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Raising awareness for energy efficiency in the service sector: *learning from success stories to disseminate good practices*

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Abstract

Energy efficiency in the service sector is a key issue because of the important growth of its energy consumption. The energy performance of buildings and equipment can be improved through technical investments, but this has to be linked with an efficient management and good practices in order to reach better energy efficiency levels in a cost-effective way. Experience feedback concerning awareness activities in the service sector highlights the interesting opportunities of energy efficiency improvements they represent.

This paper first draws a synthesis of the available feedback in this area to detect factors of success for this kind of activities. More than twenty operations from Europe and North America were analyzed looking at items such as the stakeholders involved, the actions implemented, the communication means, and the evaluation performed.

Then a case study describes an EDF pilot operation in South East of France. An awareness campaign was led in four particular EDF buildings to inform the employees of the best practices and to involve them to apply these advice. Different action packages were used to compare their efficiency. The evaluation emphasizes the success of the operation, with around 10% of energy savings (i.e. more than 270 MWh/a). More than 80% of the employees said they changed their energy behavior and other indicators show their commitment and satisfaction towards the campaign.

Finally, suggestions are made to disseminate good practices at a broader scale, especially out of the "initiated" circle. Building up a know-how from the evaluation of past experiences makes easier the development of process such as networking, experience sharing, and including these activities in energy services offers and in white certificates systems.

Introduction

The amount of GHG emissions of the service sector in Europe[1] was 456 $MtCO_2$ in 1990. In the European Climate Change Program, the target of emission reduction by 2010 for this sector is 105 MtCO2/a (in relation to 1990 emission level). Which represents around one fourth of the global target for this program (where transportation is not accounted) (EC – 2003).

In France, the final electricity consumption of the service sector has raised of 76% from 1986 to 2000, while its whole final energy consumption increased by 31% (CEREN – 2002). This is the second sectorial growth, below transportation, but above the residential sector. In the UK, the energy consumption growth of the service sector is assessed to be three time higher than for residential sector (SCRASE – 2001). Energy efficiency in the service sector is therefore a key issue.

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[1] for the European Union at 15

The achievement of the emission reduction objectives has to be done through technical improvements of the buildings, as indicated in the European Directive on the Energy Performance of Buildings. The technical potential would already be significant if the available best technologies were used, as well in the existing as in the new commercial buildings (NEUMANN et al. – 2005). But

actions on the energy consumption patterns are also needed. Raising awareness among the building users has to be included in the energy efficiency strategy, because total energy consumption in buildings is highly affected by occupants (JANSSEN – 2004, DUSCHA et al. – 2005). In fact energy efficiency is not only a matter of technology. Taking into account the energy issues in the choices of development models (LEBOT et al. – 2005) and changing behavior toward rational energy use (BOERAKKER et al. – 2005, EIJADI et al. – 2005) are also necessary.

In this paper, we focus on the raising awareness activities in the public and commercial buildings. First, we present an overview of researches and operations in this field. Second, we made a detailed case study of an EDF pilot operation done in the Provence-Alpes-Côte d'Azur region in France. Then the analysis of this case study and the experience feedback highlights key success factors in order to disseminate successful operations at broader scale. Finally, prospects are considered, especially the opportunity to include raising awareness operations in white certificates systems.

Potential of raising awareness operations in the service sector

Raising awareness actions can target building users, as well as building operators and/or decision-makers. The actions for operators and decision-makers are very important, both for optimizing the energy management of the buildings (AUNE et al. – 2005), and for encouraging the demand for more energy efficient buildings (LUTZENHISER et al. – 2001). We focus here on the actions targeting building users. But for better results, they have not to be considered separately. They should be embedded into global energy management systems (VAN GORP – 2005).

This kind of activities has been broadly studied for the residential sector (ABRAHAMSE et al. – 2005), but deep analysis of operations in the service sector are rare. Indeed, studies on energy efficiency improvements in commercial buildings often focus mainly on technical potential (TIAX LLC – 2004). But technical performance alone is not enough to reach better energy efficiency (SMITH et al. – 2005). Investments linked with ad-hoc advice reach better results (see (GREGORY et al. – 1997) cited by (HENRYSON et al. 2000)). And technical solutions can not always be applied for old buildings or equipments. The review by (NORDMAN et al. – 2000) showed that if the U.S. Energy Star program enabled important savings thanks to the use of low-power mode for PC and monitor, "additional savings could be gained if more equipment were turned off at night manually".

The lack of studies on raising awareness operations in service sector can be explained by the complexity of the analysis needed, which requires especially pluridisciplinary skills: technical, economical and sociological (PYRKO et al. – 1998). The scientific literature provides little information on the potential of these activities. For the residential sector, studies proved that an energy savings potential of around 10% seems reachable (HENRYSON et al. 2000). This order of magnitude is also commonly indicated in the available case studies for the service sector.

To characterize the potential of these operations, we looked for the available experience feedback on Internet and in scientific publications. More than twenty operations or operation groups were detailed enough, i.e. with most of the following items: kind of targeted buildings, stakeholders involved, objectives, list of implemented actions, communication means used, energy impact and/or economical balance, barriers / problems encountered, success factors (see Table 1 for some examples of operations). Case studies were much easier to find for public buildings than for private ones.

The experience feedback mostly confirms an energy savings potential of around 5 to 10%. But the definition of this potential is unclear: for global building energy consumption or for only targeted end-uses, with or without technical interventions or investments. The part of energy savings really due to the implemented actions is hard to assess accurately. Moreover, the lasting of the supposed impacts is also an important issue, as these actions are reversible by nature.

The analysis of the experience feedback highlights the main barriers for raising awareness activities:
- lack of concrete knowledge on how to use energy efficiently and on the environmental impacts linked to energy consumption
- difficulties to quantify the actions impacts, and then to give a feedback and for benchmarking
- difficulties to change behavior
- difficulties to involve the building users because they don't directly benefit by the achieved savings
- technical problems preventing good practices to be applied (e.g. radiator without thermostat)

The main responses suggested to these barriers are:
- to provide concrete examples of good practices and successful operations
- to use the several available internal communication means of the company or public body
- to propose to the building users to use a part of the savings for something they choose (sharing of the savings, improvement of the building, donation to charitable organizations)
- to organize a monitoring and a regular communication of the operation achievements

In most of the cases, the operation theory can be summed up by the following approach:
1- to better inform the building users to make them aware of their possibilities of actions
2- to encourage / to induce the users to act out (from awareness to actions)
3- to perpetuate the changes by the monitoring and the communication on the results

But this model can not always give explanations for features linked to the specificity of the building or its use for a given case. However it remains the most common model (PYRKO et al. – 1998).

The analysis of the experience feedback shows that the most significant interest among the building users is often induced by the uncommon actions. And "successful conservation measures were mostly initiated, decided and realized by a single person fairly low down in the hierarchy" (WEBER – 1999). Our analysis highlights the main success factors for raising awareness activities. This last synthesis is presented in the conclusion part of this paper.

Building up a know-how and experience sharing

The analysis of experience feedback has been done for some specific sub-sectors to constitute methodologies and good practices guidebooks. For instance, for the health care centers in Canada (OEEC – 2003) or for schools in the European Union (NILSSON et al. – 1997). Organizing a contest is also a good way to stimulate the realization of operations and to encourage experience sharing. Such contests are organized in the United States for federal buildings (HARRIS et al. – 2005) or in Europe for all tertiary buildings [9]. Networking is another efficient tool for experience sharing. Good European examples are Energie-Cités or the "e-team" projects for schools [1]. A SAVE project on this issue was led in 2002-2004 (MØRK – 2003). Another solution is to develop resource centers, as www.energyoffice.org, a SAVE project to gather experience and best practices.

But advertising is still needed so that these tools can be used at a broader scale, especially out of the "initiated" circle. Moreover, the provided information has to be reliable, which depends on the quality of the evaluation performed.

Table 1 – examples of available experience feedback

Place, kind and number of buildings	Date	Stakeholders initiators	Posters / booklet	Meetings / training	Internal communication	Raising awareness only	Sharing of the savings	Special actions	Energy and/or environmental impacts	Web-reference
Heidelberg (Germany) - 16 schools	1995-1999	Local energy agency, City of Heidelberg	X	X	X	no	yes	constitution of an energy team	from 3 to 9%/a savings (around 600 tCO2 avoided in 4 years)	[1]
Hanover (Germany) - 98 schools	1995-1997	City of Hanover	X	X		no	yes	educational activities in a global frame (local 21 agenda)	5.000 tCO2 avoided in 2 years	[1]
Glasgow (UK) - the 300 buildings of the University	from 1996	University of Glasgow	X	X	X	no	no	award for the best energy savings suggestions	assessed potential of 10% reduction	[2]
Michigan (US) – all the buildings of the University	from 2001	Michigan University	X		X	no	no	interactive campaign through Internet, included in a global eco-footprint program	Detailed study of the energy consumption but no clear impacts detected	[3]
Winnipeg (Canada) - 25 buildings of the Health Sciences Centre		Health Sciences Centre	X		X	no	no	a central contact person ; post-it put on the switch and PC let off during the night	No quantification of the impacts	[4]
Clarenville (Canada) - 15 buildings of the Peninsulas Health Care Corporation	1991-2000	the Peninsulas Health Care Corporation and its energy supplier	X	X	X	no	no	preliminary study ; operation included in a global energy management program	around 10% reduction between 1997 and 2000	[4]
Pamplona (Spain) - municipal buildings	2001-2002	Local energy agency, City of Pamplona	X		X	yes	no	follow-up by the housekeeping personnel of the equipment let off during the night	a model to quantify the savings is under development	[1]
Chalon-sur-Saône (France) - city hall	1997-98 then 2004	City of Chalon, EDF, ADEME	X		X	yes	no	quarterly balance of the energy consumption by department	Punctual reductions from 4 to 7%	[5]
UK – 9.000 office buildings of BT plc	1993	British Telecommunication	X	X	X	no	no	one energy awareness manager in every buildings	Reductions from 3 to 6%	[6]

Case study: EDF pilot operation in the PACA region (France)

Operation context

Eco Energy Plan [7]
The Eco Energy Plan is a pluri-annual energy efficiency program (started in 2002) aiming at securing the electricity supply in the East of the PACA region[2]. This program is under the responsibility of the Alpes-Maritimes Prefecture[3] and the PACA Regional Council. EDF, ADEME[4] and the Regional Council implement it. The EDF pilot operation takes part in the action theme "the Eco Energy Plan partners show the example".

The environmental involvement of EDF
This operation lies within the scope of the environmental approach of EDF (with a link for instance with the ISO14001 certification and environmental management), and within the setting of the French white certificates system. This pilot operation aims at being a reference in order to reproduce it easily.

The European Energy Trophy [9]
The European Energy Trophy is a project co-funded by the European Commission. The objective of this contest is to stimulate the implementation of raising awareness activities in the public and commercial buildings. One of the buildings involved in this operation took part in this contest, and EDF received the award of the best French operation.

Operation principles

A campaign both reproducible and custom-made
The developed methodology is reproducible to serve as reference. It defines the steps to follow and includes the existing experience to provide advice in order to insure the success of the future operations. But it let enough freedom for the operation manager to do a custom-made operation.

Indeed, the objective is also the operation to fit with any particular building. A preliminary survey among the building users enables to better know the initial energy behavior and patterns, and then both, to better target the actions and to involve the users in the operation design.

The commitment theory
The operation is based on a voluntary approach. Meetings were proposed to the employees to present them the operation. At the meeting end, these who wanted it, could sign a commitment charter. Through this, they publicly committed themselves to apply the good practices of their choice.

This approach is based on the commitment theory. This theory, coming from the experimental social psychology, enables to understand how people led to do some preliminary actions *a priori* insignificant then come to do more difficult actions, if these preliminary actions are achieved in some conditions (so-called commitment conditions: freedom feeling, public actions, etc.) (JOULE et al. – 1998).

A study made in 2000 showed the interest of such a commitment approach to induce households to save energy (BEAUVOIS et al. – 2000, FLAHAUT et al. – 2001). The commitment charter uses this approach for the professional context. It enables for instance to make the committed users real actors of the operation, and so to strengthen their involvement.

Strengthening everyone's involvement
The operation success relies on the mobilization of all building users. In this respect, the most important items of the methodology are:

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[2] this area is at one end of the national electricity transportation network (see [8] for more details)
[3] State representation in this area
[4] French Agency for Environment and Energy Management

- to propose, on a voluntary basis, an individual commitment charter
- to show the involvement of the Direction
- to insure a contact with all building users, thanks to meetings and contact person in each department making easier the dissemination of information
- to keep the campaign dynamic thanks to various actions, consistently planned, and with messages evolving with time (especially adapted to the seasons)
- to make the actions visible by providing feedback on their results
- to increase the standing of the committed users

Evaluating the operation
This operation is a field experimentation. It was designed in order to highlight the success factors. Four different campaigns were launched at the same time in four distinct buildings (see Table 2 for the details on the different action packages). One more building without any action done was monitored as control site. The energy consumption of each building were monitored on a monthly basis.

Moreover, three surveys of the employees in each building were done:
- a preliminary one, to make an initial diagnosis (December 2004)
- an intermediate one, to get a first feedback and to adapt the end of the campaign (June 2005)
- a final one, to complete the evaluation (end of 2005)

These surveys were based on forms given directly to the employees, and mainly constituted of multiple-choice questions, so that quantitative analysis of the results could be done.

Operation implementation

Table 2 - implemented action package for each site

Actions[5] ↓ Site →	Site 1 (Energy Trophy)	Site 2	Site 3	Site 4
Posters	X	X	X	X
Eco-advice booklet	X	X	+ reminder stickers	
Information meetings[6]	X	X		
Involvement of the Direction	+++	++	+	
E-mails	X			
Message when PC on	X			
Commitment charter[6]	X			
Educational exhibition	X			

(Source: EDF)

Action details:
- the posters focused on the four main targeted end-uses (lighting, HVAC, PC monitor, elevators) and were renewed every two weeks
- and so was the message configured to be automatically displayed when PC are switched on
- the booklets presented a list of 21 good-housekeeping actions customized for office buildings
- the e-mails were personally sent by the Director of the building at the beginning, half-course and at the end of the operation
- the educational exhibition lasted one week in a room where the employees could visualize the energy consumption of office equipment thanks to individual meters. They could see as well what are the good practices to reduce these consumption while keeping the same comfort level

The operation theory was:
1 – to inform the employees of both, the operation launching and concrete good practices which can be applied in office buildings
2 – to induce them to adopt and apply these good practices, especially by the commitment theory approach
3 – to inform them of the operation results to strengthen their involvement and motivation

[5] for the details of the actions, contact Bertrand Combes at bertrand.combes@edfgdf.fr
[6] actions within the commitment theory approach (see also the "operation principles" section)

The different steps of the operation are summed up in the below.

October / December 2004	January / February 2005	March / June 2005	July 2005	July / September 2005
STEPS				
Initial diagnosis and framing	Defining the action plan	Implementing the action plan	Analyzing the results	Carrying on the actions
ACTIONS				
Constituting the operation team and defining the objectives Choice of the pilot sites and control building Survey of the energy behavior and habits of the building users (at the office)	Analyzing the preliminary survey Proposition of actions Action plan validation by the operation team Creating the communication tools	Implementing the first communication flight Intermediate survey (end of June) Communicating on the first quantitative results (for the details of the action packages, see Table 2)	Checking the efficiency of the communication campaign Fitting the messages to the results of the intermediate survey and to summertime	Implementing the second communication flight Communicating on the quantitative and qualitative results Updating the operation methodology with the experience feedback

(Source : EDF)
Figure 1 – operation schedule

Operation results
Only site 1 (full action package) results are presented here. When possible, they are compared to the other sites results. Quantitative analysis of sites 2 and 3 results could not be performed, because of their too small sample size. Their results are however taken into account for the qualitative analysis.

Initial situation
The answers to the preliminary survey highlighted a global energy awareness level already high, with no significant differences between the sites. This high energy awareness level is linked with the EDF company culture. Most of the respondents said being enough (69%) and even too much (3%) informed by EDF about energy savings issues. As answering was voluntary, energy aware employees can be over-represented in the samples. The results of the surveys presented here are "gross", i.e. not corrected for this potential bias. But the analyses deduced from these results took this into account by testing if the results could be due to this bias, fully, partly or not.

The respondents said they have a "reasonable" (70%) or "very sparing" (6%) behavior toward energy. But particular potential still remains on targeted actions. Thus, 61% of the respondents said they open their window while heating or cooling is on. And only 15% said they switch off the PC monitor when leaving the office during the day (while they are 75% to do so while leaving at the end of the day).

It is interesting to notice that these potentials are not the same from one site to another. This confirms the usefulness of a preliminary study to better target the actions.

Participation
Two direct indicators enable to evaluate the employees' participation to the operation[7]:

[7] both monitored actions were voluntary (taking part in the meetings and signing the charter)

- 67% of the employees have taken part in one of the proposed information meetings
- 75% of the employees who attended a meeting have signed an individual commitment charter

Most of the employees were therefore interested in the operation, and then voluntary committed themselves.

The rate of the employees who signed the charter is a bit higher within the sample of the intermediate survey (70%) than among all building users (50%). This was taken into account in the analysis.

Evaluation of the communication plan
The intermediate survey show that, according to the respondents, the most involving communication means were the ones linked to the commitment theory approach (meetings and charter).

Otherwise, according to the respondents, the most visible communication means are not necessarily the most reminded by the respondents, neither the most efficient. Posters are the most visible communication mean. But the respondents first remind being informed about the operation by the meetings (24% vs. 9% for the posters). They also find the meetings more efficient (36%, vs. 17%).

The intermediate results also highlight that the campaign has been mostly perceived in a positive way: efficient, involving and original are the most mentioned adjectives. This is confirmed by the global appreciation of the operation assessed as enough (66%) or very (16%) satisfactory.

The comparison with the other sites strengthens the analysis about the efficiency of the different communication means.

Table 3 – appreciation of the communication plan by site (from the intermediate survey)

Site	Site 1	Site 4
Kind of action package	full	posters only
Number of building users	340	230
Number of distributed forms	250	165
Number of respondents	94	66
Were the communication means involving?	yes (79%)	yes (47%)
You find the communication plan : - excessive - appropriate - too discreet	 10% 75% 15%	 1,5% 30,5% 68%

From a qualitative point of view, sites 2 and 3 results confirm the comparison between sites 1 and 4: posters and booklets enable to inform the building users, but a more direct contact (for instance meetings) is needed to involve them in the operation.

Behavior changes
The possible behavior changes were evaluated through the intermediate survey, taking into account the preliminary survey analysis. The final survey (end of 2005) could not be analyzed yet. The questionnaires were not given directly to the persons as for the other surveys, and the answer rate was too low. A new survey is being made following the same process than for the preliminary and intermediate survey to get a better answer rate.
82% of the site 1 respondents say they have changed their behavior. The changes are mainly on switching off PC monitors (73%) and lights (55%) while leaving the office during the day, and in a smaller extent on heating and cooling (16%) and not taking the elevator (14%).

The advice on lighting and PC monitors are well perceived. They are easy to apply, and do not change the user comfort. Moreover an energy savings potential was detected for these end uses from the preliminary survey. At the opposite, advice on heating / cooling[8] and elevators get little approval. Indeed, these advice require more efforts and the users may feel as it changes their comfort. The corresponding habits are then harder to change.

The results for the other sites confirm this difference between PC monitor and lighting on one side, and heating / cooling and elevator on the other.

The comparison between sites 1 and 4 show clearly a better impact for the full action package (cf. Table 4). For the global behavior evolution, the difference between both sites is the same as for the appreciation on how involving the campaign is. The consistency between these results strengthens the analysis of the efficiency of a campaign with direct contacts.

Table 4 – behavior changes (from the intermediate survey)

	Site1	Site 4[9]
Have you changed your behavior concerning energy consumption?	82% (yes)	45% (yes)
Have you changed your behavior concerning : - lighting	55%	33%
- PC monitor	73%	23%
- heating / cooling	16%	8%
- not taking the elevator	14%	

These results may be partly explained by the high rate of committed employees in the site 1 sample. Even so, the rate of global behavior change (82%) is higher than the rate of charter signature (70%). Therefore, the global impact of the full action package can be considered as very good. Moreover for both sites, the respondents represent about 30% of all building users. This high answer rate reinforce the positive appreciation of the operation.

Energy consumption evolutions and links with the implemented actions
A first direct comparison between the annual consumption for 2005 and the average annual consumption for the previous period where data were available (2002-2004) gives a -9% decrease. After a simple Heating Degree-Days (HDD) correction for heating consumption, the result is -11,5%.

This evolution for site 1 is to be compared with the other sites evolution. Two indicators were used.

The first indicator is the average variability, defined as the ratio of the standard deviation of annual consumption for 2002, 2003 and 2004, to the average annual consumption for 2002-2004:

$$\text{average variability} = \frac{\text{standard deviation of annual consumption for 2002 - 2004}}{\text{average annual consumption for 2002 - 2004}}$$

The second indicator is the relative consumption change between 2005 and the average on 2002-2004:

$$\text{relative consumption change} = \frac{\text{2005 annual consumption - average annual consumption for 2002 - 2004}}{\text{average annual consumption for 2002 - 2004}}$$

These indicators were used first to study the total annual electricity consumption. As for two sites, the heating system is with gas and not electric, we also used the indicators for annual electricity consumption without heating, and then also for heating annual consumption apart. All these data were HDD corrected when necessary.

Even if they were build at different time, all sites can be considered with an initial efficient

[8] the advice for heating / cooling were to better use the thermostat and to limit the opening of windows as the ventilation system is already sufficient for the air change
[9] there were no messages about elevators in site 4 campaign

consumption level, because investments were made in the past to improve their energy efficiency and they all have operation contracting for their heating system.

Table 5 – energy consumption evolution by site

Site[10]	Site1	Site 2	Site 4	Site 5
Construction period	late 70's	late 80's	late 80's	early 80's
Heating system	electric	electric	gas	gas
Action package	full	partial	posters only	control site
Average annual electricity consumption (without heating) (in GWh/a)	1,5	0,5	1	0,2
Average variability for 2002-2004 HDD corrected total electricity consumption	+/- 6%	+/- 9,5%	+/- 6%	+/- 4%
Relative consumption change between 2005 and 2002-2004 (after HDD correction)	-11,5%	-8,5%	+0,5%	+6,5%
Average variability for 2002-2004 electricity consumption (without heating)	+/- 8%	+/- 11%	+/- 6%	+/- 4%
Relative consumption change between 2005 and 2002-2004	-11%	-8,5%	+0,5%	+6,5%
Average variability for 2002-2004 HDD corrected heating consumption	+/- 3,5%	+/- 5,5%	(heating consumption represents, respectively for site 1 and 2, 30% and 12% of the total annual consumption)	
Relative heating consumption change between 2005 and 2002-2004 (after HDD correction)	-12,5%	-9%		

The consumption change is significant in comparison to the average variability for two sites:
- site 1 (full action package) with a significant decrease (-11,5% vs. +/-6%)
- site 5 (control site without any action) with a significant increase (+6,5% vs. +/-4%)

Moreover, a deeper statistical analysis[11] based on the monthly consumption data from January 2002 to December 2005 confirms a significant decrease for sites 1 and 2. These results are consistent with the figures presented in Table 5 above. So the impact of the campaign seems very positive.

The above analysis plead in favor of the causality between the actions and the consumption decrease. Moreover the comparison of the consumption changes between sites 1 and 4 is consistent with the comparison of the awareness impact of both actions packages. But this causality has to be confirmed by a month by month analysis with comparisons between sites and a good knowledge of all the other events, which could have had an influence on energy consumption. For instance, the change of heating consumption for site 1 could be due to a change of the heating system settings.

Conclusions from the case study

The original approach based on the commitment theory appears to be very efficient. 75% of the employees who attended the information meeting voluntary committed themselves into the operation. 80% of the employees said they have changed their behavior towards energy. And the total electricity consumption decreased by around 10% for the period of the campaign.

Two other results of the case study are particularly interesting:
- direct contacts really improve the involvement of the building users in the operation
- good practices are more broadly applied when they require little effort and/or do not change the user comfort

The economical assessment was made through the calculation of the cost of the avoided kWh. Two

[10] site 3 energy consumption were not available while making this paper

[11] the linear model introduces a triple statistical correction : HDD and month in winter (variations due to heating and lighting), average outer temperature in summer (cooling)

extreme scenarios were used, with different set of assumptions:
- optimistic scenario: all the electricity consumption decrease is due to the operation and the operation costs don't include the time passed in the meetings by the employees
- pessimistic scenario: only the electricity consumption decrease without heating are accounted as energy savings, and the operation costs include the meeting time for the employees

Moreover, as there is no evidence yet for the lasting of the savings, only the savings achieved during the operation are accounted.

The result is a cost of avoided kWh between 1 and 4 c€ (taxes not included). For comparison the average purchasing price is 6,5 c€(taxes not included)/kWh for this kind of customer. Moreover, it has to be noticed that this operation is a pilot one. So its cost could surely be reduced in case of reproduction (for example, the design costs). This applies particularly in case of pursuing the actions in the same buildings. The gained savings should be even more cost-effective in case of a long-term strategy.

There is no available case study which enables a direct comparison between this operation based on awareness actions and another operation based on investments into control systems for specific end-uses as lighting. A measurement campaign was made within the Eco Energy Plan to better know the energy consumption of office equipment and lighting (ENERTECH – 2005), but no feedback is available about actual energy savings in similar conditions (same kind of building, of activity, etc.).

Moreover, awareness actions have not to be compared with "technical" actions as alternative options, i.e. to select one alone. The comparison is useful to prioritize action plans, i.e. to know the magnitude order of both, improvement that could be reached and corresponding costs. But the actions should be thought in a global view, for example within an energy management system, or even beyond energy issues, within the global policies of the company. For instance, the awareness actions can also be part of the organizational culture of the company.

General conclusions

Success factors for raising awareness operation in the service sector
The main success factors detected through the case study and the analysis of the available experience feedback are:
- the involvement of the head-management
- the realization of a preliminary survey to define a baseline and to better target the actions
- the coordination of the operation by a specific operation team which is representative of all the building users
- the monitoring of the results and their communication to all the building users
- the motivations used to involve the building users (savings sharing, award system, etc.)
- the originality of the communication means, their consistency and the clearness of the messages

The evaluation of raising awareness operation in the service sector
Raising awareness operations need good quality evaluation:
- to insure the reliability of the experience feedback, both for experience sharing and to perpetuate the involvement of the building users
- to detect the success factors
- to establish causality between energy savings and awareness actions

The energy savings results based on a simple monitoring of consumption data, the most used kind of results in the available experience feedback, have to be considered with precaution. Indeed the assessed energy savings (generally from 5 to 10%) have the same (or even smaller) magnitude order as the "natural" variability of the energy consumption. Therefore, the analysis of the causality between the energy savings and the implemented actions require a detailed analysis taking into account all the factors which may have a significant influence on the consumption (see the researches done about benchmarking energy efficiency of buildings as in CHUNG et al. – 2006).

However, even if it has always been difficult to clearly establish the causality between energy savings and raising awareness activities, the "gross" results of most of the case studies of such operation in the service sector are positive and encouraging. The conclusions of our case study also go in this direction. Raising awareness operations represent a potential which is not to be sneezed at. This deposit could be particularly cost-effective. But the reliability of the energy savings assessment is a key factor for the development of raising awareness operations at a broader scale. It should then be worked to define an evaluation method agreed by all the involved stakeholders. A basis for such a method could be deduced from the case study presented in this paper.

Moreover, the lasting of the impacts is another key issue. Because these actions are reversible by nature. About the persistence of the savings, "various investigations reach different results, but there is a tendency that the longer the trial period, the longer lasting the effects" (HENRYSON et al. 2000). Education and training actions in the industry was studied by the Energy Center of Wisconsin to develop systematic model to define actions "that delivers consistent, measurable and significant results in terms of lasting energy efficiency behavior change" (ANDERSON et al. – 2005). But no literature gives such results for awareness actions in the service sector.

Prospects: including raising awareness actions in white certificates systems

Raising awareness activities could be more broadly included in the service offers for energy management of buildings, as in the offers of some ESCo[12] in North America. For instance in Canada, guidebooks are made to encourage this (OEEC – 2004).

Furthermore, standard actions for raising awareness in the service sector could be defined so that they could be included in white certificates systems. Indeed, these actions represent a significant deposit, cost-effective and easy to reach. They can also take part in the development of energy services offers. Therefore, they totally fit with the objectives of white certificates systems. Moreover, these actions are not widespread yet. Their inclusion in white certificates systems could help a change of scale, from exemplary operations to common practices. The available feedback highlights the success factor needed to make these operations easily reproducible.

However the issue of the energy savings evaluation is not totally solved yet. The evaluation of some actions already included in white certificates system is not without any uncertainties neither. But the evaluation quality is here of particular importance, because awareness actions are reversible. Two possibilities of inclusive evaluation are to be further studied:

- when the awareness action is linked with another standard action: validation of a fixed relative bonus. For example, if an awareness action is implemented together with another standard action, the white certificate value of this standard action would not be 100% of the fixed energy savings, but 110%.
- for awareness actions alone: the calculation of the energy savings could be based on a fixed percentage of the global standard energy consumption of the building. This standard energy consumption would be assumed to be the consumption for a "normal" use of the buildings (with the same comfort level), as defined in the European Directive on the Energy Performance of Buildings or in labeling system (cf. Display™ campaign). Then the energy savings validation would be based on the energy bills.

The potential for raising awareness operations is significant. The available experience feedback highlights the key factors to insure the success of future operations. But the experience sharing and the development of operation remain restricted to a circle of "initiated" stakeholders. A larger dissemination of best practices could be achieved by defining reliable evaluation methods and including awareness actions in white certificates systems.

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OFFICE BUILDING ENERGY SAVING POTENTIAL IN SINGAPORE

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Abstract

The energy consumption of office buildings takes up a great amount in Singapore because of the tropical climate and insufficient energy conservation measures. In order to develop an achievable and predictive energy saving target, this study explores the prediction of office building energy saving potential in Singapore. There are two types of approaches presented here to establish the predictive model for estimating the office building energy saving potential. One is based on the system-level energy efficiency benchmark of building energy consuming systems, while the other adopts the regression correlation-ship analysis between the parameters of building energy consuming systems and the total building energy efficiency excluding car park area ($TBEE_{ex\ cpa}$).

Three buildings of the moderate-level energy efficiency and one building of the low-level energy efficiency are case-studied by using these two approaches. The whole building energy savings after retrofitting are predicted and the overall results are analyzed and compared. Additionally, energy simulation by VisualDOE 4.0 of two selected buildings among the four case buildings is conducted to verify the correctness of the energy saving potential predictive model. The study results show that all the case buildings can be improved to the high-level energy efficiency buildings through these two approaches and the saving percentage is from 20% to 40%, respectively.

Introduction

In Singapore electricity is the predominant form of the energy utilized in office buildings, which is used to operate equipment for the safety, efficiency, convenience and comfort of its occupants and users. Such equipment includes emergency systems, air conditioning system, artificial lighting, vertical transportation, ventilation, office infrastructure and other appliances [1]. According to the Building and Construction Authority (BCA) of Singapore, office buildings' energy consumption accounts for a large proportion among the total electricity consumption in buildings. This will restrict the economic development of the nation with scarce natural resources fundamental to the generation of electricity and with the increasing population and energy demand. Conducting building energy retrofitting has been demonstrated as an applicable and effective method to save energy consumption [2]. It is essential to predict the saving potential or say, to set an achievable target, before carrying out the energy retrofitting program. However, it is not easy to predict accurate building energy consumption estimation because it must take into consideration the current situation of the building, possible building energy conservation measures (ECMs) and facility management.

There are quite a few existing approaches to office building energy saving potential analysis. Because of the complex and dynamic interactions between its systems and plants changing with the internal and external environment in a large commercial building, no direct way of measuring energy demand is available. And instruments cannot measure the absence of energy use or demand to deduce the savings. However, the absence of energy use or demand can be calculated by comparing measurements of energy use and/or demand from before and after the implementation of ECM. The basic method of estimating energy saving is based on the simple comparison made by the subtraction of post-retrofit energy use from the pre-retrofit quantity with removing the influence of some other compounding factors, such as weather and usage factors [3].

Building Energy Savings = (baseline energy use or demand projected to post-retrofit conditions) – (post-retrofit energy use or demand) +/- adjustments *Eqn (1)*

(Source: ASHRAE, 1998) [3].

The energy saving is determined by comparing the before and after energy use, and making adjustments for non-ECM changes that affect energy use.

