia) with highest consumers' awareness and ability to pay for more energy efficient products. In addition to this, the Moscow city government is actively promoting energy efficiency, including energy efficient appliances.

Major commercial consumers have already come to realize economical effectiveness of energy saving, but still suffer information deficit. Improved communication can help a lot to provide adequate information on actual costs of their purchases, on existing models of procurement management, applying energy efficiency as a tool to increase gains. The Project will contribute to sharing information and establishing relationships with the major companies aimed to display the benefits obtained due to introduction of schemes of EE standards and labels of products. The Project intends to develop and verify various mechanisms of standards adjustment, particularly at the level of major commercial marketers. The measures planned will be coordinated with activities and campaigns that are already underway, for example, with the targeted city *Programme of Moscow Energy Saving for 2009-2011 and up to 2020*.

Campaigns addressing end-users will be conducted in the selected area and involve manufacturers, retailers and non-governmental organizations. Comprehensive monitoring and assessment programs will be introduced to assess the progress and feed-back, to improve the labelling schemes. The results of assessments carried out as well as relevant information on direct and indirect favorable environmental impacts (reduction of CO2 emissions) will be laid open to the public.

Expected results:

- **Development and integration of standards and norms on equipment for buildings and for big electrical household appliances;**
- **Energy efficient equipment market expansion and increase of demand for energy efficient equipment.**

Energy saving:

- **15-20 billion kW*h/year – by the Project completion time;**
- **30-35 billion kW*h/year - by the Project effect completion time.**

Reduction of CO2 emissions:

- **10-15 MT CO2 /year – by the Project completion time**
- **25-30 MT CO2 /year - by the Project effect completion time.**

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New developments in enforcing compliance with Standards and Labels in the UK

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Market Transformation Programme, UK

Abstract

Research[1] has shown that the level of enforcement of energy labelling requirements and minimum product efficiency standards in the EU is generally low. The UK, though already amongst the most active EU Member States, has embarked on a programme to deliver a substantial uplift in its monitoring of compliance with minimum product efficiency Standards[2] and Labelling regulations[3].

Defra's Sustainable Energy Using Products Unit has developed and is implementing a market surveillance and enforcement strategy to:

- Increase the quantity and effectiveness of product performance monitoring through the delivery of a substantial testing programme;
- Publish future market surveillance test reports complete with the identity of the products tested;
- Dedicate a webpage to market surveillance activity from which the complete archive of product test reports can be freely accessed;
- Improve the cooperation of bodies carrying out market surveillance and enforcement in the UK by bringing together a compliance network in order to increase data sharing and coordination;
- Considering how best to implement the EuP Directive's requirement to put in place a market surveillance authority, particularly whether this function should be contracted to a dedicated team in a central Government body or agency;
- Exploring the potential to share the costs of market surveillance and enforcement with industry.

The importance of product compliance

The Framework Directives on Energy Labelling and the Eco Design of Energy using Products are two key pieces of European legislation intended to improve the energy efficiency of energy using products in order to save around 10% of EU energy consumption. Initial work by Defra suggests that potential CO_2 savings attributable to the Implementing Measures agreed so far under the EuP Framework Directive, and complementary measures for energy labelling, could bring up to £928 million net annual benefits to the UK and save 8.9 Mt of CO_2 per year in 2020.
Non compliance with this legislation by manufacturers can reduce the effectiveness of these policies resulting in lower than anticipated energy savings. Non compliance in this context relates to inaccurate claims by manufacturers over stating the energy efficiency of their products in order to achieve a higher label class or to keep a product on the market following the introduction of minimum product efficiency standards.

Limited data means it is difficult to predict accurately the rate of non compliance in the UK. Initial estimates by the MTP suggested that around 15% of energy using products currently placed on the market could be non compliant, this is roughly in line with estimates of non compliance in other Member States[1]. However, interim results from the current MTP testing programme indicate that this could be a significant underestimate and that as many as 25% of products do not perform as stated. There is a risk that with many more products being subject to Minimum Energy Performance Standards (MEPS) and labelling requirements moving forward, the rate of non compliance could increase.

Without an effective compliance regime in place, some of the projected CO_2 savings won't be realised. The extent to which CO_2 emissions will not be saved will depend on the actual performance of the products sold and by how much their efficiency was compromised.

Detailed analysis of carbon emissions savings has only been conducted for the 11 EuP measures that which have been or will be voted upon in early/mid 2009. However, from these 11 product areas alone, non-compliance could result in missing out on saving over 0.4 million tonnes of CO_2 a year by 2020.

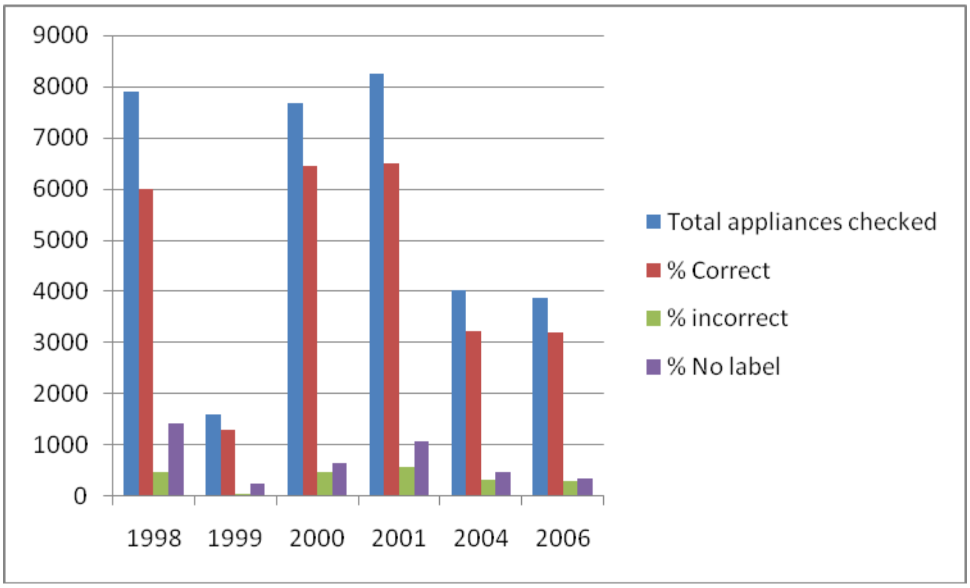
Other costs of non compliance include costs of air quality damages not avoided, financial consequences for consumers i.e. not saving as much on energy bills as expected and uneven playing field for manufacturers placing products on the market.

Regulatory responsibilities in the UK

The Department for Environment Food and Rural Affairs (Defra) is the Government department responsible for the implementation of EU Energy Labelling Regulations and the forthcoming EuP Implementing Measures in the UK. However, the responsibility for the enforcement of Energy Labelling Regulations in the UK is currently devolved to Trading Standards Officers ("TSOs") working in (over 300) local authorities.

Regulatory activity in the UK

To date, market surveillance of Energy Labelling Regulations in the UK has been primarily concentrated on the display of labels on regulated products in shops. Here compliance appears to be maintained at a level of 75-85%.



Source: Market Transformation Programme [5]

Regulatory activity in the EU

It has been reported from a partial study[1] of EU Member States that only a very small minority undertake any significant market surveillance activity. This, where it exists, is more likely to concentrate on label displays in shops rather than testing of appliances. Enforcement actions, if taken, are rarely pursued via the legal system.

Compliance Monitoring activity in the UK

Measuring the energy efficiency of energy using products accurately to determine if a product is compliant is an involved, costly process, meaning that only a very small proportion of products that are placed on the market are subject to any form of testing. Further, the verification procedures set in the respective European Directives require that if a tested product is found to be under performing, a further three products must be tested to eliminate the possibility of a rogue test result. This combination of costly, complicated testing and the need to repeat tests several times to demonstrate non compliance have proved onerous and no successful prosecution has ever been taken in the UK against a manufacturer under this legislation.

Though not an enforcement body, the MTP has, in a limited way, been carrying out product testing using the methods required in Energy Labelling and Energy Star Regulations. It has been able to share its results with TSOs and has made funding available[6] to them in order to support enforcement action.

The Table, below, demonstrates the range of market surveillance undertaken by the MTP. Copies of all of these reports can be downloaded from the compliance page on its website[5]

Table 1: Reports available from MTP

Year of publication	Report topic
2004	Energy labelling survey of internet sales sites
2004	Energy labelling survey of retailers
2005	Energy label compliance test report – domestic appliances
2006	Energy label compliance test report – washing machines
2006	Energy labelling survey of retailers
2006	Compliance test report -oil and gas fired boilers
2007	Energy labelling survey of internet sales sites
2007	Energy label compliance test report – domestic wet appliances
2007	Compliance with Energy Star requirements: desktop projectors
2007	Compliance with Energy Star requirements: desktop computers
2007	Compliance with Energy Star requirements: laptop computers
2008	Pilot study - availability of energy labelling technical files
2008	EC Directive 2000/55/EC compliance test report – lighting ballasts
2008	Energy label compliance test report – air conditioners

Defra strategic review

Defra began a strategic review in 2008. It was becoming increasingly clear from MTP monitoring that effective policy delivery was being undermined by poor compliance. Not uncommonly, the measured shortfall in product performance exceeded the 15% tolerance typically permitted for the first sample tested under the applicable EN test standards.

Further, pressure from industry for improved compliance in the market place had increased too. CECED, the European trade association for domestic appliance manufacturers, announced in 2007[7] that it would discontinue the introduction of voluntary energy efficiency agreements. They claimed that poor national enforcement of energy labelling was undermining their members' voluntary approach by allowing "free-rider" (non-compliant) products to be sold in EU markets with little risk of enforcement action being taken against them. The ANEC[1] report confirmed that this was an EU wide issue, the responsibility for which was at member state level, thus a Defra responsibility for the UK.

The strategic review identified a number of benefits of implementing a robust market surveillance and enforcement regime including:

- Delivery of the UK Government's 2007 Energy White Paper commitments on raising product energy efficiency standards, stimulating global competition and bringing greater choice in energy efficient products to UK consumers;

- Ensuring the use of more efficient products contributes towards the UK's 80% CO_2 reduction targets enshrined in the Climate Change Act 2008;

- Creating a level playing field for manufacturers and businesses. This is particularly important in the current economic climate;

- Substantial financial benefits in terms of lower energy bills for consumers, reductions in CO_2 emissions, and avoided air quality damages;

There were also several negative consequences identified of not implementing an adequate regime:

- Risk of infraction and significant fines from the EU if an appropriate enforcement system is not put in place for the EuP and energy labelling Directives;

- Environmental consequences in terms of not realising the full energy and CO_2 savings potential of these policies;

- Financial consequences in terms of highly cost effective CO_2 savings not realised (and therefore more expense) under the EU ETS;

- Public health impacts and the knock on financial consequences in terms air quality improvements not realised;

- Financial consequences for consumers i.e. not saving as much on energy bills as expected;

- An uneven playing field for manufacturers placing products on the market.

The areas identified for improvement in the strategic review included:

- The profile of existing market surveillance activities needed to be raised so that stakeholders such as industry and NGOs could be confident that the UK Government was taking action and that there was effective policing in the market place;

- The results of monitoring were not available in the public domain, thus denying the opportunity for stakeholders to examine and challenge the market surveillance work being undertaken by Defra;

- The test reports did not include the brand names of the products tested, providing little incentive for manufacturers of underperforming products to improve;

- The benefits resulting from coordination between different bodies working on market surveillance were currently not being maximised. It was not possible to fully exploit opportunities to base monitoring programmes on intelligence gained in other programmes. Neither was there a mechanism to share best practice;

- The cost of conducting full market surveillance regimes could be a deterrent for some authorities and new forms of funding or lower cost approaches needed to be explored.

Strategic review – new measures

Following the strategic review, Defra put a number of improvements into practice:

1. **Improving access to information**

A webpage dedicated to compliance has been posted on the MTP website. From this, the complete archive of product test reports can be downloaded as well as a range of other relevant information and links.

2. Raising the profile of product compliance

The (then) current practice of withholding the brand names of products tested under the MTP testing program was changed. Unless the product testing work was being carried out together with TSOs for enforcement purposes, future test reports were to be published on the MTP website complete with the brand names of products tested.

The first reports to be published complete with the brand names of products tested will be on:

- Washer/driers (24 models)
- Electric ovens (24 models)
- Lamps (280 models)

It is expected that these will be published during 2009. However, as mentioned above, preliminary results suggest that up to 25% of products do not meet the stated performance claims and for some products 100% of those tested failed to meet one or all of the stated performance criteria.

3. Improving coordination between UK market surveillance bodies

Defra has for some time hosted an informal network of bodies that carry out compliance monitoring through product testing in the UK. Defra are currently working with the following bodies to further improve and formalise data sharing and coordination between these bodies:

- Carbon Trust, a UK government funded programme helping businesses and the public sector to cut carbon emissions. They are responsible for the market surveillance of energy efficient commercial/industrial products eligible under the UK's Enhanced Capital Allowance scheme[8];
- Energy Saving Trust, a UK government funded programme focussed on helping consumers to cut carbon emissions. The Trust operates a market surveillance programme to ensure the integrity of its labelling endorsement scheme for energy efficient products[9];
- LACORS, the local government central body responsible for overseeing local authority regulatory and related services in the UK. LACORS represents TSOs in Defra's informal network;
- OFGEM, the regulator for the UK energy supply industry responsible for administering the Carbon Emissions Reduction Target[10] which is the UK Government's main policy instrument for reducing carbon emissions from existing households. Energy suppliers meet this obligation by delivering and installing carbon emissions reduction actions in domestic premises. These can include the supply of compliant energy efficient products;
- MTP, which operates product testing programmes on behalf of Defra.

4. Looking at ways of reducing the cost of enforcement procedures

Currently, laboratory testing of products is very expensive as four products are tested in order to pursue a non compliance action through legal channels.

For example, a modest market surveillance exercise of the UK market for domestic cold products could require that at least 12 individual models from each of fridges, fridge/freezers, upright freezers and chest freezers will need to be tested (= 48 products) Each test costs approximately £2200 each = £105,600. Assuming 15% (7 of the 48 products) are found to be non compliant, then a further 3 of each (= 21 products) will need to be retested = an additional £46,200

Therefore the total detailed testing costs for the domestic cold product group (£105,600 + £46,200) = £151,800 excluding the cost of purchasing the samples and any subsequent legal costs. And, to give a sense of scale, such an exercise would only cover 1.5% of the domestic cold models available in the UK in these categories .

One possibility for reducing costs that that if a product fails the first test, that the subsequent three tests required to demonstrate non compliance should be paid for by the manufacturer in order to demonstrate that the first test was a rogue result. This cost sharing will be discussed in the Compliance and Enforcement Consultation Document.

Consultation

Defra are currently/shortly to be consulting on the UK's plans for a compliance and enforcement regime.

Defra's preferred option would be to transfer the market surveillance function currently carried out by TSOs to a centralised Government controlled agency. This provides for a number of advantages:

- Economies of scale and strategic prioritisation. A single body would be in charge of overseeing systematic and prioritised product testing with a mandate to consider enforcement action if a given product fails to meet the test requirements. Coordinated action would take place nationwide thus avoiding the risk of duplicated tests while building more capacity for testing;

- Continuity of policy ownership. Ambitious product and energy efficiency policy is a key component of Defra's sustainable consumption and production agenda. By ensuring that market surveillance and enforcement are carried out at central level the Government can directly monitor the successful application of its policies and address any arising issue;

- Higher awareness of compliance activities. This single compliance body controlled by central Government would be able to work closely with product policy officials and would benefit from linkages with other regulatory bodies in charge of enforcing other product related Directives such as WEEE and RoHS. The provision of information and eventual tip-offs regarding possible offenders would be routed correctly;

- Expertise building. A dedicated amount of specialist staff would work solely on market surveillance and enforcement without having to compromise and deal with other policy priorities.

The consultation also outlines the plans to improve the penalties toolkit available to the enforcement authority. The EuP and Energy Labelling Framework Directives require Member States to put in place 'an effective, proportionate and dissuasive' penalty regime, which takes into account the extent of non-compliance and the number of units of non-compliant products placed on the Community Market.

The UK plans to both strengthen the existing criminal sanctions and introduce a system of administrative penalties to provide proportionate and flexible responses to instances of non-compliance. Administrative Penalties are civil rather than criminal sanctions and are made up of a range of actions which can include Compliance Notices, Warning Notices as well as Fixed and Variable Financial Penalties. Broadly, administrative penalties aim to:

a. Provide a sufficient deterrent against non-compliance;
b. Eliminate financial gains or benefits of non-compliant behaviour as well as changing the behaviour of offenders; and
c. Deter future offenders from committing similar offences.

Developing EU and international partnerships

The Framework Directives on Energy Labelling and the Eco Design of Energy using Products and their implementing measures apply to all EU Member States. Yet despite sharing legislation and much the same products, there is currently almost no cross-border cooperation between market surveillance authorities. Such cooperation has the potential to lead to more coordination and thus more effective market surveillance across the EU. Furthermore, the creation of EU networking and sharing of experiences can lead to the wider adoption of best practices.

The European Commission has already proposed setting up a Market Surveillance Administrative Co-operation Working Group (an ADCO) as an independent Working Group run and chaired by the Member States. The Group is expected to be a forum for co-operation and exchange of information between national market surveillance authorities. The formation of such a group is strongly supported by Defra. .

Conclusions

Defra is determined to significantly improve the impact and cost effectiveness of market surveillance in the UK in support of the Framework Directives on Energy Labelling and the Eco Design of Energy using Products. It has already begun to do so by substantially leveraging and publicising its own activities and seeks to further enhance these through improving the market surveillance and enforcement regime and through taking an active role in the development of a market surveillance ADCO.

References

[1] http://www.anec.eu/attachments/ANEC-R&T-2006-ENV-008%20(final).pdf

[2] European Commission. Commission Directive 2005/32/EC on the eco-design of Energy-using Products. Can be downloaded at: http://europa.eu.int/eur-lex/

[3] European Commission. Commission Directive 92/75/EEC on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances. Can be downloaded at: http://europa.eu.int/eur-lex/

[4] The Market Transformation Programme is a Defra funded programme supporting UK Government policy on sustainable products. Its aim is to achieve sustainable improvements in the resource efficiency of products, systems and services where these are critical to the delivery of Government commitments in areas including energy efficiency. More details can be found at: http://www.mtprog.com/

[5] http://www.mtprog.com/cms/compliance

[6] http://www.mtprog.com/spm/download/document/id/604

[7] http://www.ceced.eudata.be/ICECED/easnet.dll/GetDoc?APPL=1&DAT_IM=2068F6&DWNLD=2007-03-

[8] http://www.eca.gov.uk/

[9] http://www.energysavingtrust.org.uk/Energy-saving-products/About-Energy-Saving-Recommended-products

[10] http://www.ofgem.gov.uk/Sustainability/Environment/EnergyEff/InfProjMngrs/Documents1/TM%20Guidance.pdf

Label It and They Will Buy? The Case of Energy Efficient Class-A Appliances

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Abstract

The EU appliance energy consumption labelling scheme is a key component of efforts to increase the diffusion of energy-efficient household appliances. In this paper, the determinants of consumer knowledge of the energy label for house-hold appliances and the choice of class-A energy-efficient appliances are jointly estimated using data from a large survey of more than 20,235 German households. The results for five major appliances suggest that lack of knowledge of the energy label can generate considerable bias in both estimates of rates of uptake of class-A appliances and in estimates of the underlying determinants of choice of class-A appliance. Simulations of the choice to purchase a class-A appliance, given knowledge of the labelling framework, reveal that residence characteristics and, in several cases, regional electricity prices strongly increase the propensity to purchase a class-A appliance, but socio-economic characteristics have surprisingly little impact on appliance energy-class choice.

Introduction

Major household appliances account for 35 percent of total EU 15 residential end-use electricity consumption [1]. Refrigerators and freezers alone account for 15 percent of residential electricity end-use, with washing machines accounting for 4 percent and dishwashers, electric ovens, and clothes dryers accounting for approximately 2 percent of total residential end-use, apiece. Increasing the energy efficiency of these appliances is crucial for realizing the European Council Action Plan for Energy Efficiency target of 27 per-cent residential energy-savings compared to expected baseline growth by 2020 using cost-effective technologies [2]. The EU appliance energy consumption labelling scheme has been a key component of past efforts to increase the diffusion of energy-efficient appliances [1]. Labelling schemes are often promoted as a cost-effective measure to over-come barriers related to information and search costs, or to bounded rationality on the part of appliance purchasers [3]. In this case, the labelling scheme is designed to make consumers aware of the relative energy-efficiency of appliances and associated potential cost savings through the provision of observable, uniform, and credible standards (e.g. [4]). Evaluation studies based on aggregate observed data typically find that the existing energy labelling programs for household appliances in the EU, the US or Australia are effective in terms of energy and carbon reductions (e.g. [5]; [6], [7]; [8]; [9]; [10]; [11]). Conducting survey-based conjoint analyses to explore consumers' stated choices for washing machines in Switzerland, [12] also find that eco-labelling affects consumers' purchasing decisions. However, existing studies based on observed behaviour do not explore the socio-economic or technology-related factors behind consumers' choices.

The effectiveness of the energy labelling scheme in terms of affecting consumer's technology choice depends on two outcomes. First, consumers have to be aware of the classification system. Second, the labelling scheme has to influence consumer purchase decisions. In this paper we empirically explore both the determinants influencing consumer knowledge of the EU energy labels for major kitchen and clothes washing appliances and the factors that affect consumer choice of class-A appliances. Hence, while the data set available does not allow to address the effectiveness of the labelling scheme, it provides an important snap-shot of factors associated with knowledge of the labelling scheme and purchase of class-A appliances. The econometric analyses of household appliance choices account for a possible selection bias which results from the fact that only households who are aware of the energy labelling scheme may respond to survey questions on the energy class of the appliance.

Study framework

The econometric analyses are based on a unique data set of more than 20.000 households in Germany. In the survey we use, many respondents did not report the energy class of their appliances. One possible “solution“ would be to confine the analyses of adoption of energy-efficient appliances to those households which reported the appliance energy class. However, positive responders may have different observed and unobserved attributes, particularly with respect to awareness of energy use and concerns about environmental impacts. Hence, the analysis of determinants of consumer choice of energy-efficient appliances is potentially subject to serious knowledge-based selection bias when it is based on only households who respond to survey questions on the energy class of the appliance. Specifically, parameter estimates of the determinants of class-A energy efficient appliances may be biased. One way to control for this knowledge-based sample selection bias is to jointly estimate the determinants of class-A appliance choice and the determinants of knowledge of the energy class of the appliance (e.g. [13]).

Statistical model

Formally, the latent relationship between household attributes and choice of a class-A appliance is:

$$y_i^* = x_i B + u_{1i} \qquad (1)$$

where y_i^* is a latent measure of household preferences for the class-A appliance, x_i is a row vector of household i characteristics, B is the parameter vector to be estimated, and u_{1i} is a residual term. The observed outcome is:

$$\begin{aligned} y_i &= 1 \quad \text{if} \quad y_i^* > 0 \\ y_i &= 0 \quad \text{if} \quad y_i^* \le 0 \end{aligned} \qquad (2)$$

However information on the purchase decision is only available if the energy-class of the appliance is reported by the respondent. Respondent latent knowledge of appliance energy class is modelled as:

$$s_i^* = z_i \Gamma + u_{2i} \qquad (3)$$

where s_i^* is a latent measure of household knowledge of the appliance classification, z_i is a row vector of household i characteristics, Γ is the parameter vector to be estimated, and is u_{2i} a residual. Observed response to the survey question on energy-class on the appliance is:

$$\begin{aligned} s_i &= 1 \quad \text{if} \quad s_i^* > 0 \\ s_i &= 0 \quad \text{if} \quad s_i^* \le 0 \end{aligned} \qquad (4)$$

Estimation of class-A energy-efficient appliance choice with the sub-sample of respondents who provide a response on appliance energy class is equivalent to:

$$E(y_i^*) = x_i B + E(u_{1i} \mid x_i, s^* \ge 0). \qquad (5)$$

Assume $u_1 \sim N(0,1),\ u_2 \sim N(0,1),\ \text{and}\ \rho = \text{corr}(u_1, u_2)$, then

$$\begin{aligned} &E(u_{1i} \mid x_i, s^* \ge 0) = \rho \lambda_i \\ &\text{where } \lambda_i = \theta(z_i \Gamma) / \Theta(z_i \Gamma) \end{aligned} \qquad (6)$$

λ_i is the inverse of the Mills ratio, i.e. the ratio of the normal density function $\theta(.)$ over the cumulative distribution function $\Theta(.)$.

If the error terms of the energy-class choice equation and the energy-class knowledge equation are correlated then $E(u_1) \neq 0$ and the regression results will be biased. Maximum likelihood estimations are applied to estimate the product of the bivariate normal distribution $F_2(u_1, u_2)$ and the probability of sample exclusion $F(u_2)$:

$$\prod_{i=1}^{N_1} F_2(x_i B, z_i \Gamma; \rho) \prod_{i=N_1+1}^{N} F_2(-x_i B, z_i \Gamma; \rho) \prod_{i=N+1}^{M} F(-z_i \Gamma) \quad (7)$$

where 1 to N1 are observations for which the energy-class of the appliance is known and a class A appliance is chosen, N1+1 to N are observations for which the energy-class of the appliance is known and a class A appliance is not chosen, and N1+1 to M are observations for which the energy class of the appliance is not known.

Model specification and data

Knowledge of the energy labelling scheme is measured by household responses on the question of the energy-efficiency class of their household appliance. Specifically, respondents who indicate that they own a certain type of appliance but do not provide a labelling scheme classification of between A and G on the questionnaire are categorized as unaware of the energy-rating of the appliance.

Residence characteristics

Residence characteristics may influence both the knowledge of labelling scheme and the choice of class-A appliances. In the empirical model, particular attention is paid to the age of the residence. For example, households living in residences built after 1997 are much more likely to have purchased an appliance after the official implementation of the energy-labelling scheme in the beginning of January 1998 in Germany and, thus, to have been exposed to the labelling scheme when purchasing the appliance. Discrete indicators for residences built in 2002, 2001, 2000, 1998-1999, 1996-1997, 1993-1995, 1990-1992, and 1985-1989 are included in the knowledge of energy-class specification. New detached residences may be especially likely to be equipped with new kitchen and laundry appliances, therefore a separate indicator for detached residences built after 1997 is also included in the knowledge of energy-class specification.

Renting, rather than owning, a residence has been found in a number of previous studies to inhibit the adoption of energy-saving technologies, as it is difficult for residence owners to appropriate the savings from investments in energy-saving technologies from tenants. Households with larger residences (as measured by floor space) have on average more appliances and higher levels of energy consumption and hence are likely to have greater interest in, and knowledge of, household energy consumption and consumption saving technologies.

Household characteristics

Characteristics of the household included in both the knowledge of energy class and class-A purchase equation specifications include family size and if children under six years of age are present. The intensity of use of major appliances increases with the number of persons in the household, making it more profitable to both acquire information on the energy class of appliances and to purchase class-A appliances. A quadratic specification of age of the main household income earner is also included in both equation specifications. Older household heads may find it more difficult to process information on new technologies, or they may be less likely to have recently purchased a new appliance. On the other hand older household heads may have lower level of knowledge of energy efficient technologies, weaker preferences for state-of-the-art technologies, weaker preferences for environmental preservation, and lower propensities to carry out energy efficiency improvements. An indicator for retired heads of households is also included in both specifications. Retirees may have more free-time for shopping and, therefore, potentially greater awareness of the attributes of appliances after controlling for age [14]. The level of education is included because it may affect the costs of information acquisition, the ability to trade off investment costs versus energy-costs over an appliance's life cycle. Likewise, attitudes towards the environment and association in social groups disposed to environmentally friendly behaviour also tend to be positively related with education (e.g. [15]; [16]). The impact of a household head's management position on consumer knowledge of appliance energy classes is unclear a priori. On the one hand, senior managers and skilled professional may better understand information on appliance energy classes. On the other hand, the higher opportunity cost of time of this group of workers may reduce their willingness to invest in information. Class-A appliance choice may also be influenced by job type if senior managers and skilled professional are better able to calculate the potential profitability class-A appliances. Household income is expected to have positive impact on energy-saving investments because richer households are less likely to face income or credit constraints and because environmental concerns and awareness may increase with income [17]. Similarly, the propensity to purchase class-A appliances may increase with income levels because the income elasticity of willingness to pay for environmental benefits is positive [18]. An indicator of whether the household resides in East Germany is also included in the specification. Regional power prices are included in both the knowledge of class and class-A choice specifications, as higher electricity prices may increase energy awareness and the value of investing in information on energy-saving technologies and also generate greater incentives for the purchase of class-A appliances. Owning more than one of the same type of appliance may also be an indicator for more recent purchase of that appliance type and, thus, positively associated with knowledge of energy class. Similarly, the market in Germany has trended away from the purchase of separate refrigerators and freezers toward combination units, implying refrigerators and freezers in households that also own a combination unit may be older. For refrigerators and freezers an indicator is included for concurrent ownership of a combination unit, while for combination refrigerator-freezer units, an indicator is included for concurrent ownership of a refrigerator or freezer. An indicator of household personal computer ownership is included in both the knowledge of energy class and class-A choice specifications, serving as a proxy for ease of information access and receptivity to new technology. Also, an indicator of ownership of a class-A appliance of another type is included in the class-A choice equation specification, but not the knowledge of class specification, as the propensity to purchase class-A appliances may be strongly correlated across appliance types. Two variables with expected positive correlations with awareness of appliance energy class are included in the knowledge of class specification, but not in the class-A choice equation. The first variable is an indicator for household provision of information on annual electricity consumption that proxies for household awareness of energy use. The second variable is the share of other households in the same region with knowledge of the appliance energy class as a proxy for potential regional spill-overs in energy class awareness resulting, for example, from regional information campaigns by state energy agencies, retailers, or consumer groups.

Data

The dataset comes from a mail survey of private sector household energy consumption conducted in December of 2002 as part of a multi-topic survey of an existing representative panel of German households [19]. Overall, 20,235 households (75 percent) responded to the mailed questionnaire. The sample sizes for households that own the appliance being analyzed and supply information on all covariates are 15,526 households for refrigerators, 12,943 households for freezers, 6,993 households for refrigerator – freezer combination units, 12,814 households for dishwashers, and 19,014 households with washing machines. Knowledge of appliance energy class is low for all appliance types, ranging from 24 percent for households with a washing machine to 16 percent for households with a dishwasher. By comparison, among those households who know the energy class of the appliance, washing machines show the highest rate of class-A purchases at 65 percent, while refrigerators have the lowest rate of class-A purchases at about 54 percent. As discussed, observed and unobserved heterogeneity between those who know and those who do not know the appliance energy class suggests that these rates of class-A purchase may not be representative of expected rates of purchase for the whole sample. It is worth noting that the level of knowledge generally increases with the length of time since the EU implementation directive on the energy-efficiency classification scheme for the appliance, with the implementation directive for washing machines put in place in Germany in 1995 and the directive for dish washers implemented in 1999. Lack of purchase of an appliance after the implementation of the energy classification scheme is obviously an important factor in the observed low-levels of knowledge of the energy-class of household appliances. Given the typical lifespan of appliances of around ten to twelve years approximately one-third to one-half of households can be expected to have replaced an appliance due to the end of its lifespan in the period from the beginning of 1998 when energy-efficiency classification schemes were officially implemented for most appliances in German and the time of the survey at the end of 2002. Descriptive statistics further reveal that combination refrigerator-freezer units tend to be more prevalent in recently built residences than are separate refrigerator and freezer units, confirming the recent market trend towards combination units. However, residences with combination units also tend to be smaller than those with separate refrigerator and freezer units, suggesting combination unit purchase decisions may be partly motivated by space considerations. Finally, dishwashers appear to be luxury items, as they are disproportionately present in more educated and higher income households relative to other appliances in the study.