However, this study just concentrates on predicting the energy saving potential, in which the average monthly energy consumption of the investigated years can be assumed as the baseline energy use on the pre-retrofit conditions. As a result, the adjusted equation of building energy saving potential is shown as follows:

Building Energy Savings Potential = (average energy use or demand in the investigated years) – (predicted post-retrofit energy use or demand) +/- adjustments *Eqn (2)*

Currently, the office building energy saving potential are predicted mainly by the methods of energy efficiency benchmarking (either by whole building metered approach [4] or by retrofit isolation approach [5] [6]), computer simulation [7] [8] (based on the generic or individual building), experts' walking through and past experience [9]and by using the neuro-fuzzy network model [10], etc.

Among that, the whole building metered approach and the retrofit isolation approach to determining the energy consumption savings are similar in the concepts of saving computation but they differ in their ways of measuring the actual energy use and demand quantities to be used in savings determination. The whole building metered approach determines energy and demand savings through the use of whole facility energy (end-use) data, which may be measured by utility meters and data loggers. On the other hand, the retrofit isolation approach determines energy and demand savings through the use of meters to isolate the energy flows for the building system(s) under consideration. The approach of computer software simulation is currently a commonly used method to determine the energy consumption pre-retrofit and post-retrofit by inputting different parameter values in the range on the basis of the building energy simulation software in academic and practical field. However, the simulation softwares database are mostly not designed for the tropical context since quite a lot of default items are developed on the basis of temperate climate. Thus, this approach is only adopted for the validation of the benchmarking approach in this study. The approach of experts' walking through is very practical and is frequently applied in the industries. Moreover, the benchmarking approach is described in depth in the section of methodology and discussion.

Methodology

There are two types of approaches presented in this study to establish the predictive model for estimating the office building energy saving potential in Singapore. One is based on the system-level energy efficiency benchmark of building energy consuming systems (Approach I), while the other adopts the regression correlation-ship analysis between the parameters of building energy consuming systems and the total building energy efficiency excluding car park area ($TBEE_{ex\ cpa}$) (Approach II).

The same energy saving target based on the benchmark of $TBEE_{ex\ cpa}$ is set for the sample building by these two approaches. The validation of the final result is made by doing the building energy simulation by the program of VisualDOE 4.0 after comparing the results of approach I and II. Once the simulation result can validate the model of approach I and II, technological recommendation and economic analysis of different energy conservation measurements of the investigated building will be done to accomplish the computed energy saving potential (this part of work is regarded as future work which is not included in this thesis). The general procedure of these two approaches as a whole is as shown in the format of flow chart in Figure 1 as follows. (The dummy arrow indicates the future work.)

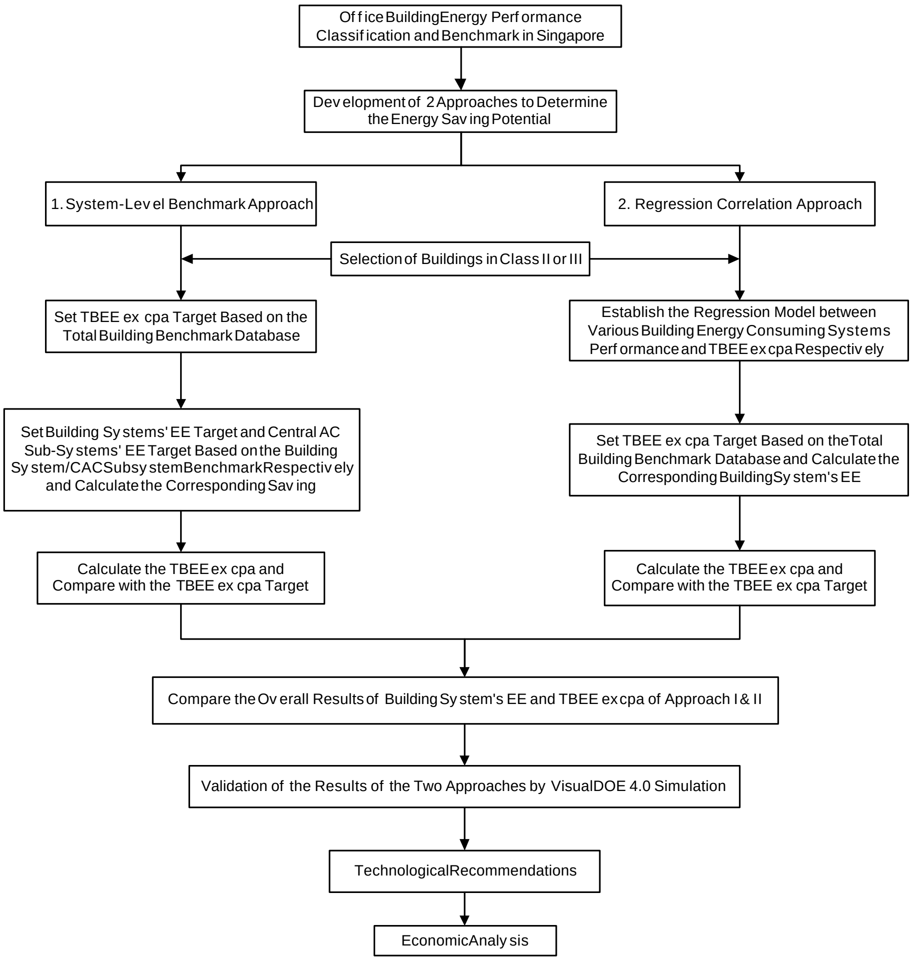


Figure 1 General flow chart of methodology of office building energy saving potential analysis

1 System-level benchmark approach

Based on the benchmarking curve for the total building energy efficiency, building energy consuming system energy efficiency and central air conditioning subsystem energy efficiency, the building owner may determine his/her building performance ranking, and set energy efficient target for its management. In addition, the systems' benchmarks clearly show where the building has underperformed in relation to various classes of building and with particular reference to a building services system. The energy services engineer can then develop energy retrofitting strategies to optimize investment return and, if budget constraints, can handle the retrofitting work in stages to demonstrate the effectiveness of energy retrofitting project.

The detailed procedures of this system level benchmark approach to energy saving potential analysis are shown as follows: First the total building energy efficiency after the presumptive building retrofit is roughly determined from the established whole building level benchmark. The targets of building systems or the AC subsystems are taken directly from the statistical analysis of the corresponding building systems or the AC subsystem benchmark curve and classification, respectively. If the statistical data is more than the original one in a certain system or subsystem, the original value will be taken as target, instead. The final TBEE $_{ex\ cpa}$ will be calculated again after obtaining the building system energy efficiency. And so the building energy saving potential is decided. There must be some difference between the target set arbitrarily and the final result calculated from the systems in total building energy saving, even though TBEE $_{ex\ cpa}$ is set at the same level as the building systems and no adjustment is made to the building systems' energy efficiency, because TBEE $_{ex\ cpa}$ is not a simple sum of the energy efficiency of all the five systems. In fact, the initial TBEE $_{ex\ cpa}$ target is only a rough reference which indicates the total saving range and direct the target level of building systems. And the building energy saving potential is entirely determined by the saving target of building systems. A detailed flow diagram presenting the application of the methodology of system-level benchmark approach is shown below in Figure 2. The details of how to apply approach I in the building energy saving potential analysis are described in the following section of case study.

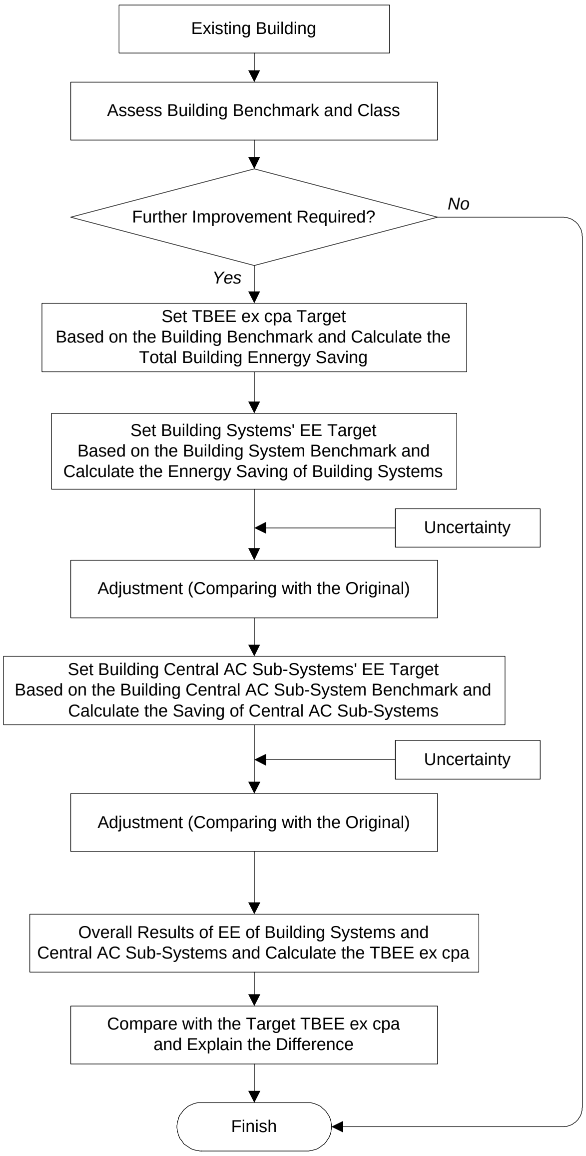
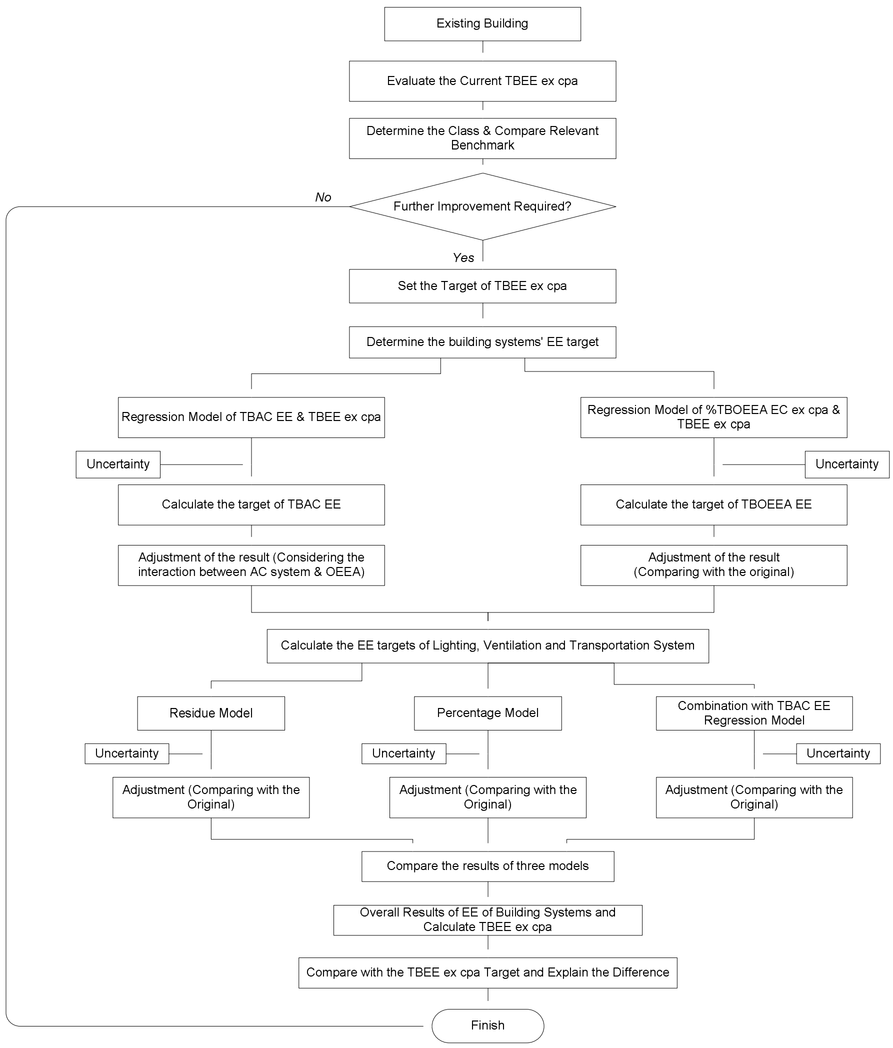


Figure 2 Flow chart of methodology of system-level benchmark approach

2 Regression correlation approach

Regression correlation approach concentrates on the data analysis of building energy efficiency of the whole building and all the five individual energy consuming systems to quantify total building energy saving potential from another point of view. The total building energy saving is achieved by saving energy for each building systems. It is naturally for the building manager to know that for a certain percentage of the total building energy saving target, i.e. 20%, how much energy should be saved for each individual system. Consequently, a uniform index of total building energy performance ($TBEC_{ex\ cpa}$ or $TBEE_{ex\ cpa}$) is used as the independent variable in the correlation regression for the five building systems. It is found that $TBEE_{ex\ cpa}$, which is normalized by operation hour, occupancy rate and usage area, is better correlated with the building system energy performance index.

In addition, according to the collected data of the fifteen buildings, regression analysis is conducted between the parameters of all the five energy consuming systems and TBEE $_{ex\ cpa}$. The reason for highlighting the energy efficiency of the whole building is that this methodology is still developed from our benchmark and benchmark is based on the building energy efficiency. Hence, the statistical analysis of the representative parameter of each system is undertaken to search for a satisfactory coefficient of determination of the bivariate linear, multiple linear or nonlinear regression. The main procedures are given as follows in Figure 3.



"% TBV EC" and "% TBL EC" is taken into consideration and plot against TBEE $_{ex\ cpa}$ (as X, the independent variable) respectively in regression curves. However, only "% TBOEEA EC" is significant and well correlated with TBEE $_{ex\ cpa}$ with R^2 being over 0.8. But if "% TBT EC", "% TBV EC" and "% TBL EC" can be combined as a whole in terms of "%(TBL+TBV+TBT) EC $_{ex\ cpa}$", it is quadratic correlated with TBEE $_{ex\ cpa}$ with R^2 being 0.8126.

3). To set the total building energy efficiency saving target point after retrofitting on the above curves, TBAC EE' and % TBOEEA EC' $_{ex\ cpa}$ can be obtained by substituting the target TBEE $_{ex\ cpa}$ in the corresponding equations. So the proposed energy savings in these two systems can be computed by calculating the difference between the current situation and target situation to generate the responding saving for each system. Besides, since the change of office equipment energy efficiency influences the cooling load of air conditioning system, the energy savings in air conditioning system warrants critical attention and needs to do adjustments.

4). There are three indirect methods for calculating the energy saving for lighting, ventilation and transportation system because their poor correlation as a function of total building energy efficiency individually and each of these three systems just takes up a very small amount of the total building energy consumption compared to that of AC system and office equipment in the previous study. Consequently, these three systems are taken as a whole or each of them is combined with TBAC EE $_{ex\ cpa}$ in order to establish another type of index in a good correlation. As for the energy savings for each of the three building systems, if they three are taken as a whole, it is feasible to identify the contribution percentage of each system among this whole part clearly with the three system energy consumption distribution for each building and then the energy efficiency saving of each system is calculated by multiplying the corresponding proportion in the pie chart; if the energy efficiency of each of these three systems is combined with TBAC EE, it is just to subtract the TBAC EE. The calculation result needs to be adjusted if it is more than the original one.

i). The residue method
Firstly, these three systems are taken as a whole and their energy savings is calculated by subtracting that of air conditioning system and office equipment from the total savings. And then the energy efficiency savings of each system are calculated by multiplying the corresponding proportion.

ii). The percentage regression method
There is acceptable correlation ship between % (TBL+TBV+TBT) EC $_{ex\ cpa}$ and TBEE $_{ex\ cpa}$ as mentioned above so the savings as a whole can be gained easily. Following the similar procedures as the residue method, then the energy efficiency saving of each system is calculated individually.

iii). The regression model of the combination with TBAC EE
It is found that the energy efficiency of each of these three systems combined with TBAC EE is well correlated with TBEE $_{ex\ cpa}$, so the sum energy efficiency can be gained easily. The calculation of energy efficiency of each system is by subtracting the TBAC EE from the sum energy efficiency.

5). To obtain the total building energy consumption saving potential after retrofit by adding up the savings of all the five systems.

Uncertainty analysis is also involved in this study, including sampling uncertainty and model estimate uncertainty according to the main types of sources of uncertainty. It is essential to quantify the uncertainty in the energy savings for a statement of measured value without an accompanying uncertainty statement has limited meaning. Uncertainty is described in the format of the interval around the measured value within which the true value is expected to fall with some stated confidence [11]. Confidence limits define the range of values that can be expected to include the true value with a stated probability.

I. Sampling uncertainty
Random sampling errors arise from chance variations between sample and population characteristics. The relative uncertainty created by estimating the mean ($\overline{Y}$) of a population of Q items from a random sample of q items with value Yi is shown in formula 3:

Us= $\frac{100}{\overline{Y}} * \sqrt{(1-q/Q)[\sum_{i=1}^{n}(Yi-\overline{Y})^2/(q-1)]/q}$ Eqn (3)

(Source: Ayyub and Gupta, 1997) [11]

II. Model estimate uncertainty

i). Standard error of the estimate (S):

$$S=\sqrt{\frac{SSE}{n-p}} = \sqrt{\frac{\sum_{i=1}^{n}(Yi-\hat{Y}i)^2}{n-p}}$$ Eqn (4)

(Source: Bowerman and O'Connell, 1990) [12]

ii). Coefficient of variation of the root mean square error (CVRMSE):

$$CVRMSE = \frac{100}{\overline{Y}} * S = 100 * \sqrt{\frac{\sum_{i=1}^{n}(Yi-\hat{Y}i)^2}{n-p}} / \overline{Y}$$ Eqn (5)

(Source: Reddy, 1997) [13]

III. Combining components of uncertainty

$$U=\sqrt{CVRMSE_1^2+CVRMSE_2^2+CVRMSE_3^2+...+CVRMSE_n^2}$$ Eqn (6)

(Source: Attoh-Okine, and Ayyub, 2005) [14]

Case study

1. Background of system-level benchmark approach

Based on the energy performance data of the various building energy consuming systems in the fifteen office buildings studied, the cumulative probability curves of energy efficiency index (EEI), the cumulative probability curve, is generated to serve as the benchmarking curve for each system and sub-systems. They are described as the respective quadratic non-linear regression equation which can represent the trendline of the curves in Table 1. All of these cumulative probability curves are also given as a reference for the case building analysis.

Table 1 The quadratic non-linear regression equation of the benchmarking curve for each building system and CAC subsystem

	Quadratic Non-linear Regression Equation
TBAC EE (kwh/m^2/year)	y = -0.0014x^2 + 0.9955x - 66.161
TBL EE $_{ex\ cpa}$ (kwh/m^2/year)	y = 0.1364x^2 - 2.8677x + 17.184
TBV EE $_{ex\ cpa}$ (kwh/m^2/year)	y = -0.3354x^2 + 11.433x - 2.6459
TBT EE $_{ex\ cpa}$ (kwh/m^2/year)	y = -0.1196x^2 + 8.7202x - 53.568
TBOEEA EE (kwh/m^2/year)	y = 0.0059x^2 + 0.1628x - 2.1608

The energy efficiency classification is defined as those with energy efficiency falling within the first top 25 percentile being Class I, those with energy efficiency falling between 26 and 75 percentile being Class II, and the rest above 75 percentile being Class III. Each of building systems again the AC subsystems is plotted to establish the cumulative percentage benchmark curves. Since the system energy saving target is set as the corresponding system average of Class I by this system-level benchmark approach, the average energy efficiency of Class I is defined as the independent value when the cumulative percentage being 12.5% on the benchmark curve of the building systems.

After substituting 12.5 as the dependent value, the corresponding class I average energy efficiency of building system or CAC subsystem can be calculated as follows in Table 2. And the corresponding uncertainty (CVRMSE) of AC system, lighting, ventilation, transportation and office equipment is 14.93%, 12.60%, 16.26%, 17.61% and 12.07%, respectively.

Table 2 the average energy efficiency of each building system

	TBAC EE (kwh/m2/year)	**TBL EE $_{ex\ cpa}$ (kwh/m2/year)**	**TBV EE $_{ex\ cpa}$ (kwh/m2/year)**	**TBT EE $_{ex\ cpa}$ (kwh/m2/year)**	**TBOEEA EE (kwh/m2/year)**
Average of Class I	90.55	19.24	1.38	8.59	37.93

2. Background of regression correlation approach

The criterion used to select the most appropriate regression model is to maximize the goodness of fit using the simplest mode or combination of models [15]. It is believed that the coefficient of determination (R^2) is the major measure to evaluate the goodness of fit of the model and p-value is to test the significance of the parameter. The value of R^2 is defined as the coefficient of determination measuring the proportion of variation in Y that is explained by the independent variable X in the regression model. Only the correlation regressions with R^2 being above 0.8 are accepted in this study, providing a nice measure of goodness of fit between the regression line and observed data points. The p-value is the probability of obtaining a test statistic equal to or more extreme than the result obtained from the sample data, given that the null hypothesis is true [16]. Here in this study the 95% confidence level is applied so only if the p-value is less than 0.05, the parameter is a significant one. The regression correlation equations are given one by one and the corresponding regression curves are neglected in the following section.

i.) TBAC EE vs. TBEE $_{ex\ cpa}$

$$TBAC\ EE = 0.9554 * TBEE_{ex\ cpa} - 48.904 \qquad \text{Eqn (7)}$$

The range of TBEE $_{ex\ cpa}$ is from 143.52 to 356.17 kWh/m2/year. The p-value of TBEE $_{ex\ cpa}$ is only 3.74E-07, which means TBEE $_{ex\ cpa}$ is statistically very significant. Meanwhile R^2 is very high being 0.8714 which means the population regression line fits the observed data points well. Following the correlation equation 7, the target TBEE $_{ex\ cpa}$ is substituted and the total building air conditioning system energy efficiency is predicted. In addition, considering the uncertainty, S is equal to 22.49 and CVRMSE is 14.44%. Because of the interaction between TBOEEA EE and TBAC EE, the overall uncertainty U is 24.98%.

ii.) %TBOEEA EC $_{ex\ cpa}$ vs. TBEE $_{ex\ cpa}$

$$\%TBOEEA\ EC_{ex\ cpa} = -0.2356 * TBEE_{ex\ cpa} + 75.71 \qquad \text{Eqn (8)}$$

The range of TBEE $_{ex\ cpa}$ is from 147.71 to 284.69 kWh/m2/year. The p-value of TBEE $_{ex\ cpa}$ is only 3.68E-05, which means TBEE $_{ex\ cpa}$ is statistically quite significant.

After combining equation 8 with the definition equation of *%TBOEEA EC* $_{ex\ cpa}$, the new equation is generated as follows:

$$TBOEEA\ EE = TBEC_{ex\ cpa} * (-0.2356 * TBEE_{ex\ cpa} + 75.71) / (100 * GLA) \qquad \text{Eqn (9)}$$

Following this final equation, the target TBEE $_{ex\ cpa}$ and TBEC $_{ex\ cpa}$ are substituted and the TBOEEA EE is calculated. The CVRMSE of TBOEEA EE is 20.38% and considering the sampling error, the overall uncertainty U is equal to 20.48%

iii.) % (TBV EC+TBT EC+TBL EC) $_{ex\ cpa}$ vs. TBEE $_{ex\ cpa}$

$$\%\ (TBV\ EC+TBT\ EC+TBL\ EC)_{ex\ cpa} = 0.0008 * TBEE^2_{ex\ cpa} - 0.5928 * TBEE_{ex\ cpa} + 121.57 \qquad \text{Eqn (10)}$$

The range of TBEE $_{ex\ cpa}$ is from 143.52 to 356.17 kWh/m2/year. Since it is a quadratic regression, both the p-value of $TBEE^2_{ex\ cpa}$ and TBEE $_{ex\ cpa}$ are both examined, being less than 0.05, which implies the statistical significance.
Combining equation 10 with the definition equation of *% (TBV EC+TBT EC+TBL EC)*$_{ex\ cpa}$, it is generated below:

$$(TBV\ EE + TBT\ EE + TBL\ EE)_{ex\ cpa} = TBEC_{ex\ cpa} * (0.0008*TBEE^2_{ex\ cpa} - 0.5928*TBEE_{ex\ cpa} + 121.57)/(100*GFA_{ex\ cpa}) \quad \text{Eqn (11)}$$

Following this final equation 11, the target TBEE $_{ex\ cpa}$ and TBEC $_{ex\ cpa}$ are substituted and consequently the predicted overall energy efficiency of lighting, ventilation and transportation system can be obtained. Taking % (TBV EC+TBT EC+TBL EC) $_{ex\ cpa}$ as a whole, n=15, p=3, so S=5.80; CVRMSE=15.96%

iv). TBAC EE + TBL EE $_{ex\ cpa}$ vs. TBEE $_{ex\ cpa}$

$$TBAC\ EE + TBL\ EE_{ex\ cpa} = 1.0335*TBEE_{ex\ cpa} - 37.507 \quad \text{Eqn (12)}$$

The range of TBEE $_{ex\ cpa}$ is from 143.52 to 356.17 kWh/m2/year. The p-value of TBEE $_{ex\ cpa}$ is only 2.21E-07, which means TBEE $_{ex\ cpa}$ is statistically very significant. It is obvious to generate the equation as shown below:

$$TBL\ EE_{ex\ cpa} = 1.0335*TBEE_{ex\ cpa} - 37.507 - TBAC\ EE \quad \text{Eqn (13)}$$

Following this correlation equation, the target TBEE $_{ex\ cpa}$ and previously calculated TBAC EE are substituted and consequently comes out the predicted total building lighting system energy efficiency. Taking TBAC EE and TBL EE $_{ex\ cpa}$ as a whole, S is 23.24 while CVRMSE is 12.64%. The individual uncertainty for TBL EE $_{ex\ cpa}$ U=v24.98^2+12.64^2% = 27.99%

v. TBAC EE + TBV EE $_{ex\ cpa}$ vs. TBEE $_{ex\ cpa}$

$$TBAC\ EE + TBV\ EE_{ex\ cpa} = 0.9108*TBEE_{ex\ cpa} - 32.351 \quad \text{Eqn (14)}$$

The range of TBEE $_{ex\ cpa}$ is from 143.52 to 356.17 kWh/m2/year. The p-value of TBEE $_{ex\ cpa}$ is only 1.4E-06, which means TBEE $_{ex\ cpa}$ is fairly statistically significant. Then,

$$TBV\ EE_{ex\ cpa} = 0.9108*TBEE_{ex\ cpa} - 32.351 - TBAC\ EE \quad \text{Eqn (15)}$$

Following the similar procedures of TBL EE $_{ex\ cpa}$, the individual uncertainty for TBV EE $_{ex\ cpa}$ U=v24.98^2+14.81^2% = 29.04%

vi. TBAC EE + TBT EE $_{ex\ cpa}$ vs. TBEE $_{ex\ cpa}$

$$TBAC\ EE + TBT\ EE_{ex\ cpa} = 0.8302*TBEE_{ex\ cpa} - 27.456 \quad \text{Eqn (16)}$$

The range of TBEE $_{ex\ cpa}$ is from 143.52 to 356.17 kWh/m2/year. The p-value of TBEE $_{ex\ cpa}$ is only 2.32E-07, which means TBEE $_{ex\ cpa}$ is quite statistically significant. The correlation equation is derived as follows::

$$TBT\ EE_{ex\ cpa} = 0.8302*TBEE_{ex\ cpa} - 27.456 - TBAC\ EE \quad \text{Eqn (17)}$$

Following the similar procedures of TBL EE $_{ex\ cpa}$, the individual uncertainty for TBV EE $_{ex\ cpa}$ U=v24.98^2+12.23^2% = 27.81%
The overall uncertainty of the predicted total building energy consumption by method 1, 2 and 3 of approach II is 32.3%, 36.02% and 39.8%, respectively after applying equation 6.

3. The overall comparison between results of Approach I and II of the case buildings

Here in the case study three buildings in Class II and one in Class III are chosen for detailed analysis. They are named as Building B, E, K and N. The reason why only Class II and III buildings are selected, not the ones in Class I, is that Class I buildings are currently so energy-efficient that they are taken as good models for the industry. But since the rapid development of building technology, if there is no change in the energy performance themselves, the Class I buildings may be left behind and be in need of retrofit in the future. Obviously, there is much more energy saving potential in Class II and Class III buildings.

The basic physical background information of these four buildings is first listed in the following Table 3.

Table 3 the basic physical background information of this building

		TBAC EE (kwh/m^2/yr)	TBL EE $_{ex\ cpa}$ (kwh/m^2/yr)	TBV EE $_{ex\ cpa}$ (kwh/m^2/yr)	TBT EE $_{ex\ cpa}$ (kwh/m^2/yr)	TBOEEA EE (kwh/m^2/yr)	TBEE $_{ex\ cpa}$ (kwh/m^2/yr)
Building K	Measured value	178.6	25.69	3.39	9.02	85.24	235.71
	Benchmark approach	90.55	19.24	1.38	8.59	85.24	159.14
	Saving potential	88.05	6.45	2.01	0.43	0	76.57
	Correlation approach	98.51	13.29	1.75	4.66	85.24	155.08
	Saving potential	80.09	12.40	1.64	4.36	0	80.63
	Absolute difference	7.96	-5.95	0.37	-3.92	0	-4.06
	Relative difference (%)	4.46%	-23.18%	10.94%	-43.51%	0.00%	-1.72%
Building N	Measured value	171.51	28.72	3.83	31.91	26.92	260.02
	Benchmark approach	90.55	19.24	1.38	8.59	26.92	137.56
	Saving potential	80.96	6.99	2.45	23.32	0	122.46
	Method 1 of Approach II	86.59	18.16	2.42	20.18	26.92	155.08
	Saving potential	84.92	10.56	1.41	11.73	0	104.94
	Method 2 of Approach II	86.59	28.16	3.75	31.29	26.92	175.99
	Saving potential	84.92	0.56	0.08	0.62	0	84.03
	Absolute difference of method 1	-3.96	-3.57	1.04	11.59	0	17.51
	Relative difference of method 1 (%)	-2.31%	-12.43%	27.17%	36.32%	0.00%	6.74%
	Absolute difference of method 2	-3.96	6.43	2.37	22.70	0	38.43
	Relative difference of method 2 (%)	-2.31%	22.38%	61.97%	71.13%	0.00%	14.78%
Building E	Measured value	111.53	20.43	0	26.44	76.89	181.96
	Benchmark approach	90.55	19.24	0.00	8.59	76.89	149.17
	Saving potential	20.98	1.19	0.00	17.85	0	32.79
	Method 1 of Approach II	97.13	14.15	0.00	14.82	76.89	155.08
	Saving potential	14.40	11.10	0.00	11.62	0	26.88
	Absolute difference of method 1	6.58	-9.92	0.00	6.23	0	5.90
	Relative difference of method 1 (%)	5.90%	-39.27%	0.00%	23.57%	0.00%	3.25%
Building B	Measured value	208.27	38.2	3.46	13.35	35.82	287.24
	Benchmark approach	90.55	19.24	1.38	8.59	35.82	142.82
	Saving potential	117.72	18.96	2.08	4.76	0	144.42
	Correlation approach	86.85	31.13	2.82	10.88	35.82	155.08
	Saving potential	121.42	7.07	0.64	2.47	0	132.16
	Absolute difference	-3.70	11.89	1.44	2.29	0	12.25
	Relative difference (%)	-1.77%	31.13%	41.59%	17.17%	0.00%	4.27%

After applying approach I and II to the four case buildings, the calculated building systems' energy efficiency by two approaches and the comparative differences are as shown in Table 4.

Table 4 Summary of the system energy efficiency by system benchmark approach and correlation approach

	$TBEC_{ex\ cpa}$ (MWh)	**$TBEE_{ex\ cpa}$ (kWh/m2/yr)**	**OHF**	**OR**	**$GFA_{ex\ cpa}$ (m^2)**	**GLA (m^2)**	**ACA (m^2)**
Building K (Class II)	11,351.2	235.71	0.927	100%	51,312.6	33,353.3	36,688.7
Building N (Class II)	3,409.1	260.02	1.012	80%	15,724.0	12,268.4	12,268.4
Building E (Class II)	6,236.4	181.96	0.974	100%	33,400	25,000	25,000
Building B (Class III)	5,064.6	284.69	1.017	100%	18,089.1	12,016	17,472.7

If the energy retrofitting in building K is undertaken as proposed above, it may be transformed from Class II to Class I building by two approaches (TBEE < 176 kWh/m^2/year). By system-level benchmark approach, the total building energy saving potential is 3,686.8 MWh/year (by 32.48%) and the ultimate total energy efficiency is 159.14 kWh/m^2/year with the uncertainty of 33.4%. By regression approach, the building energy saving potential is 3,883.1 MWh/year (by 34.21%) and the ultimate total energy efficiency is 155.08 kWh/m^2/year with the uncertainty of 32.3%. The final results by these two approaches don't vary much. The most significant difference between the results of the benchmark approach and the correlation approach lies in the transportation systems' energy efficiency. This may be due to the measured TBT EE $_{ex\ cpa}$ of this building is very high. The overall final result of building E and B is very similar to that of building K except that $TBEE_{ex\ cpa}$ of building E by approach I is slightly less than that of method 1 of approach II and $TBEE_{ex\ cpa}$ of building B is a bit smaller than that of approach II. The most significant difference in the results of these two approaches lies in AC system of building E and exists in the lighting system of building B. In addition, the overall uncertainty of the adopted methods in calculating TBEE are very close.

In building N, if the energy retrofitting is undertaken by system-level benchmark approach or by the two methods of correlation approach as proposed above, it will transfer to Class I building as expected. The final results by these three approaches are at about 20 kWh/m^2/year interval in terms of the final total building energy efficiency. So the relative difference is the biggest among the four buildings. The difference between approach I and method 1 of approach II mainly occurs in the transportation system. Additionally, because the targets of lighting, ventilation and transportation energy efficiency are close to that of the measured data by method 2 of approach II, the difference between this method and the other two is very huge in these three systems.

In summary, the final situation of building K, E and B are straightforward, since only approach I and method 1 of approach II are adopted. It is much more complicated for the case building N with the adoption of approach I and two methods of approach II. However, all of the four buildings are promoted to Class I buildings as planned by all means. Considering the corresponding uncertainty of each method, all the methods discussed above are doable for office building energy saving analysis in Singapore.

Verification and validation analysis

In this section, in order to verify the accuracy of the energy saving potential model developed, the calculated results are compared with results obtained using physical simulation model. The simulation program VisualDOE 4.0 is utilized in this study. The VisualDOE was originally developed by Lawrence Berkeley Laboratory (LBL) in the US. According to the literature review, it is well-recognized for applications with commercial building energy simulation and for performing energy saving analysis in both academic studies and industries.

Among the four buildings used for the case study, the building B which is a typical public office building with single function, and the building N which is a typical private sector office building cum retail are chosen for simulation to carry out the validation of the predictive model. In addition, for both the two selected buildings, the author was fortunate to be given relatively complete information data such as the building drawings, pictures, systems' operation schedules and parameters etc., making them best suited for the application of VisualDOE.

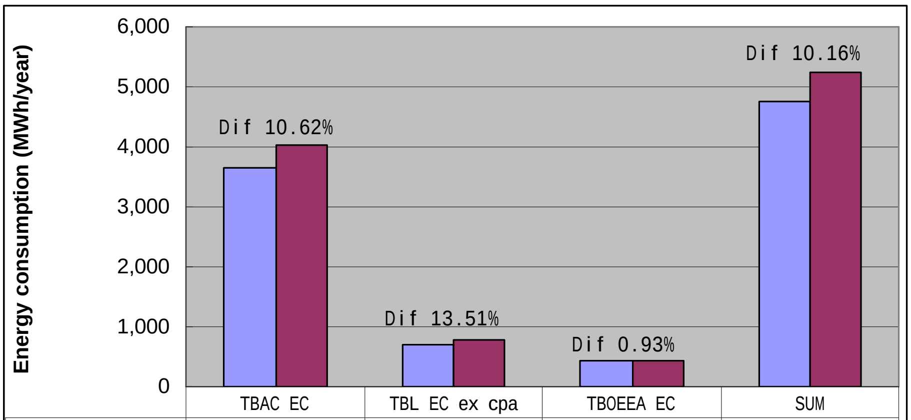
The basic building background of building B and N is described in the above sections. These include the building area, age, occupancy rate and operation hours, and so on. However, more detailed information needs to be clarified before setting up the simulation model. First the simulation of the base case is conducted to compare the simulated result and the actual building energy consumption to calibrate the simulation model. If the difference is within the acceptable range, the simulation model is regarded as being well established and representative of the original building which can be used to validate the energy saving potential model. The assumed parameters after retrofit are then used as input and the simulation program is run again to obtain simulation results which are checked against the calculated results using the two approaches. If the difference is within the acceptable range, the predictive models for estimating building energy saving potential are verified.

The car park floor area is omitted in the simulation because it is unconditioned space only provided with mechanical ventilation and lighting which normally takes a small percentage of the total building energy consumption. In addition, the car park energy consumption is not taken into the analysis of energy saving potential model. In consequence, the building without considering the car park area is simulated. On the other hand, the transportation system can not be simulated by the software of VisualDOE because of its own limitations. And the ventilation system is excluded from the simulation since its energy consumption just takes about 3% of the total building. As a result, only the air conditioning system, lighting and office equipment of building without car park area is simulated in this study. The energy consumption of three systems takes up nearly 90% of the total building energy consumption in the fifteen buildings studied. The simulation of these three systems can represent the whole picture of the building energy performance.

1. Calibration of base building model

According to the characteristics data of buildings B, and N and the Singapore reference building [17], the base building model is set up by inputting parameter and defining the setting template, project information, the properties of blocks, rooms and zones, façade and windows, HVAC system and central plant accordingly. For more details on the information and procedures involved in using VisualDOE 4.0, the VisualDOE 4.0 user manual (2004) can be referred to.

The actual electrical consumption of building B is 5064.6 MWh/yr and the equivalent space considered for the simulation for the simulation model, which is about 94% of the actual electrical usage is 4760.5 MWh/yr. It is quite desirable to use numerical comparisons as well as graphical comparisons to determine when a simulation is adequately calibrated. The annual electrical energy consumption and the various systems between the actual building and the simulated buildings is shown in Figure 4.

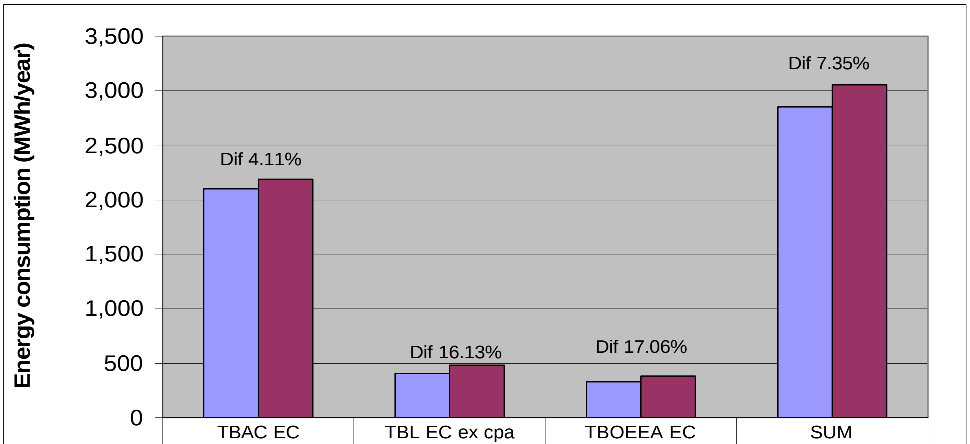


	TBAC EC	TBL EC ex cpa	TBOEEA EC	SUM
Actual Building	3,639,049	690,987	430,465	4,760,502
Base Building	4,025,366	784,337	434,488	5,244,191

Figure 4 Comparison of system energy consumption of simulated buildings and that of the actual building of building B

It is also observed from Figure 4 that the difference between the simulated model and actual energy consumption of AC system and lighting system appeared to be great at about 10.6% and 13.5% respectively. On the other hand, the energy consumption of the equipment of the base building and the actual building differs rather slightly at 0.93%. Upon comparison, the total energy consumption of the base building and the actual building differs by about 10.2%. ASHRAE 1997 had recommended an acceptable difference between simulated and actual energy usage for large existing commercial buildings to be within 10%. Hence in this case, the difference is considered fairly acceptable.
As for building N, the actual electrical consumption is 3409.1 MWh/yr and the equivalent space considered for the simulation for the simulation model, which is about 83.5% of the actual electrical usage is 2847 MWh/yr. The annual electrical energy consumption and the various systems between the actual building and the simulated buildings are shown in Figure 5.

It is also observed from Figure 5 that the difference between the simulated base building model and actual energy consumption of office equipment and lighting system appeared to be great at about 17% and 16% respectively. On the other hand, the energy consumption of AC system of the base building and the actual building differs rather slightly at 4.11%. Upon comparison, the total energy consumption of the base building and the actual building differs by about 7.35% which is within the acceptable range mentioned above. Hence in this case, the difference is considered very acceptable.



	TBAC EC	TBL EC ex cpa	TBOEEA EC	SUM
Actual Building	2,104,180.9	412,468.8	330,367.2	2,847,016.8
Base Building	2,190,632	478,992	386,735	3,056,359

Figure 5 Comparison of system energy consumption of simulated buildings and that of the actual building of building N

2. Validation of energy saving potential predictive model

When using a calibrated simulation model to investigate ECMs, it is very important to disaggregate the energy consumption by end uses. This will provide the energy auditor with a valuable and powerful tool for identifying promising, building specific ECMs. The possible ECMs can then be prioritized based on those impacting end uses with maximum consumption relative to good practice. The potential savings of ECMs may then be evaluated using the calibrated simulation model, with confidence that construction and implementation will result in savings similar to those simulated. The interactions of multiple ECMs can also be accurately determined.

In this validation process, over a dozen of simulations are conducted based on the building B and building N with different types of retrofit option in terms of different parameters input of the AC system, façade and windows to analyze and to determine the impact of the different retrofit options on the energy consumption of the building, according to the building management and energy conservation measures, such as resizing the chiller, using variable frequency fan and pump, adding external shading devices, using different glazing and daylight controls and the combinations of glazing coupled with daylight control and resize of air conditioning system, etc..

After comparing the simulation results of different input parameters, the results derived from the simulation through combination of shading coupled with daylight control and resize of air conditioning system yielded the closest results with the system benchmark approach and correlation approach with the relative difference of the sum being about 6% and 0.3%, and AC system and office equipment being less than 5%, respectively (see Table 5 and Figure 6). This indicates that the proposed methods of system benchmark approach and correlation approach presented above agree well with the energy saving simulation of building B.

Table 5 Summary of the system energy consumption of predictive model and simulation of building B

	TBAC EC (kwh/year)	**TBL EC $_{ex\ cpa}$ (kwh/year)**	**TBOEEA EC (kwh/year)**	**SUM (kwh/year)**
Benchmark Approach	1,582,094	348,022	430,413	2,360,529
Correlation Approach	1,517,509	563,112	430,413	2,511,034
Simulation	1,590,001	483,087	429,421	2,502,509
Absolute Dif with Benchmark Approach	7,907	135,065	-992	141,980
Relative Dif with Benchmark Approach (%)	0.50%	38.81%	-0.23%	6.01%
Absolute Dif with Correlation Approach	72,492	-80,025	-992	-8,525
Relative Dif with Correlation Approach (%)	4.78%	-14.21%	-0.23%	-0.34%

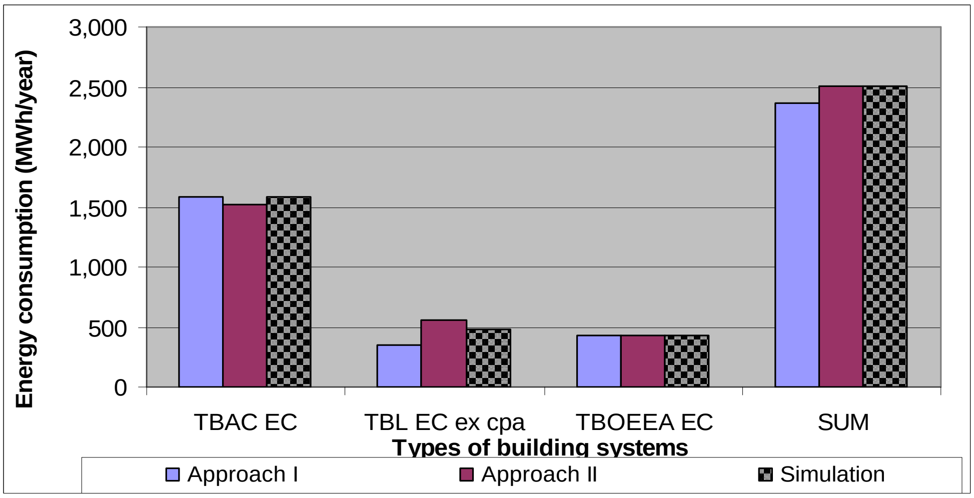


Figure 6 Comparison of energy consumption of simulated building and the estimation of energy saving predictive model by system-benchmark approach and correlation regression approach of building B

On the other hand, the resulted saving derived from the simulation method for the combination of daylight control coupled with variable frequency fan and pumps appeared to be closest to the results of the system benchmark approach and the correlation approach with the relative difference of about 8.9%, 13.2% and 3.5%, respectively (see Table 6 and Figure 7). This indicates that the proposed methods of system benchmark approach and correlation approach method 2 presented in the previous section agreed well with the energy saving simulation of building N while the correlation approach method 1 is not as good as expected. It may due to the calculated system energy efficiency of correlation regression approach method 1 is too high, esp. in the lighting system.

Table 6 Summary of the system energy consumption of predictive model and simulation of building N

	TBAC EC (kwh/year)	**TBL EC $_{ex\ cpa}$ (kwh/year)**	**TBOEEA EC (kwh/year)**	**SUM (kwh/year)**
Benchmark Approach	1,110,862	302,519	330,265	1,743,646
Correlation Approach Method 1	1,062,314	285,539	330,265	1,678,118
Correlation Approach Method 1	1,062,314	442,746	330,265	1,835,325
Simulation	1,143,265	369,278	386,735	1,899,278
Absolute Difference with Benchmark Approach	32,403	66,759	56,470	155,632
Relative Difference with Benchmark Approach	2.92%	22.07%	17.10%	8.93%
Absolute Difference with Correlation Approach Method 1	80,951	83,739	56,470	221,160
Relative Difference with Correlation Approach Method 1	7.62%	29.33%	17.10%	13.18%
Absolute Difference with Correlation Approach Method 2	80,951	-73,468	56,470	63,953
Relative Difference with Correlation Approach Method 2	7.62%	-16.59%	17.10%	3.48%

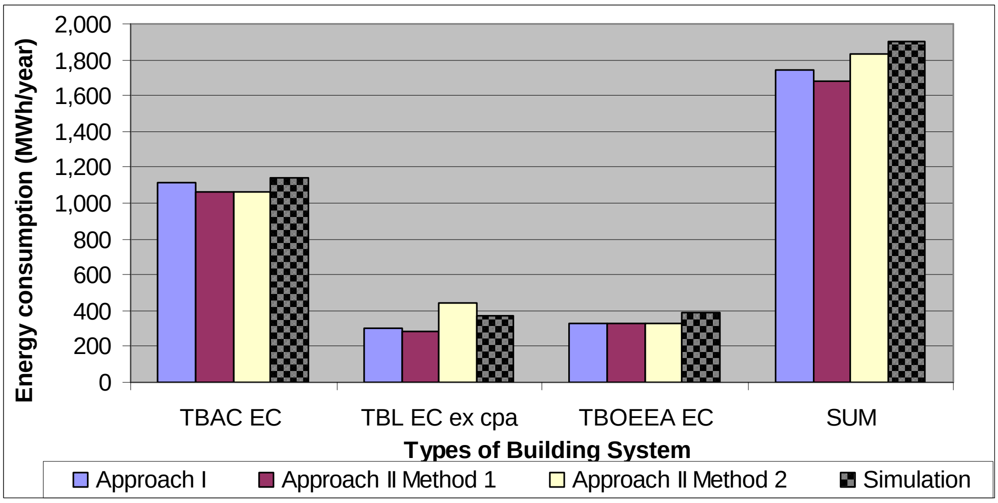


Figure 7 Comparison of energy consumption of simulated building and the estimation of energy saving predictive model by system-benchmark approach and correlation regression approach of building N

The calibrated simulation building models accurately evaluate the potential savings resulted from ECMs implemented in these buildings and the simulation results agree with the quantification of the energy savings potential accurately. The calibration process developed and presented in this paper can be used to project the savings from retrofit measures and then used as in the savings determination process. These two building simulations demonstrate a high degree of confidence in the calculated estimation results of energy saving predictive model by system-benchmark approach and correlation regression approach which can validate the accuracy and feasibility of the two approaches. As a result, this system-level benchmark approach and correlation regression approach can be considered as a simplified and realistic way of office building energy saving potential analysis in Singapore.

Conclusion

In this study, the system-level benchmark approach gives an easy preliminary to estimate of office buildings' energy saving potential within the total building system and air conditioning sub-systems individually. The interaction between different building energy consuming systems is not taken into consideration to simplify the calculation procedures. The regression correlation approach is established based on the good regression relationship between performance of building energy consuming systems and TBEE $_{ex\ cpa}$ with R^2 over 0.8. The adoption of the three methods to calculate the energy efficiency of lighting, ventilation and transportation system is quite different in the four case buildings due to the consideration on the corresponding uncertainty and comparison with the building measured data. In most cases, the residue model is applied. Meanwhile, the percentage regression model is adopted for one out of the four buildings. The uncertainty of all the adopted methods is very close, which is over 30%.

In the last part of this paper, the validation of the energy saving potential predictive model by two approaches is conducted by means of energy simulations of two buildings. The simulation results further verify the correctness of the energy saving potential predictive model. The study results show that all the case buildings can be improved to the high-level energy efficiency buildings through these two approaches and the saving percentage is from 20% to 40%, respectively.

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Energy efficient office buildings – Results and Experiences from a Research and Demonstration Programme in Germany

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Abstract
To gain access to the energy use in office buildings, the German Federal Ministry for Economy 1995 launched an intensive research and demonstration programme. In advance of the 2002 EU energy performance directive EBPD a limited primary energy coefficient of 100 kWh/m^{2}a was postulated as a goal for the complete building services technology (HVAC + lighting) for all demonstration buildings to be supported. Further condition was that active cooling has to be avoided. Techniques like natural or mechanical night ventilation or heat removal by slap cooling with vertical ground pipes were applied as well as earth-to-air heat exchangers in the ventilation system. An accompanying research was established to keep track of the results and lessons learned from about 23 demonstration buildings realized and monitored until end of 2005. As one outcome this paper summarizes the energy performance of a selection of characteristic buildings together with an overview on the summer thermal comfort situations achieved. The work will proceed during the next five years. Future results can be downloaded from the Website: www.enbau-monitor.de.

1. Introduction

1.1 Energy Use in Office Buildings
Numerous office buildings of the eighties were designed to isolate the internal conditions from the outdoor climate as completely as possible, at the cost of high energy consumption. Thermal and visual comfort as well as the air quality is guaranteed by extensive technical building services for heating, ventilation, air-conditioning and lighting (HVACL). High investment and running costs are accepted to ensure that it can control even extreme indoor conditions caused by generously glazed building envelopes. In combination with the space demand of wiring for communications technology of that time - double floors, suspended ceilings - it is quite common for technical services to occupy 20 to 30 % of the building volume . The main share of the electricity consumption is due to the HVACL facilities, not the office equipment.

Despite the heat generation associated with electricity consumption within the building (internal heat gains), the space heating demand in Mid and North European Climate is still dominating the over all energy figure due to the high proportion of glazing and the high air exchange rates. Fig. 1a gives a qualitative impression of a typical energy consumption profile as a function of the outdoor temperature, the so called ET- diagram. In addition to a base energy load which is independent of the weather, there is a contribution for heating and humidifying below the balance temperature, and for cooling and dehumidifying above it. The balance temperature is defined by the outdoor temperature at which thermal losses are balanced by the internal and solar gains. The base load is mainly caused by office equipment and the idling consumption of building services technology. The waste heat associated with the base load affects the position of the balance temperature. The higher the base load, the lower is the balance temperature. Due to the decoupling of the room air from the building mass - suspended ceilings, double floors, lightweight walls - and the maintenance of constant indoor conditions throughout the whole year, there are hardly any days when there is neither active heating nor cooling.

1.2 Thermal Comfort and Health

The diverse technical approaches to achieve a good indoor climate were often accompanied by complaints from office workers about many types of discomfort and dissatisfaction, which are summarised as the "Sick Building Syndrome". One German investigation of this phenomenon, the so-called "ProClima-Project" (Bischoff, 2003), reaches the conclusion that although buildings with air conditioning maintain an objectively good indoor climate, they are subjectively rated lower than naturally ventilated working conditions by the majority of persons questioned. The rating is significantly affected by

- the magnitude which an individual person can determine the conditions prevailing at his workplace and
- the degree of maintenance of the technical service systems.

Today an increasing fraction of office buildings are being constructed or retrofitted which allow individuals to control their own indoor climate to a large extent, and which replace almost complete isolation from the weather outdoors by a moderate interaction. Daylit workplaces and the option for natural ventilation are typical characteristics. However, a combination of integrated measures to achieve so-called "passive cooling" is a pre-requisite if summer comfort is to be ensured without actively cooling or dehumidifying the inlet air. This type of concept became known as "lean building", due to the smaller volume of the service equipment required. The task is to design buildings such that even when the weather outdoors varies greatly, the indoor conditions remain within a well-defined comfort *zone*, which meets the expectations of the occupants, Fig. 1b. The comfort zone is exceeded only for periods of extreme outdoor temperatures. The maximum acceptable number of working hours with temperatures above the comfort zone has to be discussed on the basis of simulation results in the early design phase of a building and checked against legal standards.

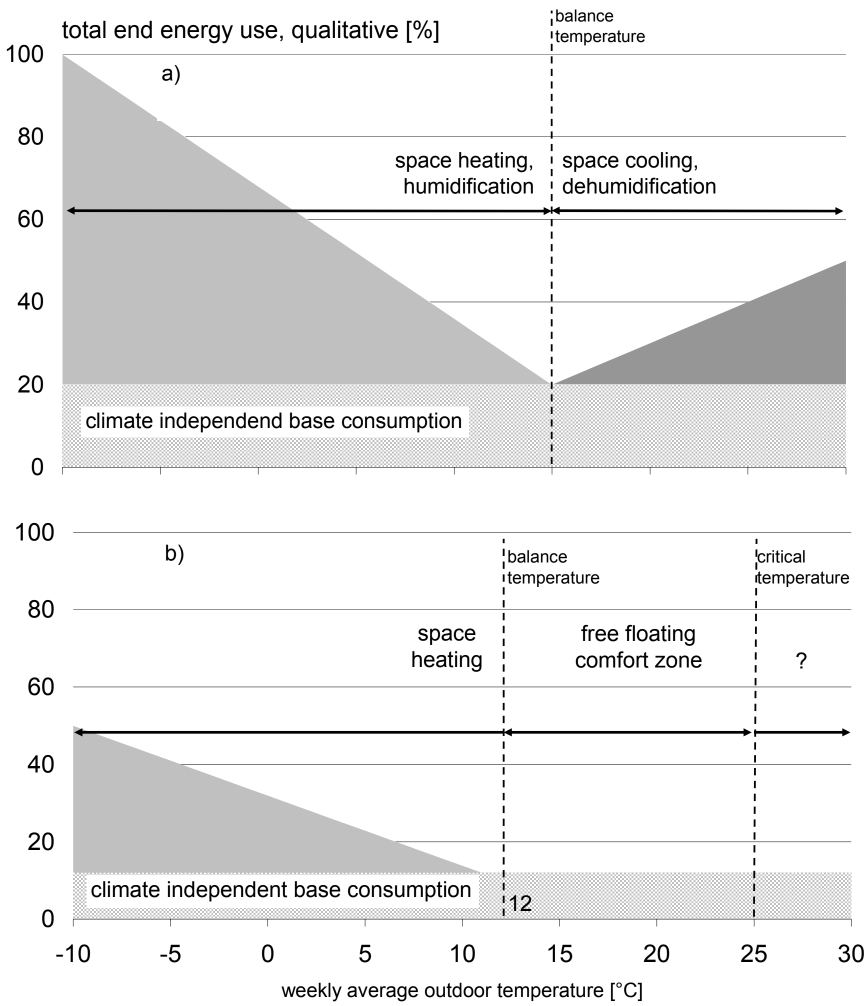


Fig. 1: Qualitative profile of the energy consumption of a “conventional building” (a) compared to a "lean building" (b), the so-called ET-diagram.

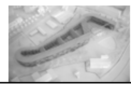
2. Results and Experiences

2.1 Energy Monitoring

Table 1 gives an overview of the projects monitored and the passive cooling concepts applied. Detailed information together with a comprehensive overview on results and experiences are presented in (Voss et al., 2005). Additional information is available via internet (www.enbau-monitor.de).

Tab. 1: Demonstration projects monitored and the passive cooling concepts applied.

Building	monitoring team	Net heated area [m²]	U_{mean} [W/m²K]	Aperture area / net heated area [m²/m²]	Night ventilation	Earth to air heat exchanger	Slab cooling	Ground pillars	
ECOTEC	University Bremen	2,941	0.54	0.13	X				
Wagner	University Marburg	1,948	0.21	0.25	X	X			
Hübner	University Hannover	2,122	0.32	0.18	X	X			
FhG ISE	Applied University Biberach, Fraunhofer ISE	13.150	0.43	0.21	X	X			
DB Netz	Technical University Karlsruhe	5,974	0.57	0.24	X	X			
FH BRS	University Dortmund	26,987	0.42	0.34	X	X			
GIT	University Siegen	3,243	0.36	0.27	X	X			
Lamparter	Applied University Stuttgart	1,000	0.30	0.28	X	X			
NIZ	Technical University Braunschweig	8,570	0.63	0.20	X				
Surtec	University Darmstadt, Passive House Institute	4,423	0.27	0.34	X	X			
ZUB	University Kassel	1,732	0.32	0.21		X	X		
Pollmeier	ZUB	3,510	0.29	0.33	X				
Solvis	Applied University Braunschweig-Wolfenbüttel	8,215	0.61	0.17	X				

Building	monitoring team	Net heated area [m²]	U_{mean} [W/m²K]	Aperture area / net heated area [m²/m²]	Night ventilation	Earth to air heat exchanger	Slab cooling	Ground pillars	
KfW	Technical University Karlsruhe	8,585	0.54	0.15	X				
Energie-forum	Technical University Braunschweig	20,693	0.69	0.17	X			X	
Energon	Applied University Ulm	6,911	-	0.23			X	X	
TMZ	Applied University Erfurt	8,976	-	0.42			X		
BOB	Applied University Cologne	2,072	0.48	0.25			X	X	
GMS	Applied University Biberach	10,650	0.43	0.24			X		
Lebenshilf e	Technical University Munich	4,623	0.38	0.24	X		X		
UBA	Technical University Cottbus	32.384	-		X	X			
SIC	Applied University Offenburg	13,833	0.74	0.23	X			X	

Data are presented for end and primary energy use respectively, taking into account the energy conversion factors for the specific conditions of Germany as given with a national standard (DIN 4701-10, 2001). Using the primary energy factor concept allows the comparison of the building's energy consumption and to rate the energy supply in terms CO_2 emissions.

Figure 2 summarises the monitoring results from buildings for which data from at least one year were available. We have chosen to present the information as a graph rather than numerically, as the boundary from HVACL to user-specific electricity consumption (PC, printers etc.) was difficult to define in some cases. This could cause quantitative but not qualitative changes to the results. Particularly for separating the electricity use for the type of energy service (e.g. electricity for lighting and for computer operation) requires a very detailed and expensive metering concept. It is not common to allocate the electric circuits within a building according to the equipment connected to them. In many cases, detailed analysis of the electricity consumption helped to identify weaknesses in system operation and aid their correction.

In order to separate the effects of reduced energy use and energy efficient energy supply, in case of CHP and photovoltaic to the primary energy balance were shown separately.

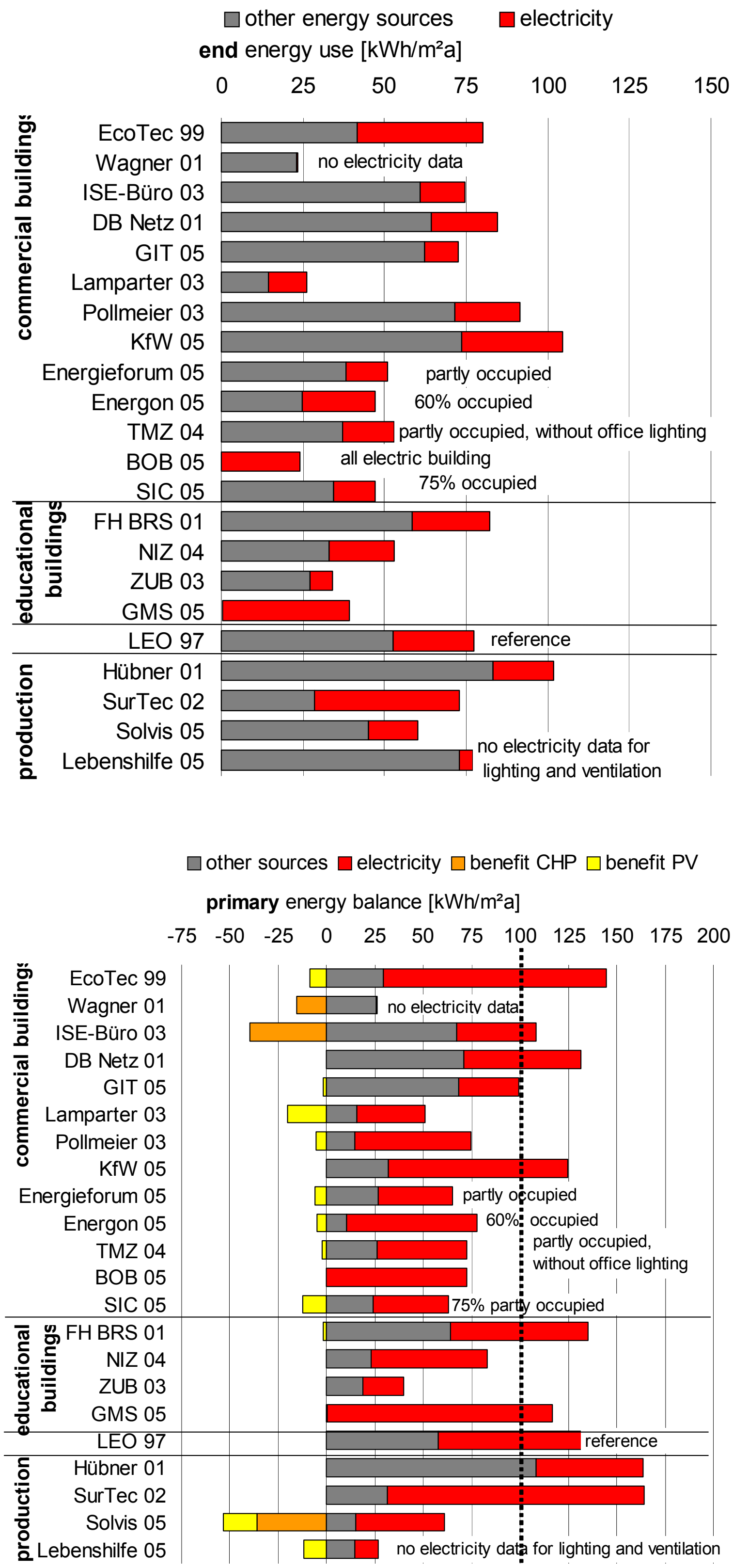


Fig. 2: Measured end energy (upper diagram) and primary energy coefficients derived from them (lower diagram).

All data refer to the heated net floor area. Data are collected from the monitoring institutions according to tab. 1. The primary energy factors and electricity credits are based on German DIN 4701 (DIN 4710, 2001): Electricity 3, fossil fuels 1.1, biomass 0.2.

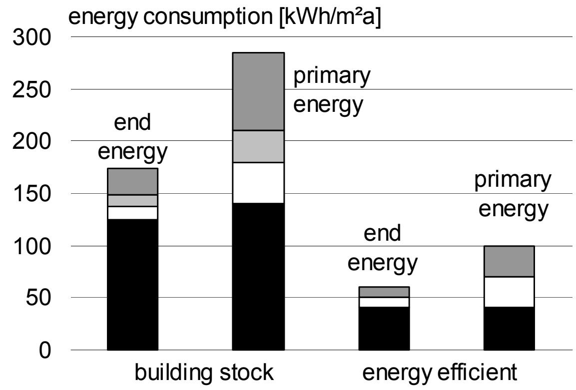
To simplify the balancing procedure, photovoltaic electricity (PV) was evaluated with the same electricity credit as for combined heat and power plants (CHP). The consumption values refer to HVACL.