Table 1: Estimates of Choice of Energy-Saving with Knowledge-Based Selection

		Refrigerator				Freezer				Refrigerator - Freezer Combination				Dishwasher				Washing Machine			
		Know Class		Class-A		Know Class		Class-A		Know Class		Class-A		Know Class		Class-A		Know Class		Class-A	
		Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Rent residence	yes = 1	0.053 *	0.030	0.087 *	0.053	0.020	0.032	-0.101	0.064	0.086 **	0.043	0.099	0.086	0.145 **	0.033	0.191 **	0.068	0.059 **	0.025	-0.028	0.047
Floor space	residence m^2	0.001 *	0.000	0.001 *	0.001	0.000	0.000	0.002 **	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.002 *	0.001	0.000	0.000	0.001	0.001
Residence built:	(base = built pre-1985)																				
2002	yes = 1	0.494 **	0.186	0.309	0.281	0.620 **	0.198	0.011	0.340	0.293	0.244	0.990 *	0.553	0.593 **	0.166	0.367	0.308	0.449 **	0.152	0.122	0.232
2001	yes = 1	0.352 **	0.149	0.247	0.229	0.202	0.160	0.000	0.292	0.354 *	0.182	0.332	0.312	0.242 *	0.139	-0.189	0.271	0.282 **	0.124	0.023	0.193
2000	yes = 1	0.398 **	0.125	0.500 **	0.193	0.372 **	0.133	0.030	0.243	0.370 **	0.166	0.027	0.298	0.335 **	0.120	0.264	0.227	0.258 **	0.107	-0.037	0.172
1998-1999	yes = 1	0.088	0.089	-0.053	0.147	0.200 **	0.095	0.004	0.174	-0.072	0.121	0.144	0.231	0.149 *	0.088	0.102	0.167	0.080	0.074	-0.062	0.118
1996-1997	yes = 1	0.002	0.084	-0.053	0.141	0.030	0.090	-0.096	0.166	-0.065	0.107	0.150	0.204	0.027	0.083	-0.185	0.159	0.021	0.067	-0.013	0.108
1993-1995	yes = 1	-0.051	0.056	-0.054	0.096	0.020	0.059	0.156	0.113	-0.097	0.081	-0.019	0.162	-0.178 **	0.061	-0.148	0.130	-0.002	0.047	0.074	0.080
1990-1992	yes = 1	-0.186 **	0.068	-0.010	0.129	-0.146 **	0.071	0.011	0.147	-0.408 **	0.111	0.225	0.325	-0.189 **	0.072	-0.192	0.154	-0.173 **	0.057	0.002	0.110
1985-1989	yes = 1	-0.057	0.053	-0.145	0.094	-0.066	0.057	-0.023	0.114	-0.055	0.079	-0.036	0.148	0.011	0.057	0.111	0.115	-0.022	0.045	0.126	0.081
Post-1997 detached house	yes = 1	0.015	0.088	0.027	0.140	0.019	0.093	0.142	0.163	-0.028	0.120	-0.050	0.216	-0.045	0.086	0.033	0.160	0.003	0.073	0.035	0.114
Retiree	yes = 1	0.221 **	0.045	0.157 *	0.086	0.236 **	0.047	-0.050	0.119	0.216 **	0.066	0.019	0.163	0.272 **	0.053	-0.045	0.142	0.181 **	0.038	0.111	0.077
Number of persons	truncated at 5 persons	0.047 **	0.015	0.008	0.028	0.029 *	0.016	-0.023	0.032	0.025	0.022	-0.052	0.047	0.034 *	0.016	0.044	0.033	0.076 **	0.012	0.044 *	0.024
Children in household	under 6 years = 1	0.053	0.046	0.045	0.076	0.054	0.048	0.092	0.088	-0.005	0.066	0.145	0.119	0.027	0.047	-0.070	0.091	-0.019	0.039	-0.002	0.062
Age	age of main income earner	0.007	0.007	0.029 **	0.012	-0.002	0.008	0.019	0.015	0.001	0.009	-0.021	0.019	0.012	0.009	0.005	0.018	-0.004	0.006	0.003	0.010
Age2		0.000 **	0.000	0.000 **	0.000	0.000 **	0.000	0.000	0.000	0.000 *	0.000	0.000	0.000	0.000 **	0.000	0.000	0.000	0.000 **	0.000	0.000	0.000
Secondary school	main income earner, yes=1	0.057 *	0.033	0.128 **	0.060	0.078 **	0.035	0.089	0.074	0.113 **	0.050	0.009	0.112	0.052	0.039	0.045	0.082	0.096 **	0.028	0.064	0.054
Management position	senior official, executive, skilled profession=1	-0.071 *	0.041	0.038	0.074	-0.073 *	0.044	-0.032	0.087	-0.065	0.061	-0.091	0.115	-0.032	0.043	0.081	0.088	-0.043	0.035	0.002	0.060
Income class	lowest = 1 and highest = 16	0.012 **	0.004	0.004	0.008	0.007 *	0.004	-0.009	0.009	0.006	0.006	-0.002	0.012	0.003	0.004	-0.001	0.009	0.009 **	0.003	0.012 **	0.006
East Germany	yes = 1	0.068	0.063	0.116	0.093	-0.025	0.074	0.060	0.123	0.226 **	0.076	-0.083	0.161	0.101 *	0.060	-0.154	0.125	0.063	0.055	-0.156 *	0.088
Regional power price	average electric price in Federal State (€cents/kWI	17.307 **	4.257	3.757	7.900	23.912 **	5.525	-12.795	10.828	9.437	7.486	1.464	9.845	15.797 **	4.731	17.872 *	9.189	10.564 **	3.775	11.710 **	5.823
Own a PC	yes = 1	0.099 **	0.031	0.005	0.060	0.089 **	0.034	-0.100	0.075	0.104 **	0.045	0.052	0.093	0.080 **	0.037	-0.048	0.083	0.061 **	0.026	-0.059	0.051
Own more than one	appliance type	-0.039	0.033	-0.029	0.058	-0.003	0.041	0.016	0.083	0.087	0.092	0.539 **	0.181	0.016	0.140	0.004	0.288	-0.021	0.078	0.012	0.136
Also own Combination	for Refrigerators and Freezers	-0.075 **	0.032	-0.222 **	0.059	0.032	0.033	-0.006	0.065												
Also own Refrigerator or Freezer	for Combination									-0.147 **	0.039	-0.177 **	0.083								
Know power consumption	annual, yes=1	0.193 **	0.027			0.197 **	0.030			0.192 **	0.039			0.213 **	0.031			0.167 **	0.023		
Region class knowledge	share of households in Federal State	2.405 **	1.007			3.145 **	0.971			0.095	1.612			2.260 *	1.308			1.291 *	0.664		
Own other Class-A appliances	yes=1			0.606 **	0.109			0.629 **	0.071			0.580 **	0.110			0.754 **	0.111			0.567 **	0.082
Constant		-4.289 **	0.697	-2.777 **	1.333	-4.917 **	0.924	0.748	1.940	-2.391 **	1.109	-0.523	1.953	-4.032 **	0.724	-4.179 **	1.713	-2.550 **	0.543	-2.674 **	1.035
Rho		0.662 **	0.197			0.237	0.339			0.362	0.464			0.401	0.320			0.557 *	0.223		
Log-likelihood		-8550.1				-7597.3				-4288.4				-6687.8				-12742.5			
No. Observations		15'526				12'943				6'993				12'814				19'014			
No. Uncensored Observations		2'676				2'447				1'428				2'043				4'596			

Note: ** indicates significance at the p=0.05 level and * indicates significance at the p=0.10 level in a two-tailed t-test

Results

Estimation results for knowledge of energy class and class-A choice equations

Parameter estimates for the knowledge of energy class equation and class-A choice equation are presented in table 1. While the results cannot be discussed in detail, a couple of general points are worth mentioning. Overall, there are fewer statistically significant associations in the class-A choice equations than in the knowledge of energy class equations. In general, the statistically significant parameter estimates tend to exhibit the expected signs. Further, knowledge of energy class is typically higher in newer residences, in richer households, in retiree households, in rental residences and if power consumption is known. As expected, knowledge of energy class also increases with higher regional power prices. Finally, the correlation coefficient for the knowledge of energy class and class-A appliance choice equations (rho) is statistically significant in two of the five cases. Hence, failing to ac-count for the selection bias caused by the lacking knowledge of the labelling scheme would result in biased estimates for the washing machines and refrigerators equations.

Results for simulations

The economic impacts of major statistically significant factors are highlighted through the series of simulations that are presented in table 2. The first row of the table shows descriptive statistics from the data on the probability that households know the energy class of the appliance and the probability of choosing a class-A appliance, given that the energy class is known. The second row then presents the results of a benchmark simulation, where the averages of the probability of knowing the energy class and the probability of choosing a class-A appliance, given that the energy class is known, are calculated for each observation based on all parameter estimates. The average calculated probabilities of knowing the energy class of the appliance are, as expected, the same as in the data descriptive statistics. However, the simulated conditional probabilities of class-A appliance choice represent the expected rate of class-A appliance choice across the whole sample, not just those who are observed to know the energy class of the appliance. These simulated conditional probabilities are lower than those found in the baseline data for all appliances. This difference stems from the fact that sample households which do not know the appliance energy class have differences in characteristics which make them less likely to choose class-A appliances than those households which know the energy class of the appliance. Thus, inference of rates of class-A energy appliance adoption from the sample of survey responders provides upwardly biased estimates of expected rates of class-A appliance purchase for the general population. The rest of the simulations focus on the impacts that changes in individual variables have on the expected probabilities of knowing the appliance class and choosing a class-A appliance for the general population. Thus, the correct reference point for each of these changes is the benchmark simulation. The first case considers the impact of new housing stock, with all residences simulated as being built in 2002. For all appliances the probability of knowing the energy class increases when residences are built in 2002. As new housing is a rough proxy for new appliance purchase, the results highlight the fact that responses to the EU labelling scheme will only occur slowly as the stock of appliances is gradually renewed as older appliances reach the end of their lifecycle. The impact of new residences on the conditional probability of choosing class-A appliances is mixed, but in all cases the unconditional probability of observing a class-A appliance (based on the product of the probability of knowing the appliance energy class and the conditional choice of a class-A appliance) increases in the new housing stock simulations.

Table 2: Simulations of Probability of Knowing Energy Class and Conditional Probability of Class-A Selection

	Refrigerators		Freezers		Combination Units		Dishwasher		Washing Machine	
	Prob. Know	Cond. Prob. Class-A	Prob. Know	Cond. Prob. Class-A	Prob. Know	Cond. Prob. Class-A	Prob. Know	Cond. Prob. Class-A	Prob. Know	Cond. Prob. Class-A
Descriptive statistic	0.172	0.543	0.189	0.551	0.204	0.562	0.159	0.596	0.242	0.649
Benchmark simulation	0.172	0.406	0.189	0.445	0.204	0.481	0.159	0.431	0.242	0.571
All new housing stock	0.321	0.439	0.388	0.429	0.294	0.797	0.329	0.516	0.391	0.545
15.4 percent electricity price increase	0.292	0.354	0.370	0.297			0.264	0.555	0.323	0.645
Income class increase	0.175	0.405	0.191	0.442					0.244	0.575
Universal secondary school	0.175	0.417	0.193	0.453	0.210	0.479			0.247	0.573
Universal knowledge of electricity bill	0.187	0.392	0.203	0.441	0.220	0.474	0.174	0.423	0.257	0.562
Universal ownership other class-A appliance		0.638		0.639		0.663		0.665		0.764

The impact of the 15.4 percent increases in real electricity prices that occurred in Germany between 2002 and 2007 is simulated by increasing regional electricity prices. In all cases, except combination units where parameter estimates are not statistically significant, increases in regional electricity prices generate a strong increase in the probability of knowing the energy class of the appliance in response to economic incentive.

For appliances with significant income parameter estimates, increasing incomes of every household by one income class, equivalent to 250 Euro per month, has little impact on either the probability of knowing the energy class of the appliance or the conditional probability of choosing a class-A appliance. Thus, rates of adoption of energy-efficient appliances are unlikely to be greatly enhanced by widespread increases in levels of economic well-being. Similarly, increased education, simulated by giving each household at least secondary school education, has little impact.

Increasing household energy awareness, simulated by assuming all house-holds know their annual electric bill, appears to generate limited increases in the probability of knowing the energy class of appliances. Since this variable is not included in the class-A energy choice equation, it only has an indirect negative impact on the conditional probability of class-A choice by increasing the weight given to households with relative low probabilities of class-A appliance purchase during the calculation of conditional probabilities of class-A purchase. Similarly, the indicator for ownership of other class-A appliances is only included in the class-A appliance choice equation. This simulation highlights the fact that the conditional probability of purchase of a class-A appliance increases strongly when households own other appliances with a class-A energy rating. The result, again, likely stem from the fact that there are unobserved factors that influence class-A appliance purchase common to all appliance types.

Policy implications

The results generate a number of implications for the refinement of energy-efficiency labelling schemes and other policies to promote the take up of energy efficient household appliances. Perhaps most obvious, given the relatively long average life of most major household appliance, the information provided in energy labels will diffuse very slowly into consumer purchase decisions. While proxies for recent appliance purchase are arguably noisy, the data provide evidence that for most appliances that conditional propensities to purchase class-A appliances increased rapidly between mandatory implementation for most appliances in the beginning of 1998 and the survey at the end of 2002. The portion of this shift motivated by increased supply of class-A appliance due to energy efficiency technology advances on the part of manufactures can not be separated from the portion due to increased demand for class-A appliances due to the EU labelling scheme with the current cross-sectional dataset. The results do suggest that consumers respond to economic incentives, as knowledge of energy classes increases with regional energy prices for most appliances. This finding suggests that policies that internalize the social costs of energy consumption will spur awareness and, therefore, adoption of energy efficient appliances. The finding also suggests that provision of economic information on the likely economic benefits of energy efficient appliances as currently discussed in the context of the revision of the labelling Directive can further influence purchase decisions. The current proposal also extends the scope of the framework energy labelling directive from household appliances to cover all energy-related products ([20]; [21]). Increased awareness of household energy use and access to information through personal computers are also likely to influence consumer purchase decisions and should be incorporated into future energy classification scheme information awareness campaigns. Greater awareness of the potential contributions of energy-efficient appliances to household energy conservation will also increase the efficiency of tax and other policies to align marginal energy consumption decisions with marginal social costs. On the other hand, simulations based on model results suggest that household characteristics in the current dataset have surprisingly little impact on the purchase of energy efficient appliances. Yet, within households, the propensity to purchase class-A appliances is strongly correlated across appliance types. Further research is needed to identify the currently unobserved factors underlying these common purchase propensities, with particular attention paid to environ-mental attitudes, psychological factors and social norms. Incorporating these aspects would delineate the role of perceived environmental benefits in household energy-efficient appliance purchase decisions, and thus complement the economics-based approach presented in this paper.

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Design of an Endorsement Labeling Program for Economies in Transition - a case from India

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Abstract

Energy labels and energy efficiency standards for appliances and equipment have proven to be one of the most promising policy instruments for improving end use energy efficiency in a country. Many countries have used these policies and delivered tangible results. One such example of successful voluntary energy labeling program is ENERGY STAR in the United States where the savings are largely the result of reduced demand for electricity that totalled an impressive 170 billion kWh—almost 5% of total U.S. electricity demand—and 35 gigawatts (GW) of peak power, equivalent to the capacity of 70 power plants of US in 2006.

The Government of India introduced the Energy Conservation Act 2001 (EC Act) in August 2001 and established the Bureau of Energy Efficiency (BEE), a statuary body to implement the EC Act. The EC Act identifies standards & labeling (S&L) as one of the major program areas for improving energy efficiency in the residential, commercial and public sectors. As part of the implementation design, BEE has decided that all targeted products under the S&L program will carry energy labels in order to help consumers in making energy-efficient purchases. A comparative label with 5-star ratings was introduced in the year 2005 with labelling of no-frost refrigerators. Now BEE is ready to launch an endorsement label for consumer electronics and office automation products.

This paper presents a case that what process was adopted in India to design an endorsement labeling program. The case is an example that can be adopted by other developing economies to design an endorsement labeling program for appliances and equipments. The paper also discusses challenges faced while designing the labeling program.

Background

India's economy is largely tied to its natural resource base and climate sensitive sectors such as agriculture, water and forestry. India's development agenda focuses on the need for rapid economic growth as an essential pre-condition to poverty eradication and improved standard of living. To meet this agenda, it requires a large scale investment of resources, technology and access to energy. The per capita consumption of energy in India is still the lowest in the world. India consumes 530 kg of oil equivalent (kgoe) per person of primary energy in 2004 compared to 1240 in China and the world average of 1770. To deliver a sustained economic growth rate of

8 to 9% through 2031-32 and to meet life time energy needs of all citizens, India needs to increase its primary energy supply by 3 to 4 times and the electricity generation capacity about 6 times.

India's energy intensity (0.16 kg of oil equivalent – per dollar of GDP expressed in purchasing parity terms) is lower than the OECD average (0.19 kgoe/ GDP – PPP) has shown a downward trend. However, in almost every sector in India, there is large variation in energy intensities of different units, ranging from almost the best in the world to extremely inefficient units as well. As a result there is a room to improve energy efficiency in India with the current commercially available technologies and the best practices.

India has 35 cities with population in excess of 1 million people, as urban population continues to rise. India's urban population is currently approximately 28%[1] of the total population, currently ranked at 69 out of 84 measured countries in the world for the highest urban population percent. The National Urban Transport Policy of India suggests that urban population is likely to stabilize at 60% of the total population, or approximately the average urban population percent of the world. It is projected that India's urban population would grow to about 473 million in 2021 and 820 million by 2051, compared to only 285 million in 2001. This shift in population will shift the type of residential buildings and the types of commercial buildings that will be in India.

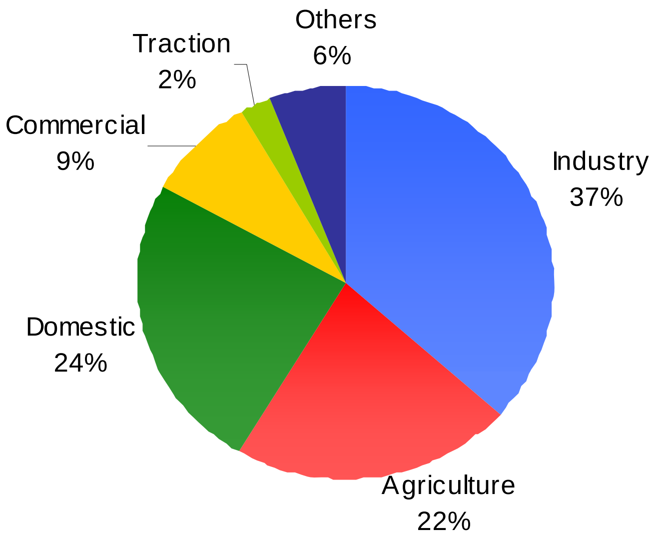

Figure 1: Electric Demand Composition, FY 2005[2]

As of 2005, the residential and commercial sector account for approximately one third of India's electric demand as illustrated in Figure 1. The high electricity demand in the residential sector is because of the high energy consumption of appliance and equipments people use in their daily life. The appliances and equipments people use in domestic sector in India can be categorized as big households like Refrigerator & Air conditioners etc and medium and small size consumer electronics products like TV, DVD players, audio system etc.

Sales of domestic electrical appliances in India posted strong growth in recent years as the Indian economy recorded another sterling year and disposable income levels in general rose. Intense competition between manufacturers, an influx of Chinese brands, and a rationalization by manufacturers to offer products to cater to the middle and lower-middle class has kept up

[1] Global Health Facts – Urban Population 2007: www.globalhealthfacts.org/topic.jsp?i=66

[2] Source: CEA http://www.cea.nic.in/

pressure on unit prices - particularly for refrigerators. Appliance manufacturers, having understood the need to localize products for the Indian household – for instance using metal receptacles in choppers and grinders - strived to introduce new features and technologies that would appeal to the Indian consumer, refrigerators with a separate compartment for onions and fresh herbs, washing machines that utilize less water, and cookers designed for Indian style cooking are becoming more common.

The biggest attraction for manufacturers is the growing middle class in India. With DEA (Data Envelopment Analysis) characterized by low household penetration, international brands have held an edge over their Indian counterparts in terms of superior technology combined with a steady flow of capital, while domestic companies compete on the basis of their well-acknowledged brands, extensive distribution network and an insight into local conditions. As a result of consumption-led growth, products such as automatic washing machines, refrigerators, microwaves, and electric fans, grew over past years, fuelled primarily by the middle and upper-middle class.

Policy Scenario in India

The Indian Planning Commission, in its recent draft report for an integrated energy policy, laid out a vision for providing energy security to all citizens of India[3]. Energy security broadly defined includes not only reducing vulnerability to supply disruptions but also ensuring that minimum energy needs of vulnerable households are met and that energy is used and supplied in an environmentally sustainable way. The three pillars of sustainable development, economic, social and environmental, all need to be addressed in the provision of adequate energy supplies. This integrated energy policy of India gives emphasis on energy conservation and efficiency, particularly through Demand Side Measures (DSM). This policy estimates 15% saving of energy is possible through energy efficiency efforts.

India has also adopted a series of measures to promote development and a reduction in the rate of increase of India's energy consumption and GHG emissions, including:

Energy Conservation Act:

In 2001, the Indian parliament passed the Energy Conservation Act 2001, which established the Bureau of Energy Efficiency (BEE) with effect from 1 March 2002 under the Ministry of Power. EC Act has initiated a market transformation towards more energy efficient buildings and appliances through Energy Conservation building codes for new large commercial buildings, and energy labelling of appliances, and promoted acceleration of industrial energy efficiency by initiating a process of establishing energy conservation norms for large energy consumers.

Electricity Act:

The Indian Parliament also passed the Electricity Act in 2003. It consolidated laws related to generation, transmission, distribution, trade and use of electricity. Among other things, it called for rationalization of electricity tariffs, creation of a competitive environment, and open access in transmission and distribution of electricity. The Act also mandated the creation of regulatory commissions at the central, regional and state levels. As a consequence, the electric utility system is being unbundled, tariffs are being rationalized, and regulatory commissions are playing an active role in enforcement of bill collection and the promotion of DSM programs in some of the larger states.

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Products and Equipment Standards and Labeling

The energy-efficiency labelling and standards-setting policy is intended to reduce the energy consumption of all household equipment and appliances without diminishing the services they provide to consumers. A successfully implemented standards and labelling policy can reduce the required investments in power plants and reduce fuel consumption for their operation with powerful economic gains (e.g., freeing up capital for investments in non-energy social infrastructure like schools, roads or hospitals) and environmental benefits (e.g., avoiding carbon emissions).

Energy efficiency labels are informative labels which are used to describe the energy performance of the products usually in the form of energy use, efficiency, or energy cost. These labels are affixed with the appliances and give necessary information to the consumers about the energy efficiency of the products. Hence with the help of energy efficiency labels consumer can make informed purchases. Energy-efficiency standards are procedures and regulations that prescribe the energy performance of products. Mandatory labelling program or MEPS (Minimum Energy Performance Standards) can also prohibit the sale of products that are less efficient than a minimum level.

Appliance labeling programs in the West have been instrumental in eliminating low-cost, inefficient appliance models and replacing them with efficient technologies, thereby improving the countries' overall energy efficiency levels. For instance, in the United States, for every $1 of taxpayer's money spent by the government on existing standards is said to result in $350 to $440 investment by consumers in energy efficiency and $610 to $760 net savings from fuel reductions. By the year 2020, standards are expected to reduce annual energy consumption by US households by an estimated 8 to 9 per cent. This would further lead to saving a cumulative total of 25 to 30 quads of energy and 422 million metric tons of carbon by the year 2015[4]

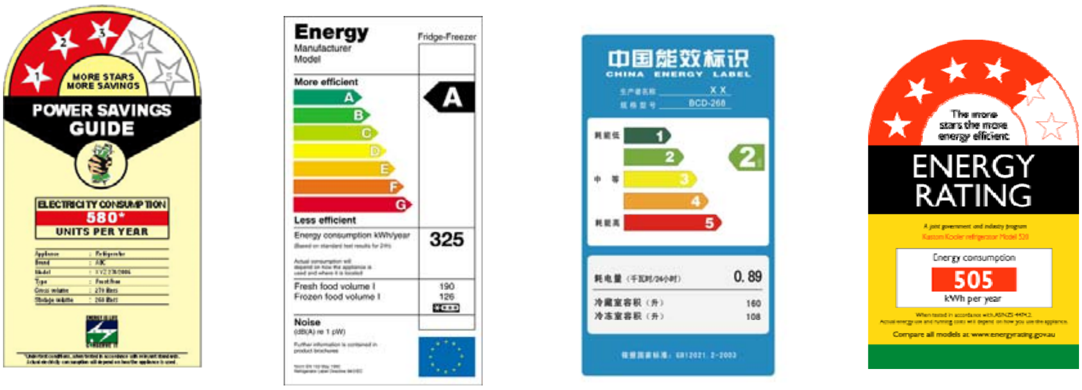
Energy-efficiency labels can be divided into two broad categories

1. Comparative label
2. Endorsement label

Energy efficiency comparative labels are the labels attached to energy-consuming products describe product's energy performance level. These labels are used to inform the energy-efficiency performance of the product to customers (industries, government, as well as individuals).EE comparative label help the customers to make the wise decision by providing the energy consumption details of the products. These labels encourage the industries to optimize the product performance on energy-efficiency.

Few examples of comparative labels are:

[4] CLASP phase 2 project document



Endorsement labeling is different from comparative labeling and so a different label design will be used. An endorsement label indicates that the product is among the most energy-efficient models available on the market. The purpose of endorsement labeling is to indicate clearly to the consumer that the labeled product saves energy compared to other products on the market that do not have the label. Endorsement labels are a "*seal of approval*" indicating that a product meets specified energy efficiency criteria. These labels are generally based on a "yes-no" cutoff (i.e., their presence/non-presence indicates that a product uses more or less energy than a specified threshold.

Few other example of endorsement labels are:

The Indian Scenario of Labeling Program

The Government of India introduced the Energy Conservation (EC) Act 2001 and created the Bureau of Energy Efficiency (BEE) as a statutory body to implement the Act. BEE began functioning in March 2002, implementing various program areas identified under the EC Act. Standards and Labeling are two major program areas being implemented by BEE. BEE works through various committees of experts and stakeholders (including representatives from industry, consumer organizations, industrial associations, etc.) who determine how the program should be implemented on a product-by-product basis.

The provisions in the Energy Conservation Act 2001 for Standards and Labelling provide for the following mandate to Bureau of Energy Efficiency (BEE)[5]:

- Notifying specified equipment and appliances for the purposes of the Act.
- Directing mandatory display of label on notified equipment and appliances.
- Specifying energy consumption standards for notified equipment and appliances not conforming to standards.
- Prohibiting manufacture, sale, purchase and import of notified equipment and appliances.
- Developing testing and certification procedures and promote testing facilities for certification and testing of energy consumption of equipment and appliances

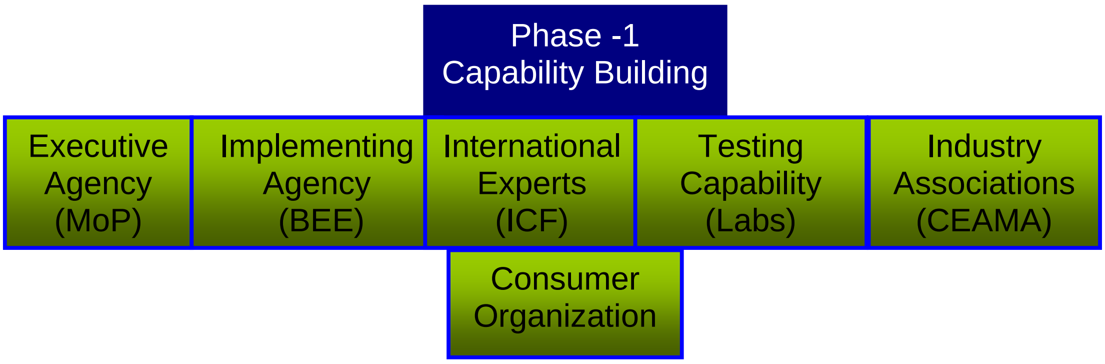
BEE has already initiated a standards & labelling program for refrigerators, air conditioners and Tube lights. This program was launched in May 2006 on voluntary basis. The labelled products however started to appear in the market only in February- March 2007. As per BEE data almost 90% of tube lights industry, 70% each of refrigerator and air conditioner has joined the scheme on voluntary basis, although the percentage of actual labelled products in the market in case of air conditioners is very low. This program is in second phase now and will be made mandatory during 2008-09.

In addition to the above program BEE now with the support of international experts is working with various committees of experts and stakeholders (representatives from industry, consumer organizations, industrial associations, etc.) to design an endorsement labelling program for implementation in India on small consumer electronics and office automation products.

As a result of the endorsement labeling, India may enjoy broader environmental and energy efficiency benefits. Consumers will reap the benefits of lower appliance operating costs through reductions in their electricity bills, and retailers will benefit from increased sales of energy efficient appliance models. It is believed that the appliance labeling program in India will yield larger benefits and lead to significant lowering of electricity consumption at a national level

Approach for Endorsement Labeling Program Design

The overall endorsement labeling program in India has been divided into three phases. In each phase all the required stakeholders are being involved.

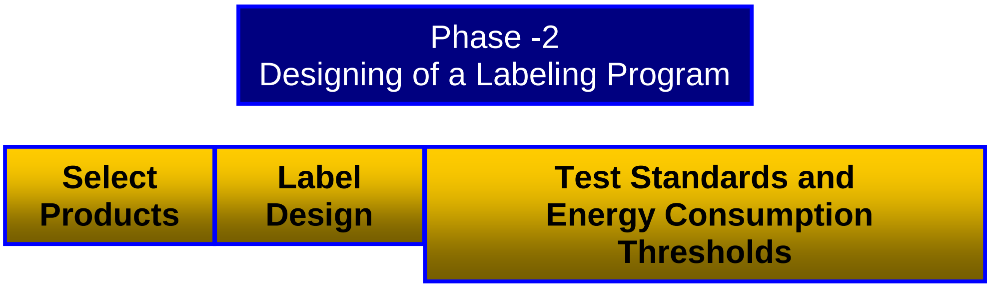


[5] BEE's standard & labeling program (http://www.bee- india.nic.in/Implementation/Standards%20&%20Labellings.html

- There is often a lack of connection between broad policy goals and the test standards, and labeling programs developed by technical experts. To address this barrier, it is important at an early stage to raise awareness among all stake holders about the benefits of energy standards and labeling programs and particularly about a specific labeling program for certain categories of products. In order to overcome the lack of know-how and experience in designing the endorsement labeling program, it was proposed to (a) build capacity and knowledge; and (b) demonstrate to senior policymakers that the proposed program meets international best practice.

- In order to build capacity within the country it becomes very important for all stake holders to learn about the similar programs happened around the world including Europe, Australia and USA. This capacity building exercise of all stake holders also helped in minimizing the repetition of mistakes because of the learning of the similar programs in other parts of the world. In the first phase of capability building a small group of people representing all stake holders of the program visited the United States to learn about the Energy Star program of US EPA. Participants learned about the US EPA Energy Star program and the challenges and issues faced by US EPA during the Energy Star program development. This was a great learning for the Indian team since they had a chance to interact directly with those who have developed a successful voluntary endorsement labeling program for wide range of products including consumer electronics.

- Equipment trade is globalized, and for many, if not most, energy-using appliances and equipment, economy borders are becoming less meaningful in determining markets, and efficiency levels. Hence, it becomes necessary to reduce barriers to trade, since appliances are internationally traded and having to retest a product for export to different countries represents a significant burden. Capacity building exercise addressed this issue by opening the door for possible collaborations and harmonization between the two countries and their energy efficiency programs.



- To initiate the second phase of the program the Bureau of Energy Efficiency (BEE) organized two meetings with the Indian delegation team after their US visit. The purpose of the meeting was to discuss the phase 2 steps for Consumer Electronics Labeling Program in India. The products selections and the formation of steering and technical committees were also completed in order to set the test procedure and energy consumption thresholds for various selected appliances and equipments. Since India is going to have its first endorsement label, it becomes necessary to design a label which communicates the right message to consumers. Hence a nation wide market research was conducted to get the opinion of all classes of consumers. Details about this market research are given in next section.

- One of the barriers which developing economies including India can face while developing new standards for equipments and appliances is cost. For example, European test standard for washing machines required $5 million to develop. The developing economies usually have limited funding and a resource for standards and labeling programs and it is very difficult for these countries to invest a significant amount of resources in developing test standards. This problem of resources and costs can be addressed in two ways: first, economies can work together to develop truly international test procedures so that all economies can less expensively adopt these test procedures; and second, economies can “benchmark” their labeling tiers with other countries, which means that each economy can rely on results of its predecessors to reduce its costs for independent market assessments and feasibility studies. In case of India, Bureau of Energy Efficiency has reviewed the test procedures and energy standards of Europe, Australia, USA and other countries before arriving on the energy performance labeling criteria for India.

Phase -3
Implementation and Promotion

Launch of Label	**Design and Implement Communication Campaigns**

Monitoring, Evaluation and Revision

- The phase 3 is still in progress. BEE has selected the Set Top Boxes as a first product to be labeled by the endorsement label. The technical committee of STBs has finalized the technical criteria of labeling and the test procedures. The technical committee has forwarded its recommendations to the steering committee which is now in a process of recommendation for the launch of endorsement labels.

- Effective implementation and carefully designed communication campaign is the key to the success of standard and labeling program. BEE is now in a process of designing a massive communication campaign to spread the awareness through television and print media among the consumers about the endorsement labeling and its benefits to individuals and the nation as a whole.

Steps Taken to design the program:

- Organize stakeholder committees
- Collect data in order to assess market and product characteristics wrt energy efficiency
- Finalize test procedures, lab specifications, minimum technical qualifications
- Develop and finalize energy efficiency criteria & thresholds for labels
- Finalize the type of label
- Develop implementation and enforcement plan
- Notify manufactures and consumers about the program through print and TV media
- Launch of labels
- Design of an effective consumer awareness campaign
- Program monitoring, review, and updates

Adopted Approach to Design an Endorsement Label

The government initiative is currently engaged in developing an endorsement labeling program that is aimed at enabling consumers to effectively gauge & differentiate the variety of consumer electronics & office equipment & any other category of product which government could take up in future household products such as VCRs, VCDs, home theater systems, microwave ovens, computers, laptops, monitors, chargers [laptop and mobile phones] and MFDs [fax, printers, photocopiers] on energy efficiency. Towards this objective, a market research company was tasked to conduct a multi-phase research study. The research study undertook the following tasks:

- Determine through valid and market research-based techniques a label design that can achieve maximum market impact, i.e. increase sales of energy-efficient products .The study came up with indications of possible improvements in label design, garnered through a process of collating consumer responses with that of retailers, manufacturers and stakeholders. Further needs and perceptions of the existing energy labels were gathered in understanding the value proposition of the labels.
- Provide information on consumer awareness and attitudes towards aspects of energy efficiency. The study also sought to provide key insights into consumers' perceptions of the value proposition offered by the current crop of available products in the above-mentioned categories, based on their energy needs, lifestyle traits and experiential behavior.
- Also test a series of endorsement labels and explore synergies and functionality aspects of the same.
- Provide cues and themes in the context of energy efficiency labeling that enhance the value proposition of the available products amongst the target audience.

Research purpose thus has been to:

- Present the significant number of chosen endorsement label designs across-section of consumers, stakeholders, retailers & manufactures recruited through demographic profiling in selected urban centers in the country.
- Determine among the above-mentioned groups; attitudes and perceptions of energy efficiency; factors that come into play in appliance purchase; awareness levels and the sources of awareness regarding energy efficiency.
- Test multiple label designs among the above-mentioned groups – comprising those exposed to the concept of energy efficiency as well as those that are not and gauge their response in terms of significance, relevance, likeability, credibility, distinctiveness, ease of understanding and usefulness of the labels.
- Responses to criteria such as motivation to purchase labeled products and the savings and environment -friendliness aspects have also been explored. Further there has been an attempt to record responses to the new labels, key messages and meanings as well as perceived benefits. Suggestions regarding improvement of the labels have been duly recorded to enable further streamlining of the designs up till the final stage.

The study is designed & executed in three phases.

Phase 1 (Qualitative): An exploratory research was undertaken with four categories (consumers, retailers, manufacturers & stakeholders). Consumers were interacted in a focus group discussion format and a total of 15 groups were undertaken with them. Twelve retailers were interacted through in-depth interview format and one FGD was undertaken with the same .Further in this phase, in-depth interviews with 04 manufacturer and 03 stakeholders were also undertaken .The phase 1 transpired from 22nd Sept to 5th Oct 2008.The findings from the phase 1 provided necessary insights and cues to further streamline the labels that were paramount for the success of the study.

Phase 2 (Qualitative & Quantitative): Prior to start of phase 2, the designers were briefed to streamline and undertake the suggested changes of phase 1. Hence, the phase 2 of the study started on the 24th of October with modified designs and lasted till 20th November 2008. In qualitative, consumers were interacted in a focus group discussion format and a total of 15 groups were undertaken with them. 17 retailers were interacted via in-depth interview format and one FGD (Focus Group Discussions) was undertaken with the category. Additionally in-depth interviews with five manufacturers and 12 stakeholders were taken. Further for the quantitative study 1450 face to face interviews were undertaken with consumers; 480 interviews with retailers and 50 with manufacturers spanning 14 locations representing 4 zones.

Phase 3 (Qualitative): The fieldwork for this phase started on 24th November and was completed on 4th of December 2008 .In this phase market research organization has conducted 06 FGDs, 04 amongst consumers and 02 amongst retailers. This stage studied just 02 label designs which were preferred outcomes from previous 2 phases. The necessary cues were taken and labels were modified in accordance

Key stakeholders involved in endorsement labeling program in India

The major players that are playing a vital role in formulation and implementation of endorsement labeling program in India are given below:

- Ministry of Power (MoP), Government of India
- Bureau of Energy Efficiency (BEE), MoP, Government of India
- State Designated Agencies (SDAs)
- Electric Utilities
- Testing Laboratories
- Manufacturers’ Associations
- Retail Organizations
- Consumer Advocacy Groups
- International Experts

Conclusion

Increasing dependence on technology:

Technology has emerged as an integral part of consumers' lives. So much so that they have come to depend on the convenience and comfort that equipment bring into their lives. Consumers across all cities and socio-economic groups do acknowledge the downside of technological advances but they are of the opinion that technology offers them more convenience which is required in present scenario. Consumers constantly seek to update themselves on the latest technologies and aspire to possessing products that offer them the benefits of advanced technology.

But the question is how does this relate to energy-efficiency?

Significantly, consumers feel that energy-efficiency is an integral part of the overall advancement in technology. As a result, energy labeling is quite relevant to the appliances in India.