The numbers following the project titles indicate the year for the measurements. The data source in each case was the university which was responsible for the measurement programme. In the case of the " ISE-Büro" building, a zone of 525 m^2 consisting purely of offices plus the adjoining access areas was selected from the Institute building with a total area of 14,000 m^2.

Beside the Hübner building the so called “production “ building have a mixed use as office and as workshop or pharmaceutical production.

Nine out of the 14 office and educational buildings presented show primary energy consumption below or close to the required limit of 100 kWh/m^{2}a, five buildings range above this limit. As the end energy use for HVACL in production buildings (workshops, factories) strongly depends on the requirements regarding indoor air quality and internal loads depends strongly on the production process, a fixed primary energy target of 100 was achieved by two of the four evaluated production buildings. It is satisfying to see that the

consumption for all of the buildings is much lower than the comparative values for the building stock according to fig. 3.
Individual design and target values are only available for some of the buildings, as no common methodology for calculation of the energy demand for cooling, ventilation and lighting was used. Heating energy demand was calculated based on the national standard (DIN 4108-6, 1994). Additionally building simulations were performed for most of the buildings. Therefore comparisons with target values are valid only building wise. The limit for primary energy use was exceeded in some cases because of unexpectedly high heating demands (DB, GIT), a high electricity consumption for lighting (FH BRS, Hübner), etc. Some of the causes are due to the building concepts; others could have been avoided by an improved energy management. The Pollmeier building avoided high consumption values for primary energy, despite unexpectedly high heating energy consumption by burning wood off-cuts from its own sawmill, representing a largely CO_2-neutral source. Combined heat and power plants result in a primary energy credit (Wagner, ISE, Solvis), as the measured gas consumption also contributes to electricity generation and thus to substitution of grid electricity. Drawing heat from a district heating network with CHP also proved to be favourable (ECOTEC, ZUB).



lighting	25	75	10	30
cooling	11	30	0	0
ventilation	13	40	10	30
heating	125	140	40	40

Fig. 3-4: Target values for energy efficient office buildings according to the programme compared to end energy use values for office buildings from the existing stock in Mid European climate according to (Weber 2002). The net heated floor area is used as the reference area. End energy was transferred to primary energy by a factor of 3 in the case of electricity and about 1 for all other forms of end energy in order to compare it with typical German situation. **Primary energy use versus building cost.** The primary energy use is more ore less independent from the cost for construction and HVAC equipment

Besides energy saving and thermal use of renewable energy, some of the buildings apply measures such as combined heat and power plants or photovoltaics to generate electricity to be feed into the public grid. This energy subsidies grid electricity to be generated on national average conditions with a mixture of power plants. In case of so called “zero energy buildings“ primary energy credits for the subsidies grid electricity balance the buildings primary energy consumption on a yearly cycle. Three projects (Wagner, Lamparter and Solvis) enter the range of a “zero energy building” by the combined approach of drastically reduced demand and more or less equivalent credits (Fig. 5).

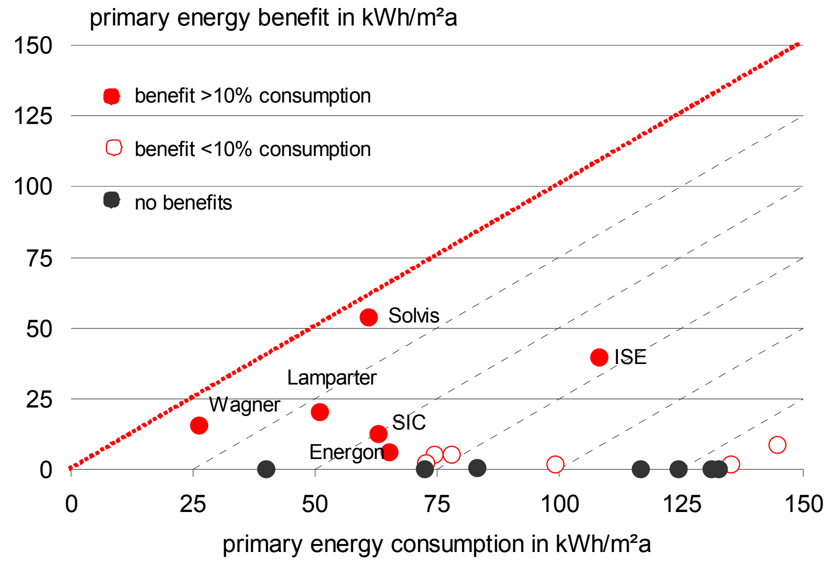


Fig. 5: Primary energy benefit versus primary energy consumption. Dotted lines show buildings with the same primary energy balance. Note: The primary energy consumption of Wagner does not include electricity for HVACL.

2.2 Passive Cooling and Summer Comfort

In order to improve indoor conditions in summer, so-called "passive cooling" concepts were integrated part of each building design in different ways and to a varying extent. Passive cooling means the interaction of all measures which act to reduce the heat gains on the one hand, and on the other, which make natural heat sinks - night air, ground – accessible. So in this paper “passive cooling” includes cooling techniques, which are not using a thermodynamic cycle process. The remaining heat loads are transferred to the surroundings with a certain time delay. Heat storage in the building construction, both during the course of a day and over longer hot periods, is substantial, fig. 6 (Pfafferott, 2004).

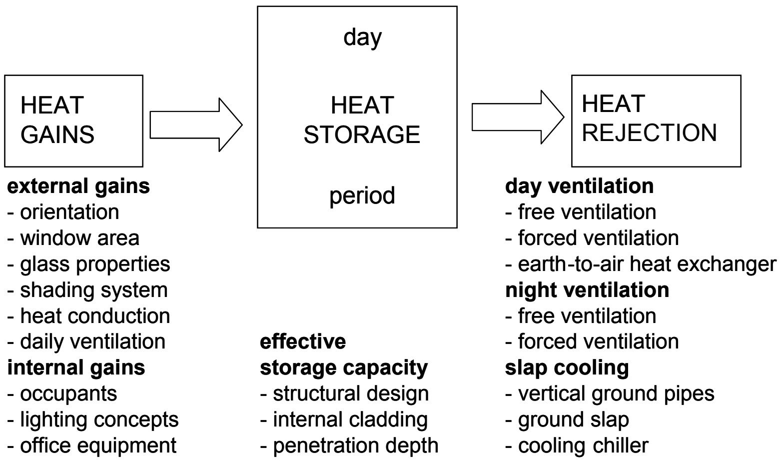


Fig. 6: The principle of passive cooling and main parameters influencing the building energy balance on a daily or longer cycle (period).

In view of the limited cooling capacity and the long time constants, the main design priority is to restrict the amplitude and dynamics of *external heat gains*. For this reason, none of the demonstration buildings includes a fully glazed facade. The average ratio of glazing to façade area was 43 % or 27 % referring to the floor area. Almost all of the buildings use external adjustable sun-shading devices with the only exceptions in the case of buildings with slap cooling systems (enhanced cooling capacity). Experience indicates that the total solar energy transmittance (gtot-value) for the glazing and sun-shading should not exceed 10 to 15 % (Zimmermann 1999). This can be achieved for internal blinds or blinds in the gap between the glass panes only in combination with solar-control glazing (g_{glass}<40 %), or by external blinds and “normal” heat protection glazing. A detailed analysis regarding manual blind use in two buildings (ISE, Lamparter) shows a strong

correlation between solar penetration depth and blind occlusion (Reinhart 2002, Herkel 2005). The external loads in this case was in the order of the internal loads (Pfafferott 2005).
Average daily total *internal heat gains* observed range between 100 and 200 Wh/m². The range refers to the density of occupation, the operation mode of the computer systems and the lighting concepts, Tab. 2.

Tab. 2: Internal heat gains detected in selected projects. Numbers refer to Wh per m² office floor area and day. Data source: Monitoring teams

	Total	persons	equipment	lighting
Wagner	100	24	66	10
DB Netz	141	30	79	32
Lamparter	100	40	-	-
FhG ISE	188	53	125	10
Pollmeier	92	21	50	21

Most of the projects realized in an early starting period of the funding programme applied night ventilation in combination with earth-to-air heat exchangers to *remove excess heat* in summer; several of the more recent projects have applied slab cooling in connection with vertical ground pipes or ground pillars due to the increased cooling capacity. For mechanical and hybrid night ventilation a COP between 4.5 an 14 was monitored which is higher as conventional cooling but shows the need for quality assurance in the design phase and in building commissioning. The evaluated earth to air heat exchanger showed an COP between 20 and 280.

Within the framework of EnBau:Monitor the passive cooling concepts were evaluated regarding the achieved thermal comfort. Therefore as part of the accompanying research standardised graphs were proposed to allow results on the indoor conditions in summer to be compared between the different projects.

Fig. 7 illustrates the results using annual cumulative frequency distributions for the temperature. If the upper limit of 25 °C according to DIN 1946-2, old edition, is taken as a reference, the buildings demonstrate that the frequency of higher temperatures can be kept lower than 10% of the usual working hours with suitable passive cooling measures.
Nevertheless this does not indicate weather an acceptable thermal comfort was achieved or not. Main disadvantage of a thermal comfort analysis in the form of a cumulative frequency distribution is that the information is lost, which indoor temperature at the same time correlates to an outdoor temperatures monitored. Four different comfort criteria, The ISO 7730 according to Fanger, the proposal for the European standard prEN15251, the former DIN 1946 and the new Dutch NPR-CR 1752 were used to compared the buildings performance regarding comfort. For a detailed discussion of these criteria see (Pfafferott 2006).

As an example for this evaluation, in figure 8 the indoor temperature data of the Pollmeier building are sorted by the outdoor temperature (Herkel, 2005). Hourly room temperature data are plotted against a floating mean outdoor temperature of the last three days. Using different comfort criteria leads to different ratings regarding the achieved comfort. If a 90% satisfaction of the user is requested, the range of violation of the comfort criteria during working hours is between 4%-10% (ISO 7730) down to 0%-2% (NPR-CR 1752)(figure 9). It is noted here is that if extreme meteorological conditions are given like in summer 2003 these buildings are upon their capacity limits of thermal comfort. The results show strongly the need for common design criteria regarding indoor comfort in the European framework.

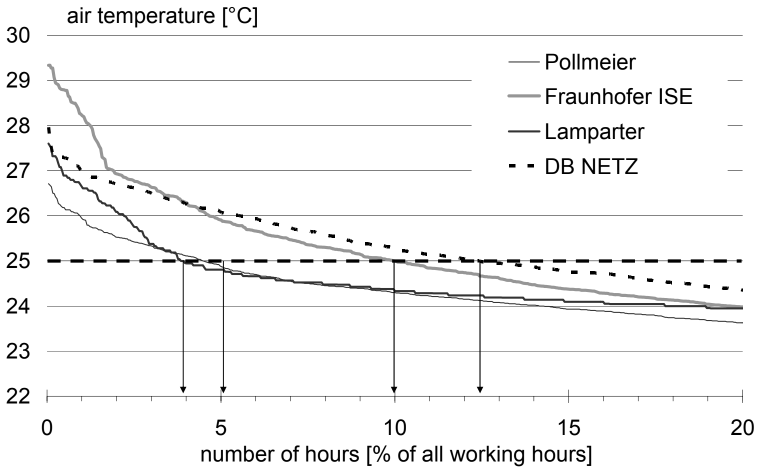


Fig. 7: Cumulative frequency distributions for the hourly average temperatures in the offices of four selected buildings. The temperature limit of 25°C according to DIN 4108 is exceeded for 4 % (Lamparter), 4.5 % (Pollmeier), 9.5 % (FhG-ISE) and 12.5 % (DB) and of the working hours during the course of one year (8°° to 17°°, 2400 h/a). Due to the type and position of the temperature sensors, the values quoted for Lamparter are air temperatures, whereas the values for the other projects approximately represent the operative temperature. The meteorological boundary conditions differ between the buildings due to their different locations (e.g. maximum outdoor temperature FhG-ISE: 37 °C, Lamparter: 36 °C, DB: 34 °C, Pollmeier: 35 °C).

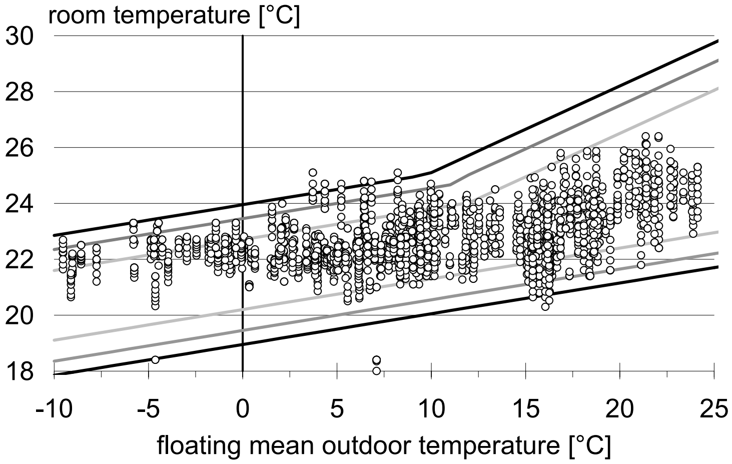


Fig. 8: Analysis of hourly temperature data monitored in the Pollmeier open space office in 2002. The lines marks the upper and lower limits of the so-called class A, B, C buildings according to the Dutch guideline NPR-CR 1752 (Raue, 2004). The guideline takes the thermal adaptation into account. The Pollmeier building (passive cooling using night ventilation) mainly meets the strict class-A-criteria for high ambient temperatures (>20°C) according to the guideline.

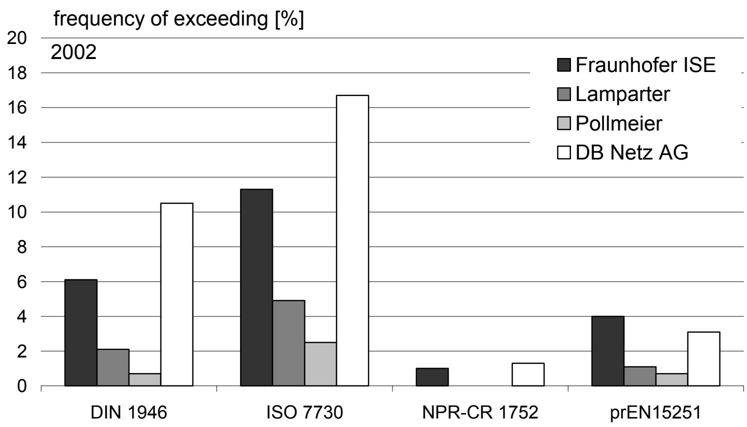


Fig. 9: Comfort analysis for four buildings in 2002. Each building is not only performing different for the four used comfort criteria: It is a basic assumption, that the criteria should qualitatively yield the same conclusion: If a building is better than another building in criteria A, it is also better in criteria B, C and D. Nevertheless, the comfort criteria can give different quantitative numbers for comfort, since the criteria are based on different studies, databases and assumptions: Criteria A can be exceeded for 5% while criteria B is only exceeded for 2% of all working hours.

Discussion and conclusions

The results of the monitored building show, that the energy demand of new office buildings can be reduced by 50% compared to the building stock without enhancing building construction costs compared to the average. The primary energy use was limited to 100 kWh/m²a for most of the participating buildings.

Future building concepts will concentrate on the goal of achieving zero energy demand on an annual base, first buildings within the program EnOB already showed the possibility of such concepts combining a low energy demand with a renewable energy supply.

The results of the passively cooled low-energy office buildings provide a high thermal comfort even without mechanical cooling or air-conditioning, when the heat dissipation in summer is enhanced by e.g. thermally activated building components or night ventilation. The evaluation of passively cooled office buildings demonstrates that during a commonly warm summer such as 2002 prevalent criteria for thermal comfort in naturally ventilated buildings (i.e. prEN 15251) are exceeded for less than 5% of the building operation time – considering realistic user behaviour.

Acknowledgements

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EVA – Evaluation of Energy Concepts for Office Buildings

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Abstract
The paper describes the objective of the EVA project to evaluate the energy efficiency and user comfort of 19 new office buildings in Germany: do they actually perform as intended in the design. The results show that the over all energy performance is similar to reference studies and considerable above low energy buildings. There is also a wide spread within the sample.

The first two out of three case studies show details of the energy analysis. The buildings which are both completely glassed perform differently in respect to efficiency and comfort. Nevertheless the analysis of both new buildings suggest that the performance might be significantly improved by means of operational changes.

The results of the third case study show that the new DIN V 18599 is applicable to office buildings and can be a helpful instrument for energy analysis and energy controlling services.

Introduction
The EVA project was started in 2004 to verify if innovative office buildings actually meet their target values for energy efficiency and user comfort in day-to-day operation. EVA is funded by the Federal Ministry for Economics and Labor (BMWA).

Today there exists basic data on the energy efficiency of office buildings in Germany. The *ages* study [1] for example gives average values for 1.700 public buildings which have a comparatively low standard of HVAC installation. The Swiss study "Energieverbrauch in Bürogebäuden" [2] shows values for 100 buildings which had been chosen to represent the Swiss building stock. A study of the Energiereferat of the City of Frankfurt analyzed 13 office buildings [3]. Like some other sources these studies do not name the individual buildings or explain clearly the reasons and causes for good performance or malfunction.

Two projects have been funded by the BMWA with the task to show in detail the function and performance of individual buildings. Within the program *ENOB* [4] more than 20 demonstration buildings have been built. All buildings included a support during the design phase and a 2-year-monitoring phase after commissioning. Enerkenn [5] carried out an individual analysis of 9 buildings by German Railways.

In addition to these studies there exists only few detailed data on energy consumption. Usually the results are not shown with the corresponding buildings and their specific qualities. The lack of knowledge about the actual performance of buildings led to an ongoing discussion and a lack of profound information for building owners, architects and engineers.

Objective

IGS therefore started EVA to analyze a sample of 19 buildings in operation. The sample covers conventional buildings as well as buildings that represent explicitly innovative concepts and technologies. Two demonstration buildings that were designed as part of the ENOB program are also included, see

Table 1.

Table 1 List of “innovative” and ENOB-buildings

	Nord LB Hannover Hannover, 2002	*Architects:* Behnisch, Behnisch u. Partner Concept: glass double façade, concrete slab cooling, energy piles, absorption chillers
	Finanz IT Hannover, 1999	*Architects:* Hascher Jehle, Berlin Concept: large glassed atrium, concrete slab cooling, natural ventilation
	Rickmers Reederei Hamburg, 2002	*Architects:* BRT Architekten, Hamburg Concept: glass double façade, concrete slab cooling, ventilation system with façade integrated air intake, energy piles, heat pump
	Braun GmbH Kronsberg/Taunus, 2000	*Architects:* Schneider+Schumacher, Berlin Concept: glass double façade, atrium with openable foil-roof, concrete slab cooling
	LBS-Nord Hannover, 2001	*Architects:* PSP Pysall-Stahrenberg u. Partner Concept: large glassed atrium, ground channel for supply air
	EnergieForum Berlin, 2003 ENOB-Building	*Architects:* BRT Architekten, Hamburg Concept: large glassed atrium, concrete slab cooling, natural ventilation, energy piles, heat pump
	Neubau Informatikzentrum Braunschweig, 2001 ENOB-Building	*Architects:* PSP, Braunschweig large glassed atrium, natural ventilation, ground channel for supply air, electrochromatic glass

The following questions shall be answered:

1. Are the innovative buildings built, used and operated in the originally intended way?
2. Do they meet the target values of the original design or reference values for energy efficiency and user comfort or are there (positive or negative) deviations?
3. If deviations are detected, what are their causes and how can buildings and operation be improved?

In addition to a comprehensive monitoring program the project will include calculations of energy demand according to the new DIN V 18599 [6].

Methodology

During the first phase of the project the buildings were comprehensively documented in their actual state of operation. On the basis of existing measurement data specific values for energy consumption have been calculated. The first phase was finished by setting up detailed evaluation concepts for 12 buildings.

The second phase includes a detailed analysis of HVAC-systems, especially heating, cooling, lighting, and ventilation. The energy efficiency is analyzed using three methods:

1. a calculation of energy demand according to DIN V 18599 using standardized values for lighting, HVAC-systems and operation
2. a calculation of energy demand according to DIN V 18599 using actual values for lighting, HVAC-systems and operation and results of spot or short term meterings
3. monitoring of energy consumption in long term meterings for dynamic systems, short term meterings for cyclic systems and spot meterings for constant systems

The different methods will help to create almost complete energy balances for all buildings. In addition the functionality of systems will be analyzed using data from building management systems. The application of DIN V 18599 will also show how large deviations to the actual consumption are and what their causes might be.

The user comfort is evaluated through a long term monitoring of air temperatures and spot monitoring of the thermal comfort in selected rooms as well as through user questionnaires in winter and summer.

Results of the first phase

Figure 1 shows the annual heat consumption for 16 EVA-buildings including the three case studies using results from the studies mentioned above as references with minimum, maximum and average values.

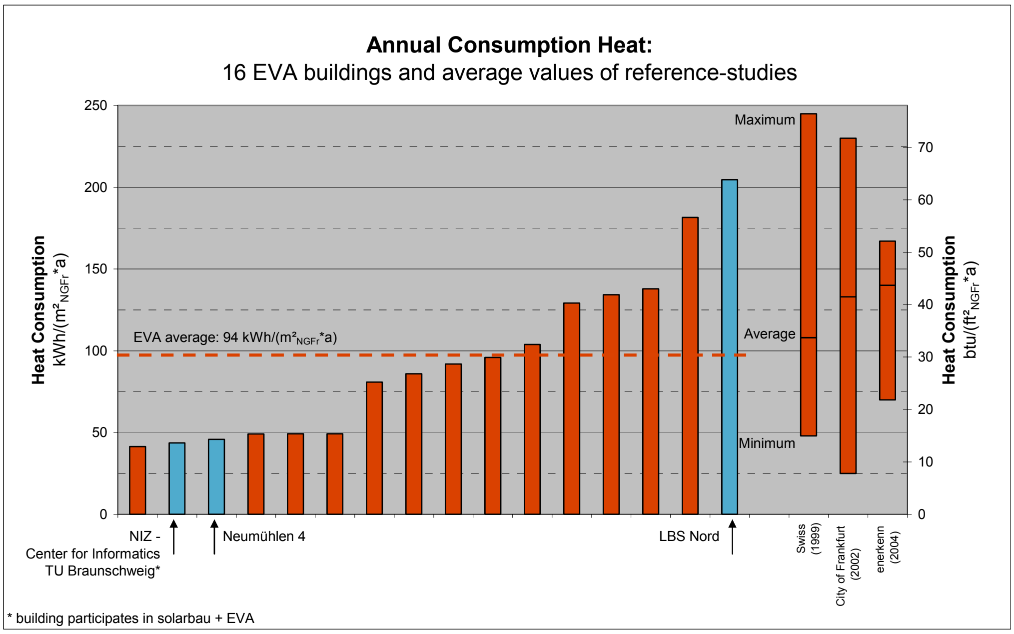


Figure 1 Annual heat consumption of 16 EVA-buildings with reference values. The values have been weather corrected according to VDI 3807. NGF_r represents the

heated net floor area without unheated atriums, parking garages and double facades.

The average value for the EVA buildings of 94 kWh/(m^2_{NGFr}a) almost equals the average of the Swiss study. All values are within the range of the reference studies. The *NIZ - Center for Informatics* at Braunschweig University was a demonstration project of the ENOB program and has an energy consumption of about 40 kWh/(m^2_{NGFr}a), 50 % of the EVA-average.

Figure 2 shows the annual consumption for electrical energy for 16 EVA-buildings and reference values.

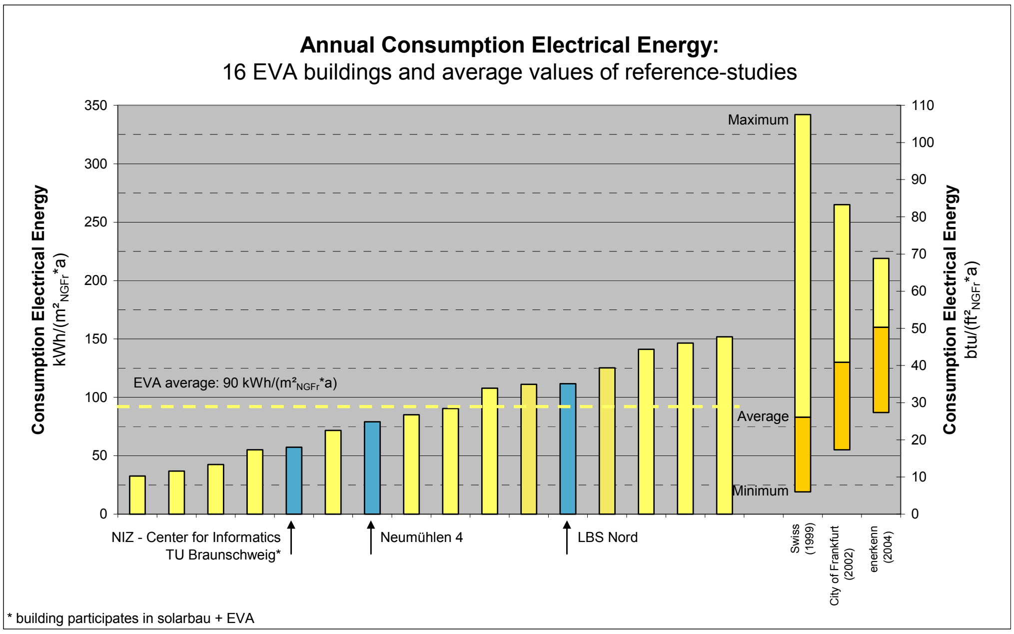


Figure 2 Annual consumption of electrical energy of 16 EVA-buildings with reference values. The consumption includes equipment, PCs, IT-servers, restaurants etc.

The average value for the EVA buildings of 90 kWh/(m^2_{NGFr}a) also almost equals the average value of the Swiss study but is significantly lower than the average values from enerkenn and the Frankfurt study. *NIZ* has a value of 57 kWh/(m^2_{NGFr}a).

Figure 3 shows the annual consumption of primary energy for 16 EVA-buildings and reference values.

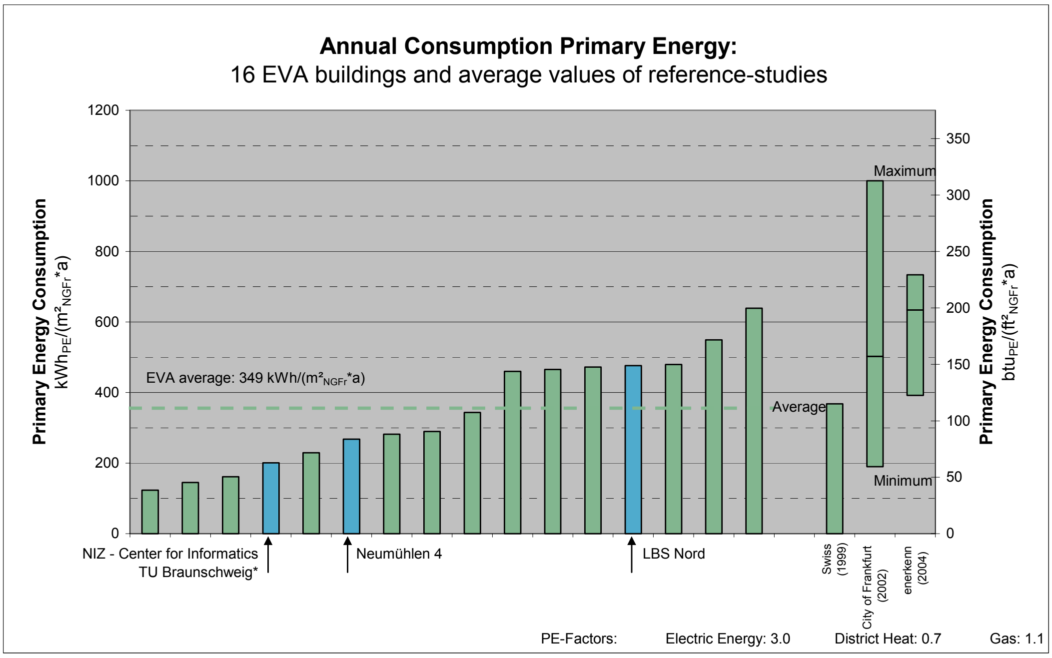


Figure 3 Annual consumption of primary energy of 16 EVA-buildings with reference values. Values have been calculated using primary energy factors according to DIN 4701-10 (district heat: 0,7; gas: 1,1; electrical energy: 3,0). For the Swiss study the factor 1,0 was used to include the heat consumption in the average value for primary energy.

As for heat and electricity the average annual consumption of primary energy of 349 kWh/(m²$_{NGFr}$a) is similar to the results form the Swiss study. The consumption of almost all EVA-buildings are below the average values of the other studies. NIZ has a primary energy consumption of 201 kWh/(m²$_{NGFr}$a).

Three examples: Neumühlen 4, LBS Nord and NIZ

For some of the buildings a part of the detailed analysis has already been carried out. Three examples will show the projects approach and typical results of the second phase.

Neumühlen 4

The building is situated in Hamburg near the river Elbe, see Figure 4. Since 2002 it provides offices for about 260 employees on 7.820m²$_{NGFr}$.

Site plan (Hamburg Team)

Neumühlen 4, seen from the south (BRT, Hamburg)

Figure 4 Neumühlen 4

The energy concept includes an almost completely glassed double facade, concrete slab heating and cooling and an exhaust air ventilation system using heat pumps as heat recovery systems. The supply air intakes are integrated into the façade. The building does not have any mechanical chillers. The only sources for cooling are 17 ground probes of 100 m each. Figure 5 shows an annual energy balance of Neumühlen 4.

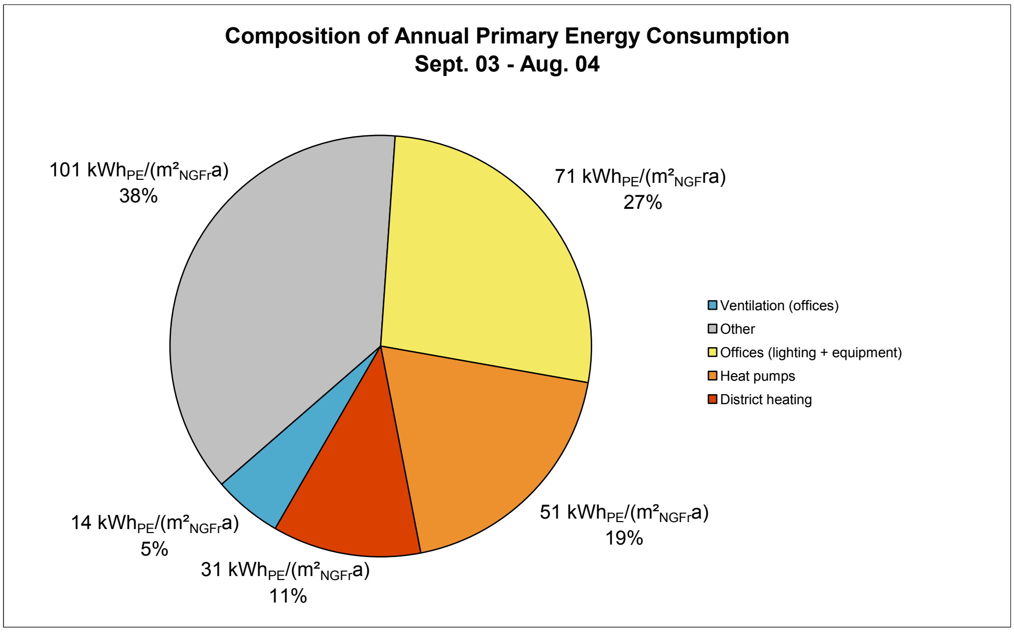


Figure 5 Annual energy balance of Neumühlen 4

The over all consumption of primary energy of 268 kWh/(m²$_{NGFr}$a) is about 25% below the EVA-average. The detailed results show that the heat pumps contribute significantly to the energy balance. The overall consumption of primary energy for heating of 82 kWh/(m²$_{NGFr}$a) is slightly lower than the EVA-average of 94 kWh/(m²$_{NGFr}$a) and lower than average reference values. The primary energy consumption for heating is below the permissible value for heating demand according to WSchVo '95, but the target of falling 20 % below could not been met.