Developing economies can refer to the example of Indian program and adopt a market driven participatory approach designed into phases and comprehensive market reach for the label design. The participatory approach between the regulators and industry can follow some of these steps:

- Select products that use large amount of energy and present in most households
- Organize stakeholder committees for the overall management of program
- Perform techno-economic analysis to understand the efficiency variation of the products
- Estimate energy saving potential and extent of market transformation
- Finalize the label design
- Conduct international comparison of test procedures and energy performance thresholds to take a decision on test procedure and energy performance thresholds
- Launch the program in market
- Support the program with an effective consumer awareness and marketing campaign
- Program monitoring, review and updates

Certain steps can be avoided based on the product scenario and the country requirement but at the same time few steps may needs to be added based on the availability of the infrastructure in the specific country. For example let say if there is inadequate infrastructure for the testing of a particular product than a focused approach for testing laboratories needs to be considered before finalizing the technical criteria for that particular product.

Overall this paper concludes that to meet the growing energy demand of the developing economies, it is very important to promote the energy efficiency policies. Standards and labeling is one of those policies which developing economies can adopt quickly and enhanced the use of efficient appliances. Since most of the developing economies have price sensitive market where quick change over from traditional manufacturing process and old technologies to most updated processes is difficult, the endorsement labeling program for energy efficient appliances can provide tangible results. Challenges to the entire process exist but a carefully designed endorsement labeling program with participation of all stake holders can definitely overcome these challenges. An easy to understand endorsement label communicating right message to consumers can definitely increase the penetration of efficient appliances and reduce the gap between energy demand and supply

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Annexure 1

The timeline for the design and implementation of the endorsement labeling program

S. N.	Activities	Timeline (Months)																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1.	Action Plan																								
2.	BEE/MOP approval to action plan																								
3.	Steering & Technical Committee formation																								
4.	Product identification																								
5.	Test procedures																								
6.	Test labs specs.																								
7.	Standard development																								
8.	Label design																								
9.	Implementation plan																								
10.	Awareness campaign																								
11.	Launching of program																								

Results of a recent survey of compliance with Directive 92/75/EEC (Energy Labelling) in all EU Member States

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Abstract

The Framework Directive 92/75/EEC on Energy Labelling of Household Appliances has been in place since 1992. Up to now, Implementing Directives have been adopted covering 8 household appliances: refrigerators, freezers and their combinations, washing machines, driers and their combinations, dishwashers, electric ovens, air-conditioners and household lamps. Under the Directive, the retail trade is obliged to provide all the appliances displayed in salesrooms with energy labels and to list technical data in table form in the sales records. The main purpose of the Directive is to harmonise the national measures publishing information about the consumption of energy and other essential resources, particularly labelling and the provision of product information, thus allowing consumers to choose the most energy-efficient appliances. The information necessary to do so has to be provided by the supplier of the individual appliance. So that the Directive fulfils its purpose, however, a satisfactory degree of compliance with the Energy Labelling Directive is necessary both at the level of the retailers and the manufacturers. In order to check the degree of compliance in retail trade, a survey has been carried out in all EU Member states and the EEA countries Norway and Iceland. The survey covered all 8 household products included in the Labelling Directive and a statistically representative range of shops in each country and of distance sales. The resulting total share of correctly labelled appliances displayed in salesrooms – i.e. those in full accordance with the Directive - across all 29 countries included in the analysis amounted to 61 %. There were, however, huge differences between countries. The worst result of the survey was observed for mail order and Internet stores. In these stores, only 5 % of appliances were correctly labelled.

Introduction

The Framework Directive 92/75/EEC on Energy Labelling of Household Appliances has been in place for 15 years. Up to now, Implementing Directives have been adopted covering 8 household appliances: refrigerators, freezers and their combinations, washing machines, driers and their combinations, dishwashers, electric ovens, air-conditioners and household lamps. The main purpose of the Directive is to harmonise the national measures publishing information about the consumption of energy and other essential resources, particularly labelling and the provision of product information, thus allowing consumers to choose the most energy-efficient appliances.

Under the Directive, the retail trade is obliged to provide all the appliances displayed in salesrooms with energy labels and to list technical data in table form in the sales records. The information necessary to do so has to be provided by the supplier of the individual appliance. There are special labelling regulations for appliances not on display to potential consumers (e. g. catalogue or Internet offers).

In spite of this success, however, there are concerns that compliance with the Energy Labelling Directive may not be fully satisfactory at the level of both the retailers and the manufacturers. A first survey of compliance with Directive 92/75 was carried out at an early stage of the Directive's implementation in European Member States. This did not include the new Member States [1]. The new survey of compliance conducted by Fraunhofer ISI, GfK and BSR Sustainability on behalf of the European Commission [2] aimed to provide evidence on the present degree of compliance with Directive 92/75/EEC in all EU Member States and the EEA countries of Norway and Iceland. The new survey consists of two parts: a survey of compliance at the level of retailers and a survey of activities carried out by Member States and other stakeholders (e.g. manufacturers, consumer groups) to ensure that the required information is provided and accurate. The focus of this paper is on the results of the survey in retail trade.

Survey Design

The survey of the retail trade covered all 27 EU Member States and the EEA countries Norway and Iceland. Different sample sizes were used related to the size of the market: the targeted sample size for the biggest countries (France, Germany, Poland, Spain and the UK) was 75 shops, for very small countries (Cyprus, Iceland, Luxembourg and Malta) 25 shops and for all other countries 50 shops. The realized sample size differed only slightly from the anticipated figures so that the total sample size amounted to 1478 shops.

Most of the shops included in the audit could be taken from the GfK retail panel[1] which GfK has set up for many EU and EEA markets. The sample structure in each country was based on the value share of the different channels in the markets for the major domestic appliances taken from the GfK retail panel. With this background information, a very precise sample could be drawn which made it possible to limit the audit to a relatively small sample without harming the overall quality. The sample was divided into the following types of outlets:

- *Electro superstores*: large-scale specialists offering electrical appliances with a broad product range and often specialised departments for the different product groups.
- *Electric specialists* (organized or independent): specialised in electrical appliances, traditionally small and medium enterprises usually with a large range but a limited display area.
- *Kitchen / Furniture stores*: offering kitchens including appliances; high degree of competence in planning and consulting services for clients; usually selling complete kitchens with numerous large electrical appliances including built-in appliances.
- *Hypermarkets / Cash & Carry*: in most countries not as important for the sale of large household appliances as the other channels because the self-service character of these shops does not comply with the clients' need for advice and maintenance services.
- *Department stores*: offering a broad range of products among which electrical appliances are only one smaller part; similar to hypermarkets, usually less important for the sale of electrical appliances than the other channels.
- *Mail Order and Internet stores*: here the audit was done based on websites and catalogues which are important for the sales of major domestic appliances according to GfK.

The shop audit consisted of two parts: a quantitative part on labelling in stores by appliance type (shop inspection) and a qualitative part evaluating the shop-owner's or manager's attitude towards the importance of energy labelling based on face-to-face interviews. This allowed an analysis to be made of compliance in the Member States by type of failure, type of shop and type of appliance and of the attitude of retailers towards the label. For the shop audit, two types of questionnaires were used by the GfK field workers:

- A *pre-defined survey sheet for inspecting the shops* which was used by the field workers to make an inventory of the appliances displayed in the salesrooms and their labelling. The degree of compliance was noted for each appliance taking into account the following criteria of compliance from the Energy Labelling Directive: display of the label, placing of the label (here distinguishing between the basic label, i.e. the colour background without concrete product information, and the product fiche, i.e. the data-strip which contains model-specific information), visibility and original size and colour of the label. For household lamps, it was only asked whether the label is present on the packaging and whether it is clearly visible.

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[1] A retail panel is an ongoing audit of a defined product group in a market in a constant number of sample stores at regular time intervals.

- A q*uestionnaire for the face-to-face interviews* with retailers on their attitude towards the label, handling difficulties, the availability of the label from the producers, and suggestions to improve the labelling.
- A *questionnaire for the he audit in mail order companies and internet stores*, including all criteria which the Energy Labelling Directive demands for appliances which cannot be seen by the potential consumer. This means that the essential information specified in the label has to be provided before buying an appliance. The Implementing Directives prescribe specific information (which varies depending on the appliance involved) which has to be provided in a specified order and in a legible format.

Survey Results

Results of the shop inspection

The degree of compliance with the Energy Labelling Directive was assessed by the following criteria of compliance from the Directive:[2]

- *Completeness* of the labelling: complete label displayed or only basic label or data strip, or both but separately placed.
- *Placing* of the label: top, front, side, back, inside
- *Visibility* of the label: not covered or obscured.
- EU label in *original size and colour*.

Finally, the *overall degree of compliance* was derived from these criteria: a correctly labelled appliance according to the Directive should display a complete label in original size and colour which is attached to the outside of the appliance, on the top or front, in such a way as to be clearly visible and not obscured.

The results of the survey can either be shown by country, by type of appliance[3] or by type of outlet.

There is a relatively high degree of compliance with the Labelling Directive in almost all countries with regard to the ***completeness of the labelling***, i.e. the complete label (basic label and data strip) is attached to the appliance (see Figure 1). Over all countries, 71 % of the appliances were labelled completely. In almost half of the countries, the percentage of completely labelled appliances was even higher at 80 % or more. A degree of compliance below 50 % with regard to the completeness of the labelling was only observed in four countries: Greece (42 %), Malta and Poland (32 %) and Iceland (4 %). The very low value in Iceland is due to the fact that 86 % of the appliances were only labelled with the basic label without the data strip. In Poland, on the other hand, more than 50 % of the appliances were only labelled with the data strip and the basic label was missing. The biggest failures with regard to completeness were that only the data strip was attached to the appliances (12 %) and that the label was missing completely (11 %), whereas the other two failures (only basic label; basic label and data strip, but separately placed) were less important (except in Iceland).

The results on the completeness of the labelling by type of appliance are very similar for refrigerators, freezers, washing machines, tumble driers and dishwashers, of which between 73 % and 76 % are completely labelled with the basic label and the data strip (Figure 2). For electric ovens (59 %) and especially for air conditioners (39 %), the degree of compliance is considerably lower and the share of appliances displayed with no label is rather high (20 % for electric ovens and 50 % for air conditioners). This means that there is a clear difference in the degree of compliance between white household appliances for which the Implementing Directives came into force more than 10 years ago

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[2] The assessment of whether appliances were correctly labelled or not did not include testing of appliances, which was not in the scope of the study. That is, appliances which may be classified in the wrong labelling class, may judged to be correctly labelled under the criteria used here.

[3] Refrigerators, freezers, washing machines, dishwashers, tumble driers, electric ovens, air-conditioners; household lamps are considered separately.

(between 1994 and 1997) and electric ovens and air conditioners, for which the Implementing Directives were only adopted in 2002.

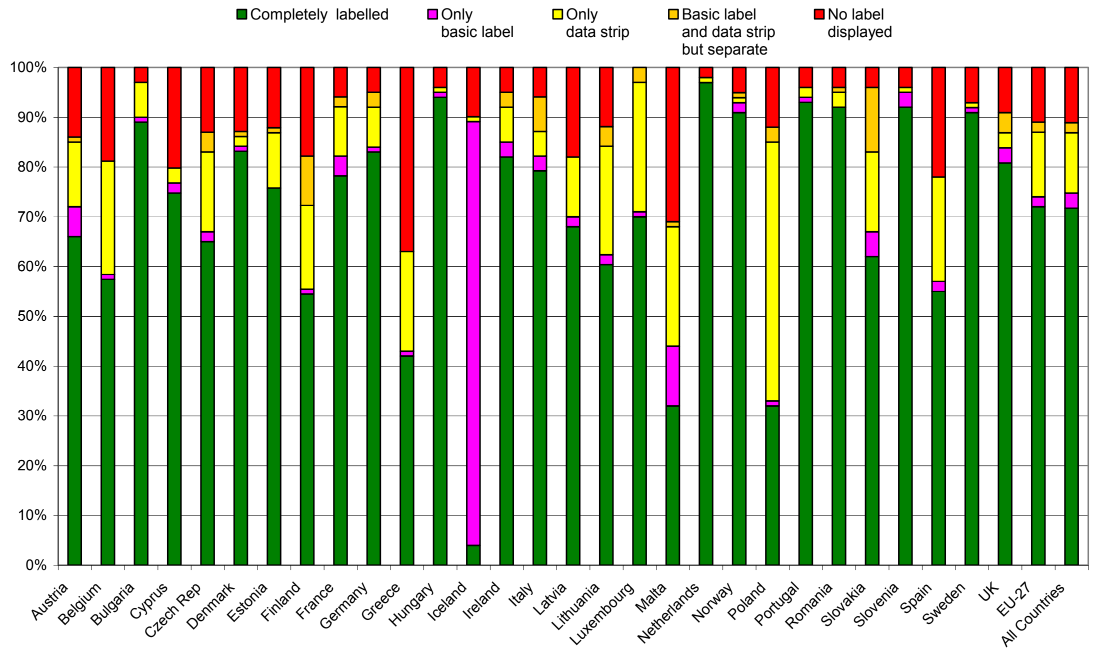

Figure 1. Completeness of the labelling per country (all appliances)

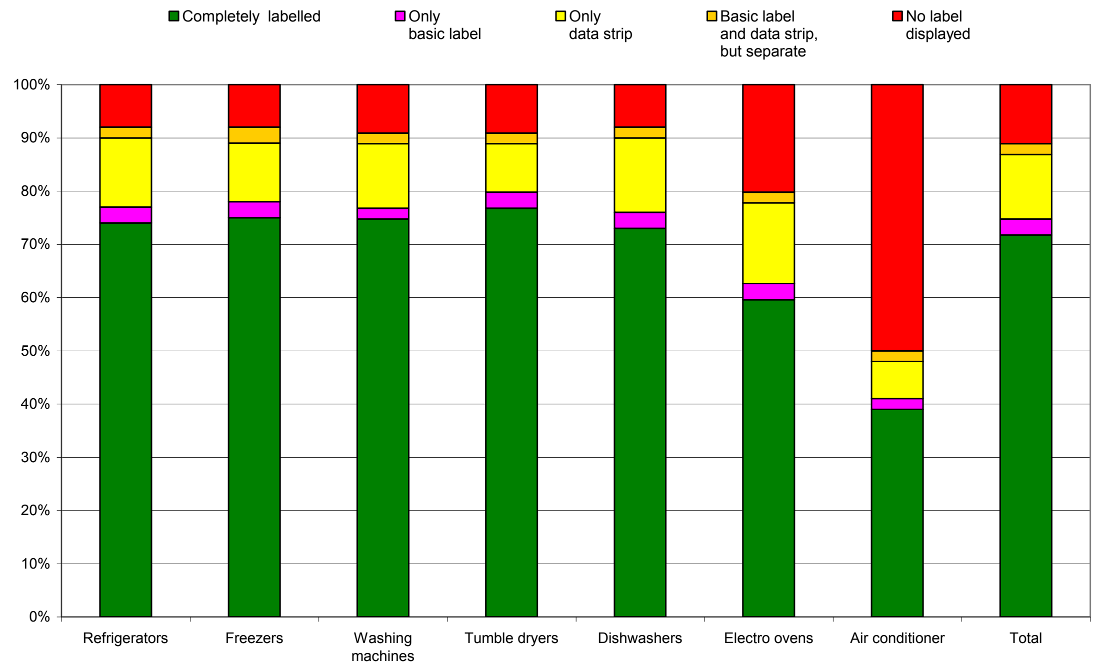

Figure 2. Completeness of the labelling per type of appliance (all countries)

The completeness of the labelling also differed between the different types of retail outlet. Whereas especially electro superstores and department stores had a very high share of completely labelled appliances at about 80 %, the respective share in kitchen and furniture stores was the lowest at only 60 %. The other types of shops lie in-between these two values. The main types of failure were either that the label was missing completely or that only the data strip, but not the basic label, was available.

With regard to ***placing the label****,* the Energy Labelling Directive demands that the label be attached to the outside of the appliance, on the top or front. For the appliances which featured the complete label, this criterion was fulfilled in most cases (Figure 3). In the case of white household appliances, only between 1 and 5 % of the labels were placed inside instead. Again, the worst level of compliance regarding the placing of the label was observed for electric ovens and air-conditioners.

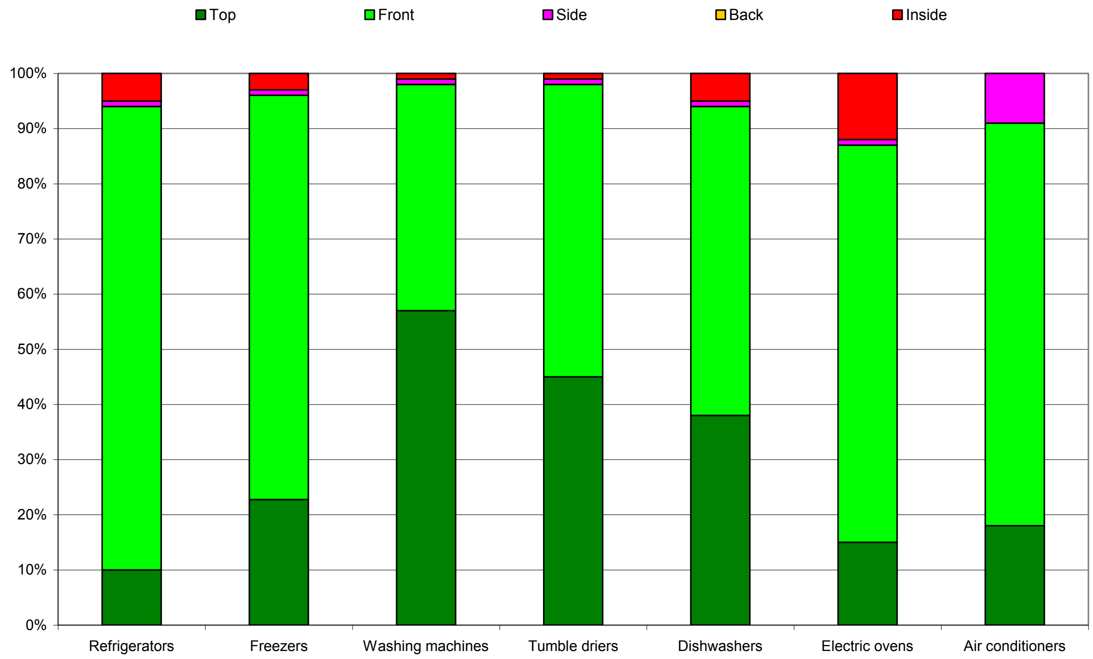

Figure 3. Placing of the label

In addition to the completeness and placing of the label, it was also checked whether the label was ***clearly visible***, i.e. not covered or obscured, and whether the label attached was of the ***original size and colour***. At more than 90 %, the degree of compliance with these criteria is very high for all appliance types except air conditioners. For air conditioners, the visibility criterion was only fulfilled in 74 % of appliances.

Taking into account all the compliance criteria demanded by the Energy Labelling Directive and its implementing Directives, the ***overall level of compliance*** can be derived from the results shown above using the following definitions:

- An appliance is defined as *correctly labelled* in accordance with the Directive if
  - the label is complete (basic label + data strip) and
  - the complete label is placed externally on top or in front and
  - the label is clearly visible, i.e. not covered or obscured and
  - the label has the original size and colour.
- An appliance is defined as *mislabelled* if one or more of the following shortcomings apply:
  - the label is incomplete, but not completely missing and/or
  - the label is not placed externally on the top or front and/or
  - the label is not clearly visible, i.e. is covered or obscured and/or
  - the label does not have the original size and colour.
- An appliance is defined as *not labelled*, if the label is completely missing.

With regard to the overall compliance per country (Figure 4), the total share of correctly labelled appliances over all countries (and for the aggregate EU 27) amounts to 61 %. This is 10 % below the level of compliance when only taking the completeness of labelling into account. 28 % of appliances were mislabelled and another 11 % were not labelled at all. Regarding the overall compliance by country, the highest share of correctly labelled appliances (between 80 and 90 %) were found in Denmark, Hungary, the Netherlands, Norway and Portugal. The country ranking is similar to that for the completeness of labelling, although there are some exemptions. Especially in Bulgaria and Slovenia, the share of mislabelled appliances is very high which means that, although 90 % of appliances were labelled completely, the share of correctly labelled appliances is considerably lower. In Bulgaria, the main shortcoming was insufficient visibility of the label; in Slovenia, the main problem was that the original EU label was not used.

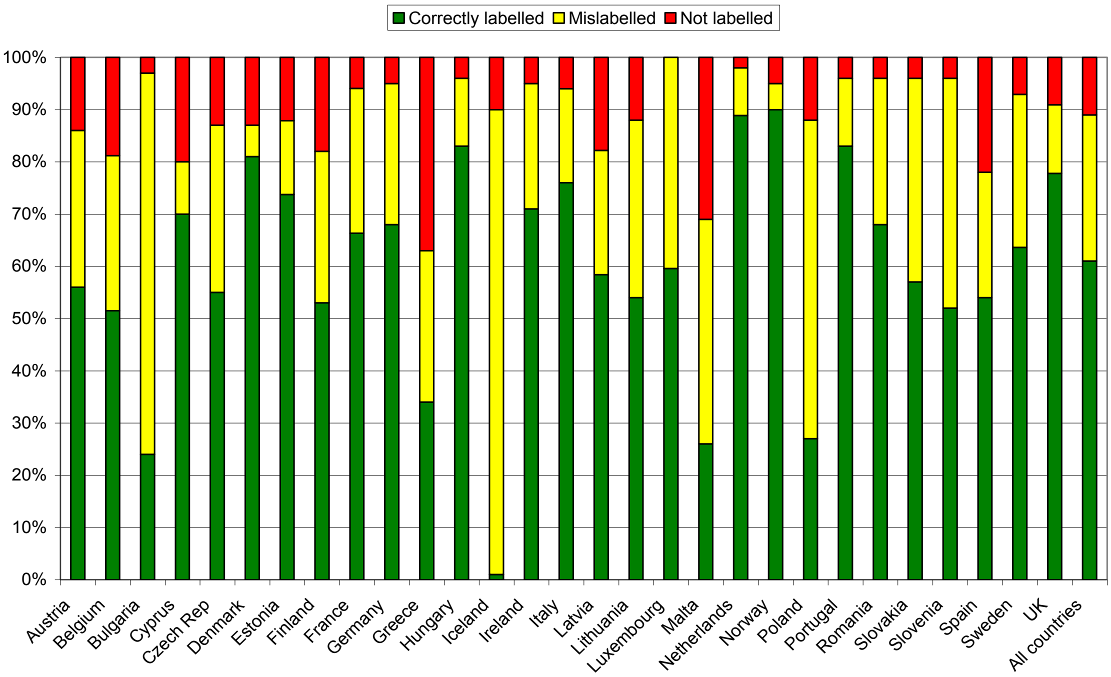

Figure 4. Overall compliance per country (all appliances)

Regarding the overall compliance by appliance type, the share of correctly labelled appliances is very similar for white appliances (between 62 and 70 %), whereas only 45 % of electric ovens and 26 % of air conditioners were correctly labelled in accordance with the Directive (Figure 5). In the case of air conditioners, the main failing was that the label was missing completely (50 %), whereas in electric ovens there was a fairly high share of mislabelled appliances (34 %).

With regard to overall compliance by type of shop (Table 1), the highest share of correctly labelled appliances was found in department stores (69 %) and electro superstores (66 %), i.e. in the big chains. In the case of electric specialists, around 60 % of appliances were correctly labelled; this share was a little lower in hypermarkets, but still considerably higher than 50 %. By far the lowest share of correct labelling (39 %) was observed in kitchen and furniture stores, i.e. sales channels where appearance is very important for sales promotion. In all types of outlets, the share of mislabelled appliances was higher than the share of non-labelled appliances. The main shortcomings, especially in kitchen and furniture stores, were the incompleteness of the label (only data strip available) and the incorrect placement of the label or data strip (mainly inside or still in bag). This shows that especially kitchen and furniture stores are obviously concerned about the appearance of the kitchens on display and therefore often place the labels or data strips inside the appliances.

For ***household lamps***, the Implementing Directive prescribes that the label shall be placed or printed on, or attached to, the outside of the individual packaging of the lamp without being obscured. Therefore, for household lamps, it was only asked whether the label is present on the packaging and whether it is clearly visible. In total, 2 633 lamps were checked, of which 94 % had labels on the packaging. In 92 % of these cases, the label was also clearly visible, which means an overall high degree of compliance in the case of household lamps. The differences between countries were relatively small. The availability of the label on the packing varied between 81 % in Cyprus and even 100 % in some countries.

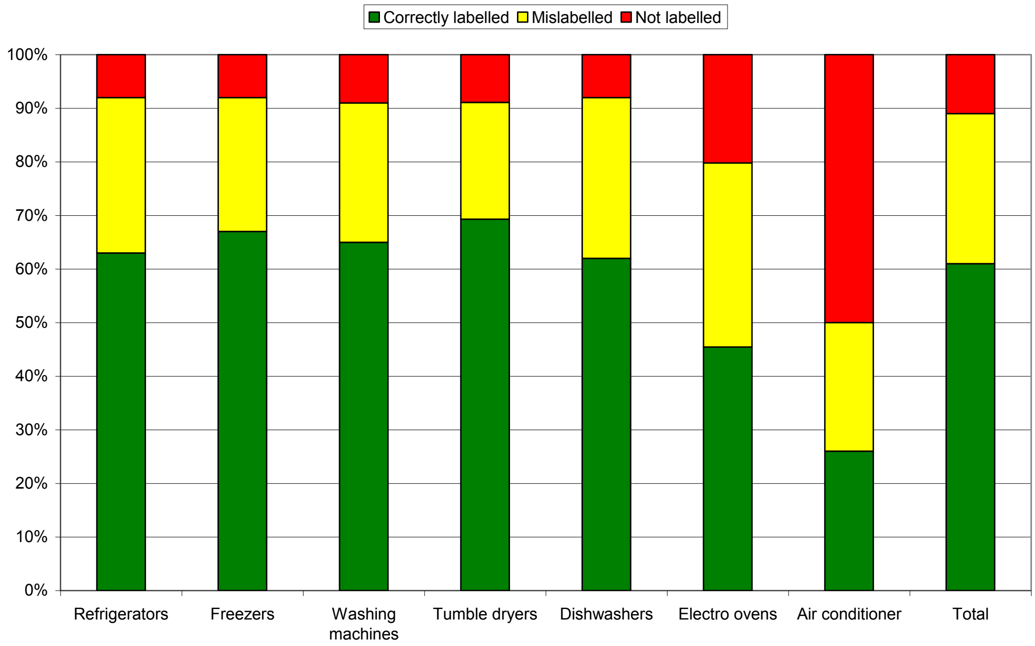

Figure 5. Overall compliance per type of appliance (all countries)

Table 1. Overall compliance per type of shop (all countries)

Type of shop	Correctly labelled %	Mislabelled %	Not labelled %
Electro Superstore	66	25	8
Electric specialist (organized)	60	27	13
Electric specialist (independent)	58	31	11
Kitchen / Furniture store	39	43	17
Hypermarket / Cash & Carry	56	32	12
Department Store	69	25	7
Total	**61**	**28**	**11**

Interviews with store managers or salespersons

The interview started with the question about the role certain *features play in the buying act* of major appliances. In general, there are no large differences in the results. The main issue, obviously, is the purchase price; less important is appliance design (Figure 6). Differences between types of shop are almost negligible.

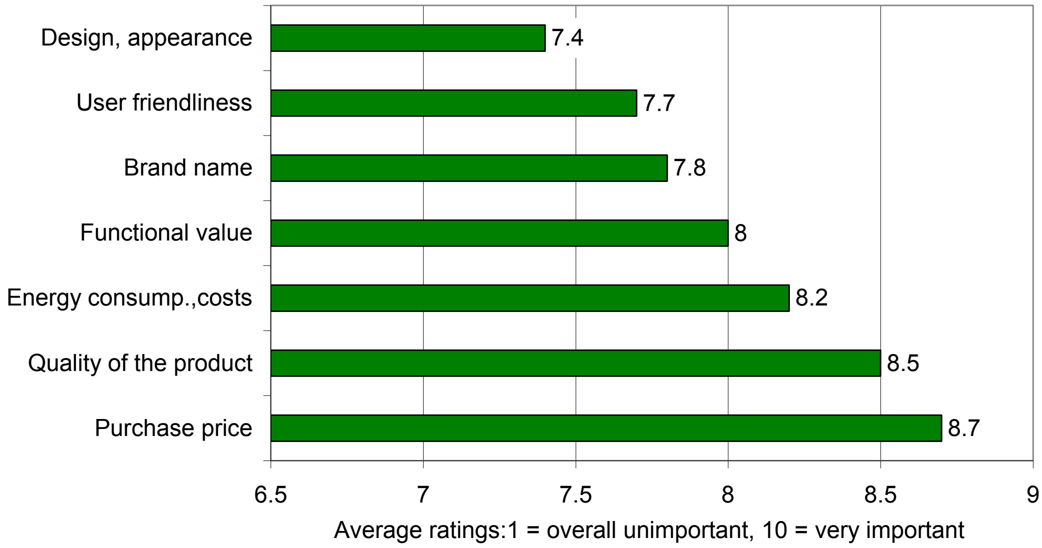

Figure 6. Relevant features for the purchase decision (all countries)

One question focused on *checking the labelling in the shop*, either by an official institution or by the store manager. In total, 38 % of respondents confirm that their shop had been checked in the last 12 months by an official institution, whereas a remarkable 84 % stated that the correct handling of the labels is checked regularly by the store manager. Considerable differences were found with regard to the type of shop: department stores were checked externally by 86 %, kitchen and furniture stores only by 20 %. A self-check was reported by 95 % of the department stores, but only by 58 % of the kitchen and furniture stores (Figure 7). The results by country confirm this divergent situation. Whereas in almost all countries, regular checking of the labelling by the store manager was confirmed by more than three quarters of the respondents, this figure is considerably lower with regard to checks made by an official institution over the past 12 months. In only four Eastern European countries – Cyprus, Czech Republic, Estonia and Romania – was an official check confirmed by more than 75 % of the store managers, whereas many countries are even below 20 %.

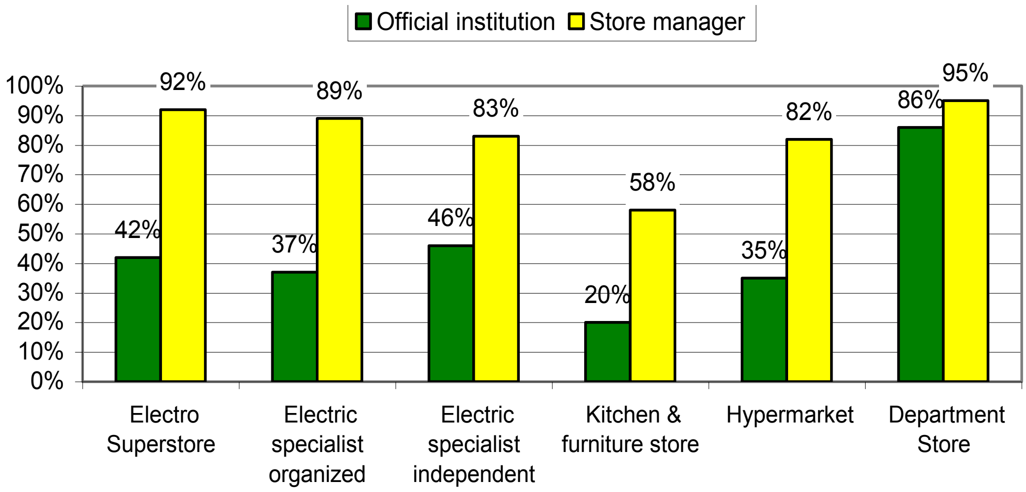

Figure 7. Checking the labelling in the shop (all countries)

The **i**nfluence of energy labels on the sales process was estimated by rating several items. An important result is the high score awarded to the statement “We think retailers can easily explain the label system”. It means that the label can be easily understood and is therefore suitable for sales communication. Once again, department stores have an outstanding position, giving an above-average score to all the statements and kitchen and furniture stores give a below average rating. This underlines once more the differences in importance attributed to the label by these types of shops. Figure 8 shows the ranking in total.

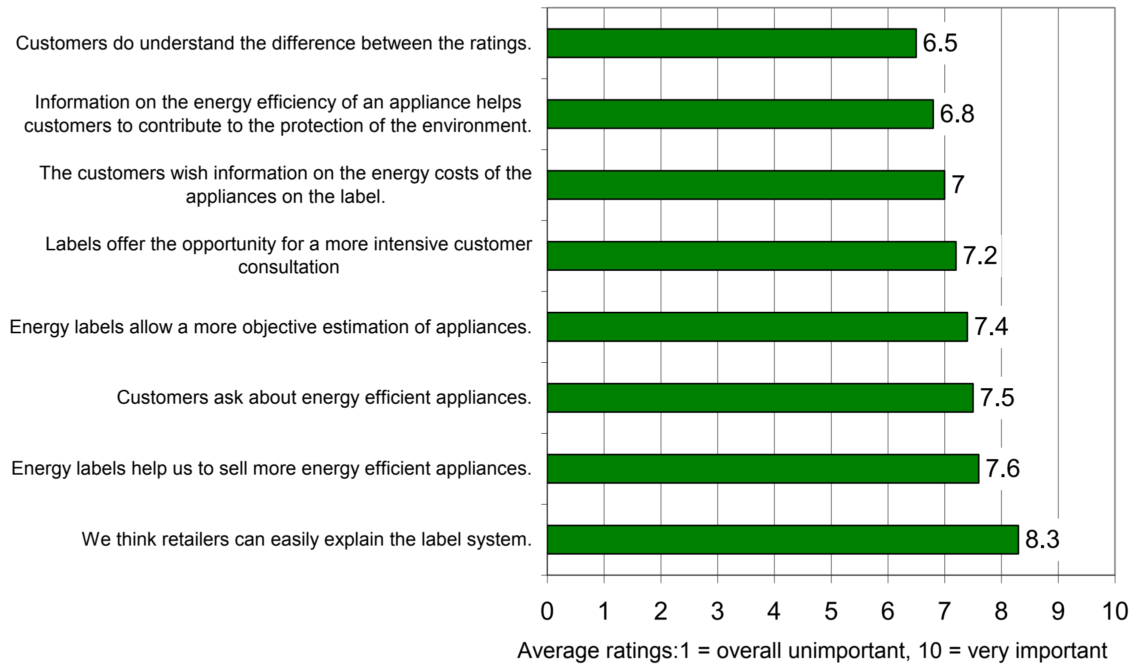

Figure 8. Impact of the label on the sales process (all countries)

Problems with handling the label were recorded in detail, distinguishing between the basic label (colour background) and the product fiche, i.e. the data strip containing the model specific information. Since only 40 % of the respondents agreed with the statement, that the basic labels are provided without delay when ordered, the provision of the label seems to be a problem. With regard to handling the product fiche, respondents were asked how often this is missing in the product documents and if so, whether this occurs more for certain product groups or certain manufacturers. In total, the respondents rated the absence of the product fiche between 10 and 20 %. Some differences between types of products were found (Figure 9).

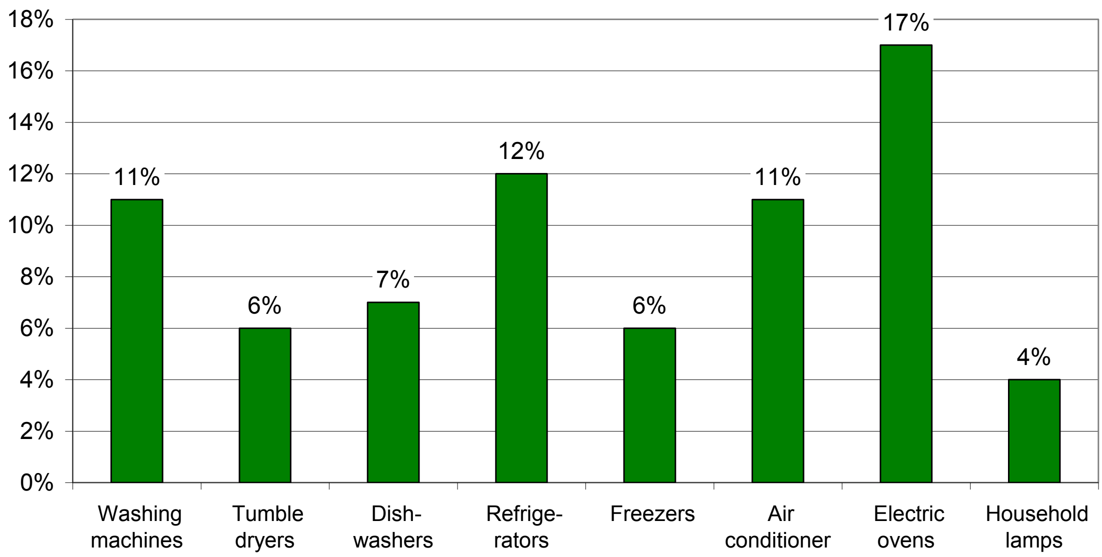

Figure 9. Missing product fiches (all countries)

The following question referred to the *general effort* concerning the time, administration and handling required for the label on the part of the retailer. On a scale from 1 = very small effort to 10 = very high effort, the overall average was 3.7. This means that the requirements are not negligible, but are relatively small. The answers from the various types of shop range between 3.4 and 3.9 which is a rather similar assessment by type of shop. The highest effort was stated by the independent electric specialist, the lowest by the big hypermarkets. Between the countries, differences are more pronounced (Figure 10). Whereas in some countries like Cyprus or Norway the general effort for labelling is assessed as very small, in other countries like Greece, Italy, Malta, Slovakia and the UK, this value increases to more than 5, which implies a noticeable effort.

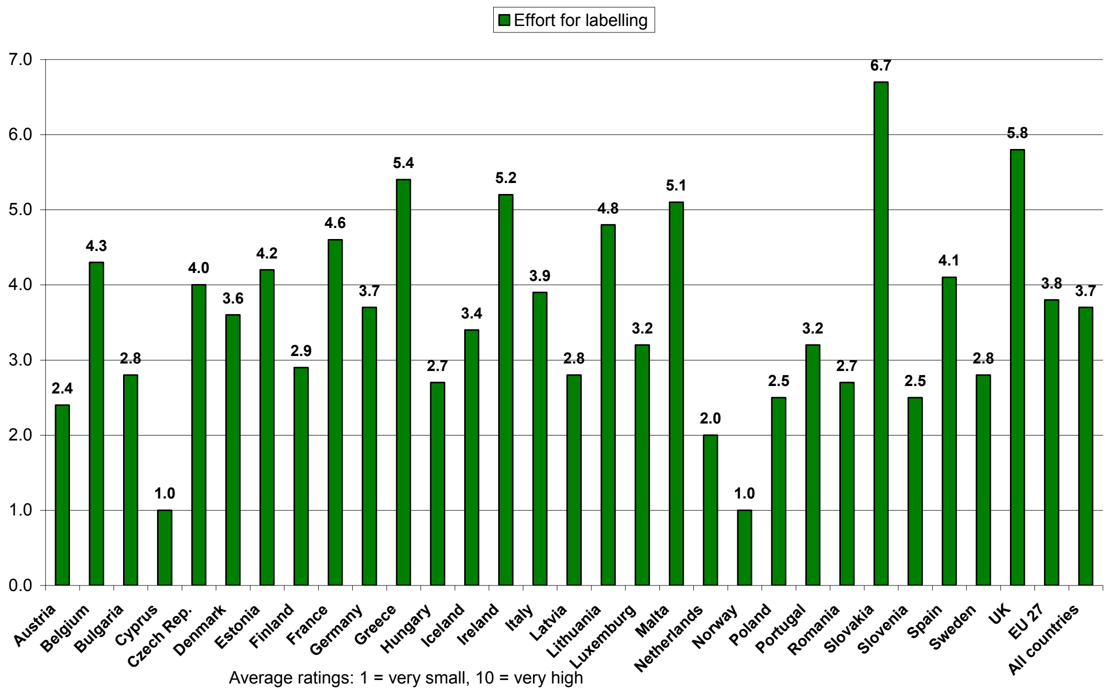

Figure 10. General effort required for the labelling per country

In the end of the interview, the store managers were asked for *suggestions about what could motivate customers* to buy more energy-saving appliances. 12 measures were ranked on a scale from 1 = strongly disagree to 10 = strongly agree (Figure 11). The measures most preferred were financial incentives for purchasing energy-saving appliances and a suggestion which addresses manufacturers: the development of more energy-efficient appliances and cheaper prices for these products. The label's design was not considered very important.

Results of the Audit of Mail Order Companies and Internet Stores

With regard to the general provision of the mandatory information and the order in which the information is provided, compliance with the Labelling Directive by mail order companies and Internet stores is very low (Figure 12). On the whole, only 5 % of the appliances were correctly labelled in accordance with the Directive, which means that the mandatory information was provided completely and in the stipulated order. For another 12 % of the appliances, the information was complete, but not in the correct order. In more than two thirds of the appliances, however, the information was neither complete nor in the right order. The mandatory information was missing completely in only 2 %. The level of compliance differed significantly between the countries, though not all countries were included in the sample with regard to mail order and Internet stores. The highest share of correctly labelled appliances was observed in Denmark (41 %), Germany (29 %) and Austria (20 %), whereas in a considerable number of countries, the share of correctly labelled appliances was even zero in the case of mail order and Internet. Regarding the level of compliance by appliance type, the differences are smaller than those between countries. The main shortcomings are that some of the mandatory information is missing and that the information is also provided in the wrong order. The highest share of complete information in the correct order was observed for electric ovens (10 %), washing machines and dishwashers (8 %).

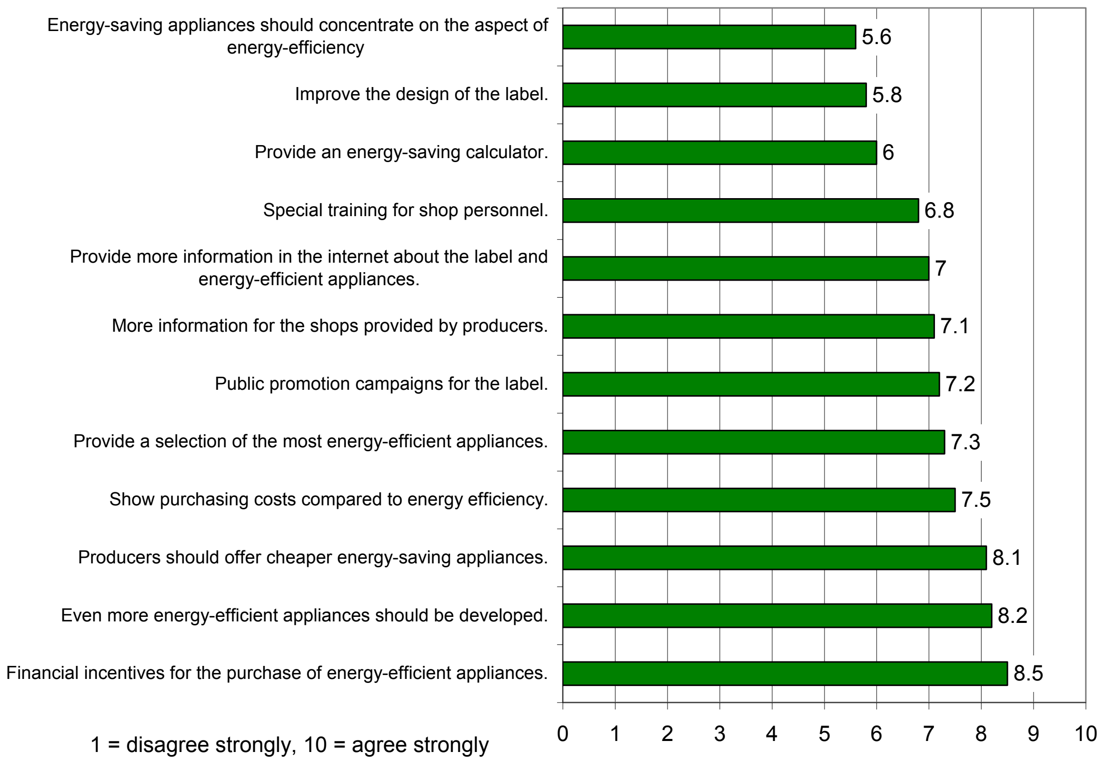

Figure 11. Suggestions to motivate consumers (all countries)

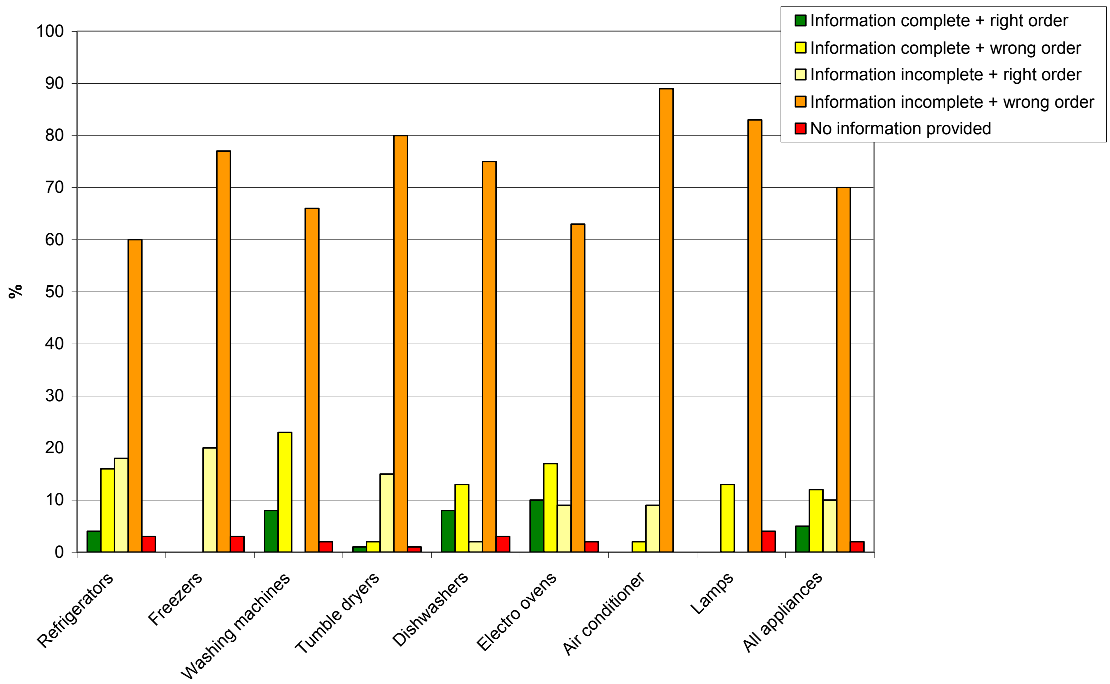

Figure 12. Provision of mandatory information in the case of mail order companies and Internet stores by appliance type (all countries)

Conclusions

With regard to compliance with the Energy Labelling Directive among retailers in shops, an overall compliance indicator was developed taking into account all the compliance criteria. The resulting total share of correctly labelled appliances – i.e. those in full accordance with the Directive - across all 29 countries included in the analysis amounts to about 60 %. There are, however, huge differences between countries: the share of correctly labelled appliances ranges from below 10 % in one country up to 90 % in Norway. This implies that country-specific action is necessary in order to improve the degree of compliance. The survey on the activities in the Member States to ensure that the required information by the Energy Labelling Directive is provided and accurate, which was carried out in addition to the survey in retail trade [2], showed that though most of the countries state to make shop visits in retail trade, these controls are made often only on complaints and only few information is available on these checks. In addition, there are very large differences in resources used for market surveillance between the Member States.

By type of appliance, the share of correctly labelled appliances was relatively high for the large white appliances, whereas the main problems occurred in the case of electric ovens and air-conditioners, which had the lowest level of compliance. This means that there is a clear difference in the degree of compliance between those appliances for which the Implementing Directives came into force more than 10 years ago and electric ovens and air conditioners, for which the Implementing Directives were only adopted in 2002. There seem to be information deficits in the retail trade on the necessity of the labelling, especially for these two appliance types. There are, however, some country-specific failures (e.g. the lack of the data strip in a very high number of cases in Iceland) which differ from the general picture and have to be tackled at the national level.

With regard to the overall compliance by type of shop, the highest share of correctly labelled appliances was found in department stores and electro superstores, i.e. in the big chains, whereas the lowest share of correct labelling (40 %) was observed in kitchen and furniture stores, i.e. sales channels where visual viewpoints are very important for sales promotion. According to the survey results, especially kitchen and furniture stores are very concerned about the appearance of the kitchens on display and therefore often place the labels or data strips inside the appliances and not on top or in front as demanded by the Directive. It seems that the regulation in its current form is least suited to this channel of distribution and is thus less accepted than in other parts of the retail trade.

The worst result of the survey of the retail trade was observed for mail order and Internet stores. On the whole, only 5 % of appliances were correctly labelled in accordance with the Directive, which means that the mandatory information was provided completely and in the stipulated order. The main failings were not missing, but incomplete information or not shown in the right order. Though the general level of compliance was relatively low in all countries, the share of correctly labelled appliances varied between 41 % in Denmark and zero in the case of a considerable number of countries. It seems that though there is a general willingness to inform buyers on the part of the retailers, the large amount of information required by the Energy Labelling Directive and the stipulated order cause difficulties for this channel of distribution.

The interviews with the store managers revealed a positive attitude among the majority of retailers in shops, both towards energy efficiency in general and the labelling of appliances in particular. Overall, the energy label was regarded as useful for the sales process. The effort required for labelling on the part of the retailer was not assessed as negligible, but as relatively minor. The interviews also revealed the importance of a regular checking of the labelling for the correct handling. Especially a regular internal check by the store managers was confirmed by more than 80 % of the respondents, while an external check by an official institution was less widespread.

References

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[2] Schlomann, B., Gruber, E., Roser, A., Herzog, T., Konopka, D.-M.: *Survey of Compliance Directive 92/75/EEC (Energy Labelling)*. Final report for the European Commission (DG TREN). Fraunhofer ISI, GfK Marketing Services, BSR Sustainability. Karlsruhe, Nuernberg 2009

The impact of Ecodesign measures on household electricity consumption in the Netherlands: even more savings are possible.

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Abstract

The Ecodesign Directive (2005/32/EC) provides a framework for – amongst others – setting minimum efficiency standards for a large number of energy-using products. The justification for and potential impacts of these measures (often including energy labelling) are described in the preparatory studies, which are carried out on EU level only. Since for many EU member states minimum efficiency standards for appliances are an important instrument to achieve (national) energy efficiency targets, assessment of the impact of Ecodesign measures on national level is desirable.

The paper describes a methodology that has been developed to calculate the impact of proposed measures for ecodesign and energy labelling on household electricity consumption in the Netherlands up to the year 2020, based upon what is available through the preparatory studies.

The results show that for the Netherlands ecodesign measures can reduce household electricity consumption (kWh/yr,hh) with 8 % compared to a Business As Usual (BAU) scenario. Labelling measures alone show a reduction of 7 % and the combined effect of ecodesign and labelling is calculated at 11 % reduction compared to a BAU scenario. Best Available Technology would result in a reduction of 34 % compared to a BAU scenario. The paper concludes with a recommendation of national policy options for certain product groups to decrease the gap between the savings from EU measures (11 %) and the (theoretical) savings from Best Available Technology (34 %).

Introduction

The Ecodesign Directive [1] provides a framework for – amongst others – setting minimum efficiency standards for a large number of energy-using products. The measures for ‘standby and off mode’ and 'simple set-top boxes' have been adopted, other measures are close to adoption, e.g., 'external power supplies' and ‘household lighting’, and more will follow in the coming years. The justification for and potential impacts of these measures (often including energy labelling) are described in the preparatory studies, which are carried out on EU level only. Since for many EU member states minimum efficiency standards for appliances are an important instrument to achieve (national) energy efficiency targets, assessment of the impact of Ecodesign measures on national level is desirable.

This paper is organized as follows. The next section describes the methodology that has been developed to calculate the impact of proposed ecodesign and labelling measures on household electricity consumption in the Netherlands up to the year 2020, based upon what is available through the preparatory studies. Furthermore, section 2 provides a short description of the scenarios for which results were calculated.

The third section provides results of the calculations, showing the impact of proposed minimum efficiency standards, labelling and the combination of standards and labelling, when compared to a business-as-usual scenario. Explicit attention is paid to calculation of energy consumption of products in non-active modes (e.g. standby and off-mode).

The final section evaluates and discusses the results and provides suggestions for supplementing national measures.

Methodology

Scope

In principle all electricity using household appliances were included in the study, amounting to 180 appliances (including variations or functions of appliances e.g. set-top boxes with and without hard disk recording functions). Products or installations that produce electricity, e.g. photovoltaic panels or microCHP and service installations, e.g. elevators and general lighting in flats, were not taken into account. Furthermore, consumption of other energy sources, e.g. gas, oil, wood, was not considered in the study. This means that for combi-boilers (present in 72 % of Dutch households in 2010), for example, only the electricity consumption is taken into account and not the gas consumption. Since generally speaking, Dutch households use gas for heating, hot water and – to a lesser extent – cooking, the study does not provide information on total household (primary) energy consumption. Therefore the conclusions and recommendations are solely based on the electricity consumption.

Table 1 shows the appliance(group)s that were included in the study. Input data for these appliances refer to 1990-2005 (historical data) and to 2005-2020 (projections).

Table 1 Appliance groups

Appliance category	Appliances	Number of appliances
Cleaning	Dishwasher*	1 appliance
	Washing machine*	1 appliance
	Dryer **	1 appliance
	Vacuum cleaner	1 appliance
	Cleaning – other	5 appliances
Cold appliances	Refrigerators and combined fridge-freezers*	single door with/without freezing compartment and multidoors in one group
	Freezers*	Upright and chest freezers in one group
Lighting	Lighting **	5 lamp types, 4 use levels
Audio/video/communication	Televisions*	4 types, 3 use levels
	Audio/video **	24 appliances / functions
	ICT*	16 appliances / functions (computers, peripherals and telephony)
Space heating and hot water	Space heating*	7 appliances / functions
	Hot water*	8 appliances / functions
Interior climate	Ventilation & cooling*	13 appliances / functions
Cooking	Cooking	11 appliances / functions
Kitchen appliances	Kitchen appliances	30 appliances / functions
Leisure	Leisure	32 appliances / functions
Personal care	Personal care	10 appliances / functions
Other	Other	9 appliances / functions

* appliances for which the ecodesign preperatory study was completed.

** appliances for which the ecodesign study was not completed but information was used

Overview of the calculation method

Figure 1 provides an overview of the input and output of the calculation model. The output is calculated as kWh/a per appliance, per household and for all Dutch households combined.

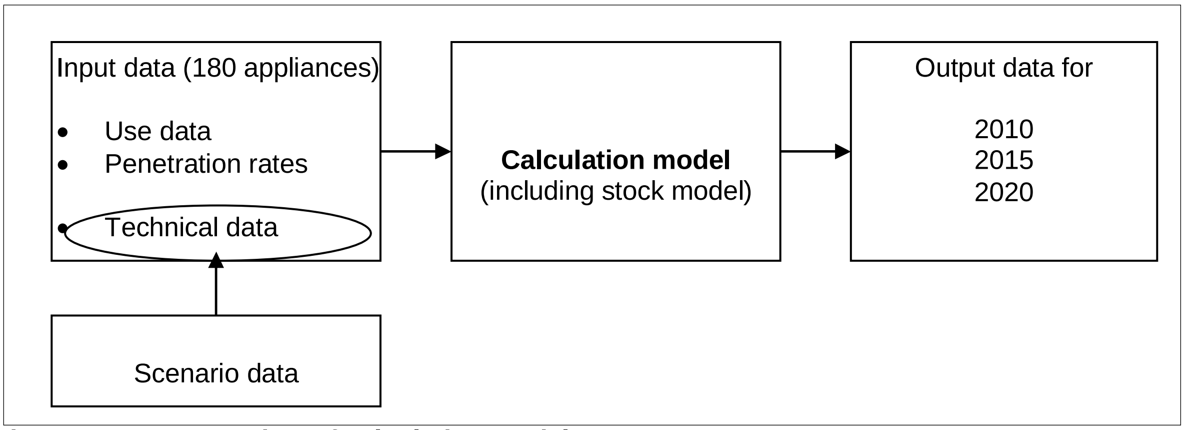

Figure 1 Overview of calculation model

The electricity consumption for an appliance is the total of the consumption in various modes or for various cycles. The annual consumption for a cycle or mode is obtained from multiplying either the number of cycles in a year (use data), e.g. washing programme cotton 40 ºC, with the electricity consumption for that cycle (technical data) or the usage time in a certain mode (use data), e.g. on or standby, by the power consumption in that mode (technical data).

The average electricity consumption per household is then the sum of the electricity consumption of all appliances weighted according to their penetration rate. E.g. for an appliance that is present in 50 % of the households, half of the appliance consumption is taken into account for the calculation of the average household electricity consumption.

Because the model calculates the electricity consumption for various years (2005, 2010, 2015 and 2020), the calculation model requires the use of time dependent data, e.g. on number of households and penetration rates. But also the calculation of the electricity consumption of an appliance (in a certain year) requires the input of time dependent data because the stock in a certain year consists of models of various years. The next paragraph provides more insight in the stock models that have been used.

Scenarios

The technical data for a certain sales year depend on which scenario is chosen for the calculation. In order to assess the effects of possible EU measures the calculation model includes 5 scenarios

1. BAU: the Business As Usual scenario. This scenario describes the situation when current trends in policy and appliances, including expected technology deployment, are continued without any additional policy measures.
2. MER: the Minimum Energy-efficiency Requirement scenario. This scenario describes the possible effects of the introduction of a minimum efficiency requirement as proposed in the framework of the ecodesign directive. Except for standby and off mode all minimum efficiency requirements are based on the proposals in the preparatory studies. For appliances where no preparatory study was available an estimate was made based on the Dutch situation
3. LBL: the Labelling scenario. This scenario describes the possible effects of the introduction of product information, either as information requirement in an ecodesign measure or as energy label under the energy labelling directive[1]. In case no EU policy proposals were available an estimate was made based on the Dutch situation.
4. LBL+MER: the combined scenario for labelling and minimum efficiency requirements. This scenario describes the possible effects of combined measures regarding labelling and minimum efficiency requirements.

[1] Contrary to the labelling directive, an ecodesign implementing measure can not prescribe a label, it can only determine which information manufacturers have to provide to end users (consumers). The format for this information however can determined by each manufacturer individually.

5. BAT: the Best Available Technology scenario. This scenario describes the possible effects of the immediate implementation of best available technology. This scenario illustrates the maximum available energy savings according to current information and is not realistic because it assumes that from a single point in time all new appliances will be at the BAT level (without considering e.g. cost effectiveness).

Please note that the scenario data only affects the technical characteristics of the appliances. Penetration rate and use characteristics are the same for all scenarios.

Stock model

In the calculation model two different stock models were used: a dynamic stock model and a linear stock model

White goods (cleaning and cold appliances) have been modelled using a ***dynamic stock model***. This means that the appliance data (technical data) refer to the year of sales of the model. The appliance data may vary per scenario: a scenario based on minimum energy efficiency requirements has a different effect on new appliances than a scenario based on labelling. Stock characteristics depend on penetration rate and product life and include a correction based on a 'waste curve' which spreads the demise of appliances of a certain sales year over several years before and after the average lifespan. Through this, the dynamic stock model allows a relatively accurate calculation of the effects of a change, e.g. in energy efficiency, in new appliance model (of a certain year) on the electricity consumption of the stock (in a certain year in the future) because it describes the stock for all consecutive years. The dynamic stock model allows the calculation of yearly sales figures which can of course be compared with actual sales figures provided by industry organisations and be used to verify the model inputs of penetration rate and product life.

For a number of appliance categories (audio/video/communication, space heating and hot water, interior climate, cooking and kitchen appliances, leisure, personal care and other) it was not useful or possible to apply a dynamic stock model. These categories were modelled based on a ***linear stock model***: characteristics of new models are described with a five year interval and the stock characteristics follow from backcasting on the basis of the average product age. No waste-curve is used and therefore the changes in characteristics can be more disjointed. For some appliance categories the input data did not differ for the various scenarios and referred to existing stock. In that case the stock model is restricted to a (linear) trend in input data.

For two appliance categories a different approach has been applied. For lighting no stock model was applied: the calculation for a certain year is carried out with (estimates for) data of that year. For televisions a semi-dynamic stock model was used, because of the complexity of the appliance category (4 types of televisions, 3 types of usage).

Results

With the input data and the spreadsheet stock model approach the results can be calculated for the 5 scenarios. The overall error of these calculations is believed to be between +/- 5% but can be larger for certain product groups were technological progress is rapid and forecasting is difficult. This is for instance the case for ICT products, especially those that are networked. For well-known / well-researched product groups such as cleaning and cold appliances the calculations are more accurate. Of course the overall error increases for scenario-years further away from the base year.

Before providing the results for the scenarios, the next paragraph will show in more detail for one appliance – the dryer – how the calculations are done. The final paragraph shows the results for the Netherlands, taking into account the number of households.

Calculation example: the dryer

The laundry dryer is used as an example to show what the effects of various policy measures[2] are on the average annual consumption of an appliance, average household consumption and the total consumption of all households together.

The BAU scenario assumes that the standard energy consumption of a dryer is 0,62 kWh/kg in 2005 (equal to current class C) which will reduce to 0,58 kWh/kg in 2020 through increase of class B (30% of sales) and class A (4% of sales) appliances. The MER scenario assumes a phase out of class D in 2010 (1% in 2005) and class C in 2015 which results in a average efficiency of new dryers in 2020 of 0,51 kWh/kg. The LBL scenario (combined with consumer information campaigns) assumes an increase of especially class A dryers although class C dryers continue to be sold. The average efficiency of new driers in 2020 is calculated to be also 0,51 kWh/kg. The combined MER+LBL scenario assumes both an increased uptake of class A driers and a phase out of class D and C which results in an average consumption of 0,48 kWh/kg. Finally, the BAT scenario assumes a complete (theoretical) uptake of class A driers as of 2010, resulting in an average efficiency of 0,30 kWh/kg.

When corrected for the real life load (which on average is lower than the rated capacity) and the residual moisture content of this load (related to washing machine spin drying efficieny which also evolves) and multiplied by the annual number of drying cycles (140 cycles/year in 2020) the annual energy consumption of the dryer can be calculated. This amounts to 321 kWh/yr per dryer for the BAU scenario, 261 kWh/yr for the MER scenario, 263 kWh/yr for the LBL scenario, 252 kWh/yr for the MER+LBL scenario and 208 kWh/yr for the BAT scenario.

Since not all households will own a drier the consumption for the average household is respectively 231, 188, 189, 182 and 149 kWh/yr in 2020 (the penetration rate for 2020 is assumed 72%, which is an extrapolation of historical trends). The total consumption of all Dutch households together - for only the dryer - ranges from 1,8 TWh/yr (BAU) to 1,2 TWh/yr (BAT) in 2020. It is assumed that the number of households increases by almost 13 % between 2005 and 2020: from 7,09 million to 8,00 million.

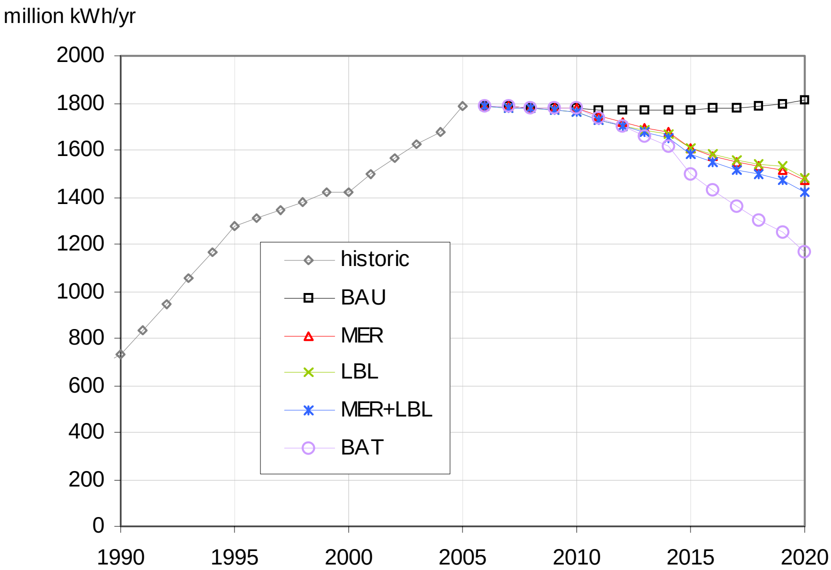

Figure 2 Total dryer electricity consumption [million kWh/yr] per scenario

Results for the average household electricity consumption

Figure 3 shows the results for the 5 scenarios regarding the average **total** household electricity consumption per year in the Netherlands.

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[2] Please note that at the time of the study the final policy proposals of the Commission were not known, so the scenarios described in this example are indicative and presented here to show the line of thought.

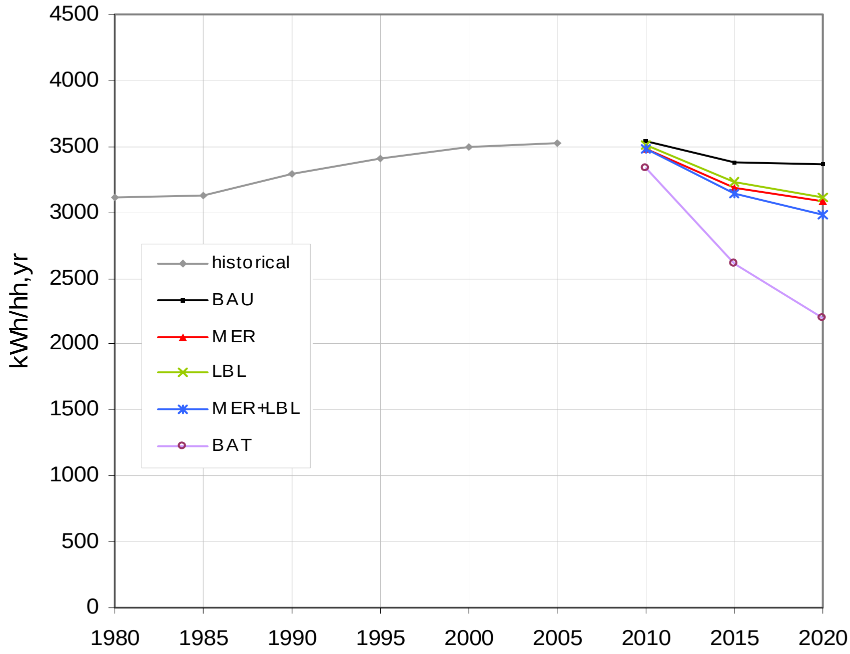

Figure 3 **Total average household electricity consumption [kWh/hh,yr] per scenario**

Already the BAU scenario shows a small reduction in the average household electricity consumption (4 %) compared to 2005. For the MER scenario this is 12 %, for the LBL scenario 11 %, for the MER+LBL scenario 15 % and for the BAT scenario 38 %. However, these reductions are not equal across the appliance categories. Figure 4 shows the contribution per appliance category to the BAU scenario.

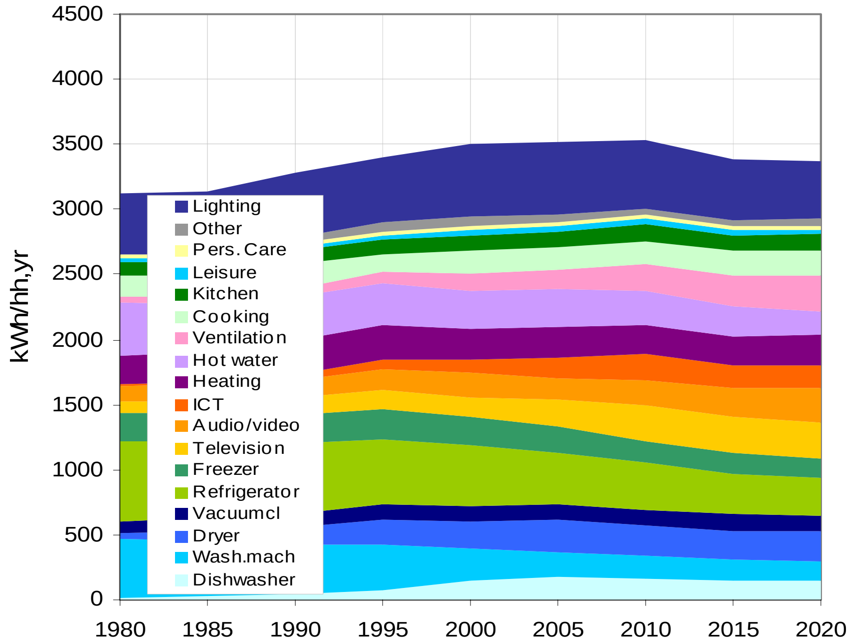

Figure 4 **Average household electricity consumption per appliance category (BAU scenario)**

From figure 4 it can be derived that the largest savings in the BAU scenario occur in the categories cold appliances, hot water and lighting. These savings are due to the current measures, resulting in a lower specific consumption, for these appliance categories.

The largest increase can be found in the categories consumer electronics (television, audio/video) and ventilation. Regarding consumer electronics the increase is due to the fact that new generations of products often have a higher power consumption, several of these products are often continuously "on" (e.g. set-top boxes) and that they have functions that increase the usage and/or power consumption of the product (streaming, hard disk recording). Regarding ventilation the increase is due to increased penetration of mechanical ventilation that is always "on". Due to the long product life, the replacement of existing fans by more efficient fans takes a long time. Please note that savings due to e.g. heat recovery and improved air tightness and/or draught sealing – which make mechanical ventilation necessary – are not visible in the results of this model because they relate to the gas consumption.

The results for the scenarios regarding appliance categories are as follows.

The minimum efficiency requirements (***MER***) will for the Netherlands be most effective for lighting, dryers, large electrical hot water appliances, and digital decoders (audio/video). No or little effect is to be expected from these measures for dishwashers and washing machines, because the efficiency of wet and cold appliances is already above the EU average.

Energy labelling (***LBL***) will for the Netherlands be most effective for vacuum cleaners and televisions, where the savings are more than doubled. No or little effect is expected for dishwashers, washing machines and lighting. For lighting the existing energy label has showed little influence on improving the efficiency of the stock: the average number of CFLs in Dutch households is around five pieces. For washing machines and dishwashers, the vast majority of the sales already for a number of years consists of energy class A[3].

The combined ***MER+LBL*** scenario in general achieves the results of either the MER scenario or the LBL scenario. So, adding one or the other measure does not necessarily result in more savings: for those appliances that consume a lot but where there are little options for consumers to choose between models (set-top boxes are mostly specified by their providers and more than 95 % of Dutch households is connected to a cable network, there is little difference in energy efficiency of electrical water heaters) MER measures appear most effective and labelling has relatively little effect. Based on experience in the past, labelling appears more effective for those appliances where there is a wide range in energy consumption and freedom of choice (large effect for vacuum cleaners, modest effect for cold appliances). The only exception are televisions; this is the only product group where additional measures have a significant additional effect: MER will save 6 %, LBL will save 15 % and the combined effect (MER+LBL) is 35 %. Note that these savings are on top of the BAU scenario in which the impact of new technologies, e.g. OLED, is acknowledged.