The user comfort is not fully satisfying at the moment. Employees complain about a low air exchange rate, high temperatures in summer and low temperatures in some parts of the building in winter. These problems have been verified by measurement. In 2004 the three rooms in which sensors had been installed showed air temperatures of more than 26°C in 60 to 120 hours during working time (8 am – 6 pm).

The detailed analysis shows that the concrete slab cooling is not working properly in the cooling mode. At 27°C outdoor and 26°C indoor air temperature during a hot summer period the surface of the ceiling had a temperature of 25°C although it should have been in cooling mode. The analysis of building management data also showed that the cooling function was not working properly.

Figure 6 Infrared image of the ceiling with concrete slab cooling on September 8th, 2005: outdoor air temperature 27°C, indoor air temperature 26°C, temperature of ceiling: 25°C.

Further analysis on all problems will analyze the reasons and is likely to help to improve of the current situation.

LBS Nord

The new headquarters of LBS Nord were built in Hannover in 2001, see Figure 7. The building for about 550 employees with an heated net floor area of 23.260 m² consists of 4 U-shaped parts each with an heated atrium in the center. The U-blocks and a 5th part are separated by green yards and altogether covered by a glass roof. The energy concept uses suspended ceilings for heating and cooling. The ventilation system exhausts air form the offices with an exchange rate of 2-2,5/h into the tempered green yards and then to the outside.

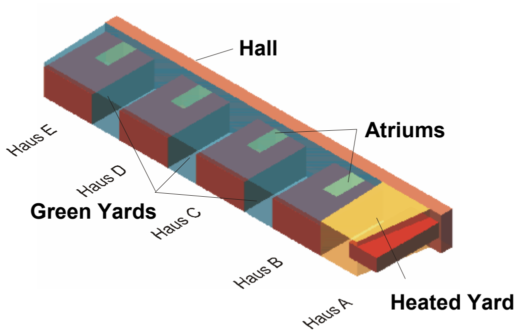


Figure 7 LBS Nord: Entrance and hall, building concept

Figure 8 shows the annual energy balance of 2003 of LBS Nord.

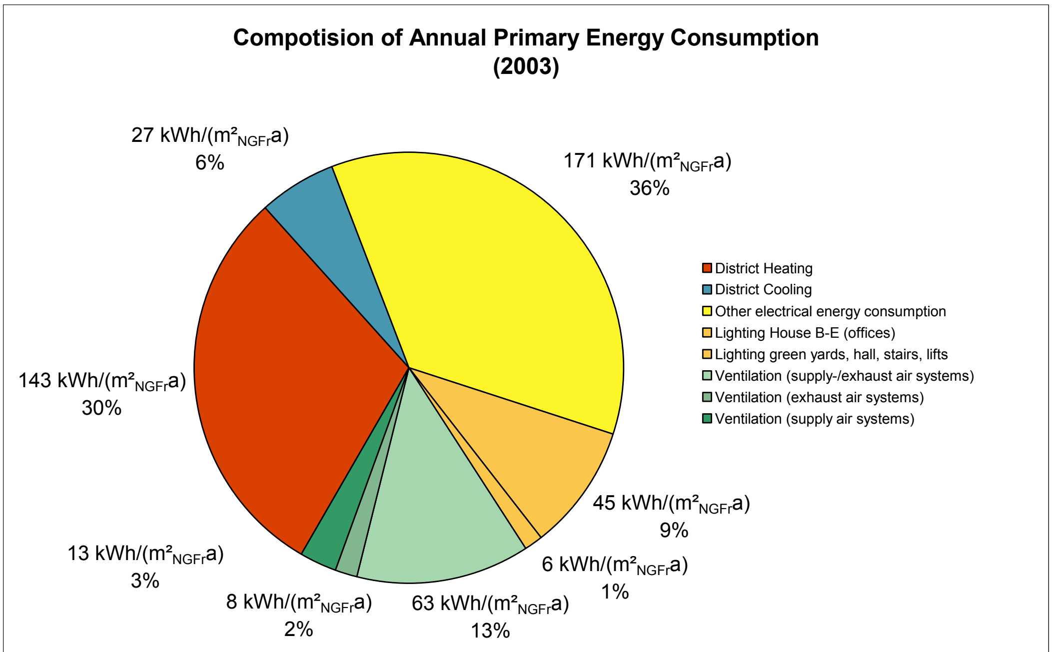


Figure 8 Annual primary energy balance of LBS Nord.
Primary factors: district heating = 0,7; electrical energy = 3,0.
Value for district cooling is converted into electrical energy with a COP of 2

The over all consumption of primary energy of 477 kWh/(m²$_{NGFr}$a) is about 35 % above the EVA-average. Although the building is completely glassed, the consumption of primary energy for cooling makes up for only 6 % of the overall primary energy consumption. The fraction of 36 % of the energy balance that could not be allocated will be further analyzed.

The building owner is satisfied with the user comfort and mentions only few complaints mainly on low humidity in winter. Measurements showed a relative humidity temporarily below 20 %. The cooling system seems to work properly since there are apparently no problems with high indoor air temperatures in summer, see Figure 9.

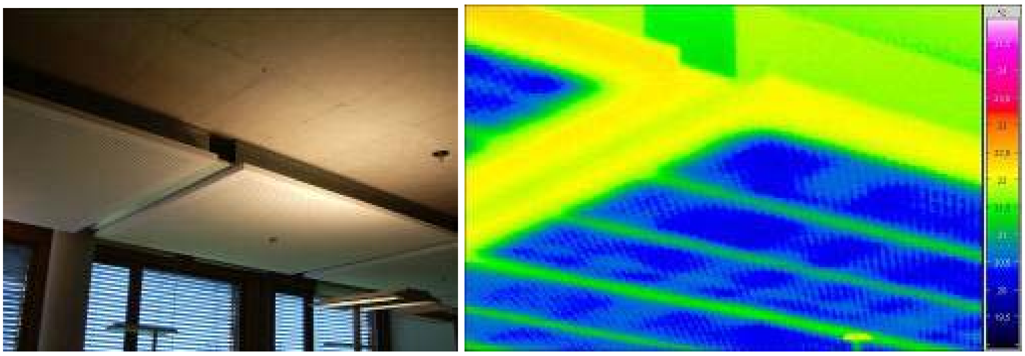


Figure 9 Infrared image of the suspended cooling ceilings on a summer day

Further measurements are carried out in six rooms since the summer of 2005 had rather moderate temperatures. The ongoing analysis will focus on energy management to identify existing ways of reducing the buildings energy consumption especially of the ventilation system.

Center for Informatics (NIZ) at Technical University of Braunschweig (TU BS)
The NIZ was built in 2001 for several institutes of Informatics at TU BS. It provides office spaces and laboratories for robotics on about 7.500 m² heated net floor area, see Figure 10.

Figure 10The NIZ built as an extension of an existing high rise office building

The energy concept is based on an atrium in the center of the building which is integrated in the buildings natural ventilation system. Rooms are conventionally heated and do not have any mechanical ventilation system. Chillers are only installed for IT-cooling and a few teaching rooms. The recooling is used to support the heating of the air for the atrium which is supplied mechanically in winter.

NIZ was one out of 23 demonstration buildings in the program *EnOB - Energieoptimiertes Bauen,* funded by the German Ministry of Economics and Labor. Energy efficiency and user comfort are still monitored within the EVA project. The building was designed to meet a target value of 100 kWh/(m²$_{NGFr}$a) for building operation (without equipment, IT etc.). It proofed to meet these targets in day-to-day operation as shown above.

NIZ was also one out of three buildings which IGS analyzed as part of a field test on the new DIN V 18599 [6] by the German Energy Agency *dena*. DIN V 18599 defines the standard calculation procedure for Germanys implementation of the European EPBD – Energy Performance of Buildings Directive.

Figure 11 shows a part of the zoning model for NIZ according to DIN V 18599.

Different zones are defined for office rooms, halls and teaching rooms as well as for different lighting systems. The methodology allows to calculate the energy demand for heating and lighting. Since the building does not have any systems for ventilation or cooling these are not considered within this calculation.

Figure 12 shows a comparison between calculated and measured data.

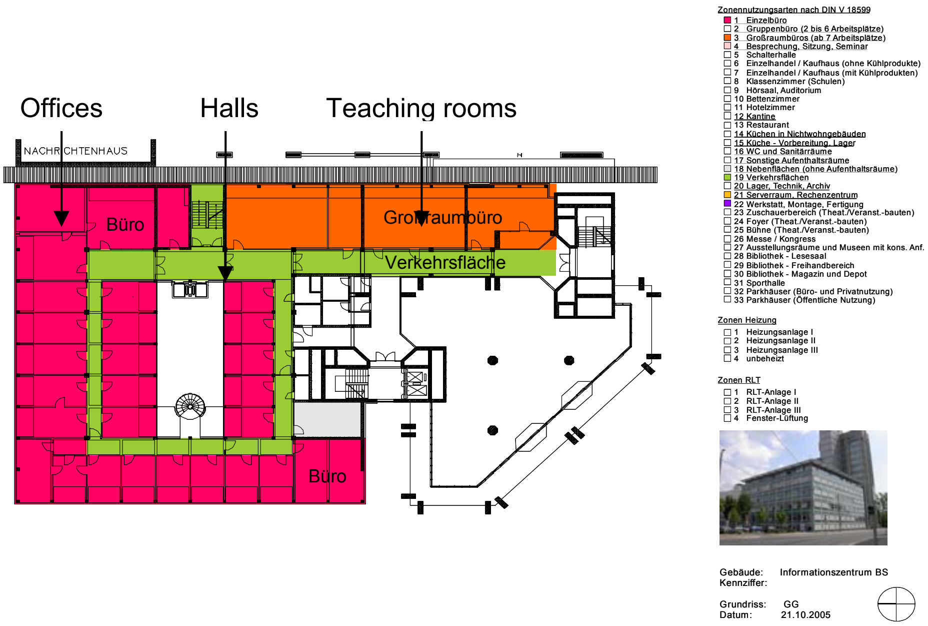


Figure 11 Model of building zones in floor plan and envelope

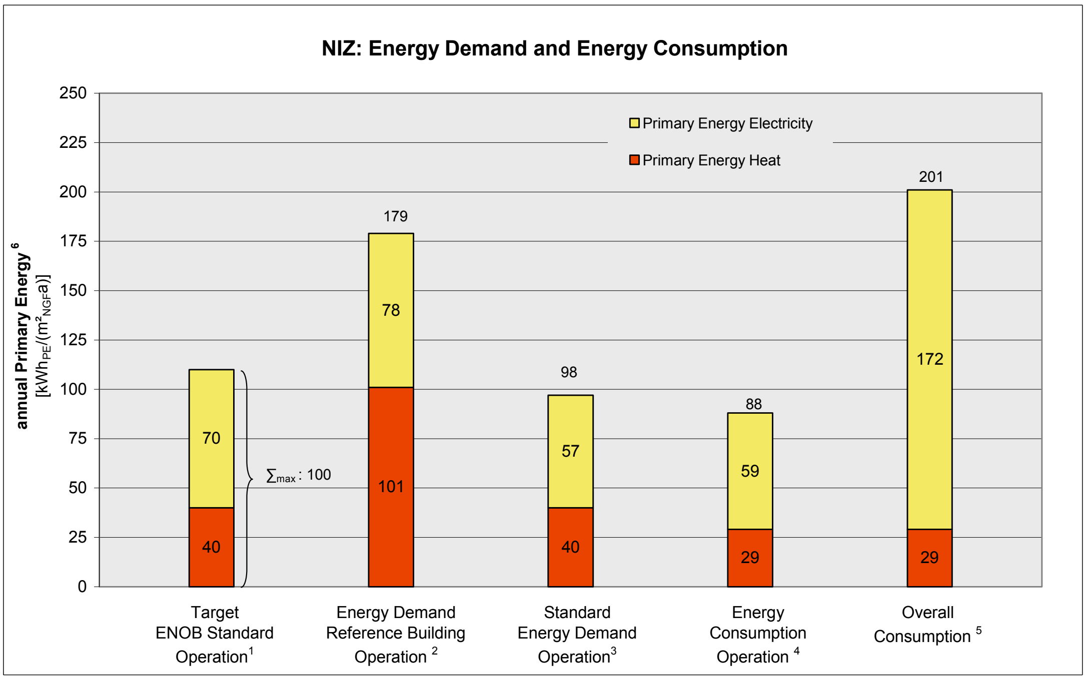


Figure 12 Calculated and measured values for energy efficiency for building operation

[1] Defined for all demonstration buildings in ENOB

[2] Calculation uses standard values for operation time, insulation etc. as defined by DIN V 18599

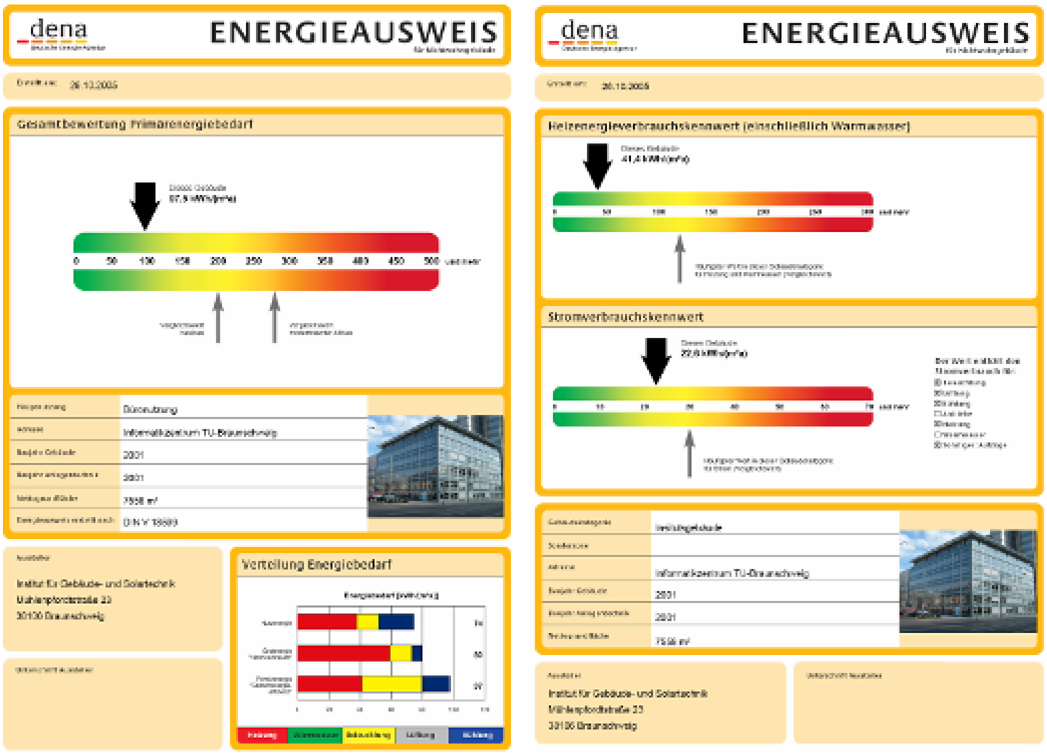
[3] Calculation uses individual values for operation time, insulation etc. as built
[4] Values for energy consumption are metered data of 2003 (weather corrected data for heat) for building operation only
[5] Values for overall energy consumption including equipment, IT-Servers etc. are metered data of 2003 (weather corrected data for heat)
[6] District heat: primary energy factor = 0,7; electrical energy: 3,0 according to DIN 4701-10:2003-08 [7]; this value would be reduced to 183 $kWh_{PE}/(m^2_{NGF}a)$ using 2,7 as primary energy factor for electricity as defined in DIN V 18599

The analysis of energy demand and consumption shows the following results:

- The results show a good precision between calculated demand and metered consumption of the primary energy for building operation with a deviation of about 10 %.
- The heat fraction in operation is about 25 % below the calculated value, the electrical energy demand (for lighting) meets the values for consumption.
- The ENOB standard proofs to be more than 50 % more efficient than the permissible values of the regular standard.
- The energy consumption for building operation makes up for only about 50 % of the over all primary energy consumption.

Since DIN V 18599 can also be applied using individual characteristics for use, operation schedule etc., it should be possible to use the method as a part of a continuous energy controlling process using demand and consumption data.

For comparison with other buildings usually the over all energy consumption of buildings is used since it is difficult and expensive to measure the operational energy consumption separately. This has to be kept in mind looking at the two types of certificates for buildings as proposed by *dena* for Germany, the “Energieausweis” for energy demand and energy consumption, see Figure 13.



Type A : Calculated energy demand   Type B: Metered energy consumption

Figure 13 “Energieausweis” –Visualization of energy efficiency for NIZ

Conclusion

The EVA building sample shows that the primary energy consumption of its buildings is similar respectively slightly below the values of reference studies.

The case studies suggest that it is not possible to relate the buildings energy consumption to single qualities like size or type of façade. Furthermore the studies show that the potential for building optimization in respect to energy efficiency and user comfort is significant especially looking at HVAC systems and innovative components in operation.

The results of NIZ show that the new DIN V 18599 is applicable to office buildings. The ENOB demonstration buildings proof that the given permissible values can be met economically. The calculation methodologies for energy demand as defined by DIN V 18599 and meterings of energy consumption can be related and used for a continuous energy controlling process.

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building
performance
congress

Mining Corporate Sustainability Reports for Building Energy Performance Data

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Abstract
The growing trend toward Corporate Social Responsibility reporting and disclosure of carbon emissions is leading to a new source of data on commercial building energy performance and potential energy savings in different parts of the globe. As a means to demonstrate their corporate commitment to sustainability and environmental responsibility and in response to shareholder demands, corporations are disclosing a wide range of Environmental, Health and Safety performance indicators.
Through a wide variety of international efforts such as the "Carbon Disclosure Project", the "Global Reporting Initiative" and other similar initiatives, a large number of corporations are publishing building (and industrial process) energy performance data on their facilities providing a rich set of energy benchmark data. Multi-national financial firms such as HSBC, Citigroup, and Nomura Holdings, commercial real estate firms such as Canary Wharf Group and Swire Properties, and global industrial giants including BP, Tokyo Electric Power, and many others, publish annual Corporate Sustainability Reports that contain specific/detailed energy use intensity data. Many of the reports also provide building water consumption information that allow for benchmarking of international best practices in water efficiency.
This paper reviews and summarizes some of the data on building energy and environmental performance available as of early 2006, assesses the quality and validity of the reported building performance data, and compares some of these data with international and other regional/local data sets of building energy performance. It also reports on initiatives underway to facilitate comparability and validity of the data among major global financial institutions.

Introduction
The growing trend toward Corporate Social Responsibility reporting and disclosure of carbon emissions is leading to a new source of data on commercial building energy performance and potential energy savings in different parts of the globe. As a means to demonstrate their corporate commitment to sustainability and environmental responsibility and in response to shareholder demands, corporations are disclosing a wide range of Environmental, Health and Safety performance indicators.

Only a few years ago, it was extremely unusual for a major corporation to report on its environmental performance. Normal corporate "Annual Reports" focused solely on the financial performance of the entity, along with a management review of the company's successes and challenges and an outlook for the future. This has changed dramatically in the past five years.

A wide variety of "Corporate Social Responsibility" initiatives have caught the corporate world by storm. In the United State, broad corporate responsibility initiatives have been coordinated through a variety of groups, with their activity being monitored by an NGO called "Business for Social Responsibility" (see www.bsr.org).

Growth in Corporate Sustainability/Environmental Performance Reporting

With growing concern around the globe about environmental issues, and climate change in particular, monitoring and reporting on environmental emissions has exploded, particularly as the Kyoto Protocol has moved toward implementation. Several initiatives have helped push this growth.

A major initiative, the “Carbon Disclosure Project”, has been launched through the “Institutional Investors Group on Climate Change” (see www.iigcc.org). The most recent report of the Carbon Disclosure Project, released in the fall of 2005 “on behalf of 155 investors with assets of $21 trillion”, outlined “key issues that make climate change an investment-relevant issue and draws upon company responses from the FT500 to highlight important trends, quantify the risks and direct attention to new investment opportunities” (Carbon Disclosure Project 2005).

The Climate Group, an NGO dedicated to advancing business and government leadership on Climate change, in 2005 issued their second edition of “Carbon Down, Profits Up”, a report that highlighted the carbon reduction activities of a variety of private companies and cities, showing that energy efficiency improvements can provide significant financial returns for these entities while demonstrating environmental leadership (The Climate Group 2005).

A wide variety of industries are reporting their energy use and emissions, particularly those that have the largest carbon footprints and therefore biggest potential financial exposure in a carbon constrained world. For many of these industries, though, much of the energy use is for industrial process, not just building energy use. Various industries have developed specific indicators, such as carbon per kWh of electricity generated, energy use/emissions per tonne of steel produced, etc. The closest normalization for reporting building energy use and performance is kWh/square meter (for more discussion of international building performance reporting and comparison, see Hinge et al 2004).

For the purpose of comparing building performance data from corporate sustainability reports it is important to look at industries and sectors where energy is used solely for buildings, or is at least a major portion of the corporate environmental footprint such that it is reported separately. The industries for which this is the case are “real estate”, which generally is just energy use in buildings, and service sectors such as the financial sector. While financial services buildings often have a slightly higher use of data and computer/ICT equipment than the overall commercial buildings sector, it is the most “homogeneous” sector among commercial buildings, allowing the best opportunity for both comparison among different companies in the sector, as well as comparison to international benchmarks. The financial services sector in particular has taken a leadership role in reporting environmental performance, and review of their environmental reports provides a rich set of data for comparison to international norms of building energy use and performance.

CSR and Building Performance Reporting in the Financial Industry

The financial industry has taken on a special role in corporate sustainability reporting. Financial institutions have a “fiduciary responsibility”, and are legally bound to act with prudence in the best interests of the people for whom they manage money.

According to a recent article in Environmental Finance magazine, “…only a few thousand individual fiduciaries… are in a position to use the almost unimaginable stores of wealth under their control to help minimise the problem of climate change” (Northrop and Sassoon 2005). Often under pressure from investor groups and NGOs, these institutions have begun to more broadly report on their initiatives in sustainability, and many are reporting specific building energy use and emissions from their operations, often at the energy use intensity (EUI) level of energy use per floor area.

A group of financial institutions were invited by United Nations Secretary-General Kofi Annan to participate in an initiative “to develop guidelines and recommendations on how to better integrate environmental, social and corporate governance issues in asset management, securities brokerage services and associated research functions" (The Global Compact 2004). This initiative prepared a report, released in 2004 entitled "Who Cares Wins: Connecting Financial Markets to a Changing World", which summarized the recommendations of industry leaders. Among the recommendations was that "Companies are asked to take a leadership role by implementing environmental, social and governance principles and policies to provide information and reports on related performance in a more consistent and standardized format".

An effort among a group of financial related companies, organized through Verein fur Umweltmanagement in Banken, Sparkassen und Versicherungen e.V. (VfU, the Association for Environmental Management in Banks, Savings Banks and Insurance Companies), has developed a set of "Internal Environmental Performance Indicators for the Financial Industry". In 1996 the VfU launched the first standard for environmental reporting and performance measurement, and published a report and supporting calculation spreadsheets that provide guidance toward a set of indicators of internal environmental performance (Internal Environmental Performance Indicators for the Financial Industry: VfU Indicators 2005). It appears that several of the funders of the VfU project utilize these indicators as inputs toward the information presented in their sustainability reports. The VfU effort assists in compiling the total environmental footprint for an institution. The project does not give guidance on normalizing to unit floor area, though does track number of full time employees (FTE) so that energy use per FTE can be calculated for comparison purposes.

Several international financial firms in particular have led the way in reporting their environmental footprint, and setting targets for reducing the impact of their operations on the environment. A number of smaller banking institutions from Europe led the way in this reporting, but in the past couple of years one of the largest banking and financial institutions in the world, HSBC, has shown leadership that deserves special note.

HSBC

HSBC Bank, headquartered in London, has over 9,800 offices in 77 countries around the globe. The company has been involved in nearly all of the recent international efforts aimed toward corporate environmental responsibility and climate leadership. HSBC has issued five annual Corporate Social Responsibility Reports, and the most recent report issues in 2004 is a good model with a lot of data presented from their corporate environmental reporting system. HSBC has sponsored a number of initiatives with The Climate Group (including the report mentioned earlier), and was recently ranked as the top "Financial Services Leader" in a review of global leaders in carbon reduction published in Business Week magazine.

In addition to the data on energy consumption (presented in both energy consumption per square meter, and per person), the HSBC website (www.hsbc.com) provides targets for energy use reductions (and other environmental indicators) by region for the next three years. This demonstrates that HSBC has done detailed analysis of the energy use in the buildings in their entire portfolio, and set management targets that will allow for measurement of progress toward aggressive reduction targets. A screen shot of the HSBC targets page from their website is shown below, and it is quite interesting to see how widely the energy use reductions vary by region for the period 2005-2007.

In addition to their detailed reporting of energy performance and setting targets for improvement, the company decided to further demonstrate environmental leadership by achieving "carbon neutrality", where they have purchased emissions reduction credits to offset its emissions from operations. In October 2005, HSBC announced that they had achieved this goal, three months ahead of their original target, by purchasing emissions credits from a variety of sources, including a wind farm in New Zealand, a biomass cogeneration plant in India, and agricultural methane capture in Germany.

Figure 1. Screen Shot of HSBC Environmental Targets and Reporting

Analysis and Discussion

With the growing number of comprehensive corporate sustainability reports that include detailed environmental performance data, including energy and environmental performance data per unit floor area or per employee, and many times including water usage normalized to these same parameter, an attempt has been made to collect and review those reports that have data included on a significant amount of building floor area in a range of different geographic areas. Some of these reports break down energy and water use by region, and in some cases even have differing performance improvement targets by region. A summary of the findings of this review are presented in Table 1 below.

In different sustainability reports, some energy data were given on a per employee basis, while others were normalized to use per unit of floor area. The summary table presents both energy use per unit floor area, and per employee, when these two different indicators were apparent through what the report contained, and also has a column showing whether the report was principally based on per employee or unit floor area basis. It should be noted that not all entries in the table were directly reported in the corporate reports, but some were calculated from reported data. The “Notes” column in Table 1 explains whether the data were reported directly, or whether it was derived or calculated based on other information that was presented by the company.

Table 1. Summary of Energy Use Data and Intensity in Financial Corporate Sustainability Reports

	Floor Area (m^2)	No. of Employees	Total Primary Energy (all fuels, MWh)	**Total energy use all fuels (kWh/m^2)**	Report Focus: employee, building area, both	Elec/ Thermal reported separately?	CO_2 Emissions from building use (kg/m^2)	Notes
ABN-AMRO	3,000,000	105,918	855,001	**285**	employee	Yes	100.03	1,2
Australia & New Zealand Bank	512,615	16,033	126,650	**247**	employee	Yes	285.07	
Barclays	1,538,000	60,000	458,830	**298**	m^2	Yes	106	
CIBC	566,709		225,026	**389**	employee	Yes	83.54	1,2
Citigroup	7,673,324	300,000	1,907,588	**249**	both	Yes	136	
Credit Suisse Group		25,233	321,916		employee	Yes		
Deutsche Bank	1,336,059	29,827	510,496	**382**	both	Yes	170	2
HBOS	905,283	56,762	281,643	**311**	both	Yes	153.33	
HSBC	5,243,000	220,055	1,496,000	**285**	both	No	94.79	
HVB Group	2,595,180	60,214	820,897	**316**	employee	Yes	134.55	2
ING			780,028		neither	Yes		
KFW Bankengruppe	156,266	2,252	83,068	**532**	both	Yes	110.51	
Lloyds TSB	1,347,314		538,000	**399**	neither	Yes	140.00	
Nationwide	289,385	13,436	103,600	**358**	employee	No	66.95	
Rabobank		50,216	168,324		employee	No		
Royal Bank of Canada		41,341	196,303		employee	No		
Royal Bank of Scotland	2,303,181	101,340	963,000	**418**	employee	No	110.00	1,3
Societe Generale Group	1,835,558	61,669	414,836	**226**	employee	Yes	2.73	
Standard Chartered		33,322		**366**	m^2	Yes		
UBS		67,424	934,000		employee	Yes		
WestLB AG - Germany	322,831	3,838	86,697	**269**	employee	Yes	126.68	2
Westpac	575,500	21,829	115,694	**201**	employee	Yes	200.00	1
Totals	30,200,205	1,270,709	11,387,597					
Average				**325**				
Weighted Average				**298**				

Notes: 1 - estimated/calculated sq.ft. from other reported data, 2 - estimated/calculated total primary energy from other reported data, 3 - estimated/calculated total employees from other reported data

Some argue that presenting energy intensity on, or normalizing to, a per employee basis is a better indicator. However, review of International Energy Agency indicator development work and other published research on indicators shows that energy use per unit floor area, usually expressed as kWh (of all fuels) per square meter (sometimes as MJ/m2) is the most widely used indicator of commercial/service sector energy intensity. For the remainder of this paper, energy use intensity, or "EUI", is used in kWh of all fuels per square meter.

The average energy intensity of 325 kWh/m2, with a weighted average of 298 kWh/m2 for the 22 global financial institutions shown in the table compares reasonably well to the global average of 265 kWh/m2 estimated for the overall commercial sector (Hinge et al 2004). This, together with the relatively close grouping of the EUI data shown for the various companies in the summary chart, demonstrates that most of the data have been verified and fall within expected norms.

A finding of earlier work on comparing building energy performance was that comparisons of specific building types is more relevant than looking at the overall commercial sector. One large dataset that allows more detailed comparison is the United States "Commercial Buildings Energy Consumption Survey", or CBECS, which has detailed energy use information on a large number of buildings in the US in all of the country's climate zones, which are similar to the range of climates around the globe. In the US CBECS dataset, the average EUI for all commercial buildings is 286 kWh/m2, while the average EUI for office buildings, the building type that most of these financial sector buildings would fit into, is 307 kWh/m2. These numbers again verify that the building energy performance data presented in the corporate sustainability reports is generally reasonable.

There are some outliers among the companies shown, particularly the Royal Bank of Scotland (RBS) and KFW Bankengruppe whose average EUI show as over 400 kWh/m2. In digging deeper into the data presented in the RBS report, it appears that there was an incorrect calculation/conversion of the floor areas, as the RBS US buildings are shown to have an EUI of almost 2000 kWh/m2. This deeper review highlights the need to check for any data outside of the expected range; most institutions appear to have done this.

It is also not entirely clear that all banks are reporting energy use as the primary energy consumption (including conversion losses, sometimes known as "indirect energy" or known as "source" energy in the US) or the delivered (direct, or site) energy. This can cause a large deviation in the figures presented, as the conversion between primary and delivered energy for electricity use can change the EUI quite significantly. Many of the sustainability reports present data on both electricity and thermal energy use; in those cases to verify that primary energy use is being reported. Table 1 also has a column that shows whether the reports have electric and thermal energy use reported separately.

Both of these issues highlight the need for more independent verification of the data presented. Several of the reports specifically call out when they've had an independent auditor review the data presented in the report, and it is expected that the use of independent auditing will grow. Based on a review of the literature about Corporate Sustainability Reporting in general, major international financial auditing firms also see this trend, and are gearing up to provide carbon and other verification and accounting services.

The challenge in directly comparing building energy intensity data between the different companies through what was reported suggests that there would be value to encourage a standardized reporting format requiring that companies present building energy intensity in kWh/m2. The results of this paper will be shared with those responsible for the Global Reporting Initiative work with the financial sector, so that perhaps comparison of EUIs will be easier in the future.

While they have not been reviewed for this paper, the corporate sustainability reports also contain a wealth of data for water use benchmarking. Around the world building water use and conservation is attracting growing attention, from both the concerns about water shortages and increasing water prices, as well as the general trend toward "green buildings" that must incorporate water conservation.

A new project is just getting underway in the US to compare the energy performance of financial corporate headquarters buildings, and share best practices among the key operating staff of these buildings. With this project, there is an opportunity to link the work done previously by the VfU Indicators project, and ongoing efforts coordinated through the Environmental Bankers Association. More information on these initiatives will be available later in 2006.

This new project, involving several major building owner/management firms in New York City, whose clients include the headquarters buildings of several major global financial firms, are having those buildings benchmarked as part of a comparison and continuous improvement project sponsored by the New York State Energy Research & Development Authority. Initial results from some of these headquarters buildings performance buildings review shows that similar buildings have a wide range of energy performance, with fairly similar building and space uses having a variance of 30-50% in the EUI (total kWh/m2).