The ***BAT*** scenario results in savings for almost all appliance categories, but large savings (> 30 % compared to BAU) can be noted for dryers, cold appliances, televisions, audio/video, ICT, ventilation and lighting. The BAT scenario assumes that from one point in time all appliances will be replaced by best available (most efficient) technology, so the results of this scenario does not depend on consumer decisions regarding the purchase of a (new) appliance (which is the case in the LBL scenario). Table 2 provides an overview of BAT as derived from the preparatory studies.

[3] According to VLEHAN (Association of Producers and Importers of Electrical Household Appliances in the Netherlands) since 2001 for washing machines and since 2003 for dishwashers over 90 % of the sales has been in energy class A.

Table 2 Overview BAT

Appliance	BAT	Energy savings compared to BAU
dryer	heat pump	-35%
cold appliances	vacuum panels, multispeed compressors	-37%
televisions	LED modulating backlight, OLED	-40%
audio/video	low power consumption in various modes	-50%
ICT	low power consumption in various modes	-40%
ventilation	improved efficiency of fans, local ventilation systems	-50%
lighting	efficient LED and CFL	-47%

Source: [2]

Finally we also looked into the effects of the (horizontal) standby and off mode regulation [3]. The effect is calculated at a saving of 37 kWh/hh,yr in 2020. In the BAU scenario standby household electricity consumption is 560 kWh/hh,yr in 2005 and in 2020 this is reduced to 523 kWh/hh,yr despite higher penetration rates of consumer electronics. In the MER scenario, which includes specific measures on standby and off mode for set-top boxes and PCs (also known as "networked standby"), standby consumption decreases further to 467 kWh/hh.yr (-11% compared to BAU 2020).

Results for the Netherlands

Despite the (small) reduction in average household electricity consumption in the BAU scenario, the CO_2 emission for all households in the Netherlands will increase from 13,7 Mton in 2005 to 14,5 Mton in 2020. This 6 % increase can be explained to a large extent by the increase in the number of households from 7,1 to 7,8 million (a 10 % increase).

In the MER scenario the CO_2 emission in 2020 is 8 % below the emission in the BAU scenario, for the LBL scenario the reduction is 7 % (compared to the BAU scenario) and 11 % for the combined MER+LBL scenario. The BAT scenario shows that – in theory – a reduction of 34 % compared to the BAU 2020 scenario is possible.

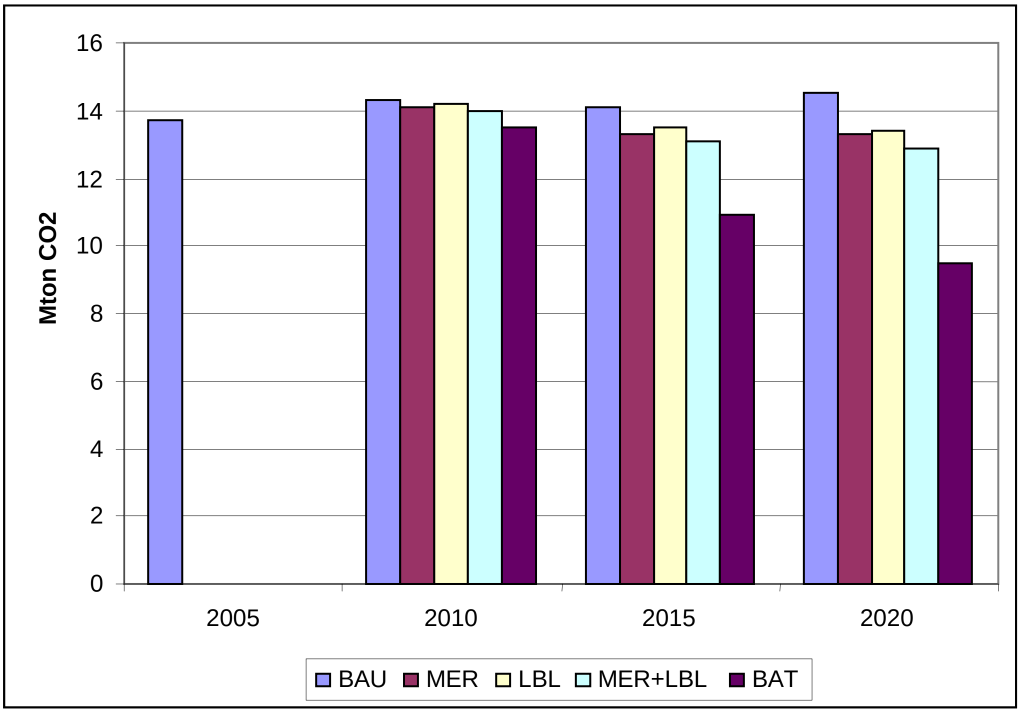

Figure 5 CO_2 emissions (due to electricity consumption) for all Dutch households

Conclusions and recommendations

The results in the foregoing section show that ecodesign measures (MER) can reduce household electricity consumption (kWh/yr,hh) with 8 % compared to a BAU scenario. Labelling measures alone show a reduction of 7 % and the combined effect of ecodesign and labelling is calculated at 11 % reduction compared to a BAU scenario.

Do these results imply that a target of 20 % reduction in household electricity consumption is not achievable? No, the BAT scenario shows a reduction of 34 % in household electricity consumption in 2020 compared to a BAU scenario. However, we have to bear in mind that the BAT scenario is not a realistic scenario because it assumes that as of 2010 all new appliances would be as efficient as the best available technology. It does mean, though, that national measures can make the difference between household electricity consumption not meeting the 20 % improvement in 2020 and doing much better. The analysis shows that national (Dutch) measures especially make sense for:

- lighting;
- heating and ventilation;
- audio/video (set-top boxes in particular) and TV;
- cold appliances and laundry dryers.

Together these appliances could save (at BAT level) some 950 kWh/yr or 28% of the average electricity consumption in 2020. In the rest of this section we will provide some recommendations on what national measures could be used[4]. First we note that regarding products national energy efficiency measures can not be mandatory, since mandatory measures are the exclusive domain of the implementing measures within the ecodesign directive.

The following supplemental national measures are discussed:

1. early replacement of appliances;
2. financing of super efficient appliances;
3. early implementation of energy labels;
4. voluntary agreements with market parties;
5. national EPBD measures.

Note that this list does not include tax credits to manufacturers or subsidies. Since the Netherlands does not have many appliance manufacturers (and certainly not of large appliances), tax credits would mean subsidizing foreign manufacturers which is not the intent of the Dutch government. Furthermore, regarding subsidies, the Netherlands has experiences with subsidies for large appliances. Although subsidies for white goods have been effective in transforming the market, they were not so *cost*-effective, i.e. had high costs per kWh saved [4].

Recommendations on supplemental national measures

Early replacement of appliances

One of the reasons that the BAT scenario results in larger savings is that it is based upon the (unrealistic) assumption that from one point in time all new appliances will be as efficient at the BAT level. That would mean that consumers only buy the most efficient appliances. Or to put it the other way around: the slow replacement of large appliances delays the savings that can be achieved by new, more efficient appliances. Therefore it is worthwhile to stimulate the early replacement[5] of large household appliances (more than 10 years old). Since the Netherlands does not have manufacturers of large appliances, retailers would play an important role in such a campaign.

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[4] Although these recommendations are based on the Dutch situation, the authors believe they can provide at least inspiration for measures in other EU countries.

[5] This implies that the old appliance is discharged of in a sustainable way and not reused as e.g. a second refrigerator in the garage or brought on the (international) second hand market.

The replacement should really be at the BAT level, not just a bit better than the current average product on the market, because only the BAT level secures the maximum savings and the new product will be in place for a large number of years.

Financing of super efficient appliances

Even if super efficient appliances have a lower life cycle cost, there is the well known problem of the purchase costs of these appliances being higher than the purchase costs of less efficient models. In some cases these extra costs might (almost) disappear when the market volume for the super efficient appliances increases but in other cases the extra costs stay because the more efficient appliance needs more components (e.g. heat pump dryer versus normal condensing dryer).

An example of financing the extra costs could be through the energy bill. Assume the extra costs for an energy class A dryer are € 400 and these are financed by the utility. Repayment of this amount by the consumer could be done by adding € 4 to the bill each month for 8 years and 4 months – not taking into account interest for the simplicity of the calculation. If the dryer is used 16 times per month and saves about 20 kWh per month, this amounts to € 4.2 savings, exceeding the monthly addition to the bill.

This type of financing could be stimulated through measures in the framework of the Energy Service Directive [5].

Early implementation of (revised/new) energy labels

The period between the time the criteria for an energy label are known (vote in the Committee) and the implementation deadline according to the Directive (including the transitional period), could easily be one year or more.

By agreement with retailers this period could be much shorter. This also means that the market transformation through the label can be accelerated and the (cumulative) savings can be larger. Already now several retailers in the Netherlands participate in voluntary agreements to provide consumers with product information at the point of sale. Especially new labels provide a good opportunity for early implementation since there is no old label with which the new label can conflict. The television therefore would be an ideal candidate for early implementation: from the moment the criteria are known, retailers could use the label.

Early implementation of revised or new energy labels could be further stimulated by making software available the produces a complete label when provided with the right input. Furthermore, early implementation of (revised) energy labels forces manufacturers to make available more efficient appliances for the Dutch market earlier than for other markets.

Voluntary agreements

In several situations, it is easier to address intermediate organisations, e.g. housing corporations, and not the end user. One reason is that sometimes the end user does not decide on replacement, e.g. regarding ventilation in rented houses. Another reason is that the end user does not bother: it is too much fuss and the (percieved) savings are not high enough. A similar problem arises in the roll-out of set-top boxes and multifunctional modems that are often specified by the service provider, not by the end-user.

Voluntary agreements can also help to involve stakeholders that are more close to the consumer and can more easily – compared to government organisations – address and influence consumers.

National EPBD (Energy Performance of Buildings Directive) measures

The EPBD enables Member States to specify measures for new buildings and for (major) renovations. Installed appliances (heating, ventilation) are part of the calculation of the energy performance of buildings that the EPBD implies.

The methodology used to show compliance with the national EPBD should therefore take into account the existence of BAT products as soon as possible and, by doing so, foster the take-up of BAT products through the recognition they receive in the EPBD implementation. The Netherlands has witnessed a similar effect for condensing heating boilers which resulted in a rapid market acceptation of these products.

Final observations

As always with policy measures, there is no single silver bullet that solves all problems in one shot. On the contrary, combined measures are in most cases more effective. To summarize the national actions table 3 provides an overview which shows the combinations of measures that apply for the selected product groups.

Table 3 Overview of combinations of national measures

	Product				
Measure	***Lighting***	***Heating / Ventilation***	***Television + set-top boxes (A/V)***	***Cold appliances***	***Dryer***
Early replacement		X		X	X
Financing super efficient appliances	X	X		X	X
Early implementation of label			X	X	
Voluntary agreements	X	X	X		
National EPBD measures	X	X			

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Pro-poor Standard and Labelling programmes? Results of a survey on S&L for domestic appliances in Southern Mediterranean countries

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Abstract

Dissemination of energy-efficient domestic appliances through mandatory labelling of energy performances and Minimum Energy Performance Standards (MEPS) is seen as a promising public policy tool to slow down the growth in residential electrical consumption. With international donors' support, the benefits of Energy-Efficiency Standard and Labelling (EE S&L) programmes are also tried to be spread throughout emerging countries, such as those of the Southern Mediterranean region. In this context, specific issues arise: How to adapt the S&L programmes to the particular Southern Mediterranean context? Notably, how does a growing urban and low-income population challenge the effectiveness of these programmes?

The dissemination of energy-efficient cold appliances to low-income consumers seems crucial to reach the full potential of effectiveness of these programmes in these countries as this will enable important national and domestic energy savings, at the same time contributing to EE national targets and to ease poor consumers' financial constraints regarding their electricity consumption.

In the frame of the ongoing European project MEDRES, which aims at assessing the development of renewable energies and EE practices and technologies in Southern Mediterranean countries, the impact of such EE S&L programmes on poor urban consumers will be analysed. Through a quantitative survey in selected households and shops in three Mediterranean countries (Egypt, Morocco and Tunisia) favourable conditions and barriers for urban poor consumers' access to energy-efficient cold appliances will be identified as well as their specific knowledge and conceptions of EE.

Acknowledgement

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Introduction

In the context of a global energy crisis and growing trends in energy consumption, the dissemination of energy-efficient domestic appliances through labelling of energy performances and Minimum Energy Performance Standards (MEPS) is seen as a promising public policy tool to slow down the growth in residential electrical consumption. After the success of the US and European Energy Efficiency Standards and Labelling (EE S&L) programmes for domestic appliances, such programmes are promoted and implemented in Southern and Eastern Mediterranean Countries (SEMC) with international donors' support (e.g. European Union, UNDP, GEF, World Bank).

In this context, however, new issues arise. In particular the high rate of low-income households and the threat of pauperisation among large shares of the urban population create new challenges for the success of EE S&L programmes. In the absence of specific strategies, the expected national energy savings will hardly be reached, as low-income consumers may miss the opportunity to buy more energy-efficient appliances, although they largely have access to modern electrical appliances now. Furthermore, the integration of low-income consumers in EE S&L strategies could allow them to reduce their energy expenditures and thus ease their general budget constraints. This is even more relevant in the case of rising energy prices, a growing burden for low-income households.

Together with our partners in the MEDRES project, we conducted an assessment of EE S&L programmes for cold appliances in three countries (Egypt, Morocco and Tunisia) with special focus on the poor urban population. We carried out a socio-economical field survey of this specific consumer group aimed at identifying favourable conditions and barriers to access to energy-efficient appliances.

In this paper we will examine the relevance of "pro-poor" EE S&L programmes on the basis of the findings of our study, answering the following questions: Is there a potential of energy savings at the low-income population level through an EE S&L programme? And to which extent do such EE S&L programmes effectively reach low-income consumers in their awareness and behaviour? After a brief review on the development and implementation of EE S&L programmes worldwide and a short presentation of the national programmes assessed in the MEDRES project (I), we will emphasize some of the specific implementation challenges in the Southern Mediterranean region (II). We'll then describe the methodological framework of our assessment (III), before presenting some of the most significant results (IV). We'll finally give some recommendations for the further developments of such programmes in the region (V).

I. Standard and Labelling programmes for cold appliances: a promising tool for Energy Efficiency policies in emerging countries?

1. Energy Efficiency and Standards and Labelling programmes on top of policy agendas

As a result of global challenges such as climate change and the scarcity of energy resources as well as an increasing energy demand, EE raised to the top of the policy agenda of many countries. EE, as a means of reduction of energy consumption without a decline in the standards of living and service quality, is a complex interplay between technological changes, changes in supply organisation and management, and changes in consumption patterns.

In the residential sector, the policy tool of Standard and Labelling programmes is seen as very promising. The main objectives of EE S&L programmes are the acceleration of the diffusion of energy-efficient appliances, and the elimination of the least efficient products, both at market and residential levels. The expected direct effects are a slow-down in energy consumption and cost savings at a national and household level, which indirectly support global climate protection goals [14].

2. Energy Efficiency Standards and Labels are conquering the appliance world

The first attempt to introduce EE standards occurred in 1962, for industrial appliances. Since then, especially in the United States (since 1976) and in the EU (since 2000), the development of stronger regulatory frameworks led to an increased adoption of EE standards. A worldwide spread, e.g. to China, Brazil, and India, took place in the 1980s. Since the 1990s the number of countries adopting new EE S&L is accelerating by factor 6, and in 2004 55 governments around the world had adopted at least one mandatory EE standard [3].

EE S&L programmes introduced in emerging countries are mainly based on the experience of OECD countries and on already tested applications. For instance, the European label has been taken as a model for Brazil, Tunisia, China, and Iran, whereas Thailand and the Korean Republic adopted the Australian S&L model.

The diffusion of EE S&L is also promoted by multilateral projects within e.g. World Bank and EU programmes and is supported by the development of implementation tools like e.g. the Collaborative Labelling and Appliance Standards Programme (CLASP) guidebook. Concerning the EE S&L for cold appliances, Table 1 shows the development of the last five decades and indicates that the above mentioned tendency in the 1990s is also true for refrigerators.

Table 1: Adoption of EE S&L programmes for refrigerators around the world

	1960s	1970s	1980s	1990s	2000s
Labels (L) *Stan-dards (S)*	*S,L:* France	*S,L:* USA , Canada, Japan *L:* Germany	*S,L:* China, Brazil, Australia, India, Norway, FSU, New Zealand, Russia, Israel *L:* Malaysia	*S,L:* EU, Czech Rep. Mexico, Singapore, Philippines, Thailand, Hong Kong, Romania, Indonesia, Switzerland, Poland, Costa Rica, Columbia, Hungary, Iran, Venezuela,	*S,L:* South Africa, Egypt, Argentina, Slovenia, Tunisia *S:* Turkey, Bulgaria,

Source: CLASP guidebook 2005, p. 19-20

3. Energy Efficiency Standards and Labelling programmes in Tunisia, Egypt and Morocco

i. Tunisia: An already well-developed EE S&L programme for cold appliances

In Tunisia, the growth in electricity demand has averaged 6.8% per annum since 1980, of which 25% is consumed by the residential sector. Refrigeration is the most important residential electrical end-use in the country and represents about 40% of the electricity consumption of Tunisian households. Without intervention, the demand for electricity associated to refrigerators was projected to increase from 892 GWh in 2004 to 2,300 GWh in 2030.

In 1996 Tunisia already approached the Global Environment Facility (GEF) for the development of an S&L programme for household appliances. This programme was implemented in 2004, supported by the GEF and executed by ANME. It includes an EE S&L programme for refrigerators. The total budget of the project was US$ 1.4 million, of which US$ 700,000 was from the GEF and US$ 700,000 from the Government of Tunisia, plus US$ 700,000 in-kind contributions from the Government of Tunisia.

From a legislative point of view, a law and some enforcement decrees define the legal obligation of energy certification for cold appliances. Different energy classes are defined following the energy performance of the appliances, from class 1 to 8, class 1 representing the most efficient appliances and corresponding to A+ or A++ of the European classification. In parallel, some Minimum Energy Performance Standards (MEPS) were defined and the progressive elimination of the less efficient categories is organized in accordance with refrigerator manufacturers and retailers in order to let them time to adapt to the new EE requirements. In July 2006, Classes 7 and 8 were eliminated; in July 2007, Classes 5 and 6 were eliminated; and elimination of the Class 4 is planned to occur in 2010.

A testing laboratory, the CETIME ("Centre Technique des Industries Mécaniques et Electriques"), was set in 2002 and is responsible for testing all the cold appliance models before they can be sold on the market. Locally manufactured and imported products have to go through the testing procedures.

The controls of the cold appliances sold on the market are being carried out by the Ministry of Trade ("Direction Générale Qualité du Commerce Intérieur"). It consists in checking the presence of the label on the products sold in the shops and the effective disappearance of the eliminated classes. In the future, the Ministry also plans to test the compliance of the appliances' actual performances with the label, with the support of the CETIME.

The refrigerators' labelling programme is being implemented for more than four years now. Noteworthy evolutions can be observed on the market since the implementation of the labelling programme: disappearance of Classes 7 and 8, strong penetration of Class 3 (whereas previously the market was dominated by Class 4 products), and appearance of Class 1 and 2. The S&L programme seems to be quite successful in transforming the market towards the predominance of the most efficient categories.

The ANME and its "Direction de l'Utilisation Rationnelle de l'Energie" (DURE) are now developing other complementary initiatives to deepen the impacts of EE measures in Tunisia and make EE work for all. For instance, a similar energy certification programme is being developed for air conditioning; communication campaigns around EE programmes are being intensified; and the DURE is also developing a replacement programme of old cold appliances with a special financial mechanism for poor households (PROMO-REF).

ii. Egypt: Limited implementation of the EE S&L programme for cold appliances

Energy consumption per inhabitant in Egypt is one of the highest of the region. This is mainly due to the abundant energy resources on Egyptian territory and to the subsidy policy carried out by the Egyptian government. There is thus an important potential for energy savings in this country.

In 1999, based on these considerations, the UNDP launched a project aimed at reducing greenhouse gases emissions in Egypt by fostering EE initiatives: the Energy Efficiency Improvement and Greenhouse Gas Reduction (EEIGGR) programme (1999-2007). This programme was co-financed by the Global Environment Fund (GEF), the United Nations Development Programme (UNDP), the Egyptian Government, the Egyptian Ministry of Electricity and Energy (MOEE), and the Egyptian Electricity Holding Company (EEHC), with a total budget of US$ 5.9 million.

The main objective of this project was to overcome institutional and technical barriers to EE diffusion, and to increase the public awareness on this issue. Two main initiatives were undertaken in the residential sector: a programme for the development of thermal regulation in the building sector; and an S&L programme for three domestic appliances (washing-machines, refrigerators, and air conditioning).

The S&L programme was enforced by a ministerial decree. This programme put in place a comparative label, based on the European model, with five horizontally graded bars of different colours, grade (A) representing the highest efficiency and grade (E) the lowest, as well as some minimum energy performance standards, based on the Canadian model. Different stakeholders were involved in the national implementation of the S&L programme for cold appliances: the MOEE, the EEHC, the Egyptian organization for standards and quality (EOS) and various NGOs. A testing laboratory was set at NREA to test and label domestic products, and EOS is responsible for labelling foreign imports.

But, after the elaboration phase, strongly supported by international donors and experts, the implementation was entrusted to national authorities, who face difficulties in effectively implementing this project, both, the thermal regulation and the S&L programme [11].

A first national assessment of the effectiveness of the S&L programme[1] showed a low understanding of the label objectives by manufacturers, low consumer awareness, low trust of compliance with announced labels and standards from the supplier side, low retailer understanding and promotion of labels with high EE, lack of data on consumer demand structure (preferences, constraints etc.); and lack of data on supplier compliance (supply structures, procedures).

iii. Morocco: an EE S&L programme under development…

In Morocco, the rapid economical growth has created a worrying situation of energy stress, growing energy dependency and real risks of power shortages. Additionally the country's electrification rate has increased dramatically during the last years (from 60% in 1996 to more than nearly 90% today), as a result of the rural electrification programme, and the residential and service sectors are currently representing a third of the country's energy consumption.

In this context the authorities have set up a new national energy strategy ("Plan National d'Actions Prioritaires", 2008-2012). On the demand side, EE is put forward as one of the main tools of this new strategy with an ambitious objective of reducing energy consumption of 15% by 2020.

As a result of this new awareness on EE issues, the CDER, our partner in the MEDRES project, will see its role evolving from a national agency dedicated only to renewable energies to an EE agency. The CDER is notably expected to contribute to the planned energy audits and labelling in the residential and services sectors.

In parallel, the Ministry of Energy and Mines, and the CDER, in cooperation with the UNDP and the GEF, launched in 2008 a project on EE in the building sector. In that frame, it was also proposed by the CDER and other services of the Ministry to implement an S&L programme for electrical

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[1] [1] www.undp.org/gef/05/documents/writeups_doc/cc/Energy_Efficiency_GGs_**Egypt**_notes_CC1.doc

appliances, including refrigerators. At the time we wrote this paper it was still not clear when this programme could be implemented.

II. Specific challenges in Southern and Eastern Mediterranean regions for the implementation of Energy Efficiency strategies

1. A complex energetic situation

i. A region of economical and demographic growth, resulting in a worrying increase in energy demand

For the Mediterranean region as a whole (i.e. including Northern countries), the population has grown impressively from 285 million inhabitants in 1970 to 465 million in 2006. This growth is particularly strong in Southern and Eastern Mediterranean Countries (SEMC) where the population is growing five times faster than in Northern Mediterranean countries. The forecasts for the coming year show two major trends in SEMC: i) The rapid growth of urbanisation: by 2025, SEMC's cities are expected to host some additional 100 million inhabitants, compared with 2000 levels; ii) In the same period, GNI is expected to grow at an average rate of 2.7% annually.

These trends, in conjunction with the improvement in the standards of living in these countries, will result in an important increase in energy demand. In the SEMC, the total consumption of primary energy should reach 560 million tonnes of oil equivalent (toe), compared to 220 million in 2000, and the electricity consumption is expected to triple in the same period. This situation is highly unsustainable, considering the limited resources in the region and the already high energy bill of these countries. One of the main current challenges for SEMC is thus to maintain their economical growth, foster their development, while at the same time control their energy demand.

ii. Residential consumption: high saving potential

Among the different economical sectors, the residential sector is presenting a very high saving potential. Indeed, the more general access to electricity in the SEMC, due to improved electrification rates, in combination with the amelioration of the standards of living in these countries, led to an unprecedented increase in residential electricity consumption.

Table 2: Electrification rates in some Southern Mediterranean countries (2006)

Electrification rate (%)	**Algeria**	**Egypt**	**Morocco**	**Tunisia**
National electrification rate	97	98.5	88	98.7
Rural electrification rate	97	98.5	88	98.7
Urban electrification rate	-	99.7	99	99.8

Source: MEDRES WP1, 2006

iii. Tariffs and subsidy policies

Several SEMC adopted subsidy policies in the 60s to enhance the countries' industrialisation as well as social progress and welfare. But such policies are no more in line with nowadays' situation of global energy stress. Indeed, they maintain at artificially low levels the energy tariffs, whereas the supply costs and the international energy prices increase. They also give a distorted signal to consumers who are not encouraged to save energy. The impacts on the level of consumption of such subsidized tariffs are visible in the following table: whereas Morocco and Egypt have a similar level of GDP per capita (at purchasing power parity), electricity consumption in the residential sector in Egypt is more than twice the Moroccan residential consumption per capita. This is mainly due to the important difference in the national kWh prices.

Table 3: Relation between electricity consumption and electricity prices in the residential sector of Southern Mediterranean countries

	Electricity consumption per capita 2004 (kWh)	KWh prices (minimum - maximum) 2006 (US$ cents)	GDP ppp per capita 2004 (US$)
Morocco	**194**	**8.7 – 14.1**	**3,623**
Algeria	264	2.4 – 6.0	5,592
Tunisia	275	5.6 – 8.0	6,544
Egypt	**440**	**1.5 – 1.5**	**3,471**
Lebanon	760	2.3 – 13.3	4,112
Turkey	385	8.9 – 9.8	6,203

Source: Sénit, 2008

Moreover, subsidy policies are less and less sustainable for governments' and electricity companies' budgets. Indeed, with the raise of electrical demand, governments are forced to invest huge amounts of money to maintain the subsidised tariffs. In Egypt in 2005 for instance, the government spent nearly 110 million Euros to compensate the low electricity tariffs [11]. This puts the government in a complex situation: it's becoming more and more problematic and costly to maintain these subsidy policies; but at the same time, a growing number of low-income households are benefiting from these subsidies and a sudden increase in electricity tariffs could lead to a social crisis.

iv. An emerging common need of EE policies

Southern Mediterranean Countries are currently getting aware of the need of EE policies and programmes to contain the increase of their energy consumption and energy bill. Even if all countries of the region do not face the same constraint in terms of their energy situation - some of them are net exporters of energy (Egypt), some others are dependent on external supply (Morocco, Tunisia) - EE is currently emerging as a common concern. For energy producer countries, the main objective is to contain national consumption and thus to maintain a stable level of energy exports that represent one of the main national income sources, especially in a situation of high international energy prices. Preserving energy resources stocks and anticipating their drying up is also a strong concern. Some estimates [1] foresee the drying up of oil reserves in the region by 2025. Egypt could even become an energy importer in the coming years. For importer countries, EE policies should help reduce their energy dependency towards international markets and thus their energy bill.

v. Residential consumption patterns: fridge as a basic appliance

Electrical appliances, and among them cold appliances, are becoming a basic good in the consumption basket of households in the SEMC. Indeed, the household refrigerator equipment ownership in these countries rose during the last years, as a corollary of an improvement in the living standards and progress in education. In Tunisia for instance, the cold appliances rate increased from 58% in 1984 to 79.8% in 1999, and represented 88.9% in 2004 (STEG, 2005). This represented 1,921,000 appliances in 2004, in comparison with 1,541,000 in 1999, and only 473,000 in 1984.

2. Urbanisation and pauperisation: important challenges for Energy Efficiency policies

If we take the examples of the MEDRES project's partner countries (Algeria, Egypt, Morocco and Tunisia), we observe that they all have important rates of urbanisation: from 43% in Egypt to 65.3% in Tunisia (2006) as indicated in table 4. These rates are foreseen to increase in the coming years, under the effect of natural population increase and rural depopulation.

Table 4: Demographic and economical data for some Southern Mediterranean countries

	Algeria	Egypt	Morocco	Tunisia
Population (million)	33.5	71.3	30.5	10.1
Urban population (million)	21.3	30.7	17.3	6.6
Rate of urbanisation (%)	63.3	43	55.5	65.3
GDP PPP (billion $)	206.4	293	122.3	89.3
GDP per capita PPP (PPP$2000)	6169	4107	4012	8819
Unemployment (%)	12.3	10.6	11.2	14.3

Source: MEDRES WP1, 2006

This growing localisation of SEMCs' population in cities goes hand in hand with the deterioration of some urban dwellers' living conditions. Although the MENA (Middle-East and North African) countries are considered as a middle-income region by the World Bank, some poverty indicators show a precarious situation for some parts of the population.

The poverty indicator "population living with less than 1 US$ per day" shows rather non-alarming results on the first sight (around 2% in Egypt, Tunisia and Morocco) but if the indicator is raised to 2 US$, the rate increased to 43,9% in the case of Egypt, the equivalent of approx. 31.9 million people. Morocco has the highest percentage (7%) of population below the minimum level of dietary energy consumption in the region. When considering the Human Poverty Index (HPI) – an indicator developed by the UN to measure the deprivation in already developed countries - the rates are even more eloquent: 30.9% of the population of Egypt is below this HPI, 34.5% in the case of Morocco, and 19.2% for Tunisia [8]. Poverty and pauperisation are thus a real concern in this region, even if official figures tend to minimize it. Moreover, the emergence and expansion of "poverty pockets" or "slums" in urban areas indicate that urban poverty is also increasing in the region and with a higher vulnerability of the population than in rural areas. The increased labour force of low-skill and low-paid workers in urban centres due to migration from rural areas is feeding the expansion of the informal economy, at the margin of legal work structures. This results in the growth of precarious employment situations and the degradation of purchasing power for numerous urban dwellers.

III. Development of an adapted methodology to assess the EE S&L programme for cold appliances in the Southern Mediterranean context

1. First field observations and identification of the challenges for S&L programme development in Egypt, Morocco and Tunisia

Some field observations done in April 2008 in Egypt, Morocco and Tunisia led to the following conclusions regarding the current state of implementation of the programmes:

i. EE: a growing common concern in the region and the development of S&L programmes

The three countries show a very different situation in terms of the state of programme implementations: Tunisia is the most advanced country and its S&L programme is considered as a model in the region. Egypt has officially adopted an S&L programme but is facing difficulties to implement it successfully; whereas in Morocco, awareness is growing slowly on this issue and the S&L programme is only in the pre-definition phase. This uneven situation provides a good field for cross-country comparisons, allowing sharing and transfer of experiences between countries.

ii. Dynamic cold appliance markets: seizing the replacement opportunity

The cold appliance market in these three countries proved to be dynamic, with important annual sales, a rapidly-growing demand and dynamic local supply chains. In Tunisia for instance, 120,000 refrigerators are sold each year (2003) and this figure is expected to significantly grow in the coming years as the number of households will continue to grow, average living standards are rising and access to affordable credit is increasing [5]. Moreover, taking into consideration the first massive spread of cold appliances in the 90's, and given the appliances' lifespan, a massive future replacement of the old appliances stock is foreseen in the coming years, which makes the effective diffusion of energy-efficient appliances even more crucial.

iii. The low-income consumers: an important but forgotten target group for EE policies

Cold appliances are becoming a basic good in the consumption basket of households and this is also true for low-income consumers. However, it can be assumed, and most of the expert interviews we carried out strengthened this belief, that these low-income consumers mainly possess old and inefficient cold appliances, the income constraint remaining an important barrier to the diffusion of the energy-efficient appliances. Moreover, these low-income consumers are mostly affected by the increases in electricity prices and they would really benefit from energy-efficient appliances that would allow them to reduce their electricity bill and ease their budget constraint.

2. Methodological framework: a three-fold assessment of the S&L programmes

We designed a three-fold assessment of the EE S&L programmes which aims at producing knowledge and data at the following three levels: (i) at the programme design and implementation level: Identify success factors and barriers in the region; (ii) at the market level: Understand purchase and selling behaviour in poor urban areas; (iii) at the consumer level: Assess cold appliances' stock and use in low-income households.

3. Survey implementation

To assess the above mentioned dimensions, we designed socio-economical field survey questionnaires focusing on two crucial levels of diffusion for EE S&L programmes: households and selling points. Several target groups were addressed: households, customers, selling staff and managers. Additionally, an inventory of the refrigerators offered in shops was carried out. The survey was implemented in November 2008 in periurban areas of the countries' biggest urban centres.

i. Egypt

The household survey was carried out in 100 households in a poor neighbourhood in an area called "El Basateen" located in Greater Cairo. The shop survey was carried out in different districts of Cairo by NREA. Managers and selling staff as well as customers were interviewed in 3 large supermarkets and 5 small appliance shops.

ii. Tunisia

In Tunisia the survey was implemented in a popular area of the North of Tunis: the "Cité Ettadhamen" in the "Gouvernorat de l'Ariana". 80 households were interviewed, and some shops of different sizes were visited and surveyed in the same area. This includes small shops as well as one big supermarket (Carrefour).

iii. Morocco

The survey was carried out in different parts of Rabat city, its sister-town Salé, and in the neighbouring city of Kenitra. About 90 low-income households were interviewed and about 15 shop keepers and supermarket managers were interviewed. The study was conducted by employees of the CDER.

4. Scope and limitations of field results

Our results do not claim to be quantitatively representative of national or even regional level, but surely offer an interesting qualitative insight to the issue. Our findings could serve as an initial data base to support further political actions on the topic.

IV. Main results and findings of the survey

1. Urban low-income households and cold appliances: high-potential for national energy savings

Urban low-income consumers represent a fast growing share of the population and a real challenge for EE policies. Our household survey sample, chosen within this category of urban dwellers, is aiming at representing this specific socioeconomic group. Some of the main socioeconomic characteristics of our sample are described in table 5.

Table 5: Socioeconomic characteristics of household sample

	Egypt	Morocco	Tunisia
Average monthly income (national currency and approx. Euro-equivalent*)	434 EP (57 EUR)	4435 DH (400 EUR)	363 DN (194 EUR)
Households with all school-agers attending school (%)	20 %	57 %	65 %
University degree among household members (%)	31 %	48 %	19 %
Living space (m²/person)	14	21	18
Living space (people/50m²)	3,6	2,3	2,7
Electricity supply available/ often interrupted	100% / 92%	98% / 51%	95% / 44%
Water supply available/ often interrupted	100% / 90%	100% / 32%	95% / 11%

Source: MEDRES WP3 household survey, 2009

As it was initially assumed, these households have specific consumption patterns and use of fridges (see data in table 6).

i. Current stock of refrigerators in poor urban households: old and inefficient appliances

The first important observation to be made is that these households mainly own old and inefficient refrigerators: the average age of households' fridges vary from 7.7 years in Morocco up to 10 years in Tunisia (see table 6). Only a small quarter of the households' current fridges were bought within the last two years, and a big third of them already had to be repaired. Nearly none of the interviewed households are in possession of a labelled fridge.

ii. No clear will of replacement in the short-term

Despite they mainly possess old and inefficient fridges, the interviewed households show no clear will of replacing their fridge in the short term (see table 6), probably due to their tight income constraint, when it would be a priority to remove the old and inefficient appliances from the market.

iii. Problematic replacement behaviours: inefficient appliances stay on the market

These households also show certain problematic replacement behaviours regarding an effective replacement of inefficient fridge stock. Indeed, when asked what they would do with their old fridge if buying a new one, the households declare they would neither give it to the disposal, nor recycle it. Old fridges mainly stay in use, used as an additional fridge by the same household, or given to family members or friends, or even sold to some other household (see table 6). Additionally, we observed a tendency towards bigger fridges: most of the households declare they would change their fridge for a bigger one, which is also a concern for energy conservation.