Conclusions

In the past the key sources of building energy performance data have been either large national or regional data sets, or smaller sets of building energy use data collected and aggregated for a specific purpose. As more data about actual building energy performance becomes available, and the understanding that consumption can vary dramatically for very similar buildings grows, it will be important to have more sources of data to compare performance by different building types and between different geographic/climate regions.

Many of the industries that are now providing energy and other environmental footprint data through their sustainability reporting have significant usage beyond just building energy use, and that data may be useful for specific industry efficiency comparisons. The financial industry, though, provides a good snapshot of office building energy use around the world and is a useful verification for other international comparison work.

Better understanding of how buildings perform relative to similar peer buildings allows for much better dissemination of best practices in the design, construction, and most importantly, operation of buildings. The growing proliferation of sources of data from sustainability reporting such as reviewed in this paper will allow for continued improvement in building energy performance.

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Intelligent energy and water performance assessment in municipal buildings

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Abstract
Energy audits are an essential aspect of the promotion of energy efficiency in non domestic buildings and businesses. Energy auditing activity is becoming increasingly important, with the implementation of new instruments for promoting energy efficiency in buildings, such as the Directive on Energy Performance in Buildings and the proposal for a Directive on End-Use Efficiency and Energy Services. Across Europe, there are several terms and definitions of what an energy audit is, for instance in the UK this energy audit is referred as energy survey. In this paper we use the term energy audit based on the definition used in the proposal for a Directive in End-Use Efficiency and Energy Services.

The paper presents a discussion of the relevant issues from published literature on energy auditing and on the evaluation of energy efficiency programmes. The focus is on the quality of the energy audit results and its cost with the overall success of the auditing activity measured in terms of effective energy savings or carbon emission reductions.

From experience gained in the field and from the review of published literature, it was found that there are still significant opportunities for innovation in the field of energy audits, in particular opportunities for improvements in the cost-effectiveness and quality of energy audits. This might be attainable by the development of new integrated methodologies, tools and techniques to reduce the time needed to identify energy saving measures, related to audit costs or other transactional costs such as time the client/business spends on collecting energy and other relevant data.

The paper presents a new approach for assessing energy and water performance assessment in buildings based on the use of metered (half-hourly) data collected by the monitoring and targeting system using automatic meter reading systems, energy analysis techniques and communication technologies. Results from the energy and water monitoring and targeting system used in Leicester City Council buildings are presented and assessed in terms of its cost-effectiveness.

The application of readily available metered data and advanced energy analysis techniques can be an important tool for improving the cost-effectiveness of the activities being pursued by Member States for the implementation of the Directive on Energy Performance in Buildings and the future Directive on End-Use Efficiency and Energy Services, and of course for achieving the international carbon emission reduction targets.

Background

Terms and definitions - Energy audit
Energy audits or energy surveys are generally the first step in assessing energy performance and identifying energy saving opportunities in buildings. There is no unique definition of what an energy audit or an energy survey is. The definition and understanding of what energy audits involve varies between countries. The definition of energy survey, energy assessment and energy audit, are often

interchanged on translation. For example, what in mainland Europe is generally referred to as an energy audit, is understood in the UK as an energy survey. In the UK the term energy audit is used when referring to a simple study that just determines the quantity and cost of each energy input to the building, as in (CIBSE 1991). However, there are other authors in the UK refer to the energy audit process as involving the assessment of the energy management structure within an organisation in relation to an energy matrix tool, (Harris 1992).

Hereon, and in order to contribute to the harmonisation of terms and definitions, we will use the term energy audits and the definition included in the proposal for a Directive in Energy End-Use Efficiency and Energy Services, which states that an energy audit is a systematic procedure that obtains adequate knowledge of the existing energy consumption profile of the building site, industrial operation, etc.; identifies and quantifies cost-effective energy savings opportunities; and reports the findings.

Recent research has been focusing on several issues concerning the usefulness, cost-effectiveness and quality of commercially available energy audits and energy efficiency programmes that include subsidised or even free audits. The main findings of published literature on energy auditing are presented in the following sections.

Energy auditing programmes

There is some energy auditing activity in most EU countries. This began following the oil crisis in the 70's and early 80's, reduced during the period of low oil prices in the 90's and is now enjoying a resurgence with action to reduce energy related carbon dioxide emissions.

The support of energy auditing activities by energy efficiency and energy auditing programmes has been a common practice in several EU countries. These programmes have been developed in order to support the implementation of a national energy policy and they are usually focused on a particular sector and include energy auditing activities as an element of the programme. However, and despite all this activity, little attention has been given to monitoring and evaluating energy auditing activity and assuring that they offer energy audits at a minimum cost and maximum quality. In particular very little information was found on the objective and accurate evaluation of cost-benefit of energy efficiency, energy auditing programmes or other initiatives that are based on energy auditing activities. In light of the restructuring of the European energy markets, and in particular with the future introduction of a new instrument on the demand side - the Directive on end-use efficiency and energy service, the study of the cost-effectiveness of energy auditing programmes it is now very timely. The bibliographic references found on the evaluation of energy auditing programmes (in the English language) are presented and briefly discussed in the following section.

One of the first papers found is (Jordal-Jorgensen 1995), who presents the results of the Danish Heating-Audit Scheme (HA), an energy auditing programme that has been operating since the early 80's and that currently funds about 5000 energy audits per year. Although this study is on domestic buildings, is relevant, because of the methodology used in the analysis of the economy of energy audits. There are 2 perspectives to which energy audits cost-effectiveness and investment in energy efficiency has to be analysed (in the form of present value of the measures carried out, i.e. investments in energy efficiency):

- Private economy perspective, shows the economic result of the heating audit to the private households;
- Socio-economic perspective, shows the result of the HA scheme to the society as a whole, calculated in monetary terms.

The study included a survey to householders, and it was found that 25% of the total energy efficiency measures were carried out, 8% had been partially carried out and 47% were rejected. Interestingly 79% of the respondents replied that the energy saving measures would have been implemented even if the energy audit had not been carried out. The authors considered that half of this replies were truthful and accounted for 40% of free-riders in order to calculate the present value of investments in energy efficiency. They concluded that the:

- The HA Scheme is relative expensive (both from the private economic and socio-economic perspective), however there are valuable side-effects that are not considered in the analysis such as: improved indoor-climate, employment creation and added information when buying a house.
- Cost-efficiency of the scheme could be improved if only the most important energy saving measure were included (insulation, automatic boiler controls, etc.) and limit audits to buildings with larger potential for energy savings.

(Larsen 1999) assessed various energy auditing schemes in Denmark not only aimed at the domestic sector but also at industry. The aim was to know “How much energy was saved as a result of the energy audit, and what was the result from an economic viewpoint?”. Ibid. continues and analyses the response by energy authorities using 3 different decision-making theories in order to explain why loss-making schemes have been upheld or expanded.

For the analysis a model of audit evaluation and a cost-efficiency analysis was used. Consultancy costs plus investment costs were compared with the value of energy saving (derived from the energy audit). Similar to (Jordal-Jorgensen 1995), cost-efficiency was calculated for 2 different perspectives: private economic (economic gain of the client using market prices and excluding subsidies) and socio-economic (costs from external environmental effects – marginal abatement costs of CO_2, SO_2 and NOx). The aim was to identify who gain and who loses from the different energy auditing schemes: the client, the society or the consultant. The free-rider effect was also taken into account, in order to exclude investments in energy efficiency that cannot be attributed to energy audits.

Results from the analysis of 5 energy auditing schemes: Heating Consultancy (buildings above 1500m^2 and 120 kW boilers), Energy Consultancy Scheme (for single-family houses), Oil burner registration (oils burners lower than 120 kW), Electricity audits in large industries (Industries with electricity consumption between 5 and 50 million kWh/year) and Electricity audits in small industries (Industries with electricity consumption between 1 and 2 million kWh/year), were the following:

- Actual energy savings is much smaller than the so-called technical potentials (1 to 5% per annum for households, 3% per annum for electricity use in large industries and 4% per annum for electricity use in small industries);
- The only scheme yielding positive results (both socio-economic and private) is the Electricity audit in large industries scheme;

In Australia the results of a survey to 100 Australian businesses that participated in an energy auditing programme, which subsidised 50% of the cost of the energy consultant fee, is presented in (Harris et al. 2000). The main aim of this study was not to assess the cost-effectiveness of energy audits, but to investigate the factors that influenced companies to invest in energy efficiency, particularly why recommendations of energy audits are sometimes ignored and what is the actual uptake of subsidised energy audits. From the results of the survey to businesses it was possible to conclude that:

- 80% of the energy audits recommendations were implemented in an average of 6 recommendations per site;
- Companies stated that energy audits were worthwhile;
- The auditing scheme was probably cost-effective to the companies (Net Present Value analysis performed does not include hidden and other transactional costs);
- Audits are worthwhile to many businesses even without government subsidies;
- Promotion of energy efficiency should concentrate on the desirability of a firm taking, what the authors named an - enterprise-wide view of their energy efficiency, perhaps suggesting that an expert be consulted.

Another study is presented in (Gruber et al. 2003), and although it is focusing on the barriers towards the uptake of energy efficiency in SME’s, it includes results some results that are important in the discussion of the effectiveness of energy auditing programmes. In Gruber’s research econometric techniques were used to assess the determinants of the barriers to energy efficiency for the German commerce and service sectors, mostly public and private SME’s. The main aims of this research were to estimate the importance of different barriers to energy efficiency for German companies and to test if there is empirical support to the claim that energy audits are an effective means to overcome barriers to energy efficiency in SME's as often suggested. This research was based on a survey, of 2848 managers of enterprises and public institutions, which included questions on economic and technical factors that affect energy use and also questions about energy management, measures taken and obstacles for energy efficiency. In the regression analysis, energy audits were considered to be an independent variable that took the value 1 if an audit had been carried out (other independent variables were also considered, such as company size, sub-sector and energy consumption).

The barriers to energy efficiency or dependent variables were: lack of time, lack of information about energy consumption patterns, lack of information about energy efficiency measures, company investment priorities, uncertainty about future energy prices, landlord/tenant dilemma. The findings of this study suggest that:

- Energy consumption, size and audit exhibit an expected negative sign even when they are not statistically significant;
- Carrying out an energy audit will help reduce the barriers to energy efficiency analysed;
- Lack of time appears to be a problem to all sub-sectors analysed (except for public or quasi-public organisations);
- Lack of information about energy efficiency measures appears not to be a problem for any sub-sector in particular;
- Organisational priorities appear to be biased against energy efficiency in small industrial and commercial enterprises, when compared to other sub-sectors;
- The landlord/tenant dilemma seems to be a problem for half of the sectors analysed.

Another important result presented in this paper was that past experience on energy consultancy programmes showed limited success to small grants for energy audits in SME's. Apparently most of the companies preferred a short but cost-free initial audit and wanted to pay the follow-up detailed audit on their own as soon as a reliable estimate about the saving potential existed. Nevertheless it is stressed that energy audit programmes for SME's should not be too complicated and require companies to fill out tons of forms for which they don't have time.

Recently, an evaluation of the Danish free-of-charge energy audit programme was conducted and it was presented in (Dyrh-Mikkelsen et. al 2005). This energy auditing programme exists since the early 1990s, and it provides energy free-of-charge energy audits to all enterprises with electricity consumption above 20 MWh/year. The programme also promotes other energy efficiency activities and campaigns. A comprehensive evaluation of the free-of-charge energy auditing programme was performed in 2004, using the Danish evaluation guidebook which aimed to assess the cost-effectiveness of the programme from various perspectives, the government use of public money to subsidised energy audits, consumer satisfaction and the cost-effectiveness from the society point of view. From the three different complementary evaluation methodologies it was possible to conclude that:

- About 48% of the identified energy savings potential has been realised, and that the simple payback of this implemented measure is in average 3.6 years;
- It was not possibly to confirm that a reduction of electricity consumption (or stagnation) takes place after an energy audit compared with a control group that has not received an audit, based on the data available (the analysis was inconclusive);
- In a small sample of 10 case-study enterprises, considered to be success examples of the programme, 5 to 6 advices were received and in the total of 56 advices received, 36 were implemented. Implemented measures are the ones that have a shorter payback period;

Another important conclusion of the study, if not the most important, was that the potential savings and investments relied on estimates included in the audit reports, and that it was important to have metered data, from automatic metering systems, in order to have more conclusive results of the evaluation.

From the review above, the cost-effectiveness of most of the reviewed energy auditing programmes is not conclusive and unfortunately the causes of the apparent low cost-effectiveness of the programmes are not clear. However, it may be possible extrapolate that (short) free energy audits can be a driver for improved energy efficiency and therefore energy auditing programmes can be considered a valid instrument for the reduction of CO_2 emissions. Therefore, it is important to assess the cost-effectiveness of the energy auditing process, i.e. of the approach, the methodologies, the techniques and the tools used by energy auditors.

Increasing the cost-effectiveness of building energy performance assessments

The cost-effectiveness of energy audits was described in an European Commission - Joint Research Centre (JRC) study presented in (Heckle et al. 1990). They analysed the results of energy audits carried out by 4 different consultants from 3 European countries (France, Italy and Switzerland) on the same set of buildings. The objective was to compare commercial energy auditing methods from the point of view of accuracy and cost-effectiveness. Audits were compared not only to each other but also to a more detailed benchmark survey conducted by JRC researchers. Large differences were found between the results of all the audits, what might result from the different methodologies used by the different consultants.

However, no audit was consistently very much worse or better than the others. Furthermore, the benchmark study identified a considerable number of potentially cost-effective energy-saving measures, which were completely overlooked by commercial audits. Consultants based their recommendations on a relatively small number of common energy saving opportunities, which may indicate strong reliance on general checklists. (Heckle et al. 1990) found no correlation between the level of detail and cost of the audit and its overall cost-effectiveness, and that energy consultants tended to base their recommendations on a relatively small number of common energy saving opportunities, which may indicate strong reliance on general checklists.

Supported by the results of the studies presented above, researchers called for an expert system for large scale energy auditing in buildings (Caudana et al 1995). A prototype of an informatics tool was developed for improving the energy auditing in existing buildings named BEAMES (Caudana et al 1995). This tool is knowledge-based software with different functional modules (statistical module, pattern association, candidate energy saving opportunities list, analytical evaluation of energy savings, etc.). The tool was intended to be a support and field guide for professionals (engineers, architects, technicians) on the field, building energy saving companies and energy utilities involved in Demand Side Management (DSM) programs. One of the mains aims of developing this tool was to improve the quality of energy audits (and its cost-effectiveness) by: reducing the time for pre-audits, reducing the time for compiling reports and enabling consultants to have more time to perform on the field measurements to specific targeted areas of expected energy saving opportunities (identified in the pre-audit).

The methodology for assessing building energy performance under BEAMES is quite simple. Initially there is a pre-audit phase allowing the auditor to know the necessary level of complexity (and cost) of the audit and supply a list of candidate energy saving opportunities on which the auditor could focus his attention and plan appropriate measurements. After the pre-audit phase is completed the

BEAMES provides guided assistance for measurement techniques, audit procedures and implementation strategy options (using several databases of building standards, images, videos and internet resources). A follow up of BEAMES research outcome was THEBIS – Thermie European Buildings Information System (http://thebis.jrc.it). THEBIS is a database containing details of the most advanced and successful European building demonstration projects, which is only a module of what would be the BEAMES software tool. Apparently no further developments were made on the development and application of the BEAMES prototype.

Another European project developed an energy auditing tool to be used directly by the energy end-user. The Self-Help Energy Efficiency Business Advisor (SHEEBA) software package was developed in order to help small businesses in the identification of energy saving opportunities, (Fleming et al.

2000 and 2002). The software provides a wide range of information on energy management issues, energy analysis tools and a reporting facility of potential energy efficiency improvements and energy cost reductions. The objective is to convey the knowledge and experience from energy surveys with powerful energy analysis techniques in a cost-effective way to SME's and others involved in promoting energy efficiency. SHEEBA has two main elements:

1. Site specific advice - audit and energy analysis tool

The software uses what is called energy analysis techniques of first resort, described in the UK's Energy Efficiency Best Practice Programme Good Practice Guide 125 – Monitoring and Targeting for small and medium sized companies (ETSU et al. 1998). The input is energy (electricity, gas, etc) consumption – for a minimum period of at least 12 months, production and degree-days information. It will then identify relationships between these quantities and display the results of the analysis on the screen in the form of charts and tables. The user can also fill out a questionnaire that is based on surveys checklists for identifying the most common energy savings opportunities found by consultants.

2. General advice – quiz, glossary and encyclopaedia of energy terms

The glossary provides the definition of a wide range of energy terms and the encyclopaedia uses text, images and videos to describe different aspects of energy efficiency measures. The CD-ROM encyclopaedia contains information on equipment: such as boilers, lighting, compressed air systems, motors, monitoring and targeting techniques, and a section on energy science history. There is also a quiz available, providing entertainment whilst testing users' knowledge of energy efficiency issues. The SHEEBA software was tested on a wide range of small businesses and buildings in the UK, Spain and Portugal, and it was found that there are alternative approaches to taking a consultant to a site to identify energy saving opportunities. Furthermore, the CD_ROM proved to be a very effective way of distributing energy efficiency advice to businesses. However, the energy analysis tool had some limitations, particularly if the energy consumption data used was derived from estimated readings.

There are other tools and software packages for energy auditor and practitioners, which aim to improve the quality and cost-effectiveness of energy audits. A review of energy auditors tools used in European countries can be found in (Väisänen, H et al. 2003). These tools are usually developed according to the needs of the aims of the energy auditing programme, but more importantly, these tools have to take in consideration the existing audit market and consultancy market. Usually the best approach is to combine a different energy auditing tools, such as guides, handbooks, check-lists, software tools, benchmarking or even data bases on energy conservation options.

Currently, energy and water data in short- time series (usually in half-hourly, quarter-hourly intervals) is becoming easier and cheaper to get, and it is now available to a large number of buildings and sites. In addition, the advance in technology has been decreasing the cost of automatic energy and water metering hardware and software in the last few years, will lead to an increasing use of this technology in building energy assessment. In fact, the proposal for a Directive on End-Use Efficiency and Energy Services, in its Article 13 states that Member States will need to ensure accurate and informative metering and billing of energy consumption, and this will only be possible if advanced metering technology and intelligent monitoring analysis techniques will be place. Therefore in the near future it would be expected to have extended metering of buildings, in particular non-domestic buildings.

On the other hand, one could argue that there is a significantly large potential for the application of metering technology and short time series energy and water data in building performance assessment. In addition the use of this data together with advanced analysis techniques could be used to develop instruments to improve the cost-effectiveness of conventional audit schemes. This is required by the proposal for a Directive on End-Use Efficiency and Energy Services, in its Article 12. Trial approaches on the use of electricity short-time series data and innovative analysis techniques have already been tested on non-domestic buildings, in UK office buildings (Ferreira et al. 2003) and UK secondary schools (Stuart, Fleming, Ferreira and Harris, in press).

The experience of the Leicester energy agency suggests that energy audits by themselves were not the best tool for building energy management. They employ a different methodology for the identification of savings and evaluation of energy efficiency and renewable energy projects. The collection and analysis of half hourly electricity, gas and water data, using an intelligent energy and water metering and monitoring system in their municipal buildings.

In conclusion, energy audits are important, however energy management is a continuous process, and energy auditing has to be effectively combined with automatic metering systems and monitoring and targeting techniques/software in order to achieve the best results.

Intelligent energy and water monitoring in Leicester City Council buildings

A new approach for assessing energy and water performance assessment in buildings based on the use of metered (half-hourly) data. Data is collected by the monitoring and targeting system using an automatic meter reading system, information technology and energy analysis software. An overview of the energy and water monitoring and targeting system used in Leicester City Council buildings is presented and assessed in terms of its cost-effectiveness.

Leicester City Council collects utility data using a proprietary system which combines information technology and proprietary software package. Electricity, gas and water meter readings are taken at half hourly intervals and usually recorded onto a data logger locally. Data is also collected from district heating heat meters and from automatic weather stations. Each day the 48 readings from each (electricity, water and gas) meter are transmitted by low power radio to one of seven main receivers, similarly to the system presented in (DETR 1996). The main receivers then forward the data on to a central receiver located in the energy office where it is stored and analysed. It is possible to test the relationship between energy use and weather and/or occupancy. The proprietary software is used to plot it as charts at various resolutions; it also provides regression analysis and generates alarms when consumption falls outside predetermined levels. In summary the proprietary software main features are:

- Graphical display of data (including profiling with target setting);
- Regression analysis with degree-days (assess weather related consumption);
- Cumulative sum of the differences from an existing pattern of consumption;
- Year on year comparison;
- Reporting functions, including exception reporting.

Currently the Leicester City Council system collects and performs analysis on gas, electricity and water data for 223 buildings, including:

- Schools
- Libraries
- Leisure centres/Swimming pools
- Administration offices
- Elderly persons homes
- Warden assisted accommodation
- Maintenance depots

The cost to set up the energy and water metering and monitoring system is of the order of € 2,000 per site, but it can be as high as € 12,000 in more complex sites, where many sub-meters need to be replaced.

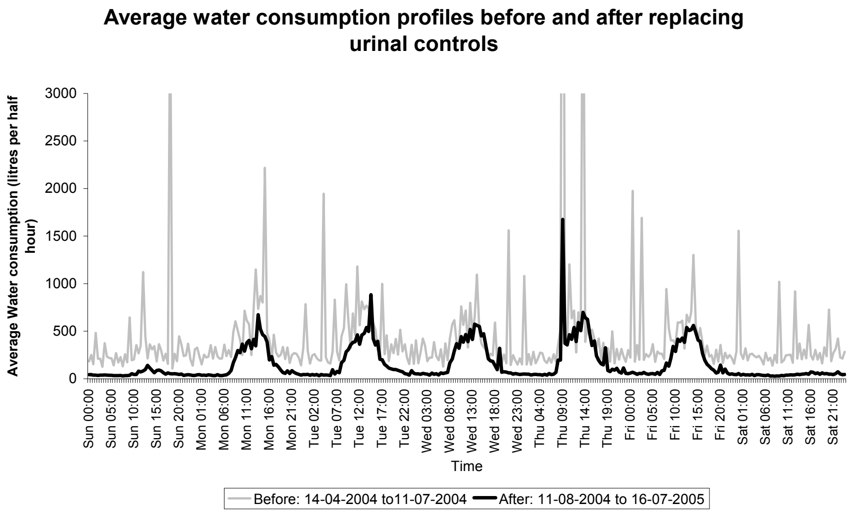
To date the system has identified problems that have been implemented and have led to annual savings of approximately 40,000 cubic meters of water, 670,000 kWh of gas and 135,000 kWh of water. This equates to a saving of around € 100,000. In addition to this, a further € 100,000 of savings has been identified that are yet to be implemented. Identified savings are mainly in the form of water leaks, overnight consumption and heating control problems that may remain undetected if it were not for the half hourly metering. The benefits of this system are that it identifies the potential for investment, it assists in diagnosing a problem and it allows potential savings to be accurately quantified. It should be noted that the data monitoring does not generate savings itself, it simply highlights waste and assists in the diagnosis of waste where it already exists. This kind of data monitoring allows for focused energy audits to be performed where a known problem exists. It even allows the timing of a visit to be chosen to ensure the phenomenon under examination is occurring at the time.

Application examples of the intelligent energy and water monitoring system

A number of example cases of energy and water savings detected, corrected and verified using Leicester City Council intelligent energy monitoring system are presented in the following section

Community College

This building had high overnight consumption and on investigation it was found that the urinal controls were faulty. These were replaced on 8 urinals at a cost of € 2,300 and the overnight consumption fell by equivalent to € 7,670 per year. The following chart presents the situation before and after the corrective action was taken.

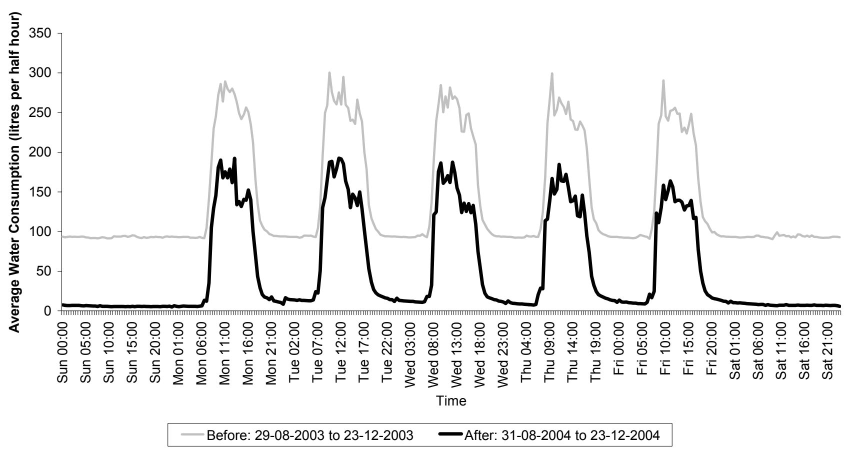


The data also shows a reduction in spikes, this may be due to the same measure or simply due to raised awareness of the potential savings to be made from water conservation.

Administrative building

Again high overnight consumption led to an investigation that identified a water leak. The leak was fixed resulting in a saving of about €3,850 per year.

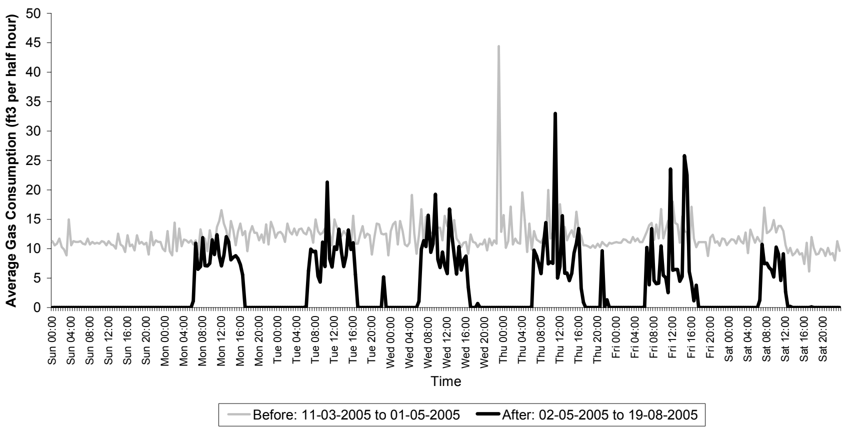
Average water consumption profiles before and after repairing leak



Housing Office

Once again, the simple method of comparing overnight consumption with peak load highlighted this one for investigation. It had been operating with no heating timer. Installation of a timer reduced overnight consumption to zero and saved about €2,250 per year.

Average weekly gas consumption profiles before and after applying heating controls



Other applications and futures uses

Another application of this system was to use the collected data into in Display™ Campaign simulation tool in order to calculate and more importantly classify the building according to its energy and water performance. Display™ Campaign is within the scope of the Directive on the Energy Performance of Buildings, (Schilken et al. 2005). Display is a certification scheme for municipal buildings and also an information tool to raise the public awareness of energy consumption. Leicester municipality is one of Display's pilot partners. The most visible part of Display is a poster, based on the now well-known principle of energy labels for household electrical appliances and which has been adapted for use on public buildings. It features a range of classes from A to G for the overall primary energy consumption, the resulting CO_2 equivalent emissions, and water consumption. In 2005, Leicester had conducted the building energy and water performance classification of 100 municipal buildings using Display. Buildings energy and water performance assessment was conducted using real (metered) energy and water consumption data.

Leicester City Council is using the metered energy and water consumption short time series data to develop training materials in the interpretation of the data by occupants, which ultimately will promote behavioural changes and energy savings with high cost-benefit.

Conclusions

Energy audits are an essential instrument for building (and industry) energy management, and the promotion of end-use efficiency and renewable energy. However, there is room for innovation in this field, particularly in what concerns the methodology, the techniques, and tools used by auditors. There is the need to guarantee the overall effectiveness of the auditing process that is aiming to improve energy end-use efficiency, i.e. implement energy saving measures (water savings, renewable energy technologies, etc.).

The cost-effectiveness of most of the reviewed energy auditing programmes is not conclusive. There is no clear indication of how cost-effective are energy auditing programmes, nevertheless it may be possible to increase the quality and the cost benefit of energy audits, and consequently of the auditing programmes in general by using instruments and tools that will reduce the auditors time on site, transactional costs and other costs inherent to the energy auditing process. Furthermore, evidence was found that that (short) free energy audits can be a driver for improved energy efficiency and therefore energy auditing programmes can be considered a valid instrument for the reduction of CO_2 emissions.

Energy management is a continuous process, and in order to have sufficient information to measure and evaluate energy savings it is necessary to have in place a reliable energy and water monitoring system. From the analysis of the preliminary results of Leicester City Council intelligent energy and water monitoring system it is possible to conclude that the analysis of readily available short time period metered data and advanced energy analysis techniques, can help identify energy saving opportunities in non-domestic buildings. This should be particularly useful for the implementation of the Directive on Energy Performance in Buildings and the future Directive on End-Use Efficiency and Energy Services.

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A Decision Support Model Using Expert Knowledge for Building Energy Management

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Abstract

The buildings are one of the fastest growing energy consuming sectors. In light of climate change and liberalization of energy market, building energy management has become an important necessity and a frequently used term. This is mainly due to the growth of commercial and public activities and their associated demand for heating, cooling, ventilation lighting etc. The automated buildings' operation aiming at guarantying desirable levels of living quality as well as energy saving for environmental protection constitute an important investment priority of modern enterprises.

Moreover, the use of intelligent energy systems can be an important source of energy consumption in the current period with a wide dissemination of information and communication technologies. Towards this direction, Building Energy Management Systems (BEMS) are currently being developed to be applied in buildings, namely the "intelligent buildings". These central co-ordination systems are responsible for the control and management of all buildings' operations and incorporate a number of sensors, activators and units of control.

In the above context, the main aim of this paper is to present a decision support model that will be based on a BEMS using the expert knowledge for a typical building. This intelligent model will contribute to indoor air quality of the building, while assuring the possible energy saving.

In particular, this model will be the main core of the presented BEMS system, which via the "experience" will be able to make diagnosis of internal building conditions and decide the suitable interventions that will be materialised via various activators (such as switches, valves, etc) of the building's energy systems. The model's most important characteristics are the following:

- It will take into consideration the specific requirements of spaces as well as the users' consumption patterns trying to optimize buildings' energy behavior.
- Its conceptual will be as broad as possible so as to have the flexibility to be applied to a wide spectrum of buildings.

Last, through the application of the intelligent model in a typical commercial building, its impact on energy consumption and indoor quality will be discussed.

Introduction

Nowadays, the buildings are one of the fastest growing energy consuming sectors, trying to satisfy increased residents' requirements for thermal comfort, visual comfort and indoor air quality. Specifically, it is estimated that the amount of energy consumed in the buildings in European Union (EU) reaches 40–45% of total energy consumption [1], about two thirds of which is used in dwellings.

In particular, energy demand growth in the tertiary sector reached 1,4% per annual (pa) in the period 1990-2000. Despite the expected continuation of restructuring of the EU economy toward the services, energy demand growth in the tertiary sectors is projected to slow down the next decades. This trend reflects saturation effects, changes in the fuel mix and the significant improvements in terms of equipment efficiency. Furthermore, energy demand growth in the household was limited to

0,7% pa in 1990-2000, because construction technologies, design techniques, materials and equipment have evolved rapidly, allowing plenty of scope to incorporate energy efficiency features into new buildings and appliances, but also saturation effects at the level of end use such as space heating, water heating and cooking. The energy demand in this sector is estimated to grow by 1% pa in the next year exhibiting a sight increase compared to the last decade [2].

In addition, energy usage in buildings of EU is responsible for approximately 50% of Greenhouse Gas (GHG) emissions [3]. As a result, the energy efficiency is a necessary as well as a very important keyword for the sustainable development both in developed and developing countries. This evolution has to be enhanced now, because the Kyoto protocol has entered into force in last February [4] and activities to promote and increase energy efficiency especially in the end-use sectors are an important contribution to the achievement of the energy and environmental goals set and the reduction target of GHG emissions. In particular, the European Commission (EC) goes further and states that if its indicative target of reductions in final energy consumption in buildings is realised, then savings of around 100 million tonnes carbon dioxide per year, which equates to a reduction of around 22% can be achieved. As a result, the objective of the Directive 2002/91/EC, which will enter into force in January 2006, is to "promote the improvement of the energy performance of buildings within the European Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness" [5].