Table 6: Cold appliances consumption patterns and use in poor urban households

	Egypt	Morocco	Tunisia
Average age of households' fridges (years)	9,7	7,7	10
Presence of labelled fridge in households (%)	4	10	3
Fridges staying in use after replacement (%)	83	77	40
Planned replacement in the near future (%)	24	40	19

Source: MEDRES WP3 household survey, 2009

2. Urban low-income households and cold appliances: potential for domestic cost savings

A vast majority of the interviewed households express the need to save energy in their daily life, as electricity bills are representing a quite important share of their monthly income (5 to 8%). Some of the households already had problems to pay their bills in the past, and an important share of them assumes this can become a problem in the future given the evolution on electricity prices (see table 7). These figures show a certain potential for energy savings for low-income households. This will be even truer facing the forecasted decline of energy price subsidies in the future.

Table 7: Household needs for energy cost savings

	Egypt	Morocco	Tunisia
Expressed needs of saving energy in daily life (% total sample)	91%	81%	64%
Problems to pay electricity bills in the past (% total sample)	28%	43%	20%
Expected problems to pay bills in the future (% total sample)	84%	39%	45%
Average share of the income spent in paying the electricity bill monthly (bill in % of income)	8%	5%	6%

Source: MEDRES WP3 household survey, 2009

3. Urban low-income households and Energy Efficiency: lack of knowledge and awareness

Despite the previously observed situation showing a need for energy-efficient habits in low-income households, we observed a striking lack of awareness and knowledge on EE. Low-income households show little knowledge of EE issues in general and of EE labels in particular. Some differences between the countries can be observed, which can be related to the different stages of implementation of EE measures and programmes in the three countries. But generally, the level of understanding is low (see table 8).

Table 8: Household awareness and knowledge on EE

	Egypt	Morocco	Tunisia
Have you ever heard about EE? (Yes answers, % total sample)	10%	43%	56%
Have you ever seen an EE label? (Yes answers, % total sample)	7%	21%	35%
Knowledge of what an EE label means (% total sample)	26%	23%	25%

Source: MEDRES WP3 household survey, 2009

The limited impact of EE measures on urban low-income households, as observed in the households survey, can be explained by two sets of reasons, at the market and programme level.

4. Commercial channels and the diffusion of energy-efficient cold appliances: obvious market failures

First, the structures of the market as well as some specific market barriers are impeding low-income consumers to effectively access the most efficient appliances. Our survey highlighted some of these limitations.

i. Price barrier

Price is the first obvious barrier to the diffusion of energy-efficient refrigerators, given the specific income constraint of low-income consumers and the relatively high prices of energy-efficient appliances. The following table shows that the prices of the most efficient appliances, as observed in the shops, is sometimes by far exceeding low-income consumers declared capability to pay.

Table 9: Households' capacity to pay versus fridge prices

Households' capacity to pay	**Egypt**	**Morocco**	**Tunisia**
Average monthly income	434 EP	4435 DH	363 DN
Average budget they would spend on a new fridge	281 EP	4789 DH	671 DN
Fridges prices	**Egypt**	**Morocco**	**Tunisia**
Prices for class A or 1 fridges (min./mean)	1300 / 3627 EP	500 / 5926 DH	1249 / 1249 DN
Prices for class B or 2 fridges (min./mean)	1490 / 5221 EP	2900 / 5729 DH	490 / 941 DN
Prices for class C or 3 fridges (min./mean)	2159 / 4029 EP	n.a.	219 / 1012 DN
Prices for class D or 4 fridges (min./mean)	n.a.	n.a.	419 / 856 DN
Prices for class E or 5 fridges (min./mean)	2800 / 4504 EP	n.a.	556 /626 DN
Prices in small shops (min./mean)	1300 / 3128 EP	2900 / 7300 DH	289 / 798 DN
Prices in big supermarkets (min./mean)	899 / 5391 EP	500 / 6224 DH	219 / 1221 DN

Source: MEDRES WP3 household survey, 2009

ii. Another important barrier: the information gap

Secondly, the information related to EE and labels seems to be hardly accessible to low-income consumers for several reasons:

- Lack of penetration of EE and label information and communication tools in the shops: during our shop survey, we did not observe any specific communication related to EE and/or labels inside the shops (poster, booklet…) apart of the labels themselves;
- Labels are not always visible on the exposed fridges in shops showrooms;
- Lack of understanding and training of the selling staff on EE issues and labels, which is also a strong impediment to consumers' awareness. The following table shows that managers and selling staff do not fully understand EE labels neither use this kind of argument with their customers.

Table 10: Shop manager and selling staff understanding and use of EE

(% selling staff/ % manager)	Egypt	Morocco	Tunisia
Knowledge of what an EE label means	50% / 83%	78% /86%	75% / 100%
Uses the argument of EE / promotion of EE in the shop	17% / 33%	78% / 29%	88% / 67%
Particular advice for low-income customers	33% / 17%	67% / 57%	50% / 0%

Source: MEDRES WP3 shop survey, 2009

This information barrier may be particularly strong for low-income consumers who are usually less informed on energy issues and have a tighter budget constraint.

iii. Incomplete market transformations

In the surveyed countries, we observed that labels and most efficient appliances are not systematically present on the market. The expected market transformations resulting from the implementation of S&L programmes are still incomplete.

Table 11: Presence of labels in shops

	Egypt	Morocco*	Tunisia
Rate of effectively labelled fridges in shops' showroom	52%	35%	94%
Most present energy class	B	A	3

Source: MEDRES WP3 shop survey, 2009 * In the case of Morocco, as there is still no national label, present labels are "imported" ones (the European ones in most of the cases).

5. Limited programme effectiveness in reaching low-income consumers

Globally, this survey is showing a limited impact of the S&L programmes on the low-income consumers' category. We tried to identify, through the observations made in the survey, some of the "failures" at the programme design and implementation level:

i. Failure in effectively transforming the market

In the case of Egypt notably, systematic labelling in shops and evolution of the manufacturers' offer towards efficient appliances is not effective.

iii. Communication failure

Information on labels and EE does not effectively reach the low-income consumers. They proved to be poorly informed on the S&L programme of their country, whereas they would really constitute a favourable group for the appropriation of such policies.

iii. Lack of specific mechanisms targeting the low-income group

With the exception of one planned measure in Tunisia - a specific financial facility for low-income consumers to replace their fridge – the programmes design and implementation in the three countries is or was paying too less attention to this specific target group and no specific measures were planned upstream.

Conclusions and recommendations for design and implementation of "pro-poor" S&L programmes in emerging countries

Finally, we would like to make the following conclusions and recommendations to allow a better access of low-income consumers to energy-efficient appliances and thus deepen the impacts of the EE S&L programmes in place or to be developed in similar countries:

The survey shows that low-income consumers are currently not included enough in the EE S&L programmes' definition and implementation. Regarding their potential for energy savings, they should be considered as an important target group for EE policies. Indeed, in the case of refrigerators, urban low-income households show a remarkable potential for energy savings at the national and regional level considering the general spread of basic electrical appliances and the assessed inefficient fridges stock in these households.

Specific mechanisms targeting this group should be implemented as for instance: specific communication, strong incentives to replace their old equipments but also recycle them, financial facilities, etc. The impacts of not addressing these specific consumers' needs and constraints could be an interesting subject for further research.

Given the positive impacts EE could have on easing the budget constraint of low-income consumers, the option to design and implement EE programmes in line with poverty reduction strategies and actions should be investigated. In particular, national social structures or actors could be an interesting support to spread EE to the poorest.

The incomplete and unsatisfactory state of the market transformations expected from the S&L programmes, as well as some identified market barriers, are calling for further State intervention to: support market transformation by promoting EE training and communication in the commercial networks, by working with manufacturers to reduce the appliances' prices…

Globally, communication towards and common action with all stakeholders should be intensified, as there is currently an important lack of understanding and knowledge on EE labelling.

On a cross-country level, developing regional cooperation and coordination of EE actions also seems crucial for the future of EE achievements in the region. Indeed, some transfers of experience from a more advanced country to another in a learning phase could allow more effectiveness in rapidly implementing EE measures. Regional harmonisation of the S&L could also contribute to the creation of a regional market.

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Beyond A: the future of the energy label

CECED examines options for improving the EU energy label for household appliances, making the case for a new labelling system

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Abstract

The energy label is a tool that was introduced in 1992 as a way to communicate the energy efficiency of an appliance to the consumer. The household appliance industry was the first to use the energy label and has recorded major successes in the area of innovation that have been communicated with the use of the label.

Today the energy efficiency of some appliances has surpassed the capability of the existing label and discussion has been ongoing for over a year on ways to update the label.

CECED, the European Household Appliances Manufacturers Association, supports a new scale that fosters innovation. The energy label is a tool that must evolve along with the energy efficient successes that have already been achieved with its help over the past 15 years. This paper will explain the industry's point-of-view on why the energy label tool needs improving as we work toward the goal set by the Kyoto agreements.

Introducing CECED

Founded in 1958, CECED, the European Committee of Domestic Equipment Manufacturers, has operated a permanent office in Brussels since 1997 in an effort to better represent its members vis-à-vis the institutions of the European Communities.

The main objective of CECED is to represent and defend European Industry interests. The Association acts as a partner in dialogue with the EU's political and regulatory institutions and also interacts with the media, non-governmental organisations representing a range of different interests (including consumers and environmental groups) and other interested parties. CECED provides a forum for the industry to reach consensus on issues of common interest such as product/process standardisation and regulatory initiatives. This consensus-building role can also lead to concrete commitments or agreements within the industry that can become the basis for EU policy initiatives.

CECED member companies employ over 200,000 people, are mainly based in Europe, and have a turnover of about €40 billion. If upstream and downstream business is taken together, the sector employs over 500,000 people.

Direct Members are Arçelik, Ariston Thermo Group, BSH Bosch und Siemens Hausgeräte GmbH, Candy Group, De'Longhi, Electrolux AB, Fagor Group, Gorenje, Indesit Company, Liebherr Hausgeräte, Miele, Philips, Saeco, Groupe SEB and Whirlpool Europe.

CECED's member associations cover the following countries: Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CECED examines options for improving the EU energy label for household appliances, making the case for a new labelling system

In 1992 the energy label was introduced for major household appliances. It worked so well in fostering innovation and the progress of energy-efficient products that, today, the highest class has been achieved and even surpassed, i.e. almost every new product has an energy efficiency rating of Class A.

CECED believes that the A-G classification has been successful. However, technological progress and innovation, know-how, and investments by manufacturers (over €15 billion in 15 years), have changed the mix of the offer faster than anyone expected.

Today there are cold appliances that deliver higher efficiency than Class A. In 2003 a European Directive introduced A+ and A++ classes for refrigerators and freezers because the entire scaling system had already been overstretched. The present solution with A+ and A++ categories for refrigerators has worked well for consumers as well as manufacturers. Today new products offering an additional 20% improvement in technology come onto the market every 4 years while keeping the sale price constant.

In the period January to April 2000, Class A cooling appliances amounted to 18.3% of the sales (in volume) in 10 western European countries according to the Growth for Knowledge Group (GfK)[1]. At that time there were virtually no units that existed in a higher class. However, in the same period in 2008, Class A products numbered 66.7% of the market; Class A+ claimed another 22.3% and Class A++ had already achieved a noticeable 1.3% share. That means that Class A and higher rated refrigerators represent 90.3% of today's market, while Class C and lower rated appliances have been virtually wiped out.

The European white goods industry is a leader in energy efficiency. Interestingly enough, additional improvements in the energy efficiency of cold appliances in Europe are in the pipeline and will be ready to be launched in the not too distant future. They could potentially reduce electricity consumption significantly compared with today's Class A++ refrigerators. All stakeholders need a tool to communicate energy efficiency capacity higher than today's current Class A++ rating.

The overcrowding of the top class of energy efficiency is also no longer exclusive to cold appliances. Currently, washing machines are the only other appliance which can be positioned but not labelled, in a class higher than "A". Class A+ for washing machines has been allowed to be mentioned outside the official energy label and with certain limitations but only as a market communication message. GfK data show that in the 10 Western Europe countries, A and A+ units claimed 93.2% of the market in January–April 2008. By comparison, during the same months in 2000, Class A washing machines claimed 27.5% of the market, while A+ did not even exist. The evolution of the washing machine has been even faster than that of cold appliances. The above data outline a scenario in which the energy label tool is seriously lagging behind technology and the market about which it is supposed to be communicating.

The dynamics of prices

Since the introduction of the energy label, the price-energy efficiency ratio has always been on a descending trend, to the advantage of consumers who can buy better performing appliances at lower prices. In eight years, consumers paid 41% less for equivalent performances in Class A. Class A+ models followed the same trend in a four-year period.

Today, the leading class of energy efficiency for cooling appliances is A++. In order to communicate this higher level of innovation the market must remain open to competitive change. It can adjust to new price levels when a technological leap is made by a producer if there is an energy label that helps communicate this improvement. Industry is willing to communicate innovation when it has a better product ready to launch on the market. What it requests now is an updated energy label that will help with this message.

There are two additional elements contributing to the complete picture: products, and the manufacturing/distribution chain. The European energy label did an excellent job in setting a common reference for these elements. Products in the higher classes conquered the market rapidly and demonstrated resilience against price erosion. As a consequence, manufacturers invested heavily in

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[1] The Growth from Knowledge (GfK) Group; *Energy Labelling in White Goods – the Experience in Western Europe*.
GfK is one of the largest market research companies in the world. www.gfk.com.

innovation.

CECED is calling for a revised energy label that will make it possible for industry to continue to bring innovation to the market as quickly as possible. It wants the values behind the scale to remain stable so that the energy efficient message remains consistent. There should be no rescaling of products.

There are alternative options being discussed. One option advocates keeping the A-G energy label as it is, periodically changing the meaning of energy classes. It wants the top energy efficient appliances to be devalued when a better appliance comes on the market so that the best class will always be "A". This means a change of the definition of "A" and penalising most top performing products.

Devaluing current energy efficient appliances risks undermining consumer confidence in the label because the meaning of "A" will not remain constant. Innovation will be penalised because changing the value of "A" will downgrade top products into lower classes. Therefore, devaluing energy efficient appliances is not a sustainable industrial policy whereas an improved label could supply the market with room for 10-15 years of further innovation and progress on energy efficiency.

Consumers not lost and alone

When considering a change in the energy label, it is the consumer who is the centre of the system; the acid test of every new policy. A policy can be successful only if consumers are properly addressed. However, the consumer cannot be seen as someone who is lost and unable to understand anything beyond the simplest message. On the contrary, the consumer should be treated as a thinking individual who is able to make sensible purchasing decisions based on reliable information.

Supporters of the A-G rescaling claim that consumers know the simplicity of the message "buy A". It has to be said that today consumers are faced with the evolution of that concept because of the existence of A+ and A++ products and they have been able to cope with the concept quite well. In several European Countries sales of A+ and A++ appliances account for more then half of the market. Therefore, Class A is no longer the only driving decision maker for consumers. They have grasped the concept of energy efficiency and are asking for a tool that will communicate that to them in a clear and consistent manner.

Behaviour change: the myth

It is popular to believe that awareness is enough to bring about change but we challenge that assumption when dealing with the energy label. When interacting with the label, consumers have to trust the European policy, understand which class is best in terms of energy efficiency and energy saving, and buy the top in quality and performance. If a communication programme focuses only on building awareness about the new energy label it would miss the scope because it would see the new label as a target or objective, while it is only a tool. No change in consumer behaviour would be achieved. Research by Dr. Ree Meertens[2] of Maastricht University confirms that habits have the negative effect of reducing thought and deliberation, curtailing the search for information, and acting as a brake on change. Furthermore, people repeat actions in stable scenarios.

This means that awareness only indirectly affects behaviour and that a change in awareness does not necessarily lead to a change of behaviour. The real issue is the change of the energy label itself. How do we change to a single yet powerful tool that helps the consumer make an informed decision? This will be explored further in the next sections.

Energy labelling: two options
A-G rescaled

[2] Dr. Ree Meertens, Associate Professor Department of Health Education and Promotion, Maastricht University
Why doesn't awareness building lead to behaviour change?
Presentation at the Amsterdam Forum, an energy efficiency conference held in the Grand Hotel Kranapolsky, 23 May 2008.

The rescaled A-G option keeps the background the same as it is presented today. However, periodically when a more innovative appliance is brought to the market the A-G scale would be revised, forcing all existing appliances down to a lower energy rating class every time the energy efficiency scale has been revalued because new and more efficient products are on the market complying with rules and timings, which are still to be decided. A product which in a certain year was meeting the criteria for class A could then be devalued to Class B or lower under the new classification in a different year.

Such an option requires the label to include a date explaining what the energy efficiency class is worth. As different products are expected to be rescaled at different times, the leading class could identify a whole range of energy efficiency levels, not the best available. The argument to "buy A because it is the best" will not always be applicable. Attention should be paid even to the possible reaction of a consumer discovering the Class A appliance that he purchased earlier has been devalued to a "B" or "C". This could cause confusion and a loss of trust in the communication tool. There will likely be no comprehension of change and improvement.

Even if rescaling happened at regular intervals, overlapping must be expected when a transition (i.e. rescaling) is due, during which time there will be a mixture of old and new labels present on the same product on the market.

As consumers will find Class A products of different ages, they have to be made aware of the difference in energy efficiency. Communication plays a vital role and it should be ongoing, to reflect these energy efficiency changes. Such communication would be a defensive message, i.e. the explanation of the difference between the rescaled labels which visually appear the same.

Improved energy labelling

The opportunity to always show the best product means immediate visibility to consumers and the possibility to obtain a proper return on investments for manufacturers who can release an innovative product onto the market when it is ready instead of having to wait for a predefined date for rescaling energy efficiency levels.

It is in the highest interest of the market that investment is made to inform the consumer as much as possible about the availability of a new class of energy efficiency so as to gain a competitive advantage. Such a positive message will influence customer behaviour, leading to a long-lasting transformation of both customer and market.

The European domestic appliances industry is a world leader in producing energy efficient products. We believe in the merits of the EU energy labelling scheme, but we are asking for a revised label that will work into the future.

A recap of pros and cons

Constantly rescaling A-G is an option that is still missing vital elements to make it viable and ready to be enforced. The co-existence of old and new labels will send contradictory signals to consumers and make it difficult to make an informed choice.

A new energy label can and should be designed to last for the long term giving reliable and trustful information to consumers about the natural evolution of the market toward higher efficiency levels.

The Evaluation Methods of China Monitor Energy Efficiency Standard

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Abstract

By statistic of the monitor test result, four monitor energy efficiency evaluation methods were compared on the size-compatibility, data distinguishability and comprehensiveness. Size-compatibility requires that the results of different sizes could be compared. The method should comprehensively consider the performance aspects linked with power. The results difference between "power-saving" and "power-consuming" monitors need to be distinguishable and bigger than the system error. The basic content and requirement of China monitor energy efficiency standard was also introduced.

Introduction

Evaluation method is the key of one energy efficiency standard, which will affect not only the present monitor market but also the future energy saving design trend. This discussion includes four evaluation methods, i.e. Pixel/W, Sq.m/W, cd/W and lm/W.

Pixel/W is used by Energy Star in both LCD and CRT monitor evaluation [1]. Sq.m/W, which initially is Sq.inch/W, came from the draft of Energy Star TV standard draft [2]. New China monitor energy efficiency standard adopted cd/W, while lm/W is efficiency of electro-optical converting.

The statistic data used are provided by China Information World (a major IT media in China) monitor sample test reports from 2005 to 2006[3] [4] [5]. The sample collection in the tests has not focus on specific market segments, which can be considered random.

1. Monitor Evaluation Methods

Lumen per watt is luminous efficiency of each electronic device for emitting light. Monitor produces image, i.e. light, by consuming electric power. The ratio of total luminous flux to total power, including the consideration of viewing angle, brightness and screen size, could be a good evaluation method for LCD monitor. However there is no CIE standard method to measure a flat light source flux. A monitor power standard thus will have difficulty to adopt this method.

Candela per watt considers the ratio of power consumption and luminous flux intensity on the normal direction of screen. It's the device's efficiency to convert power to normal directing luminous flux intensity. If the argument that screens are most frequently observed from the normal direction were tenable, cd/W kept practical physical significance. Candela can be measured by brightness and screen area, both of which have standard measurement methods.

The reciprocal of pixel per watt is the power consumed on single pixel. The reciprocal of sq.m. per watt is power consumed on unit screen area.

luminous flux of the screen was calculated from the screen area multiplied by the illuminance measured by Eldim conoscope EZ160R at the screen center. Luminous intensity was product of screen area and center brightness, which was measured by Topcon BM5A.

2. Screen Size Influence on Result

The major monitor size changes graduately with the market choices. The mainstream size 17" normal was replaced by 19" wide and 19" normal this year. This size will keep changing. The different mother glass size will also lead sight differences among the "same" size segment, such as 22" wide and 21.6" wide. A better energy efficiency evaluation method should provide a value which can be compared across the sizes. Different sets of energy level criteria for each different size are thus not necessary. One single standard can be extensively suitable for all LCD monitors.

The monitor data, total 74 monitors, were divided into 4 groups by size, i.e. 17" normal, 19" normal, 19" wide and 20" wide. The influence of screen size was studied by one way ANOVA. Two values were observed (table 1), i.e. F-ratio and P-value.

Table 1: One way ANOVA result of the data grouped by size.

Approach	F-ratio	P-value
lm/w	1.56	0.206
cd/w	1.33	0.271
Pixel/w	14.46	0.000
Sq.m./w	14.51	0.000

P-values of Sq.m./W and Pixel/W are much smaller than the common alpha-level 0.05. Their evaluation values could be concluded to have significant differences between sizes. P-values of cd/W and lm/W indicate that the population means by sizes have no significant differences.

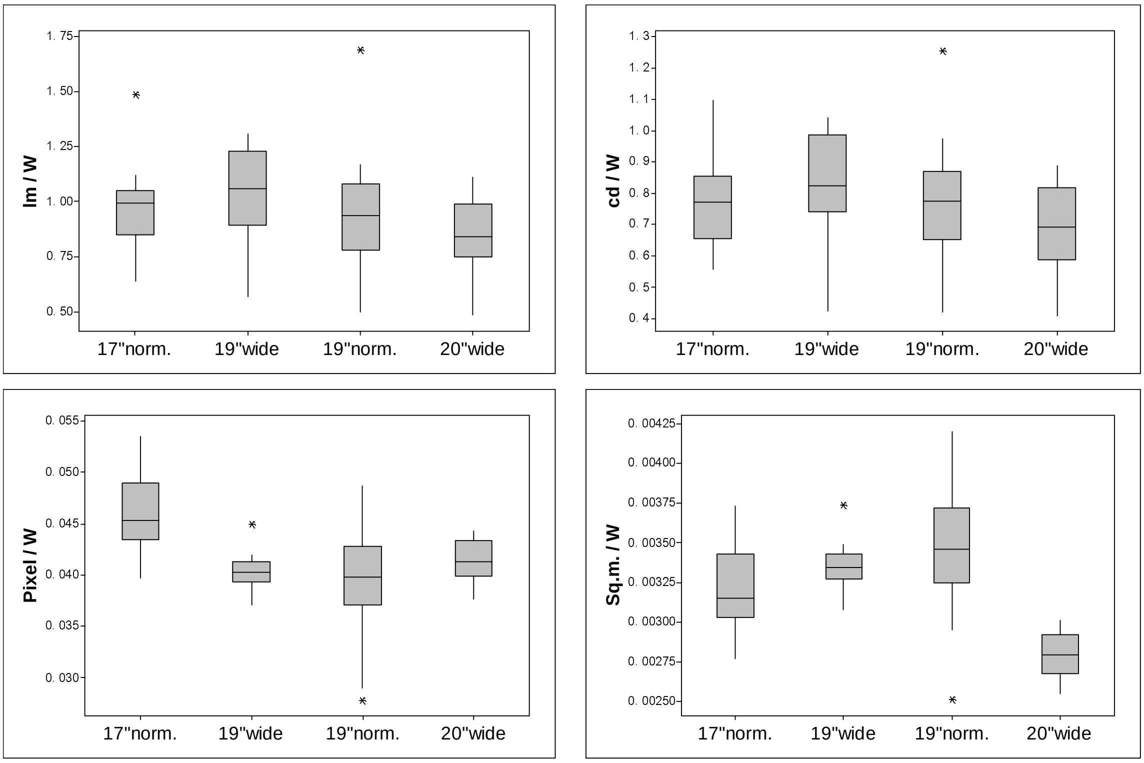


Figure 1: The Boxplots of the data grouped by size.

3. Result Distinguishability

Error will be introduced in by people and instruments. There are also differences between each power meter and luminance meter. The evaluation results between "good" and "bad" units should have the gap bigger than these errors and differences, which can ensure the energy level decided by results is repeatable between parties.

The ratio of MSA to MSE is big, i.e. F-Ratio, for Pixel/W and Sq.m./W. To keep the MSA influences out, groups by size are kept be used in this comparison. If Variation Coefficients, i.e. the ratio of standard deviation to mean value, were observed, lm/W and cd/W delivered bigger distinguishability than Pixel/W and Sq.m/W.

Table 2: Variation Coefficient of each Evaluation Method.

Sq.m./W

Size	Sample#	Mean	StDev	StDev/Mean
17"norm.	25	0.0032091	0.0002632	8.20%
19"wide	9	0.0033572	0.0001801	5.36%
19"norm.	30	0.003454	0.0003433	9.94%
20"wide	10	0.0027902	0.0001573	5.64%
The average of Variation Coefficient				**7.29%**

Pixel/W

Size	Sample#	Mean	StDev	StDev/Mean
17"norm.	25	0.046094	0.003708	8.04%
19"wide	9	0.040411	0.002167	5.36%
19"norm.	30	0.039579	0.004507	11.39%
20"wide	10	0.041341	0.002233	5.40%
The average of Variation Coefficient				**7.55%**

cd/W

Size	Sample#	Mean	StDev	StDev/Mean
17"norm.	25	0.7649	0.1316	17.20%
19"wide	9	0.8252	0.1877	22.75%
19"norm.	30	0.7613	0.1695	22.26%
20"wide	10	0.6832	0.1439	21.06%
The average of Variation Coefficient				**20.82%**

lm/W

Size	Sample#	Mean	StDev	StDev/Mean
17"norm.	25	0.9636	0.17	17.64%
19"wide	9	1.0392	0.2332	22.44%
19"norm.	30	0.9431	0.2188	23.20%
20"wide	10	0.8445	0.1819	21.54%
The average of Variation Coefficient				**21.21%**

4. Performance Factors Comprehensiveness

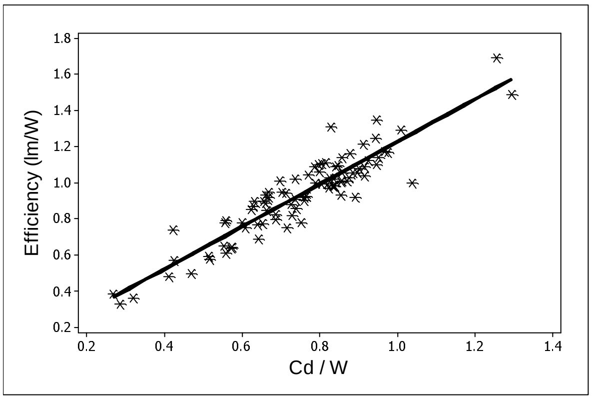
LCD monitor performance items are related with power consumption, i.e. the bigger, the brighter the screen is, the more power consumed. The performance items were calculated their correlation with power consumption (Table 3). Contrast has no relationship with power, while the other five all do. However, a bigger correlation coefficient does not mean this item is a better choice to be considered with power together than others.

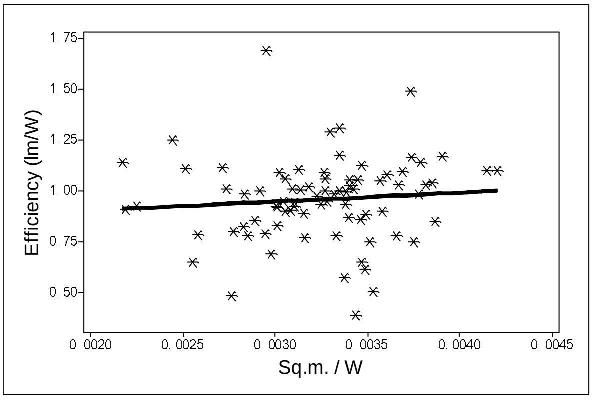
Table 3: Performance Items correlation with Power Consumption.

Item	Correlation with Power	P-Value
Contrast	0.077	0.473
Luminance	0.799	0.000
Area	0.849	0.000
Brightness	0.427	0.000
Pixel	0.888	0.000
Lum. Intensity	0.802	0.000

Besides the items listed, lunminance viewing angle is also related with power, i.e. a wider the viewing angle will consume more power. Among the four evaluation methods, lm/W considers more performance factors than others, i.e. brightness, area and viewing angle.

From the stand point of comprehensiveness, lm/W is best of the four evaluation methods. Dot plot comparison (Fig. 2) showed cd/W is closer to lm/W. The difference brought by ignoring luminance viewing angle thus is not significant between monitors. The power differences brought by area and brightness are not neglectable.





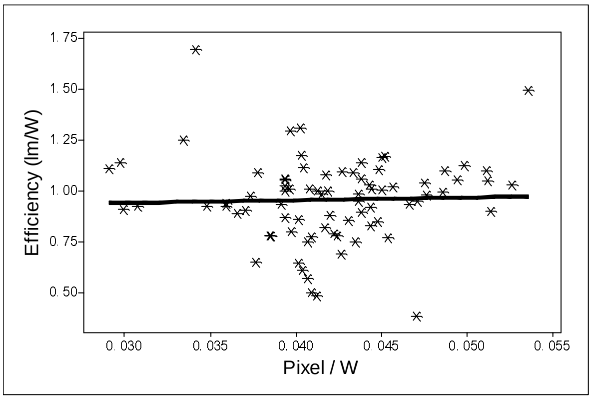


Figure 2: Dot Plot of lm/W V.S. Other Three Evaluation Methods.

5. China Monitor Energy Efficiency Standard

As very important office equipments, computer monitors were necessary to have energy efficiency standard to control their power consumption. The stand-by power is less than 30% of the total power consuming, so Energy Star, EuP and Australia all have developed or are developing the energy standard considering on-status power consumption. In China energy efficiency standard, on-status power was also included in the evaluation, and considered as one key criteria of grading. As the biggest monitor manufacturing country, China will have its monitor efficiency standard lead the improving of technique development, also help the monitor power saving globally.

The China Standard Certification Center has been working on the monitor power saving certificating from 2005. However being restricted by the national standard, the on-status power consumption has not been included in. In Jun 2006, Standardization Administration of China kicked off the project of monitor power efficiency standardization, which was also included in the appendix standards of national energy conservation law. The drafting committee finished the draft in 2007 Q4 and passed the stakeholder gatereview. In 2008 Apr., the standard got approved and published, which was coded as GB21520-2008 and effective 7 months after, ie in Nov. 2008.

The standard covers the CRT and LCD computer monitors, who are working under the wall slot voltage and may have tuner but whose major implementation is designed for computers. Due to application ranges can not be totally replaced with each other, the standard gives two grading ladders for CRT and LCD under same power evaluation method, i.e. the canderla per watt methodology.

The grading ladders consist of 3 levels, minimum requirement level, energy saving level and target energy saving level. The minimum requirement, i.e. level 3, is the bottom line of market permitted energy efficiency. The monitors with efficiency lower than this line are perhibitted to sale in the China market. The energy saving level, i.e. level 2, is the voluntary energy saving certificate requirement, which is only required in the government procurement. The target energy saving level is a premium line when setting the standard, which will be the energy saving level 3 years after the standard effective. It raised the bar for the whole industry to develop energy efficiency techniques.

Table 4: Levelling in China Monitor Energy Efficiency Standard

Display Type	Level 1		Level 2		Level 3	
	Energy Eff (Cd/W)	Power-off (w)	Energy Eff (Cd/W)	Power-off (w)	Energy Eff (Cd/W)	Power-off (w)
CRT	0.18	1	0.16	3	0.14	5
LCD	1.05	0.5	0.85	1	0.55	2

6. Conclusion

With the analysis, lm/W and cd/W values can be less influenced by screen size, which have more size-compatibility and data distinguishability also. From these points of view, the two evaluation methods are better than Pixel/W and Sq.m/W. However, the lack of CIE standard test method of flat light source luminous flux will be the barrier to lm/W application in monitor standards. Meanwhile, cd/W can be achieved by widely used standard methods and has good correlation with lm/W, which suits a better LCD monitor power standard.

The China monitor energy efficiency standard has taken effective for half year. The cd/w based evaluation method was approved by practice to effectively differentiate the super-eco, i.e. the 2 CCFL monitors, and helped the eco monitor advocating.

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Heating

Reducing the Carbon Footprint of Existing Domestic Heating: A Non-Disruptive Approach

Martin O'Hara

Danfoss Randall Limited

Abstract

There is insufficient time between today and 2020 for renewable energy technologies to greatly impact the carbon footprint of the existing domestic housing stocks' heating systems, hence the 20% savings the EU has committed to has to come primarily from other approaches. Of the homes we will be living in by 2020, over 90% are those that we live in today. This paper looks at what can be applied to existing domestic boiler space heating installations to produce savings in system energy efficiency, and subsequent carbon reduction, by better use of heating control technologies alone. By improving the space heating controls, while retaining the same user interface as today's existing technologies, it can be shown that up to 10% reduction in energy consumption and a similar carbon emission reduction can be achieved without the need for plant change or changing the user interaction with the heating system. Test results on gas boilers without condensing capability (still a large installed base), as well as more modern high-efficiency condensing boilers and modulating flame boilers, running a standard domestic space heat load of 13kW, have proven that controls alone can greatly impact the efficiency and hence carbon emission of a domestic heating system.

Introduction

Like most EU governments, the UK is committed to trying to achieve the 20% reduction in carbon emissions by 2020. There are many steps to achieve this goal, but in 2005 the UK put in place a buildings regulation change it hoped would improve the efficiency of UK domestic heating by up to 14% when a change of heat plant (primarily domestic gas boilers) is required. The UK building regulations (known as Part L) changed to effectively allow only high efficiency (HE) condensing boilers to be installed in domestic heating systems (with a few exceptions)[1]. This regulation change brought about an almost overnight switch from older non-condensing boilers in new installations, with the above stated expected increase in domestic heating of 14% seasonal efficiency benefit.