In the above framework, the EC aims to promote methodologies, policies and tools that are related to energy efficiency as well energy management towards the success of its ambitious targets. Analytically, the integration of computer technology into building services systems is promoted and has become known popularly as Building Energy Management Systems (BEMS). Automated buildings' operation based on indoor energy management systems aims at preserving the comfort conditions for buildings' occupants and minimizing energy consumption and cost. Such systems are able to monitor and control many of the activities and services associated with buildings and facilities and not just energy. However, the term BEMS has now become more widespread to cover a large area of "facilities management". The majority of recent developments in BEMS have followed the advances made in computer technology, telecommunications and information technology.

Currently, modern and innovative techniques are applied to a significant number of cases in BEMS [6–10], demonstrating a significant reduction of total energy consumption compared to a conventional system. Moreover, the use of intelligent energy systems can be an important source of energy consumption in the current period with a wide dissemination of information and communication technologies. Towards this direction, BEMS are currently being developed to be applied in buildings, namely the "intelligent buildings". Based on the international literature's survey that is presented by Metaxiotis et al in 2005 [11], there are no studies joining the intelligent systems in the energy sector with the BEMS.

In this context, the main goal of this paper is to present the decision support model namely "Intelligent BEMS (I-BEMS)" that is based on a typical BEMS using the expert knowledge for buildings' energy management. In particular, the presented decision support model uses a knowledge-based expert system, which can control how the building operational data deviates from the settings, can carry out diagnosis of internal conditions and optimise building energy operation. In addition, this decision support model will aim at guarantying desirable levels of living quality as well as energy savings for environmental protection.

Apart from the introduction, the paper has the following sections:

- The second section is devoted to the presentation of the adopted methodology for the development of a decision support model using expert knowledge for building energy management.
- The third section is devoted to the presentation of the computerized decision support model in terms of its architecture, the parameters used, the developed rules and the appraisal of its pilot application.
- The last section summarizes the main conclusions drawn up from this paper.

The Methodology

Generally, the system infrastructure is based on the characteristics of a typical BEMS logic [12]. As illustrated in the following Figure 1, the I-BEMS philosophy is based on the general idea of a model with the capability of adaptability to any building's specific requirements, provided that appropriate "mapping" of the building areas and its elements is elaborated according to the decision support system's inputs and outputs.

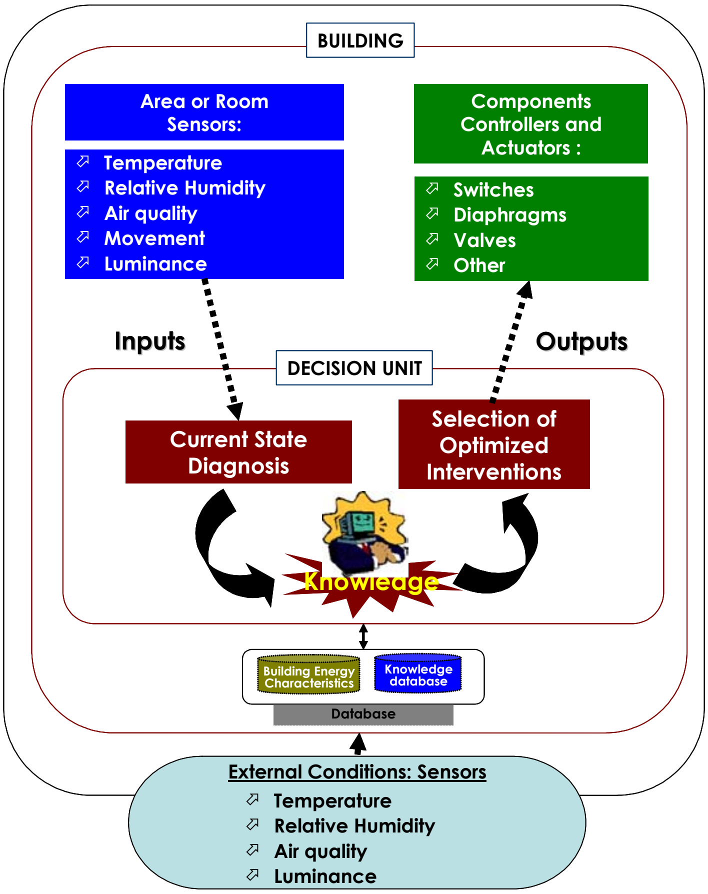

Figure 1. The I-BEMS Philosophy

The proposed model includes the following components:

- *Spatial Indoor Sensors*: Sensors that measure or record temperature, relative humidity, air quality, movement and luminance in the building areas.
- *Outdoor Sensors*: Sensors for the outdoor conditions such as temperature, relative humidity and luminance, which are essential for the efficient operation of the system.
- *Controllers*: This component category contains switches, diaphragms, valves, actuators etc.
- *Decision Unit*: A real time decision support unit with the following capabilities:
  - ✓ Interaction with the sensors and diagnosis of the building's state.
  - ✓ Application of the building energy profiles.
  - ✓ Combination of expert and intelligent systems techniques in order to provide the appropriate decision depending on the building's requests.
  - ✓ Communication with the building's controllers for the application of the decision.

- *Database:* It includes the database for the building energy characteristics and the knowledge database, where all essential information is recorded.

The followed procedure represented by a logical flow diagram is shown in the following Figure 2.

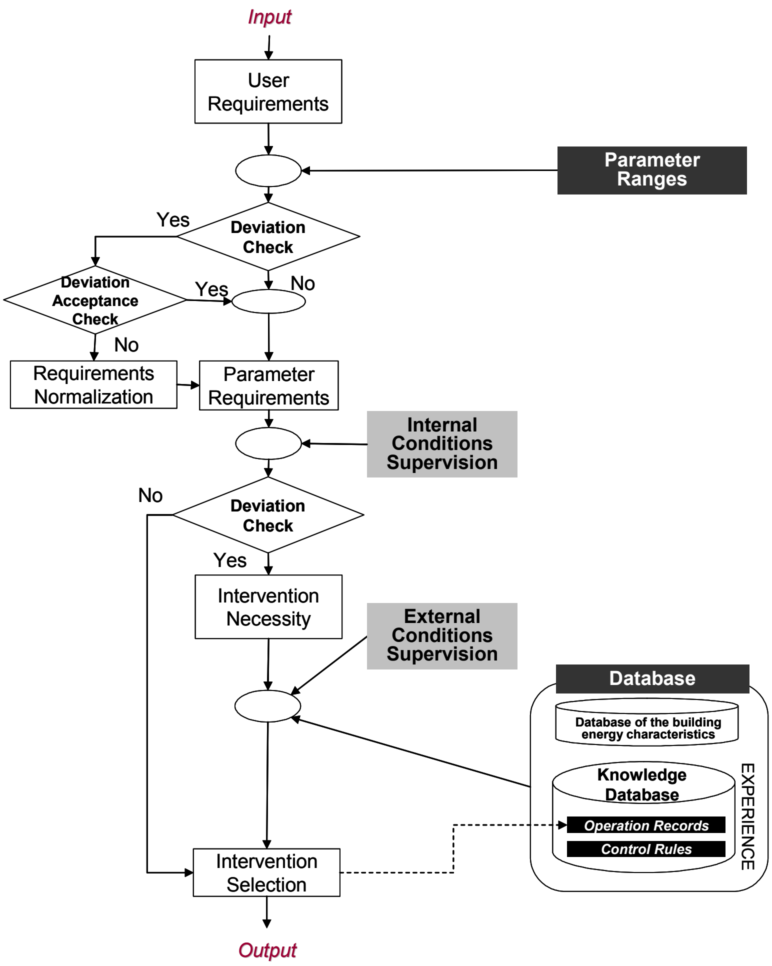

Figure 2. The Procedures of I-BEMS

More specifically, the procedure is defined below:

- *User Requirements*: Users inside the building define their requirements for indoor conditions setting values to control parameters such as temperature, relative humidity, air quality and luminosity.
- *Parameter Requirements*: User requirements are compared to defined parameters' ranges. For each area type, specific parameters' ranges have been defined, which provide comfortable indoor conditions. These ranges are described in the guides of ASHRAE [13]. The comparison result is the following:
  - ✓ If there is no deviation between user input and the parameters' ranges (No), then, user input is selected.
  - ✓ If deviation between user input and parameters' ranges occurs (Yes), then, the system proceeds as described:
    - ⅄ If the system status is set to "Manual", the system ignores the deviation and uses the user input.

  - ⅄ If the system status is set to "Auto", the system normalizes user's input within parameters' ranges choosing values with minimum deviation from user's input.

- *Intervention Necessity*: Determination of user requirements is followed by the recording of current indoor conditions through appropriate sensors and the deviation between them is calculated.
  - ✓ If there is no deviation between current and user input state, the control procedure exits without intervention.
  - ✓ If deviation occurs, then the intervention necessity appears.
- *Intervention method*: When intervention necessity appears, the system decides upon the appropriate intervention method. Through a logical and comparative sequence, using input and knowledge data, the decision unit defines the intervention method and produces adequate signals for the building's controllers. The definition of intervention method's process uses the following data sources:
  - ✓ Indoor and outdoor conditions records as well as the state of building openings (such as windows and doors) because the contribution of external conditions is very important for the effective control of the building's cooling and luminosity, in the framework of energy savings.
  - ✓ Data from the system's database which includes the database for the building energy characteristics and the knowledge database, described in detail below:
    - ⅄ Database for building energy characteristics: Includes information about the building's structural components such as the building's areas or rooms and their cooling, heating, lighting and other units. Moreover, types of areas and rooms in the building are defined through parameterized recording of their characteristics along with their corresponding operation records. This database, also, contains information about spatial energy consumption in the building and the default internal conditions about each building area. Therefore, a fully updated description of the building's state, including measurements and technical specifications of every component is originated.
    - ⅄ Knowledge database: Knowledge database stores information, which constitutes of system's expert knowledge and intelligence. Through the knowledge database the system recalls information about building areas or rooms and uses them in the decision process. Knowledge data are divided into the categories below:
      - o Historical records: User requirements and system decisions are recorded and stored in database. This is a very important and innovative system feature. This feature allows tracing of high consumption situations and their causes, as well as evaluation of areas and rooms behavior through the intervention methods that are decided by the system.
      - o Expert rules: Rules defined for the decision unit are, also, stored in the knowledge database. The rules are applied on the building's state and user requirements providing logical and expert reasoning to the system.

System's decisions are a sequence of signals and commands to the controllers and actuators for the application of system's output.

At this point, the importance of the knowledge database in the system's operation should be noted. More specifically, the historical and the energy profile's data, which are stored in the knowledge database, have the ability to modulate (with the help of the rules) intelligent interventions in order to ensure the thermal comfort and the energy savings. In particular, the system has the ability to:

- ⅄ Evaluate and compare the current building loads with the desirable ones (from the historical data) and in case of extreme energy consumption to cut down some of these, based on each area's special needs.

- ⅄ Calculate thermal and air quality indices through the use of historical data and to determine the areas' adaptability to the imposed interventions.

- Activate the appropriate procedures for the preheating and switching off of the equipment in certain time moments depending on the registered energy profile.

The IT Methodology's Development

Architecture

The decision support unit was implemented with the following software tools and applications as it is described in Figure 3:

- The "MS Access" was used for the development of the database for the building energy characteristics and the knowledge database.
- The "Visual Basic 6.0" was the programming language that provided interconnectivity through the database, sensors and controllers of the building.
- The "Clips", which is an expert system shell (C language integrated production system), was embedded in the system, to provide processing of system's rules and inference to the decision process. In particular, the "CLIPS" provided a complete environment for the building of rule and object-based expert systems and reduced the effort and cost involved in developing an expert system. The version 6.2 released in spring 2002 was used to develop the current system [14].

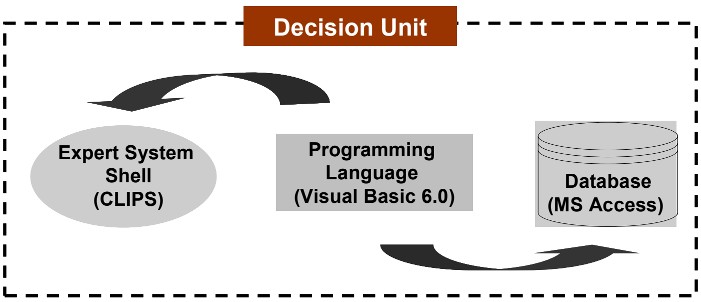

Figure 3. The Architecture of the I-BEMS' Decision Unit

It is important to mention that the energy characteristics and knowledge databases are fully dynamic, allowing system administrators to define new buildings, types of rooms or areas, components and rules. In the following paragraphs, parameters of the decision system will be defined and a brief description of the rules will be conducted.

Parameters

The aim of the expert control system's design was to utilize dynamic rule sets altered by the data recorded from the operation system. This feature led to the definition of finite sets of areas and control points. In this context, a typical building was modeled and control points were defined for the indoor conditions and the electro-mechanical components of the building. Categorization of control points is presented below:

- *Input*: The first set includes parameters concerning the indoor conditions and the time scheduling.
- *Output*: The second set of parameters concerns the system controllers and actuators.
- *Supportive Parameters*: This set of parameters is divided into two categories, the following:
  - ✓ The first one is about the thermal and air quality of the area or room that is under control. More specifically this set includes indicators about the convenience or difficulty to control a specific area or room.
  - ✓ The second category contains information about the current state of each area or room and the requests about them.

Rules

Considering the followed procedure, a set of control rules has been created covering all probable requests of a typical building. These rules, which combine input and output parameters, are categorized as shown below:

- Internal comfort conditions.
- Building energy efficiency.
- Compatibility of decision support unit.

The first basic control rules' category ensures indoor comfort conditions for every area or room in the building. It consists of the following four subcategories:

- *Indoor temperature/relative humidity*: Supervision of temperature and relative humidity levels using sensors and adjustment according to default levels for each room type or use.
- *Air quality*: Monitoring of indoor air quality using CO_2 concentration sensors and adjustment to default levels for the specific area or room.
- *Luminance*: The main objective of this category is the achievement of normal luminance in the areas of the building. Monitoring of luminosity levels is achieved via sensors and necessary adjustments to the lighting appliances are conducted.
- *Movement*: Monitoring of movement inside building areas and rooms is being conducted through movement sensors. Components operation is modified according to the presence or not of people in the building.

The second basic control rules' category includes rules dealing with energy efficiency of a typical building. This category consists of the following subcategories:

- *Starting / ending optimization*: Rules about system starting and ending according to each area or room working hours have been composed including pre-warming and smooth power down procedures for the energy saving objective.
- *Procedural hierarchy*: This sub category's rules deal with intervention hierarchy for the temperature, relative humidity, air quality and luminance adjustment with main objective the achievement of energy savings. In this context, rules about cooperation between building components and outdoor conditions are included. Some brief examples of this cooperation are the use of fresh air for cooling and the use of outdoor lighting through moving shutters for increasing indoor luminance.
- *Energy management optimization*: Includes rules that control energy consumption of each area or room in the building. The main objective of these rules is to locate high consumption periods during operation and the systems that are responsible. In this context, rules that perform actions for elimination of consumption peaks without discomfort whenever possible are elaborated.

For each of the above basic categories, the following main type of rules exists, which provide the decision unit procedural steps.

- *System initialization*: These rules define allowed ranges for input variables about temperature, relative humidity and air quality that should be used for comfort and energy savings.
- *Intervention necessity*: Includes rules defining appropriate thresholds for interventions like heating, cooling, hydration, dehydration, ventilation and lighting.
- *Deviation scaling of indoor conditions*: Rules about deviation between user requirements and current area or room conditions quantification for all control parameters are included in this rule type.
- *Intervention selection*: Rules of this type define the selection of actions in order to cover the intervention needed. These actions include switching on/ off of buildings' components and determine the components that will be used to adjust indoor conditions.

- *Intervention intensity determination*: It includes rules that determine how intense interventions will be according to each area or room indicators and controlled component scaling.

In some simple cases, such as air quality adjustment or lighting, one rule may belong to two types, joining deviation scaling and intervention selection for example.

The third control rule category is about compatibility of decision unit resolving inconsistent requests. These rules resolve incompatibility issues, such as the need to switch on/ off components at the same time, defining the final selection of intervention ways.

A Pilot Appraisal

The proposed management system was applied to a typical office building in Greece. The use of energy in buildings such as public and private buildings, schools, hospitals, hotels and athletic facilities, constitutes of 30% of total national energy demand and contributes about 40% of carbon dioxide emissions in Greece [15]. Heating and refrigeration of buildings consume the largest part of energy expended in domestic uses [16]. Taking into consideration that only about 3% of buildings in Greece have been constructed after 1981 (when heat insulation regulations were put into effect), it may be concluded that the limited application of insulation in the majority of residences causes significant energy losses in Greece [17].

The specified building used for the I-BEMS application is consisted of 3 floors and a total surface of 485.22 m^2. Energy demands of the building are fully covered by electricity and other means of energy production are not present. More specifically, building energy loads consist of the following:

- Lighting (inside and outside the building).
- Hydraulic elevator.
- Heating, Ventilation and Air Conditioning (HVAC) central system.
- Computers and office equipment (printers, faxes).
- Server room (including telephone centre, servers, routers and networking equipment).
- Electric pumps used to discard pluvial water.

The building is equipped with a typical BEMS with the components shown below:

- Separate micro-controllers, sensors and actuators for luminance, temperature and air quality control.
- HVAC central system with local controllers for each area or room in the building and central computer assisted control.
- Access control and human presence system.
- Energy consumption gauges.
- Separate central control management software for areas or rooms.

With respect to the above, the appropriate “mapping” of the building areas and its elements were elaborated, as shown in figures 4 and 5. In this context, a fully updated description of the building’s structure, including technical specifications for every component was originated. Following, the system was applied, tested and optimized on the building for a time period of about a year.

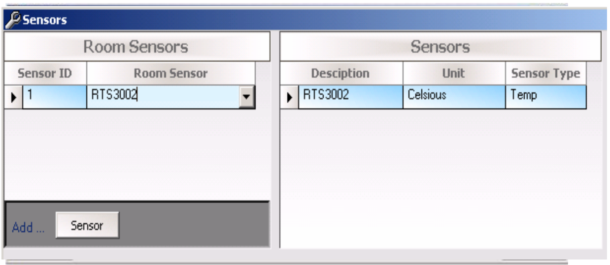

Figure 4. Room Types Specifications **Figure 5.** Sensor Types Specifications

Application results were categorized according to the managed indoor comfort conditions (temperature, relative humidity, air quality and luminance) and energy consumption. The results for each category are presented below:

- Temperature - Relative Humidity - Air Quality: Room condition measurements showed that temperature, relative humidity and air quality levels were in the defined ranges varying according to user requirements. Discomfort situations almost never occurred especially due to effective relative humidity and air quality control. Preheating and switching off procedures contributed to the energy comfort both in summer and winter. Especially in winter, external air was never used for heating but, shutter control allowed sun light to improve heating procedures.
- Luminance: Luminance levels inside building areas or rooms also ensured comfort conditions. In addition, satisfying control of building shutters and lights was achieved. Sometimes, the priority to save energy through HVAC operation lead to closed shutters and lights during summer sunny very hot days but, it proved more energy efficient.
- Energy saving: Cumulative operation data about building energy consumption compared to previous year consumption records revealed a significant energy saving result of approximately 10%. In particular, the building's annual electricity consumption was reduced from 106,5 MWh (October 2003 – October 2004) to 95 MWh (October 2004 – October 2005). More detailed examination of collected information showed that energy savings were higher during warm days.

Conclusions

The promotion of energy efficiency in the buildings is absolutely necessary today, taking into consideration the force of directive 2002/91/EU towards the effective operation of the buildings by January 2006, as well as the increased impact of the climate change on the final energy sectors towards the period 2008-2012. The above facts bring out supportive tools such as BEMS, as key means for establishing the EU ambitious targets.

In the above context, an Intelligent Building Energy Management System was developed in the current study. Indeed, models such as the current one are needed to support the energy policy goals in a consistent way, as well as to satisfy increased residents' requirements for thermal comfort, visual comfort and indoor air quality.The I-BEMS enables central monitoring of energy consumption in a number of public sector buildings using expert knowledge. Energy efficient controls include the intelligent monitoring and optimized start/stop of heating systems and lighting controls. Thanks to a high level of collected data, a reliable energy profile can be created, where error decisions can be detected and eliminated.

Based on the results of the pilot application, it can be considered that the presented I-BEMS operation was satisfactory, since it contributed to improved indoor air quality of the building, while assuring the possible energy saving. It can be observed, that energy savings can be obtained applying several simpler and probably cheaper energy saving measures. However, based on the current study, the significant perspectives of the expert knowledge usage for improving buildings energy management were illustrated. Such systems provide the ability to translate the building's energy knowledge into several rules (physical behaviour, priorities of intervention, etc.) and into electronic commands to actuator devices.

In addition, the system's interface was characterized as very friendly and facilitative, based on the users' comments on its pilot application. Moreover, its open architecture allows easy and continuous updates and unlimited horizontal and vertical expandability. Therefore, the system's design allows its application to a large number of building categories so as to assure its flexibility.

Acknowledgment

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Thermal Performance and Sustainability Assessment of a Health Building in a Maritime Climate – A Case Study in Sheffield, UK

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Abstract
Sustainability has acquired great importance due to the negative impact of various developments on the environment. Sustainable building is now a global issue and its life cycle influences the life cycles of the planet drastically. As a result, it is important to say that, in order to achieve better building performance and sustainability that could also help to reduce pollutions and improve the environment, sustainable building design and development is vital. This paper demonstrates how building monitoring and simulation analyses could be used in a rational and innovative way for better building performance and sustainability, and provides a case study that investigates the potential overheating periods and explores the possibility of minimising its impact by the control of daylighting and window shading.

Introduction
Sustainability has acquired great importance due to the negative impact of various developments on the environment. Sustainable building is now a global issue and its life cycle influences the life cycles of the planet drastically. This being said, it is vital that sustainable building design and development is in the agenda for working towards better building performance and sustainability in the built environment and therefore help contribute to reducing pollutions and improving the environment.

Figure 1: Student Health Building and Simulation Model.

The University of Sheffield's new Student Health Centre, which was completed in September 2004, has won two prizes at the annual Royal Institute of British Architects' (RIBA) Yorkshire Awards 2005. This building was specially designed to be naturally ventilated and lit. Despite the fact that the building has a high-quality design and incorporated the use of environmentally friendly measures, there has been a number of complains from occupants about higher room temperatures, which relates to the cause of thermal discomfort. The quality of daylight is very important and the optimisation of window shading is equally necessary while maintaining thermal comfort within buildings. The following studies carried out for better building performance and sustainability, such as analyses involving building monitoring of internal conditions in specific rooms and examining overheating periods during summer season.

Building Monitoring

Post-occupancy monitoring has been undertaken to investigate the internal conditions in specific rooms and measuring overheating periods in the Student Health Building. The following floor plans are to give an idea about which rooms the temperatures were monitored with an indication to sensors'/loggers' location and the building's orientation (see figure 2).

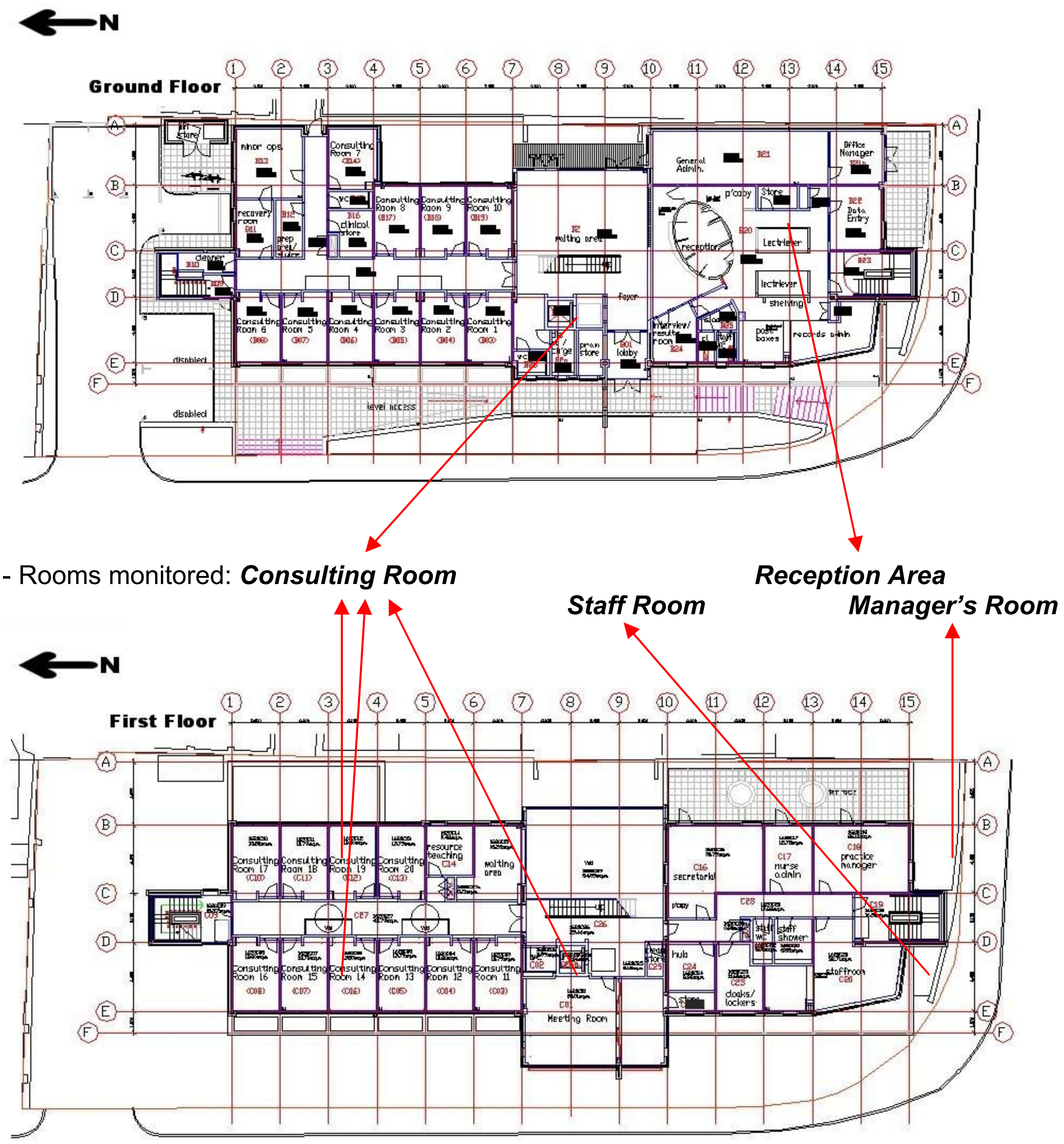


Figure 2: Floor Plans and Rooms Monitored.

The following tables (see tables 1-4) consist of the data measured over a four weeks period at 20 minutes intervals during summer 2005, and the mean internal temperature and relative humidity recorded in six different rooms within this building. Additionally, the following figures (see figures 3-6) show the overall change recorded during these weeks on charts.

Table 1: Mean Internal Temperature and Relative Humidity Recorded During 14-22 Jul 05.

Room	Mean Internal Temperature (IT) (°C)	Mean Relative Humidity (RH) (%)
C18	26.47	35.47
C20	24.58	42.29
C10	26.19	35.34
C08	22.97	43.97
Reception	25.03	41.2
B03	25.66	43.61

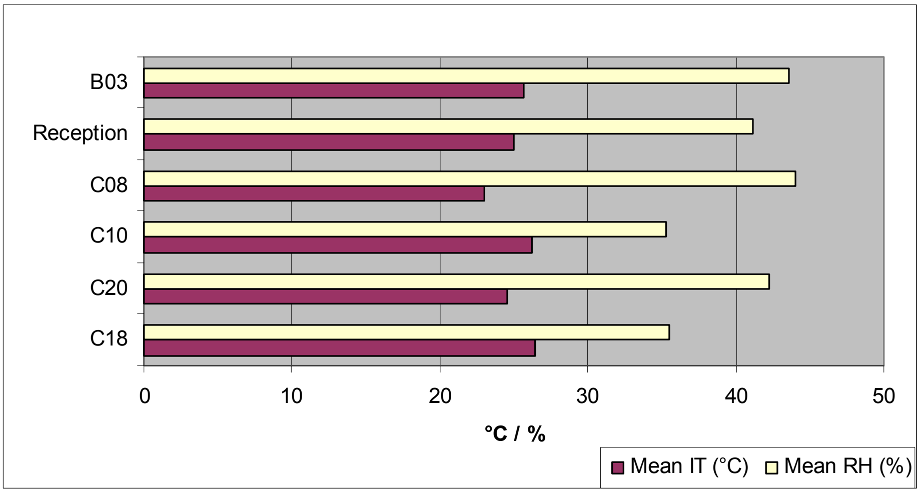


Figure 3: Mean Internal Temperature and Relative Humidity Recorded During 14-22 Jul 05.

Table 2: Mean Internal Temperature and Relative Humidity Recorded During 25 Jul-2 Aug 05.

Room	Mean Internal Temperature (IT) (°C)	Mean Relative Humidity (RH) (%)
C18	21.87	44.23
C20	21.53	52.95
C10	23.59	41.31
C08	20.2	52.89
Reception	22.97	46.55
B03	23.42	48.01

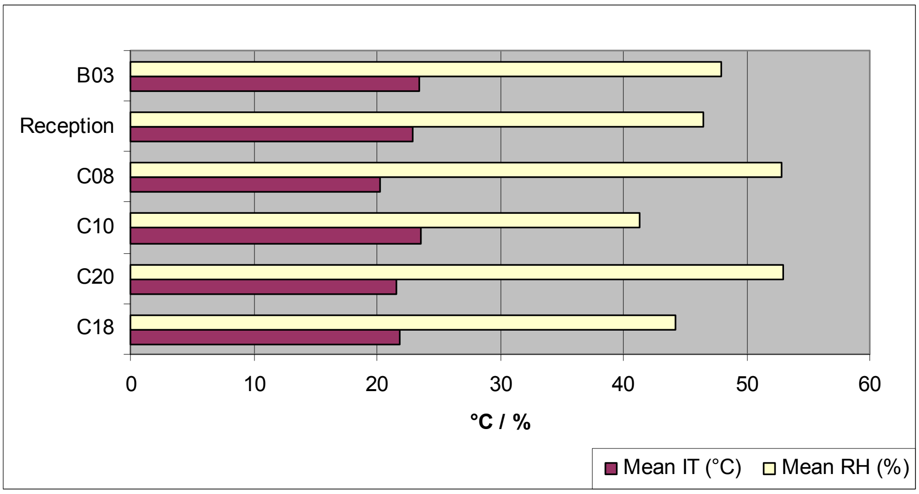


Figure 4: Mean Internal Temperature and Relative Humidity Recorded During 25 Jul-2 Aug 05.

Table 3: Mean Internal Temperature and Relative Humidity Recorded During 9-17 Aug 05.

Room	Mean Internal Temperature (IT) (°C)	Mean Relative Humidity (RH) (%)
C18	23.98	42.34
C20	22.83	50.08
C10	23.7	43.88
C08	22.39	49.56
Reception	23.62	47.03
B03	23.98	48.19

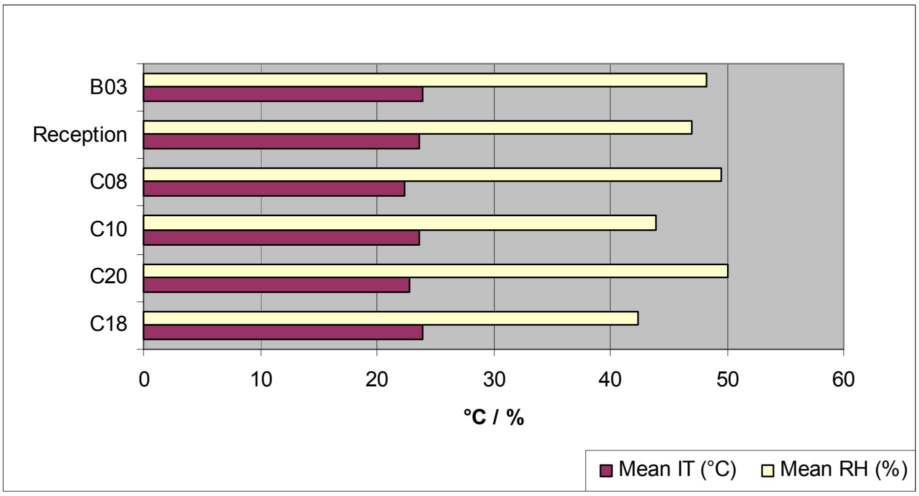


Figure 5: Mean Internal Temperature and Relative Humidity Recorded During 9-17 Aug 05.