Unfortunately the resulting changes of plant alone failed to provide the expected improvement and as well as a relatively low carbon saving, home owners complained of a lack of saving in their energy costs when they had replaced what is a relatively high cost part of their heating system[2]. Changing the boiler is a disruptive process to a household, as well as an expensive one, particularly where flue issues and condensate traps are difficult to fit retrospectively to some existing installations. As a consequence many installers report an increase in the requests for repair of existing boiler plant rather than change to a HE boiler, further defeating the carbon saving goals of government.

As an industry, the controls association in the UK; TACMA, and Danfoss Randall Ltd in particular, started a project to examine how the change of the system thermostatic control alone (a non-disruptive approach) could impact the efficiency of not only newer HE boilers, but also older non-condensing boilers and more advanced modulating-flame boilers more commonly found in the Benelux regions. The project, known as the Advanced Controls Project, looked to see how a change in the operation of a relatively simple room thermostat, and in particular how advanced control algorithms in electronic controllers could impact existing installed domestic heating system efficiency.

Although work had been conducted by the UK government on improving the modeling of UK domestic heating systems by computer based simulation[3], it was decided to use real-system testing that could simulate the impact in a genuine installation, using available domestic boilers in the TACMA Advanced Controls Project. Latterly the possibility of using computer based simulation to extend the test scenarios has been performed [4], but the result of these simulations is outside the scope of this paper.

Laboratory Controlled "Test House"

Danfoss Randall Ltd has a laboratory controlled "test house" (figure 1). This consists of a 20 cubic metre single brick room with plastered internal lining (comfort house) surrounded by 50 cubic metres of controlled temperature air-flow (annular space), which represents the outside air temperature. The test house has a 1.3kW radiator to provide heat from the boiler to the room and a hydronic load dump allowing up to 25kW of additional load to be drawn from the boiler under room control (this load dump represents the rest of the house). The boiler is installed in a separate part of the laboratory hence does not contribute directly to the system space heating. Consequently, although operating on a single controlled room (as is typical in a UK dwelling), there is a "whole house" draw of energy from the heating system.

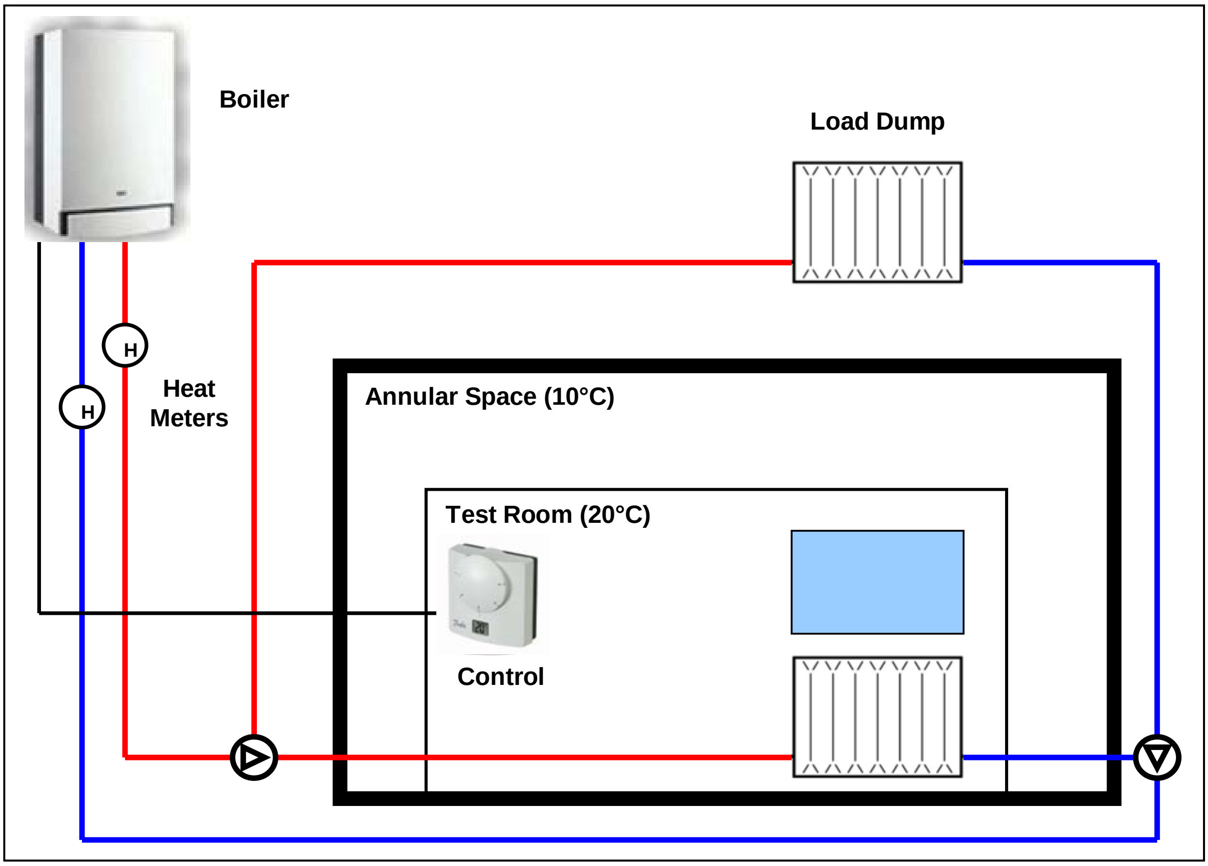

Figure 1: Schematic Representation of Test House

The above system allows the effect of room control alone to be accurately monitored as we are able to set-up repeatable external temperature and system load conditions on the same boiler with the same radiator in the same test room (house). The only difference between each system test run is the room controller we use to determine the system activity.

The heat transfer into the room is by natural convection from the radiator, as it would occur in a real home, hence the speed of reaction of the control (placed on the wall opposite the radiator) and the delivery of heated water to the radiator is consistent with how these system components react in a real home. The main artificial concept is the fixed external temperature, in reality this would vary and although the annular space temperature is programmable it was decided to maintain a fixed temperature to enable repeatability tests to be easily conducted and to remove additional variability controlling this parameter may introduce.

UK Spring/Autumn Weekend Profile

The tests presented here all had the same time-temperature profile on the system. The annular space (external temperature) is maintained at a constant 10°C, the test room is allowed to cool to 15°C before commencing the test and the room control set at 20°C. The test is a single run of 12 hour operation representing a weekend profile, turning the system on once and controlling at a fixed temperature; a single start-up and then constant control. The total system load is 13kW at start-up.

Boilers and Controllers Tested

Four types of dial-set thermostatic room controller were used for these tests (figure 2) on three different boilers. Two of the boilers; a standard non-condensing and a HE condensing type, had the same three room thermostats; a mechanical gas-filled bellows thermostat, an electronic thermostat that operated in on/off mode and an electronic thermostat with proportional-integral (PI) control operating in chrono-proportional (time-proportional) mode set to Chrono-6 (6-cycles per hour) for the tests shown here. Physically the electronic on/off and Chrono-proportional thermostat was the same device; the operating mode is an installer selected option.

The third boiler available is a modulating-condensing boiler with an OpenTherm digital interface, this boiler had the same mechanical and electronic on/off controllers used above, plus a modulating OpenTherm controller (Danfoss ORT-10) to determine the best control options.

This paper is primarily interested in the impact of the control methods on each boiler type, hence no comparison between the three specific boilers will be provided, and due to slightly different boiler parameters (e.g. maximum load capacity and water temperature) it is in fact unfair to make comparisons between the boilers based on the data shown here.

Figure 2: Simple dial-set thermostats used for tests (from left; mechanical thermostat, electronic on/off and PI Chrono-proportional and OpenTherm modulating control).

Results

All tests were done with the thermostats set to 20°C, however, some variation on this set-point is to be expected and the mean value was allowed to be within ±0.5°C of this target temperature. The set point was determined as the mean value of the room temperature cycle, not the minimum value as is often used.

At the end of each test the total energy consumption was recorded, both gas and electricity. This has been used to determine the total cost and carbon footprint of the resulting tests to determine which control schemes offer the best efficiency for the equivalent comfort level. Although flue gasses for the gas boiler are capable of being directly measured, the electricity contribution to carbon emissions is not, hence for the purposes of this report and to maintain consistency, the reported carbon emissions are calculated from the fuel consumption rather for both gas and electricity using National Energy Foundation contribution factors[5].

Non-Condensing Boiler

The non-condensing boiler is the stock type of boiler fitted in the UK up to 2005. There are known to be over 15 million installations in domestic dwellings of this boiler type in the UK alone still in regular use and until they fail beyond economic repair this will remain the case for years to come.

Comfort Control

The room comfort levels achieved in this test (figure 3) show that the electronic on/off and the chrono-proportional (PI) controllers provide significantly better overall comfort levels that the mechanical thermostat which has a peak-to-peak temperature swing of over 1.5°C compared to 0.8°C for electronic on/off and 0.2°C for the chrono-proportional controller. It is observed on both the electronic on/off and chrono-6 comfort controls that the boiler hit maximum water temperature just as the room entered the control band (shown by the slight dip in room temperature as the boiler is switched off internally). In the case of the basic electronic on/off control this quickly is recovered, but this maximum temperature limit caused a slight delay in the PI-controller, as there is no boiler feedback the algorithm drops out of control and takes some time to regain proper room control again. This is an accident of the position of the maximum water set point and the load demand, when run with a room demand of 21°C or a higher maximum water feed temperature this effect was not observed.

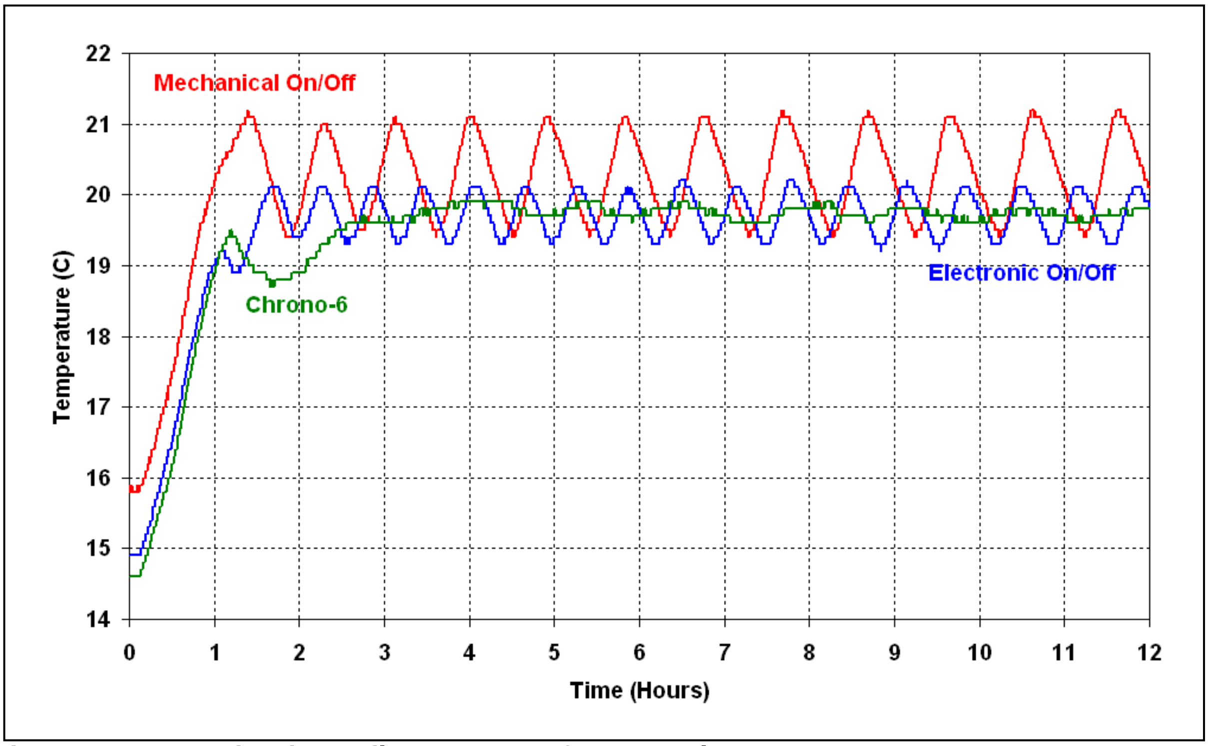

Figure 3: Non-Condensing Boiler Room Comfort Control

Energy Consumption

The results for the non-condensing boiler show that the better level of comfort control offers significant savings in energy and reduced emissions (table 1). Even changing from a mechanical control to a narrower band electronic on/off control can save 12% on the fuel and carbon, using the tighter control of the chrono-proportional control gains a further 2% over the heating cycle used here.

Table 1: Non-Condensing Boiler Energy Cost and Carbon Emissions

Control	**Energy Cost (€)**	**Energy Saving (%)**	**Carbon Emissions (kg CO_2)**	**Carbon Saving (%)**
Mechanical On/Off	4.19	-	16.20	-
Electronic On/Off	3.69	11.94	14.25	12.02
Electronic Chrono-Proportional	3.63	13.39	14.00	13.60

High Efficiency Condensing Boiler

The HE condensing boiler is a SEDBUK Grade-A stock type fitted in the UK since April 2005 when the Part-L building regulations came into force. There have been approximately 4.5 million installations of this type of boiler in the UK since 2005 (source: HHIC) and this number is growing at the expense of the non-condensing type above.

Comfort Control

The room comfort levels achieved in this test (figure 4) again show that the electronic on/off and the chrono-proportional (PI) controllers provide significantly better overall comfort levels that the mechanical thermostat that in this case has a peak-to-peak temperature swing of 2°C compared to 1.2°C for electronic on/off and 0.3°C for the chrono-controller (once in the control band). With this more modern and faster-reacting boiler the chrono-6 control gives very fast precise control and again significantly improved comfort levels compared to the other two control methods.

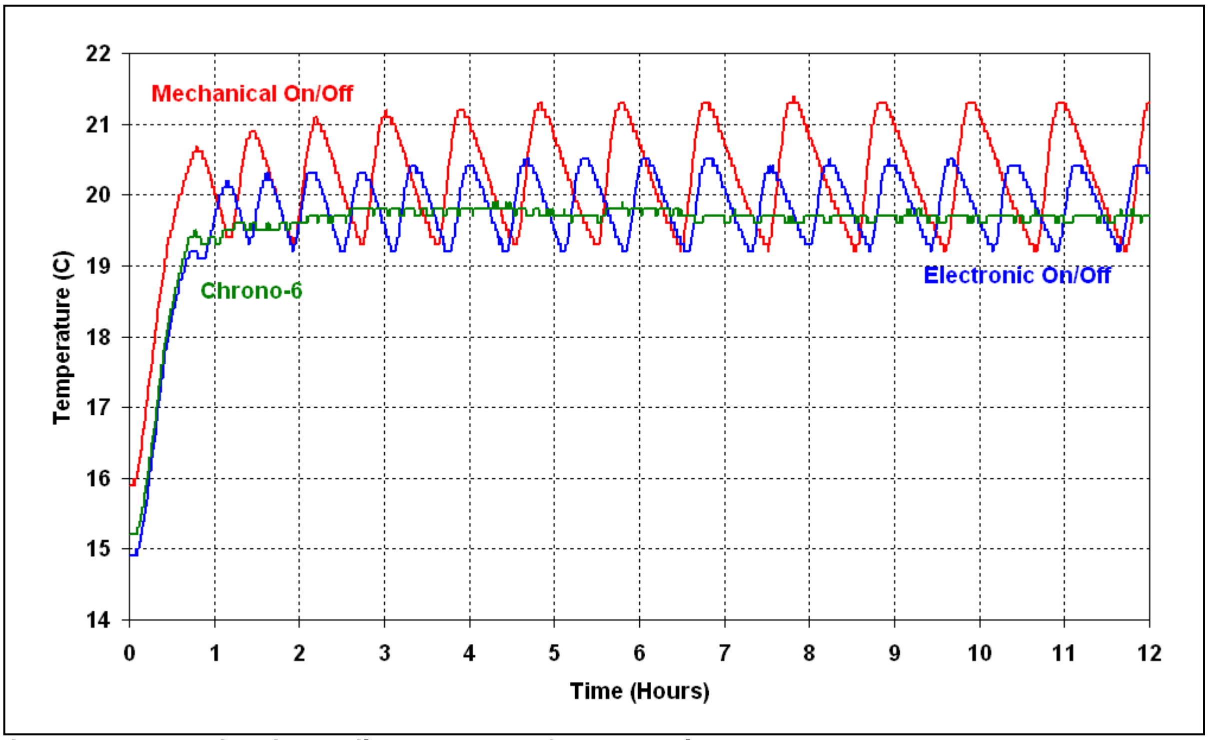

Figure 4: HE Condensing Boiler Room Comfort Control

Energy Consumption

The savings benefit of the better electronic on/off control over the mechanical thermostat is only small with the HE condensing boiler at just over 2%. Since this is a higher efficiency boiler in the first place the benefits of the tighter thermal regulation alone clearly does not have such a large impact as it did with the non-condensing boiler. However, very large savings can be obtained, close to 10%, by using the chrono-proportional control algorithm for control of the HE condensing boiler compared to mechanical on/off control (table 2), the reason for this can be easily observed by looking at the return water temperature profiles for the system (figure 5).

Table 2: HE Condensing Boiler Energy Cost and Carbon Emissions

Control	Energy Cost (€)	Energy Saving (%)	Carbon Emissions (kg CO_2)	Carbon Saving (%)
Mechanical On/Off	3.04	-	11.76	-
Electronic On/Off	2.98	2.13	11.51	2.18
Electronic Chrono-Proportional	2.74	9.91	10.54	10.37

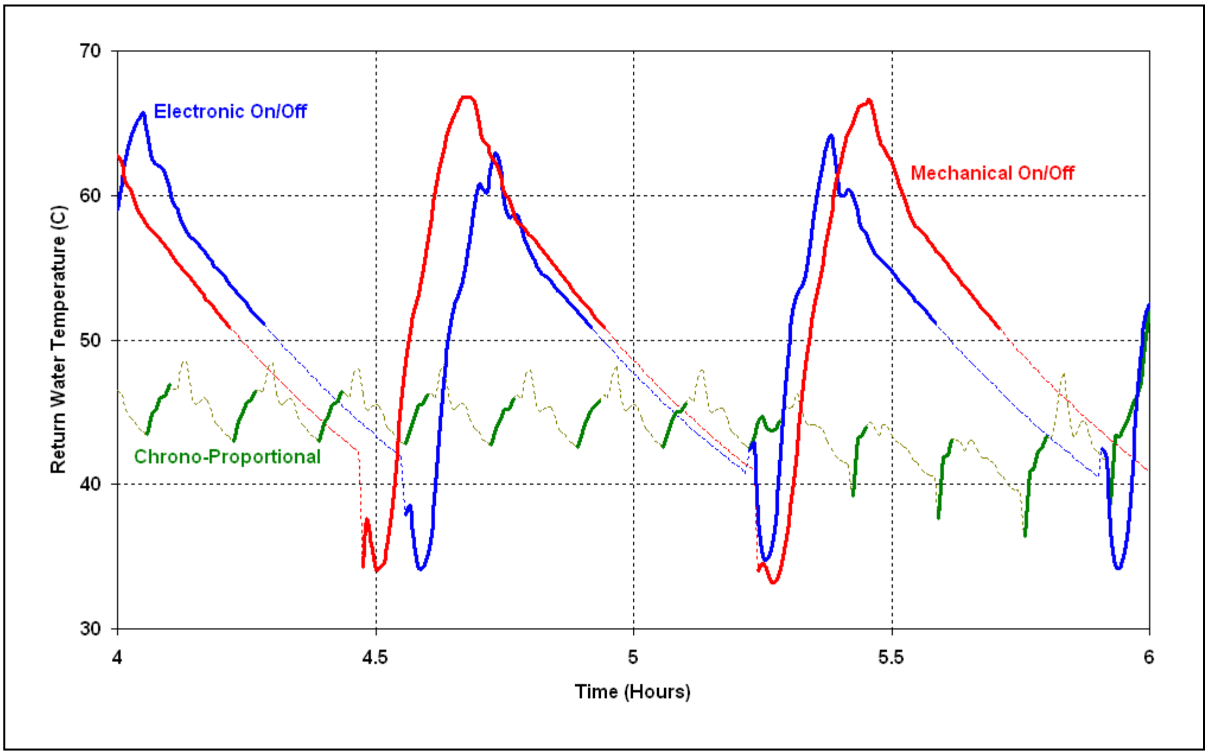

Figure 5: HE Condensing Boiler Return Temperatures for the Three Control Types

During the initial heating phase, all the controllers will operate the HE condensing boiler in its condensing mode since they are all "on" for approximately the first hour of the test run (the start-up phase, see figure 4). However, by zooming in on the boiler return water temperatures during the central period of the test cycle, when all three thermostats are in their control band, significant differences can be observed (figure 5). The return water temperature using the mechanical or electronic room controller is never in full condensing mode during the "on" cycle due to the relatively slow response of the control, meaning that there is too much heat lost during the off period from the water in the system to maintain the condensing temperature at the boiler. The chrono-proportional control forces a faster operation and the return temperature is observed to be almost permanently below the condensing temperature and hence the boiler is running at optimum efficiency all the time.

Modulating-Condensing Boiler

The OpenTherm enabled modulating-condensing boiler, is also a SEDBUK Grade-A type. These are not yet a common product on the UK market but have seen success in Holland and the Benelux regions. Many boiler manufacturers do sell these products with proprietary controls throughout the EU, but as they are bundling controls and boiler there is little explanation of the technology. The boiler will work with simple on/off control signals (hence operation with mechanical and electronic on/off room controllers), but is designed to operate with a room controller than can send a digital signal to control the boilers flame modulation level to satisfy the room demand. Hence this control-boiler combination can offer digital modulating of room comfort from a modulating flame boiler, this enables low temperature water heating once the control band is entered and assists with low-level demand optimisation.

Comfort Control

As can be observed from the room comfort plot (figure 6), the modulating control offers exceptionally well controlled room temperature with less than 0.2°C fluctuation over the majority of the test cycle once in the control band. The mechanical and electronic on/off controllers on the modulating-condensing boiler provide no better levels of control than they do on the HE condensing boiler, suggesting that unless the controls are optimised and a digital modulating control is used with this type of modulating boiler, the householder is not fully benefiting from the ability of the boiler to modulate the flame.

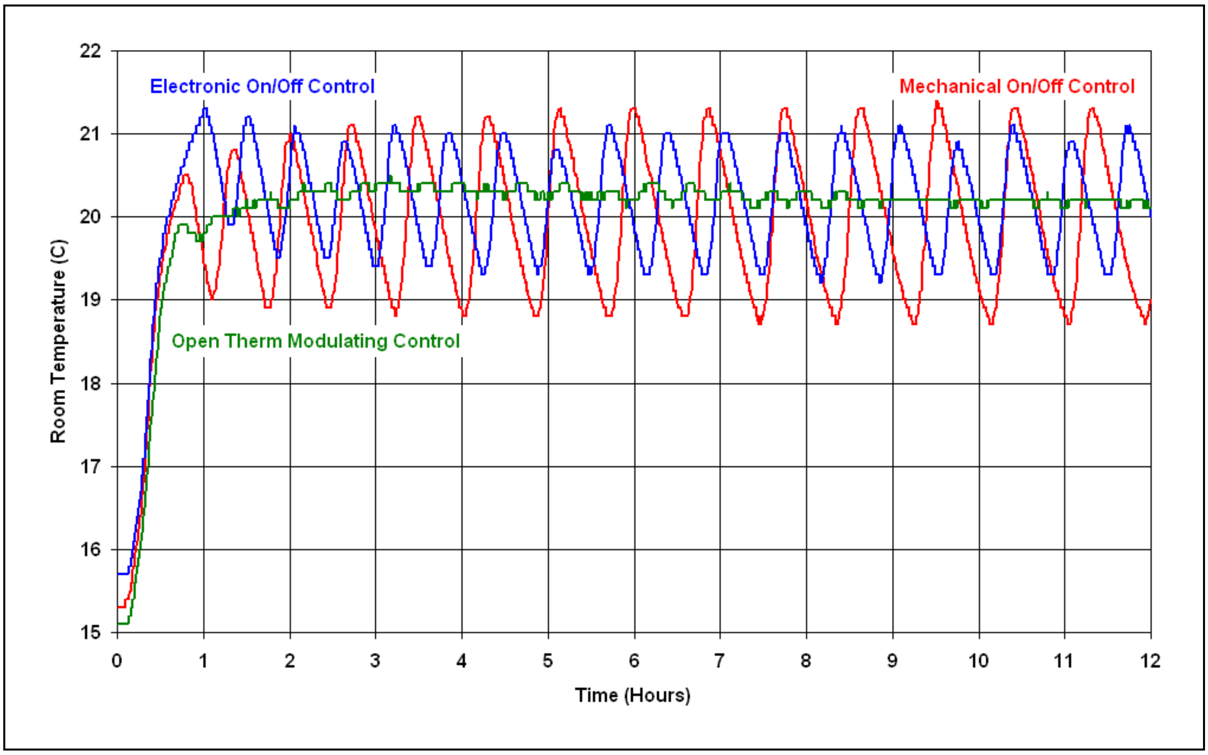

Figure 6: Modulating-Condensing Boiler Room Comfort Control

Energy Consumption

Here the electronic on/off controller is giving significant savings of up to 10% over the mechanical thermostat (table 3), this is primarily due to the faster reaction speed rather than the tighter control. The modulating-condensing boiler has internal control electronics that is able to provide some down-modulation of the flame with faster on/off signals and this is enabling the more economical running of the boiler using the electronic controller (this can again be observed in the return water temperature, not shown here). When using the optimised digital controller, savings of over 14% are possible over the mechanical room controller and the boiler is capable of being run at very high efficiencies, even when operating in the low load of the control band.

Table 3: Modulating-Condensing Boiler Energy Cost and Carbon Emissions

Control	Energy Cost (€)	Energy Saving (%)	Carbon Emissions (kg CO_2)	Carbon Saving (%)
Mechanical On/Off	3.92	-	15.18	-
Electronic On/Off	3.50	10.4	13.58	10.5
Modulating (OpenTherm)	3.35	14.3	12.91	15.0

Cost-Benefit and Carbon Impact Analysis

Clearly a room thermostat is significantly lower cost than a boiler, hence the savings that these results suggest can be achieved simply by replacing mechanical room thermostats with electronic equivalents and can be done at less than 5% of the cost of replacing the boiler. The payback time is equally small, with typical space heat fuel savings representing in the region of €80 per annum suggesting a payback of under 1-year for replacing the control alone, compared with over 10 years payback for a change from a non-condensing to HE-condensing boiler or modulating flame boiler (and assuming the boiler efficiency benefits can be realised).

Even with the projected savings for changing the boiler itself, it is the disruptive effect of a boiler change that will discourage many home owners as much as the cost. Unless there is a suitable flue for the boiler and appropriate drain-off for the condensate traps the total installed cost may prove prohibitive for some systems. There will also be many home owners that simply will not want the decorative mess that is associated with such a change of heating plant as a boiler replacement.

It had been assumed that non-condensing boiler efficiency could not be improved and that only a change of this boiler type to a HE-condensing or modulating flame type could improve the system efficiency. This is shown here not to be the case, even older systems with non-condensing boilers can have their efficiency improved by over 10% simply by the replacement of the room control from an electromechanical type to an electronic on/off or Chrono-proportional type (see table 1).

Given that electromechanical room thermostats are the most common type installed and possibly present in over 70% or more of existing domestic installations combined with single home boilers, in the UK alone this could represent over 16 million homes. The energy savings here would suggest every home owner could save over €80 per annum with the change of thermostat alone and the UK as a whole save in the region of 6.4MToeCO_2[6, 7].

Where boiler plant has already been replaced with HE-condensing type, further savings can be achieved by improvement of the control. It is the lack of replacing the control at the same time as the boiler that is probably responsible for the poor system performance that installed HE-condensing boilers have achieved and lack of owner satisfaction that is reported in the press[1, 2]. Similar energy cost savings can be obtained by the home owner (€60 per annum), due to the lower installed base of around 2.6 million in the UK annual savings would represent 0.36MToeCO_2, but this could be ongoing for all new installations.

Combined CO_2 reductions of the control changes given here represent some 4.4% saving on the total domestic carbon emissions for UK homes[7]. It is believed similar results could be obtained for other northern and central EU countries where boiler to radiator central heating is the dominant space heating system.

Note: Total consumption figures based on 200 heating days per annum.

Conclusion

Modern electronic controls are capable of providing high levels of room comfort in domestic heating systems that utilise gas or oil boiler to wet radiators. The higher comfort levels also come with significant energy savings, even when coupled with older traditional non-condensing boilers. Homeowners can reduce their fuel bills and carbon emissions by over 10% in a non-disruptive manner in most home systems by simply replacing any mechanical thermostatic room controller with an electronic thermostatic controller capable of operating in a chrono-proportional mode. Where a boiler is capable of modulating its flame further savings are possible by optimising the room control and using a digital modulating controller.

Table 3: Optimum Boiler-Control combinations and predicted savings over base-line electromechanical controlled system.

Boiler	Control	Energy Saving (%)	Carbon Saving (%)
Non-Condensing	Chrono-proportional	13.4	13.6
HE-Condensing	Chrono-proportional	9.9	10.4
Modulating (OpenTherm)	Modulating	14.3	15.0

A low cost, non-disruptive, change of thermostatic control can provide improved system efficiency without compromise on comfort. In fact improved comfort and improved system efficiency can be provided simultaneously without having to change any of the heating system plant or installation.

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Raising the Efficiency of Boiler Installations (BOILeff)

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Abstract

Insufficient installations of heating systems lead to low seasonal efficiencies of new boilers. Test cases demonstrate that new boilers could achieve high efficiencies but unfortunately their real performance is much lower. This observation could be verified by the German research Project "Optimus" which deals with the optimization of installed heating systems and by an implemented field test in Germany to evaluate the operation of gas fuelled condensing boilers. Starting from this analysis that many boiler installations suffer from serious shortcomings, the BOILeff project was initiated to develop and to assess two new market approaches for improving the efficiency of boiler installations. The first market approach is a high quality declaration. This declaration is included in the contract between installers and end consumers. It provides a checklist of quality criteria for a high quality installation. The second approach is a performance guarantee. The installer should be able to pledge a certain seasonal efficiency of the boiler by his high quality installation. A field test of about 50 installations is evaluating the practicality and effectiveness of both new approaches during the heating period 2008/2009. The BOILeff activities could contribute to a new voluntary measure under discussion to increase the energy efficiency in heating systems and build-up on article 8 (inspection of boilers and heating systems) of EPBD and relate to the Ecodesign Directive.

Introduction

Space heating is the largest component of energy consumption in households in virtually all Member States, accounting for 67 % at the level of the EU 15, followed by water heating and appliances (EEA 2008). [1]

Demonstrations based on laboratory analysis show that new condensing boilers achieve efficiencies of over 100 %[1], both for gas and oil boilers. This contrasts with selective results from field studies in real conditions, where the seasonal efficiencies of boilers were up to 15 to 20 % lower than under optimal conditions in demonstration cases. [2][3] While new condensing boilers are already high efficient with little room for improvement, the installations of heating systems still offer broad opportunities for efficiency improvements.

Starting from the observation that there exist serious shortcomings in common heating system installations, the project BOILeff consisting of the project partners Austrian Energy Agency, Wuppertal

[1] Based on the lower heating level (LHV)

Institute, Innoterm, the Regulatory Authority for Energy (RAE), and the University of Rovira i Virgili aims to improve the quality of boiler installations by developing and testing of two new market approaches.

Typical weaknesses of boiler installations

In the first phase of the project 75 audits of typical residential buildings with a nominal power range of about 20 kW have been carried out in Austria, Germany, Hungary, Spain, and Greece to document the major weaknesses of boiler installations in the different countries. The following installation weaknesses were revealed:

- Incorrect boiler sizing (no heat load calculation performed) (66 % of investigated systems)
- Too high exhaust gas losses, surface losses and/or ventilation losses (72 %)
- Insufficient insulation of armatures and pipes (93 %)
- Missing control systems (thermostatic valves, etc.) (57 %)
- No hydraulic balance performed (95 %)

In total 27 major weaknesses were identified, summarised, published in form of a list and communicated to the relevant stakeholder groups (installers, end-consumers, etc.) in order to raise awareness concerning energy efficient heating systems in new installations. A summary of results both of performed audits and typical weaknesses are available in [4] and [5].

These results were also the basis for developing of two new market approaches:

- The first approach is a declaration of high quality installation (DHQUI), and
- the second one is a performance guarantee (GPQU).

The declaration contains a set of quality criteria for a high quality installation. This declaration should become part of the quotation of the installer to the end-consumer. The second one – called performance declaration – includes a guarantee of the installer to achieve a certain “high” seasonal efficiency of the heating system. This second information to the end consumer justifies the “extra” costs – a high quality installation usually costs more than a cheap “standard” one – and indicates the expected seasonal efficiency and(!) the expected future energy savings of the new heating system.

These new services are needed to raise the awareness of the end-consumer in order to differ between high and low quality heating installations and to support the installer to sell more expensive but higher quality installations. Both services get tested and evaluated by field tests involving about 50 heating systems in the heating period 2008/2009.[2]

Declaration of High Quality Installation (DHQUI) and Guaranteed Performance Quality (GPQU)

The typical business case of BOILeff installations (residential buildings with a nominal heat load of about 20 kW) includes the modernisation of old heating systems. When the heating system breaks down and the building owner receives the information from the installer that a repair service is very expensive and doesn’t pay off any more, then the developed BOILeff services should take place.

An end-consumer can usually only judge the investment costs for his future heating system. He is not in the position to evaluate the quotation whether the new heating system will perform in an energy efficient way or not. The end-consumer receives in the quotation only information about components, materials and a summary of working hours (in the best case) necessary to install the new heating system or to make changes in the old system.

For this reason, the end-consumer can evaluate the quotation only according to the price, not to the quality. Consequently, installers have difficulties to establish quality-orientated business models. In order to address this issue, a set of quality criteria was developed to assure installations in an energy efficient way.

The declaration of high quality installation includes the following major criteria:

[2] In the time when writing this paper the field tests are still ongoing.

- Implementation of a heat-load calculation
- Installation of a high efficient boiler technology (e.g. condensing boilers)
- Calculation of the hydraulic system for dimensioning of the circulation pump
- Installation of high efficient circulating pump(s)
- Correct dimensioning of the domestic hot water demand and installation of the corresponding storage tank
- Implementation of the hydraulic balance of the heating system
- Implementation of pipe- and armature insulation

A detailed discussion showing and(!) explaining the different criteria would be beyond the scope of this paper; the documentation is available in [6]. The different criteria and the implementation possibilities of this declaration by installers got discussed in several stakeholder meetings in the different countries taking into account their perspectives in developing this new service and resulting in up-dated and country-specific versions of DHQUI.

As already pointed out high-quality installations will be more expensive than cheap standard installations. For this reason the installer has to provide the end-consumer additional information justifying the higher costs by showing the energy savings in the long run.

With the performance guarantee (GPQU) the installer guarantees the end-consumer a high seasonal efficiency of his new heating system. For the calculation of the seasonal efficiency and the energy savings of the new high-quality system compared to the old heating system, a calculation tool was developed taking into account typical business situations of installers. The calculation method of this tool was developed by the German University of Applied Sciences in Wolfenbüttel and is called “finger print method” using the following input parameters:

- Calculated heat load of the building
- Standard outside temperature
- Indoor temperature
- Building insulation standard
- Insulation of the pipes
- Temperature distribution of the system
- Dimension of the domestic hot water storage tank
- Performance data of the boiler
- Number of tenants
- Number of bathtubs, showers, etc.
- Average outside temperature in the heating period
- The number of days of the heating period

Because this additional information to the end-consumer is crucial for implementing high quality installations on the market (due to the higher costs), more details of the performance guarantee are given in the next chapter.

Applying the “finger print method” in the performance guarantee (GPQU)

During the first visit(s) at the customer site the installer has to record the required input data for the calculation tool. Subsequently, he performs a heat load calculation of the building followed by calculations of the average power for the consumption of domestic hot water ($\dot{Q}_{TWW}$) and distribution losses ($\dot{Q}_d$).

Next steps include the identification – usually listed on the specification sheets – of the boiler capacity and the stand-by losses both of the old and the new boiler. After that, the calculation of the mean heat load ($\dot{Q}_{h,m}$) within the heating period has to be performed. From this value the mean boiler capacity ($\dot{Q}_{K,m}$) is derived and in consequence the mean fuel input ($\dot{Q}_{F,m,1}$) within the heating period is derived using the following equations:

$$\dot{Q}_{h,m} = H * (t_{HG} - t_{a,m})$$

H = Specific heat load of building $[kW/K]$ Equ. (1)

t_{HG} = Average temperature level starting heating $[K]$

$t_{a,m}$ = Mean ambient temperature in the heating period $[K]$

$$\dot{Q}_{K,m} = \dot{Q}_{h,m} + \dot{Q}_d + \dot{Q}_{TWW}$$

$\dot{Q}_{h,m}$ = Average heat output $[kW]$ Equ. (2)

$\dot{Q}_d$ = Losses of distribution system $[kW]$

$\dot{Q}_{TWW}$ = Power for domestic hot water $[kW]$

$$\dot{Q}_{F,m,1} = \left(\frac{1}{\eta_K} - \frac{q_B}{\eta_K}\right) * \dot{Q}_{K,m} + \frac{q_B}{\eta_K} * \dot{Q}_{K,N}$$

q_B = Specific standby losses [-] Equ. (3)

η_K = Efficiency of boiler [-]

$\dot{Q}_{K.m}$ = Average boiler capacity [kW]

$\dot{Q}_{K,N}$ = Nominal output of boiler [kW]

The second step includes the calculation of the mean fuel input ($\dot{Q}_{F,m,2}$) outside the heating period (summer period). The heat input for the domestic hot water production ($\dot{Q}_{TWW}$) and the distribution losses ($\dot{Q}_d$) have to be used as follows:

$$\dot{Q}_{F,m,2} = \left(\frac{1}{\eta_K} - \frac{q_B}{\eta_K}\right) * (\dot{Q}_d + \dot{Q}_{TWW}) + \frac{q_B}{\eta_K} * \dot{Q}_{K,N}$$ Equ. (4)

As a result of the calculations the “finger prints” of the old and the new heating system are plotted. Figure 1 shows both the dependency of the combustion power on the outside temperature and the socket for the domestic hot water.

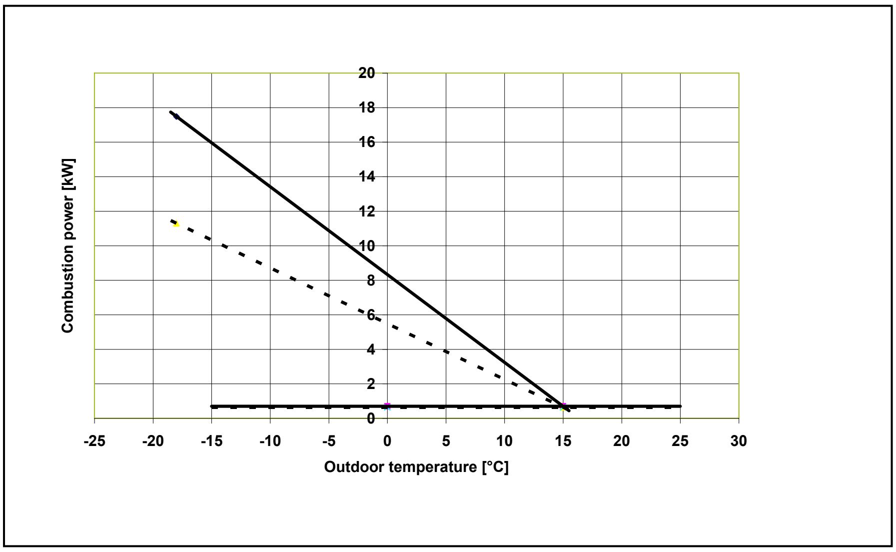

Figure 1: “Finger prints” for a typical single family house with a heat load of 10 kW equipped with an old boiler [30 kW / η=76%] continuous lines and a new condensing boiler [11,5 kW / η=95 %] dashed lines [7]

The calculation of the seasonal efficiency of the boiler (respectively heating system) (η_a) is based on the operating hours in the heating period (winter season) (h_{HP}) and in the summer season (h_{SZ}) (following equations (5) and (6). The operating hours are linked to the site-specific climate situation using statistical data sets (usually available from the central offices for meteorology and climatology).

$$Q_F = \dot{Q}_{F,m,1} * h_{HP} + \dot{Q}_{F,m,2} * h_{SZ}$$
$$\dot{Q}_{F,m,1} = \text{mean fuel input in the heating season [kW]}$$
$$h_{HP} = \text{operating hours in the heating period [h]}$$
$$\dot{Q}_{F,m,1} = \text{mean fuel input in the summer season [kW]}$$
$$h_{SZ} = \text{operating hours in the summer season [h]}$$

Equ. (5)

$$\eta_a = \frac{\left(\dot{Q}_{K,m} * h_{HP} + \left(\dot{Q}_d + \dot{Q}_{TWW}\right) * h_{SZ}\right)}{Q_F}$$
$$Q_F = \text{Fuel input [kWh]}$$
Other parameters already defined in equations (2), (4), (5).

Equ. (6)

Finally, the fuel consumption based on the average seasonal energy consumption (Q_F) by using the higher heat value (HHV) of the used energy carrier can be calculated. After comparing the seasonal efficiencies of the old and the new boiler system a comparison between the efficiencies of both boilers (respective heating systems) including the fuel consumption will be performed. Consequently, the end-consumer receives information concerning the efficiencies and future energy (and cost) savings. An example showing high efficiency savings in a typical Austrian refurbishment case with an old heating system from the 1970s is shown in Figure *2*.

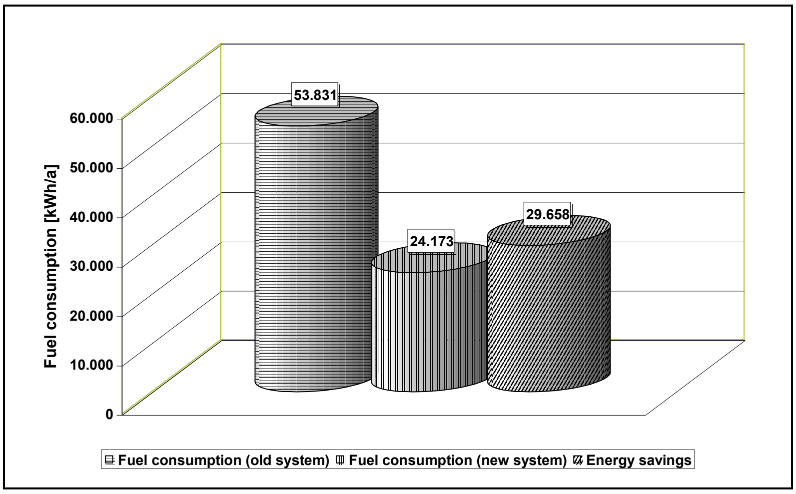

Figure 2: Energy savings based on “finger print” method using an Austrian refurbishment case with an old heating system from the 70s (boiler systems are the same as in Figure 1) [7] (Source: Austrian Energy Agency)

Field tests

Presently, the high quality declaration and the performance guarantee are tested and evaluated by field tests. For the field tests typical residential buildings with a heat load up to 20 kW have been taken into account. The field tests include about 50 installations in Austria, Germany, Hungary, Spain, and Greece, and are carried-out in the current heating season 2008/2009.

For the field tests, every heating system was equipped with additional test equipment as follows[3]: oil meter[4], heat meter placed in the heating circuit, heat meter placed in the domestic hot water circuit, and additional heat meters if necessary (e. g. for solar thermal systems or in case of an additional

[3] The principal measurement concepts were discussed in detail prior to the installation of the meters and published in [9].
[4] Gas metering includes the standard gas meters of the gas utility companies.

heating circuit). The readings run till May/June 2009. For this reason the final results of the field tests will be made available by July 2009. At this stage, first results of 12[5] Austrian cases are shown below (see Table 1 and Figure 3).

Table 1 Ongoing field tests in Austria[6] [8]

Nr.	Type of building	Fuel	Location	Heat load of the building [kW]	Calculated seasonal efficiency by the "finger print method" [η]	Measured seasonal efficiency [η]
1	flat	gas	Vienna	13,1	88,1	88,8
2	flat	gas	Vienna	3,3	85,7	88,4
3	single family house	gas	Herzogenburg (Lower Austria)	5,8	85,1	88,1
4	single family house	gas	Vienna	11,4	92,0	N.A. [7]
5	single family house	gas	Maria Enzersdorf (Lower Austria)	4,65	85,7	85,4
6	single family house	gas and solar	Herzogenburg (Lower Austria)	11,2	89,4	91,3
7	single family house	gas and solar	Linz (Upper Austria)	7,5	89,6	88,2
8	single family house	gas	Pucking (Upper Austria)	12	92,2	89,5
9	single family house	oil	Schwanenstadt (Upper Austria)	8,3	87,1	85,8
10	single family house	oil	Pucking (Upper Austria)	9,8	90,8	83,5
11	single family house	biomass and solar	Klosterneuburg (Lower Austria)	4,15	76,4	73,9
12	single family house	biomass and solar	Seekirchen am Wallersee (Salzburg)	11	88,9	90,9
13	small multi family house	gas and solar	Neupurkersdorf (Lower Austria)	22	93,3	94,9

The first evaluations show a performance of gas condensing systems between 86,2 % and 96,6 % (HHV). The performance of the oil condensing systems varies between 82,3 % and 88,0 % (HHV). The pellets boiler shows an average performance of 90,9 % (LHV) and the firewood fuelled boiler shows an average performance of 73,9 % (LHV). (see Figure 3)

When comparing the achieved seasonal efficiencies with the guaranteed efficiencies based on GPQU the following conclusions can be drawn:

- Seven systems (Five from eight gas systems; two biomass systems) have a higher seasonal efficiency than calculated.
- Three gas systems show a negative deviation (compared to the calculated value) of < 3 %.
- The two oil systems have a negative deviation from the calculated values of 1,3 % and 7.3 %, respectively.

Taking into account technical reasons why one of twelve system shows a deviations > 7 %, it can be concluded that guarantees with a security band of three percentage points can be issued by installers when the installations are based on DHQUI. Already at this stage, it is expected that these preliminary results will be confirmed by the final evaluation in July 2009 (including also the test results of the project partners Germany, Hungary, Spain and Greece).

[5] Unfortunately in one single family house in Vienna the refurbishment of the heating system and the installation of the metering equipment couldn't be finished until March 2009. For this reason only 12 readings are available till now.
[6] The calculated and measured seasonal efficiencies of gas and oil fuelled systems are based on the higher heating value (HHV). The calculated seasonal efficiencies of biomass fuelled boilers are based on the lower heating value (LHV) because the condensing technology has not been deployed successfully in biomass boiler systems up to now.
[7] Unfortunately the refurbishment of the heating system and the installation of the metering equipment couldn't be finished until March 2009.

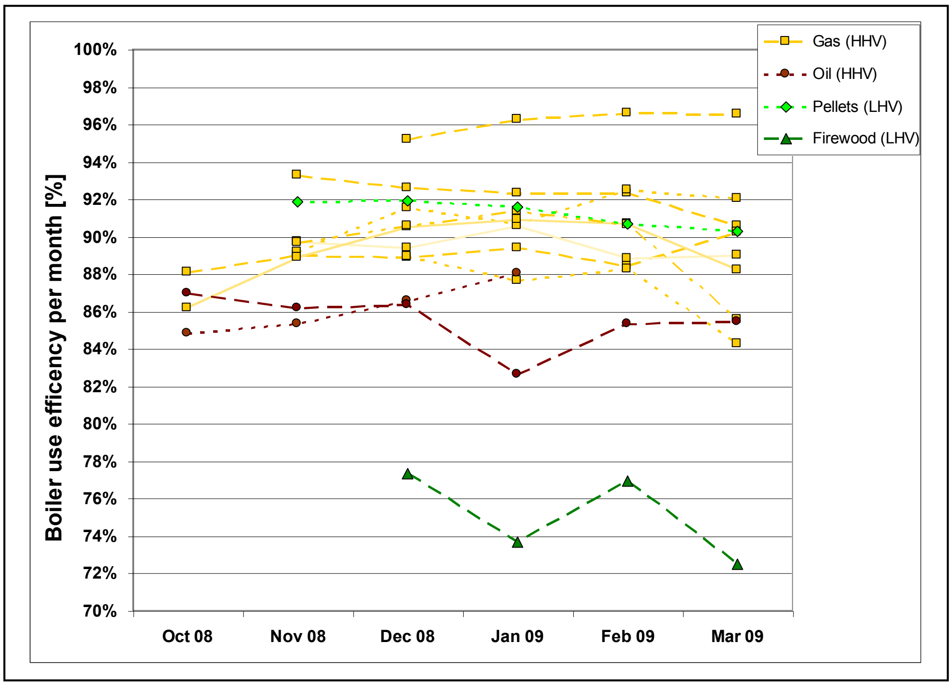

Figure 3: Progress of the monthly use efficiencies[8] of 12 Austrian BOILeff installations including eight gas condensing systems (orange lines), two oil condensing systems (brown lines), one pellets system (light green line), one firewood system (dark green line) [8]

Compared to seasonal efficiencies of standard systems, the first metering results of BOILeff installations show excellent performance. The BOILeff systems achieve efficiency improvements – compared to standard systems – for gas systems of 13 %, for oil systems of 10 %, for the pellets system of 17 %, and for the firewood system of 7 %.[9]

Presently, the total energy demand for heating and domestic hot water amounts to 62.545 GWh in Austria. Taking into account that new heating systems follow BOILeff quality criteria (DHQUI) energy savings between 2.700 and 4.300 GWh can be achieved compared to a business as usual (BAU) scenario; representing a savings potential between 6,4 and 13,3 % (see Figure 4).

The possible savings in greenhouse gases are between 3,85 and 4,74 Mio t. Compared to the BAU scenario 0,6 Mio t (AEA scenario) and 0,9 Mio t (OPT scenario) can be realised (see Figure 4). Space heating contributes significantly – with about 14,2 Mio t. CO_2eq. or 15,6 % – to the total green house gases of about 91,1 Mio. t. For this reason policy measures aiming to improve heating systems are strongly recommended and these measures will pay-off in significant reductions of green house gases.

[8] The seasonal efficiencies of gas and oil fuelled systems are based on the higher heating value (HHV). The seasonal efficiencies of biomass fuelled boilers are based on the lower heating value (LHV) because the condensing technology has not been deployed successfully in biomass boiler systems up to now.
[9] Seasonal efficiencies of standard installations in Austria are: gas - 76 % (HHV); oil - 75 % (HHV), pellets - 74 % (LHV), firewood - 67 % (LHV) [10].

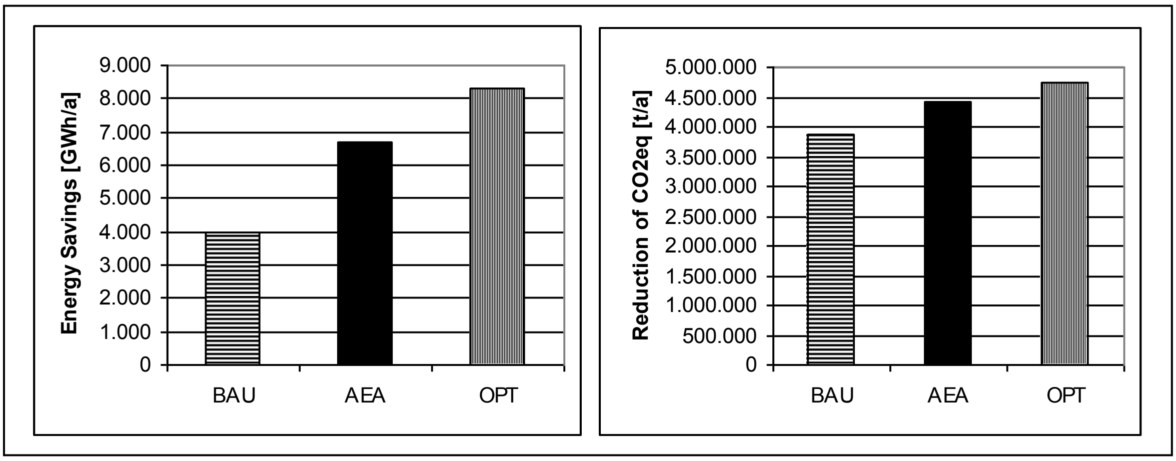

Figure 4: Energy savings (left side) and reduction of CO2eq. per year in Austria based on three scenarios [11]:

1) **BAU – business as usual: The present stock will be replaced by new standard heating systems**
2) **OPT(imum) scenario: The present stock will be replaced by new high efficient BOILeff installations**
3) **AEA scenario: The present stock will only be replaced partly by high efficient BOILeff systems taking into account appropriate building categories, principal agent problems, fuel switch, etc., the other part will be replaced by new standard heating systems**

Conclusion

The objective of the European project BOILeff is to improve the quality of boiler installations by developing two new services for the heating industry: a declaration of high quality installation (DHQUI) and a performance guarantee (GPQU).

The high quality declaration (DHQUI) contains a set of quality criteria for a high quality installation of the heating system. This declaration should become part of quotations from installers when selling new installations. The second one – the performance guarantee – includes a guarantee of the installer to achieve a “high” seasonal efficiency and(!) significant energy savings of the new heating system. This second information to the end consumer justifies the higher investment costs; usually a high quality installation will cost more than a cheap “standard” one.

These new services are needed to raise the awareness of the end-user in order to differ between high and low quality heating installations, creating WIN/WIN/WIN situations for the installers by higher turnover rates, for end-consumers by lower energy consumptions in the long run and for the society by increasing the security of supply, by decreasing the import dependency from fossil fuels and by the reduction of greenhouse gases.

In the present heating period (2008/2009), both services are tested and evaluated by 50 field tests in Austria, Germany, Hungary, Spain, and Greece. Up to now, preliminary results are available from 12 Austrian cases. Compared to seasonal efficiencies of standard systems BOILeff installations show improvements of the seasonal efficiency between 7 % and 17 % depending on the fuel used. Taking into account that new heating systems follow BOILeff quality criteria (DHQUI) energy savings between 2.700 and 4.300 GWh can be achieved compared to a business as usual (BAU) scenario It is expected that these preliminary results will be confirmed by the final evaluation in July 2009 (including the test results of the project partners Germany, Hungary, Spain and Greece).

Furthermore, in some countries like Austria it is foreseen that the implementation of the declaration of high quality installation (DHQUI) is also used as additional subsidy criteria when launching boiler exchange programs. Moreover, these new services and quality criteria should build-up on the activities presently under way concerning the implementation of article 8 (…the inspection of hot water boilers used for heating of buildings) of EPBD directive and contribute to the discussion when implementing the ecodesign directive (Energy using Products - 2005/32/EC) (LOT 1 – Boilers and LOT 2 – Water Heaters).

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Intelligent Energy Europe

Policies for reducing environmental impacts and improving energy efficiency: the case of solid fuel small combustion installations

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Abstract

This paper presents the key findings of the EuP Preparatory Study Lot 15 on solid fuel small combustion installations (SCIs), which will serve as a basis for establishing implementing measures on SCIs in the context of the Ecodesign Directive. The analysis comprises the definition of the scope of the study, a market analysis, user behaviour aspects, a systems analysis, an environmental assessment of the current products, and a technical analysis on improvement potentials. The improvement options consider life cycle costs and especially the point of least life cycle costs for the consumer, whereas "best available technology" might serve as a promotional target. The analysis takes into account all major technical parameters relevant for solid fuel SCIs and looks at the role of fuel type in affecting the environmental performance of SCIs. The approach used throughout this study is the MEEuP methodology, which prescribes how the life cycle oriented environmental assessment is performed.

Background

In the context of the Ecodesign Directive [1] established by the European Commission, several product-specific preparatory studies are in progress/ have been completed; including one on the ecodesign of solid fuel small combustion installations (SCIs) (Lot 15 [2]). The Ecodesign Directive is a key component of the EU's policy for improving the energy and environmental performance of energy using products (EuPs) on the EU market, by setting a framework for integrating environmental aspects in the earliest stages of the products design. Heating equipment was identified as one of the priority product groups by the Directive, and the study on water-heating equipment (Lot 1) is already completed [4] and implementing measures are currently being drafted [5]. The results of the Lot 15 study are due in October 2009.

Ecodesign preparatory studies comprise technical, economical, and environmental impact assessments which will provide the technical basis to draft any possible implementing measures (legislation) for setting generic and specific ecodesign requirements of Energy using Products (EuP). The analysis follows a common approach for all preparatory studies, the Methodology for Ecodesign of Energy-using-Products (MEEuP) [3]. This methodology includes a definition of the product categories, a market analysis, aspects of user behaviour and related barriers for ecodesign, an analysis of existing products identified as representative of the European situation, an environmental assessment of average products defined as Base Cases, a system analysis, an in depth technical analysis of improvement potential, and finally a policy and scenario analysis. The MEEuP also includes a spreadsheet model (EuP Eco Report) using an internal database that converts material quantities from Bill of Material (BOM), energy consumption data and economic data into standard environmental indicators and Life Cycle Cost (LCC). The final results of the Lot 15 study are due in October 2009.

Product scope and existing legislations and testing procedures

Product scope

Solid fuel SCIs provide space heating to a room or an entire building, either directly, or indirectly via a central heating system. Direct heating appliances are typically used as an occasional, secondary heat source, whereas indirect heating appliances tend to be used continuously and as the main heat source. The separation is not always obvious, since direct heating appliances may also be fitted to hot water boiler for indirect heating. Solid fuel SCIs can burn either solid biomass fuels, such as wood logs or manufactured wood wastes (wood chips, wood pellets), or solid mineral fuels such as anthracite, brown coal or peat briquettes. The scope of the study is limited to domestic and small and medium non-domestic combustion appliances, with an upper capacity of 500 kW. Accordingly, the study comprises six types of direct heating appliances, which are typically domestic appliances with a heat output below 15 kW on average:

1. Open fireplaces
2. Inserts
3. Closed fireplaces
4. Cookers – although their primary function is cooking they are also used for heating in the domestic context
5. Stoves
6. Pellets stoves

The study also encompasses two types of indirect heating appliances, which can be used either in the domestic or non-domestic sector, and have heat outputs ranging from 20 to 500 kW:

7. Boilers
8. Pellets boilers

All solid fuel appliances consist of a combustion chamber, where the fuel is burnt, and one or two air inlets to ensure proper combustion. However, solid fuel appliances can differ widely in their efficiency at converting fuel energy into useful heat, depending on their design. The simplest appliances, such as open fireplaces, have efficiencies below 20% due to losses through the chimney and a poor un-controlled combustion process. In contrast, more modern appliances may have forced air controls, thermostats, separated fuel and combustion chamber, or an automatic fuel feeding mechanism, which enable a fuller combustion of the fuels by allowing high combustion temperatures, adequate mixing of fuel gases and combustion air, and secondary burning of combustion gases. In this way, pellet stoves for instance, can reach efficiencies of up to 90%.

Existing legislation and standards

The Lot 15 study also provides an analysis of existing legislations, voluntary initiatives, and testing procedures related to solid fuel SCIs in Europe and in the rest of the world. All product categories within the study scope are covered by relevant EN standards (either existing or under development), most of which are harmonised with the main European Directives. The standards include requirements related to functional parameters, such as heat output and efficiency (for a set nominal output), as well as emission requirements for selected pollutants (by m^3 of oxygen content in the flue gases). The standards also specify the fuel quality to be used for the testing routines, but they do not specify a reference method for the measurement of emissions. Quality comparisons among different types of appliances are therefore not possible based on test standard results. The Technical Committee CEN/TC 295 is currently working to solve this issue.

The European legislations relevant to solid fuel SCIs were already discussed in Lot 1 in the context of boilers) study and are not discussed further here. However, a profusion of labels and voluntary schemes have been developed at the national and regional level to distinguish better-performing appliances among some or all categories of domestic solid fuel SCIs (e.g. Blue Angel, Nordic Swan, Flamme Verte). These labels and voluntary schemes typically set minimum requirements for direct emissions of air pollutants and/or efficiency.

In the rest of the world, the USA and Switzerland have possibly the most advanced certification schemes, with strict limits on PM emissions and independent testing of appliances in the USA and stringent emission limits on PM, CO and NOx in Switzerland.

Economic and Market Analysis

Approach

Market data for solid fuel SCIs is not readily available, since solid fuel SCIs have a highly fragmented market, which covers a wide range of product types and ways of operation, and which can differ widely among Member States (MS) and within regions. PRODCOM cannot serve as a useful market data source, since it does not cover all products within the scope of Lot 15. No other attempt at making an EU-wide estimate of sales and stock figures of solid fuel SCIs was identified. Therefore, a market analysis was conducted, based on the response to questionnaires sent to stakeholders (essentially manufacturers of SCIs), as well as on a review of existing market analysis reports.

For MS for which no market data was available, extrapolations were made based on country groupings. Since the EU encompasses a large variety of heating profiles, reflecting differences in climate, housing design, but also culture, history, energy resources and fuel supply, straight extrapolations of average EU sales or stocks are not realistic. Therefore, six country groups were defined, based on the number of heating-degree-days, the availability of mineral fuel resources and of wood resources (estimated by the forest cover), as well as based on 'cultural similarities'. It is assumed that within a country group, sales and stock figures per dwelling can be estimated based on country group's average sales/stocks figures per dwelling.

The accuracy of the figures presented can be challenged but they are believed to provide a robust estimate for the purpose of this study. They clearly show that the yearly sales of the products are higher than the 200,000 unit threshold set in the Ecodesign Directive. Data related to product price (for the consumer) and electricity tariff were also collected during the study.

Market stock and sales data (2010 outlook)

Solid fuel SCIs are long-lived appliances, which last 20-25 years on average, and up to 50 years. This creates a large market inertia, characterised by very large stocks relative to sales.

In 2007, approximately 73 million of solid fuel SCIs were estimated to be installed in the EU-27 (Table 1). Indirect heating solid fuel SCIs (boilers) amount to approximately eight million in the EU-27 and represent less than 5% of all boiler sales, a proportion which tends to be decreasing. With an estimated 65 millions direct heating SCIs installed, approximately 20% of the dwellings in the EU-27 can be considered to have such an appliance. Stoves and fireplaces represent the majority of the stock of direct heating appliances, with 26 millions and 30 millions appliances respectively (Table 1).

In 2007, approximately four million solid fuel SCIs were estimated to have been sold in the EU-27 (Table 1). For direct heating appliances (90% of all sales), the annual growth rates of sales oscillates around 10%. Most boiler sales are replacement sales (62% of sales in 2006 are for the replacement of an existing boiler), given that it is very costly to install a central heating system *de novo*. Sales of the newer products, such as pellet boilers and pellet stoves, are still heavily localised within the EU, but tend to exhibit very high growth rates of 30% to 50% per year. Accordingly, the market for solid fuel appliances may reach five million appliances by 2010.

Table 1: European stock and sales in 2007 for solid fuel SCIs

Appliance category		Stock	Sales
Direct heating	Open fireplaces	850 000	16 000 000
	Closed fireplaces / inserts	849 100	16 139 000
	Stoves	1 306 700	25 901 000
	Cookers	464 200	7 594 000
Indirect heating	Boilers	313 000	7 846 100
Total		**3 783 000**	**73 480 100**

Market trend and 2020 outlook

Sales of solid fuel SCIs are expected to continue increasing in the coming years, due to structural and technical factors. The growing prices of competing energy sources (oil, gas), coupled to favourable international policies, such as 2020 target to reach 20% of renewable energy use in the EU [6], suggest that the demand for solid fuel appliances should increase in the coming years. In addition, the development of the pellet market in the past eight years, with its highly efficient and environmentally-friendly appliances, is poised to continue. Indeed, after having passed its first bottle-neck due to pellet supply problems, the pellet industry is now better structured to cope with the demands of its growing market [2]. However, the market growth of SCIs can be slowed down by the removal of political support or subsidies, lack of standards regarding fuel quality, and poor consumer information.

Average consumer price

Solid fuel SCIs are costly products, that cost on average € 2000 at purchase and € 1000 to install. For solid fuel boilers, this can rise to € 3500 and € 1500 (note: figure would seem very low for boilers) respectively. However, the maintenance and repair costs are very small, averaging € 500 for direct heating appliances and € 1000 for indirect heating appliances, over the entire lifetime of the product. Although solid fuels are generally cheaper than alternative energy sources, fuel remains the main operating cost for solid fuel SCIs. Fuel prices vary widely over time and throughout EU-27 and depending on local availability. However, informal markets can contribute significantly to the fuel supply of SCIs, for instance wood fuel is often collected for free from forests. In order to be conservative, in this study, average EU-27 fuel prices are estimated based on published data, regardless of the amount of fuel provided from informal markets.

Consumer Behaviour

Real-life efficiency

The environmental impact of solid fuel SCIs is tightly linked to fuel quality and consumer behaviour. Different fuel types differ in their chemical composition and calorific content, which affects the ease with which they can be burnt and the type of quantity of emissions released in their combustion. In addition, the moisture content and size of the fuel can affect the quality of the combustion process. When burning fuels with a high moisture content (> 20% water content), most of the heat is used in evaporating the moisture rather than burning the wood, resulting in reduced combustion efficiency, typically characterised by higher PM emissions. Moreover, fuel pieces should be small enough to ensure the good mixing of the fuel with combustion air, but also be big enough to ensure sufficient but not too fast volatilisation of combustion gases.

Users can affect the quality of the combustion process by the way in which they fit, operate, and care for their appliance. The heat output of the appliance should be matched to the function it is aimed for, otherwise, if the appliance is e.g. under-sized appliance, fuel overloading will be required to meet the heat demands of the building, resulting in poorer efficiency and higher emissions. In addition, the configuration of indirect heating systems, the insulation and corrosion resistance of the chimneys also contribute to the real-life efficiency of the appliance. During the operation phase, consumers can use either too little or too much fuel, or let too little or not enough air into the combustion chamber, they can also use inadequate or poor quality fuel for which the appliance may not be suited, all of which can reduce the efficiency of the combustion by as much as 100% compared to standard conditions. Finally, insufficient cleaning of the grate or non-replacement of the seals can also reduce the real-life efficiency of the appliance.

Use patterns

Considerable variability in usage is observed among the different MSs, and even at the regional level within a MS. However, no comprehensive data on use patterns of solid fuels SCIs exist for each MS. Therefore, use patterns were estimated with on a top-down approach, based on Eurostat’s total solid fuel use figures in 2007 in the EU-27. Energy use for indirect heating appliances was then estimated based on average energy consumption in a house, as estimated in Lot 1 study on central heating boilers. For direct heating solid fuel SCIs, energy use estimations were based on the relative energy use of the different types of appliances, determined from literature data, and on the EU stocks of direct heating SCIs.

Product Assessments

Approach

In order to evaluate the life cycle impacts of complex SCIs, a technical analysis of individual real life products representative of the European market was performed, with a focus on the collection of material data (Bill of Materials, BOM) for solid fuel SCIs in different configurations (i.e. with/without additional technical features) and energy consumption data for different operating modes (e.g. on mode, active standby mode). Such data was compiled to serve as inputs to define average European products i.e. the Base Cases.

Bill of Materials

SCIs are typically made either of stainless steel, cast-iron, or of a combination of both metals. Some appliances also use refractory stone in the combustion chamber or for the surround, and ceramic glass for windows. In all cases, plastic and metal parts, seals and insulating materials represent a negligible part of the BOM (<10% of the weight of the appliance). The more modern solid fuel SCIs may also include some power usage for extractor fans, circulating fans, or automatic fuel-feeding mechanisms, as well as electronic controls. Power usage ranges between 0.14 to 0.4 kW, depending on the number of controls. Solid fuel SCIs are installed by a professional and are typically packaged in carboard and/or wooden boxes to ensure maximum product protection.

Establishing the Base Cases

The MEEuP indicates the analysis of one or two Base Cases. However, in order to cover appropriately the broad range of technical specifications and functionalities of solid fuel SCIs, 8 Base Cases are currently foreseen, as summarised in Table 2. When relevant, Base Cases are analysed for the main wood and mineral fuel used in that category of appliance.

Base Cases 1 and 2 cover fireplaces, Base Case 3 cookers, Base Case 4 and 5 stoves, and Base Cases 6 to 8 boilers. The base cases are representative of older appliances, which still represent most of the stock of installed solid fuel SCIs in EU-27. Sales on the other hand are representative of the more modern appliances of that category, which are currently sold on the EU market. Pellet boilers and pellet stoves have not been included in this definition as they are already considered to represent best available technologies.

Table 2: Base Cases

	Output	Efficiency	BOM (% total weight)	Power usage (kW)	Sales* (Million units)	Stock (Million units)
(1) Open fireplace	15 kW	15%	> 80% stone/ceramics	0	0.85	16
(2) Closed fireplace	10 kW	55%	> 80% steel or >75% cast-iron	0	0.85	16
(3) Traditional cooker	10 kW	505%	> 85% steel	0	0.46	7.6
(4) Traditional stove	8 kW	45%	> 90% steel or > 90% cast-iron	0	0.7	7.7
(5) Modern stove	8 kW	60%	> 90% steel or > 90% cast-iron	0	0.3	3.8
(6) Manual boiler (natural or forced draft)	25 kW	70%	> 90% steel or > 90% cast-iron	0	0.14 (45% boiler sales)	5.7 (72% boiler stock)
(7) Automatic boiler (stoker or push-down fuel feeding system)	25 kW	80%	> 90% steel or > 90% cast-iron	0.14	0.09 (30% boiler sales)	1.6 (20% boiler stock)
(8) Automatic boiler (100kW) (underfeed stoker or moving grate fuel-feeding)	100 kW	85%	> 90% steel or > 90% cast-iron	0.14	0.08 (25% boiler sales)	0.63 (8% boiler stock)

*Sales refer to newer, advanced appliances rather than to the traditional ones

Next steps

The next steps will consist of the environmental impact assessment of real-life and average European products (base cases). Options to improve the environmental potential of solid fuel SCIs already installed will then be explored, based on best available technologies (BAT) and best not yet available technologies (BNAT). The costs of implementation, increase in consumer prices, duration of the re-design cycles will be taken into account in that assessment.

The study is still ongoing and open to discussion. Manufacturers and distributors of solid fuel SCIs not yet involved are welcome to share their experience and feedback on the results provided, and to join the stakeholders. This will ensure reliable and coherent technical analysis, which sould lead to legislation based on feasible and effective energy savings. For more information and to follow the progress of the Lot 15 study, please visit the project's website www.ecosolidfuel.org

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Abstract
This book contains the Proceedings of the 5th International Conference on Energy Efficiency in Domestic Appliances and Lighting, Berlin (DE), 16-18 June 2009. The EEDAL'09 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'09 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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