Table 4: Mean Internal Temperature and Relative Humidity Recorded During 17-24 Aug 05.

Room	Mean Internal Temperature (IT)	Mean Relative Humidity (RH) (%)
C18	26.42	36.47
C20	24.38	45.35
C10	25.55	37.98
C08	23.01	47.41
Reception	24.52	42.82
B03	24.61	47

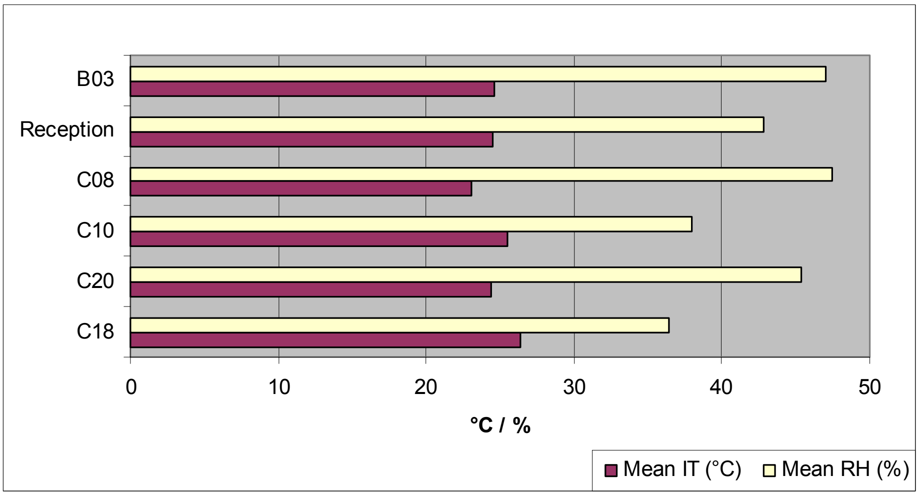
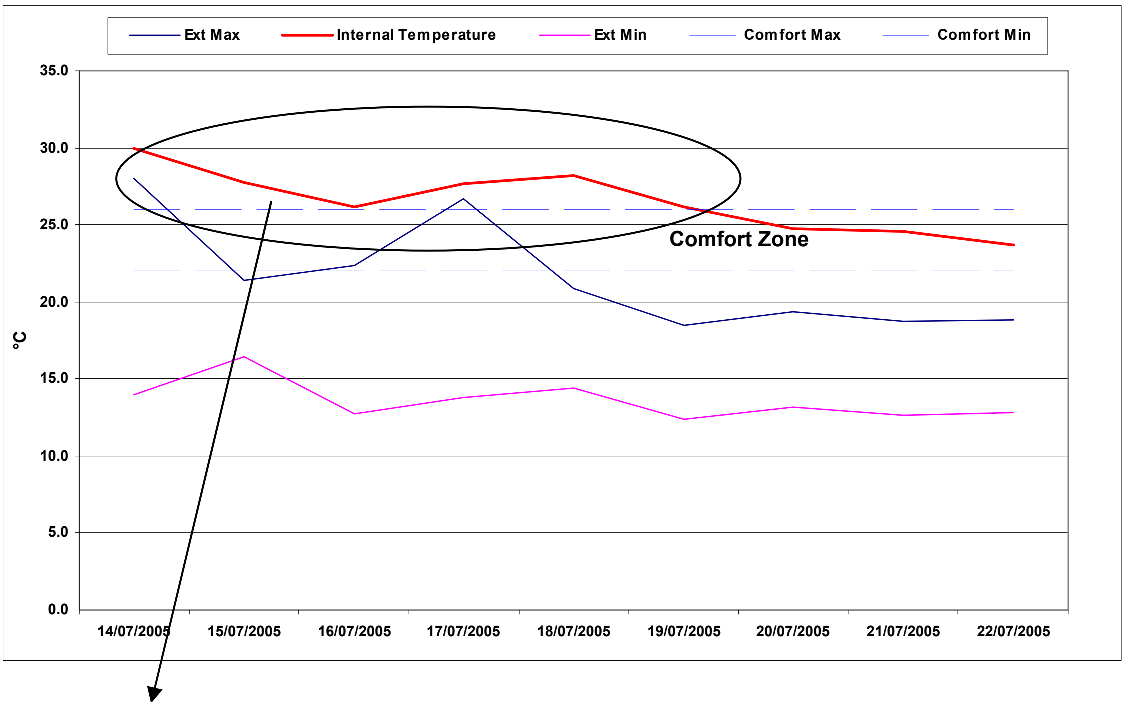


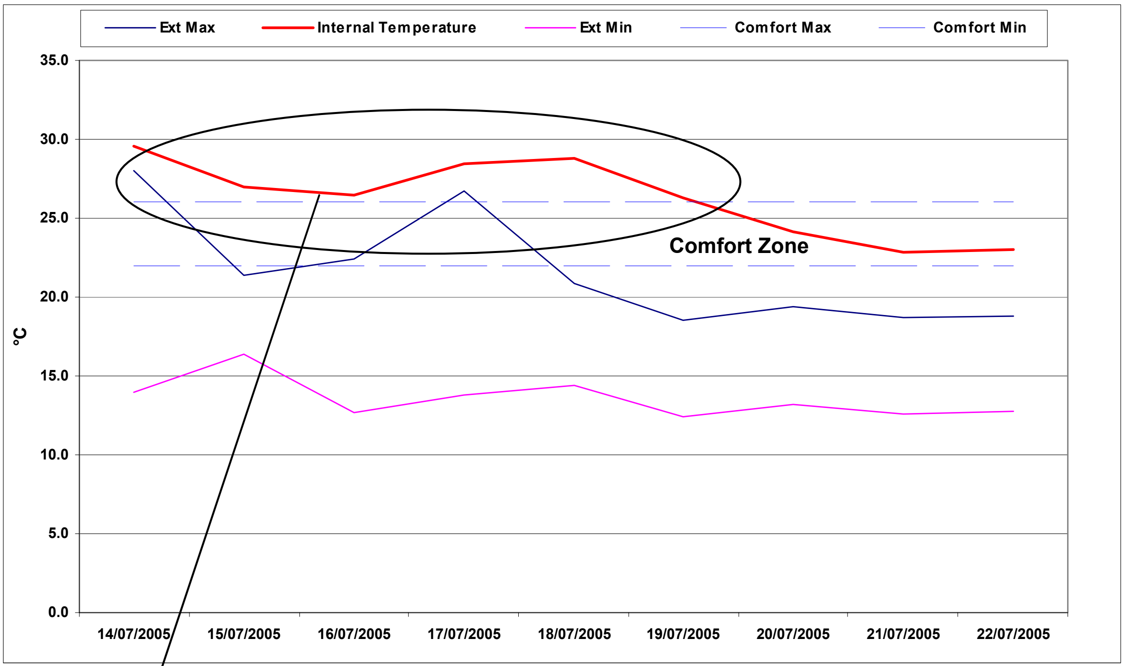
Figure 6: Mean Internal Temperature and Relative Humidity Recorded During 17-24 Aug 05.

The thermal comfort of a human being is dependant on the thermal balance of the body, which is in turn dependant on parameters such as; air temperature, mean radiant temperature, relative air velocity, relative humidity. As regards the Student Heath Building, the following figures (see figures 7-10) show the overheating periods recorded on a weekly bases in specific rooms during summer 2005. As it can be seen clearly on below graphs; there have been significant overheating periods and therefore the occupants, especially in rooms C18 and C10, have experienced thermal discomfort.



- Overheating period.

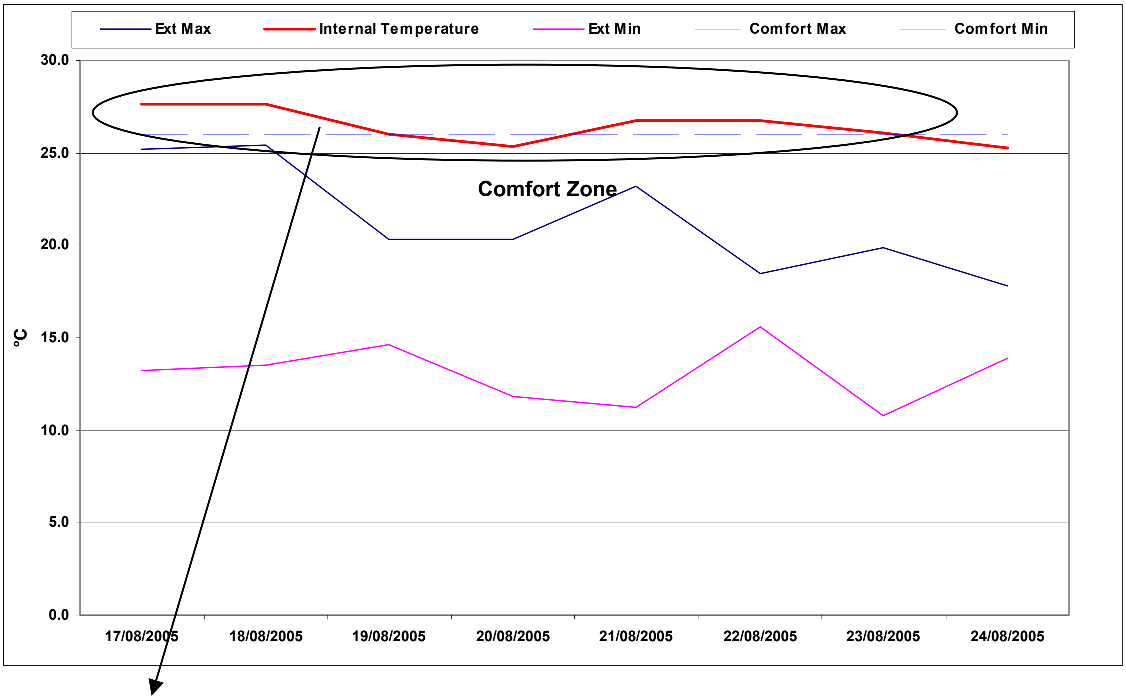
Figure 7: Overheating Periods in Consulting Room C18 During 14-22 Jul 05.



- Overheating period.

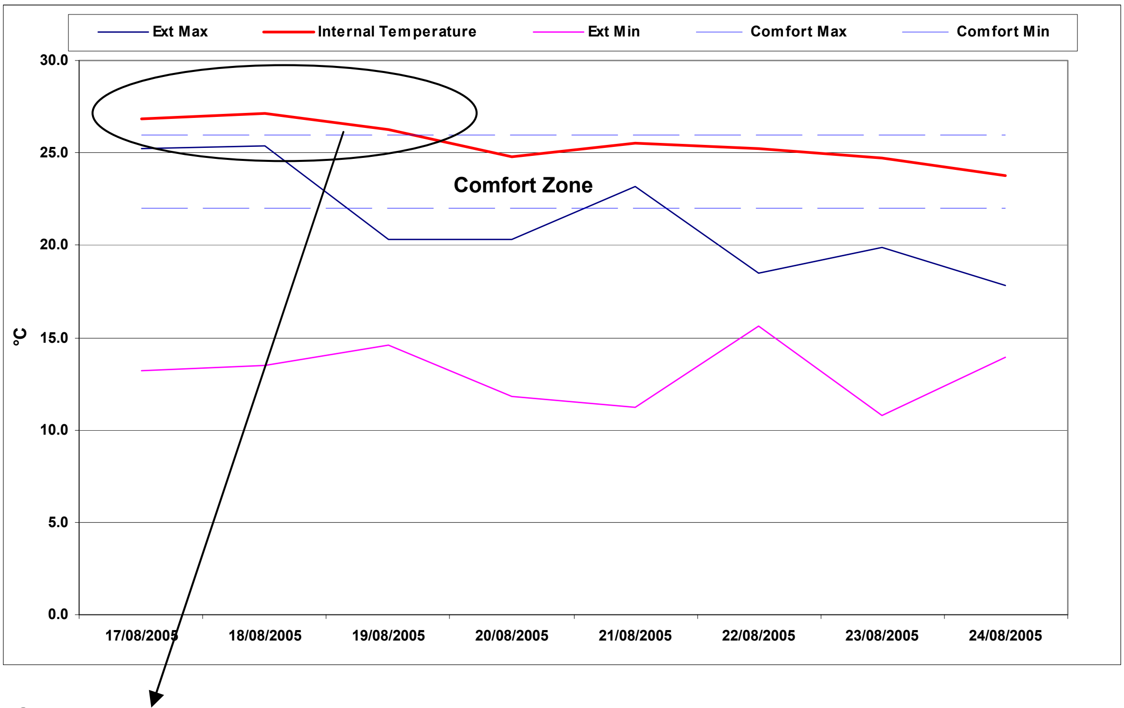
Figure 8: Overheating Period in Consulting Room C10 During 14-22 Jul 05.

Please note that the minimum and maximum external temperatures (Ext Min and Ext Max) used on these graphs are obtained from the nearest Met Office available in the area and the internal temperature used is the average for each day recorded by sensors/loggers during summer 2005. In addition, the 'Comfort Zone' is defined according to the CIBSE Concise Handbook's recommended values for each specific space within this building (i.e. office space, consulting room, etc.).



- Overheating period.

Figure 9: Overheating Period in Consulting Room C18 During 17-24 Aug 05.



- Overheating period.

Figure 10: Overheating Period in Consulting Room C10 During 17-24 Aug 05.

It is clear that close attention will have to be paid to the way the natural ventilation is provided and the use of daylighting within this building in order to avoid such problems with thermal comfort. The temperature within the building has the greatest influence on thermal comfort. It is important that there is neither under nor over heating. As a result, heat gains from occupants, computers, lights, etc. need to be calculated carefully as they can provide a considerable heat load, which could again affect thermal comfort.

Building Performance and Simulation Analysis

The study in this part consist of Thermal and Lighting Analysis, and Design Modifications carried out by computer simulations (using Ecotect and Radiance) to establish the thermal discomfort levels, the quality of natural lighting and the optimisation of window shadings. Furthermore, the results of these computer simulations can be used for comparison with the post-occupancy monitoring findings and would therefore also help to develop certain operating strategies.

Thermal Analysis

The following analyses are compiled to show the thermal discomfort levels in degree hours provided on yearly bases in specific rooms in this building. In these calculations, both example rooms used (see figure 11 and 12) are neither air-conditioned nor heated, however are occupied, and therefore perform discomfort calculations showing the amount of time the internal temperature of these rooms spend outside the specified comfort conditions for each month.

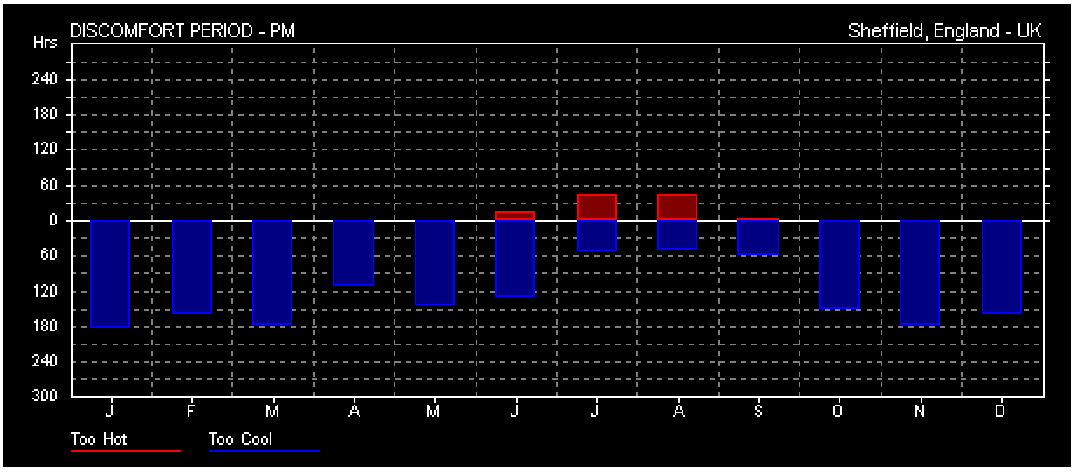


Figure 11: Annual Thermal Discomfort Period in Degree Hours in Room C18.

Table 5: Thermal Discomfort Period in Room C18.

MONTH	**TOO HOT (Hrs)**	**TOO COOL (Hrs)**	**TOTAL (Hrs)**
Jan	0	184	184
Feb	0	160	160
Mar	0	176	176
Apr	0	108	108
May	0	143	143
Jun	15	125	140
Jul	48	48	96
Aug	48	48	96
Sep	4	57	61
Oct	0	150	150
Nov	0	176	176
Dec	0	161	161
TOTAL	**115**	**1536**	**1651**

Occupancy: Weekdays 09-17 / Weekends 00-00 (1 Person)
Comfort: Adaptive - Free Running (± 1.75)
Comfort Band Temperature: 22-26 (°C)
Air Change Rates: Air Infiltration: 0.50 / Wind Sensitivity: 0.25

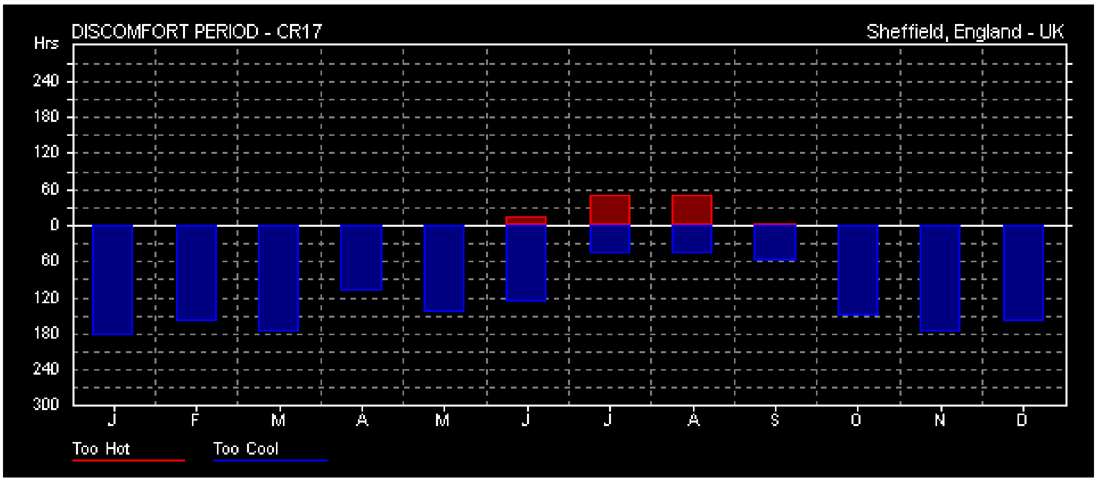


Figure 12: Annual Thermal Discomfort Period in Degree Hours in Room C10.

Table 6: Thermal Discomfort Period in Room C10.

MONTH	TOO HOT (Hrs)	TOO COOL (Hrs)	TOTAL (Hrs)
Jan	0	184	184
Feb	0	160	160
Mar	0	176	176
Apr	0	109	109
May	0	146	146
Jun	15	128	143
Jul	47	49	96
Aug	48	48	96
Sep	4	58	62
Oct	0	155	155
Nov	0	176	176
Dec	0	162	162
TOTAL	**114**	**1551**	**1665**
Occupancy: Weekdays 09-17 / Weekends 00-00 (2 Person) Comfort: Adaptive - Free Running (± 1.75) Comfort Band Temperature: 22-26 (°C) Air Change Rates: Air Infiltration: 0.50 / Wind Sensitivity: 0.25			

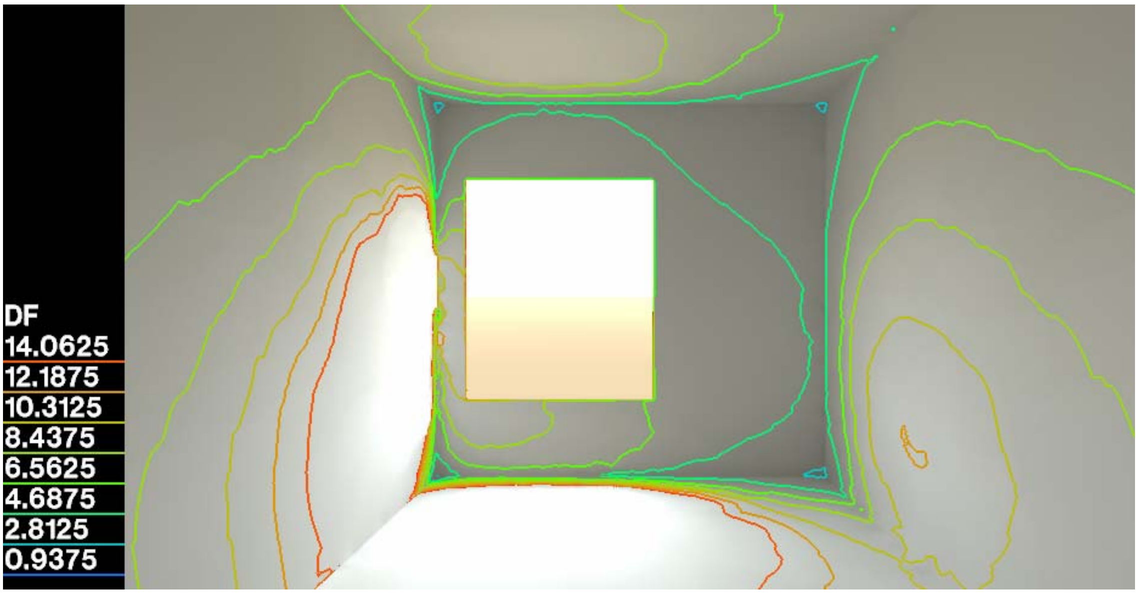
In above tables/charts, Degree Hour discomfort values simply weight each hour of discomfort by the number of degrees outside the comfort band. Thus, both charts for these two specific rooms selected as examples, picks a significant thermal discomfort during summer season, which also explains why the monitoring findings for summer 2005 have shown significant overheating periods. As a result, this indicates that there are some weaknesses in both the design strategies as well as operational methods used and therefore, it is again clear that close attention will have to be paid to the alternative strategies for natural ventilation and the control of daylighting and window shading within this building in order to avoid such problems with thermal comfort.

Lighting Analysis

The quality of daylight is very important and it generally recognised that a Daylight Factor (DF – the relationship between the amount of natural light available at a location within a building compared to the amount available at the same time outside the building) of 2% is appropriate for the room to be perceived as being 'naturally lit'.

For this part of the study, the simulation studies carried out were aimed at establishing the daylight factors in consulting rooms, as there were certain design issues with the design of windows; both related to the use of daylighting and the privacy within these rooms. The following two consulting rooms are selected as examples. These analyses have been considered under overcast sky conditions, as the daylight factors calculated under these conditions would provide more appropriate values for further evaluation in these rooms (considering the worst case scenario) (see figure 13 and 14).

on the Vertical Surfaces



on the Working Plane

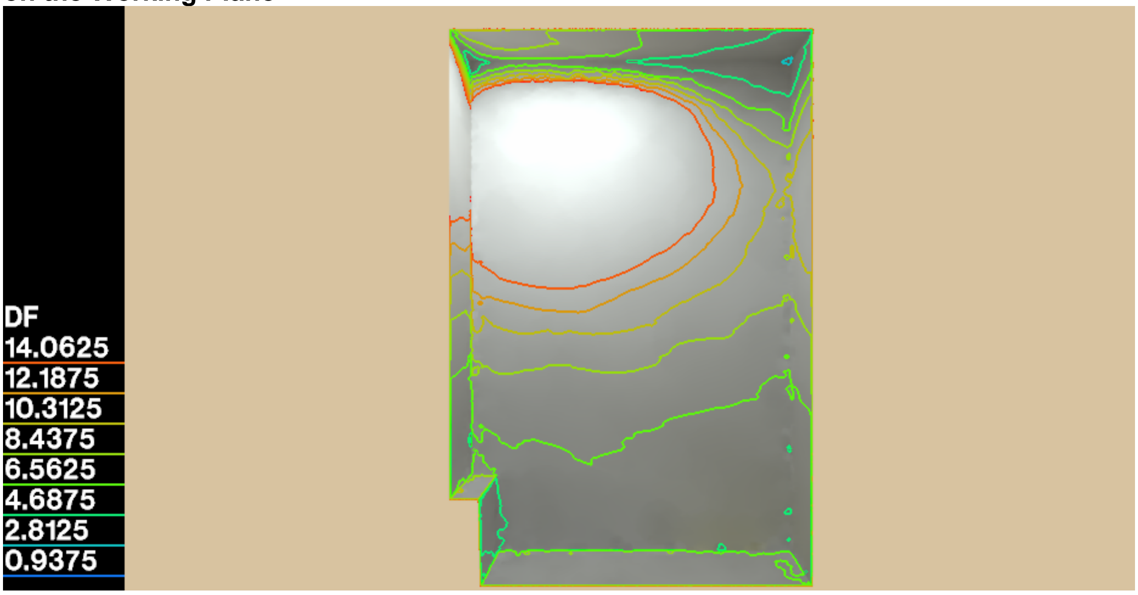
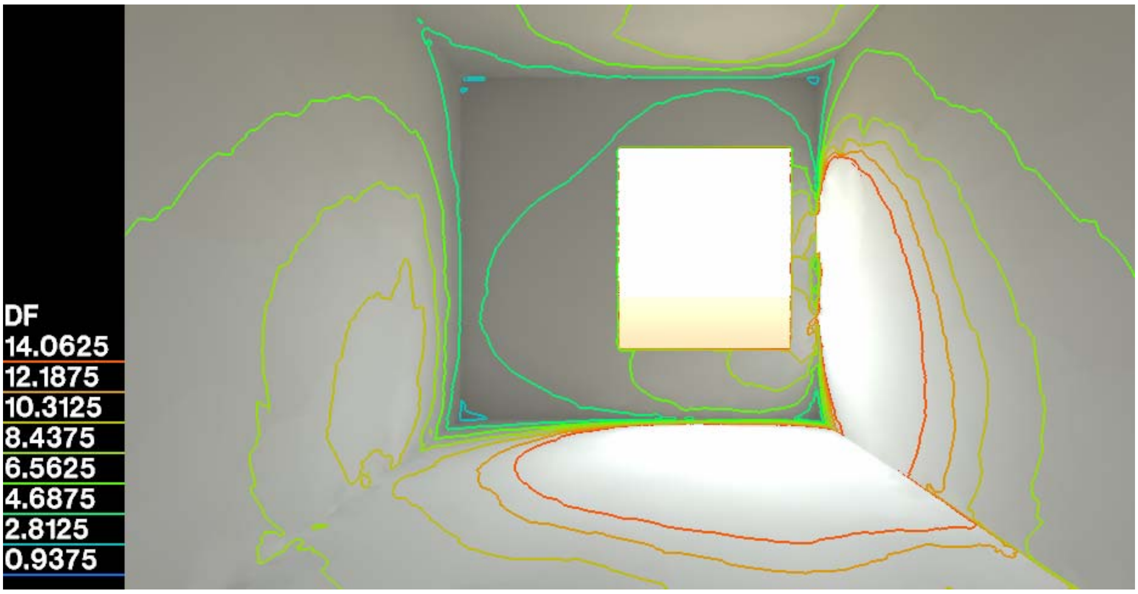


Figure 13: Daylight Factors in Consulting Room C10:

on the Vertical Surfaces



on the Working Plane

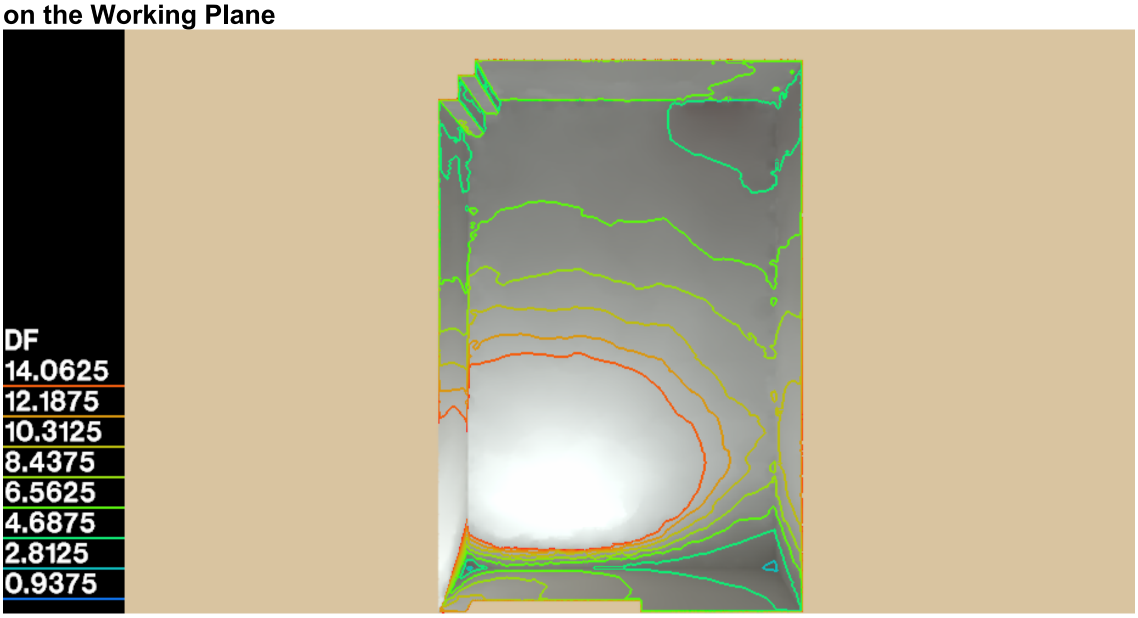
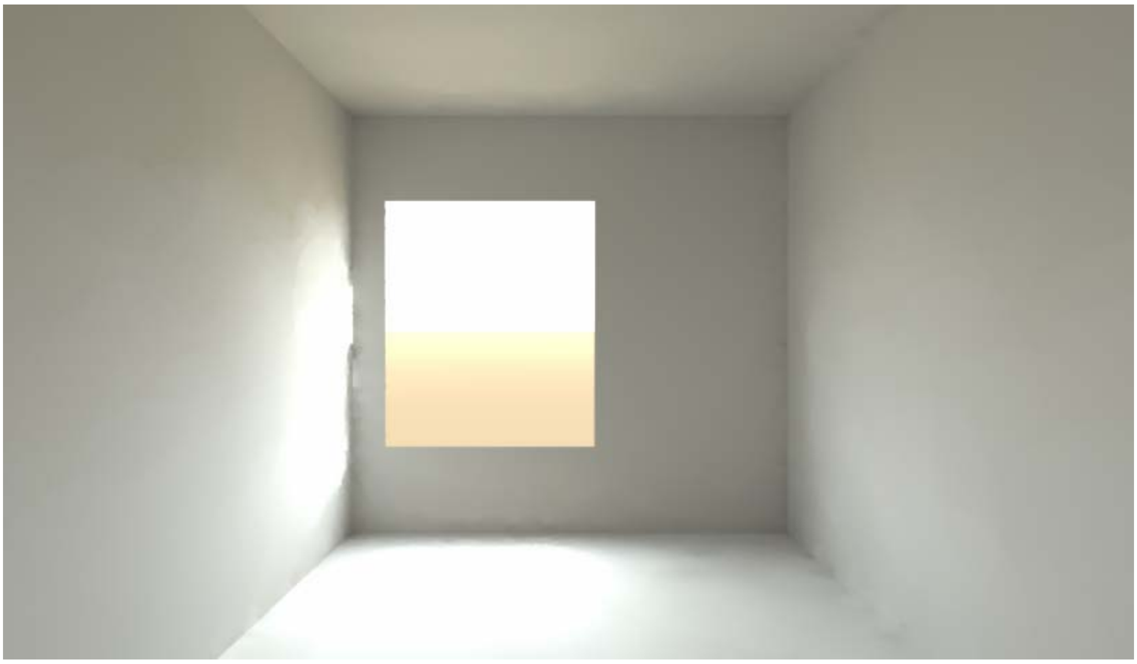


Figure 14: Daylight Factors in Consulting Room C08:

This is also further demonstrated in the Radiance simulations shown in figures 15 and 16, see below:

Vertical Section



Horizontal Section

Figure 15: Overcast Sky Conditions Radiance Simulations in Consulting Room C10:

Vertical Section

Horizontal Section

Figure 16: Overcast Sky Conditions Radiance Simulations in Consulting Room C08:

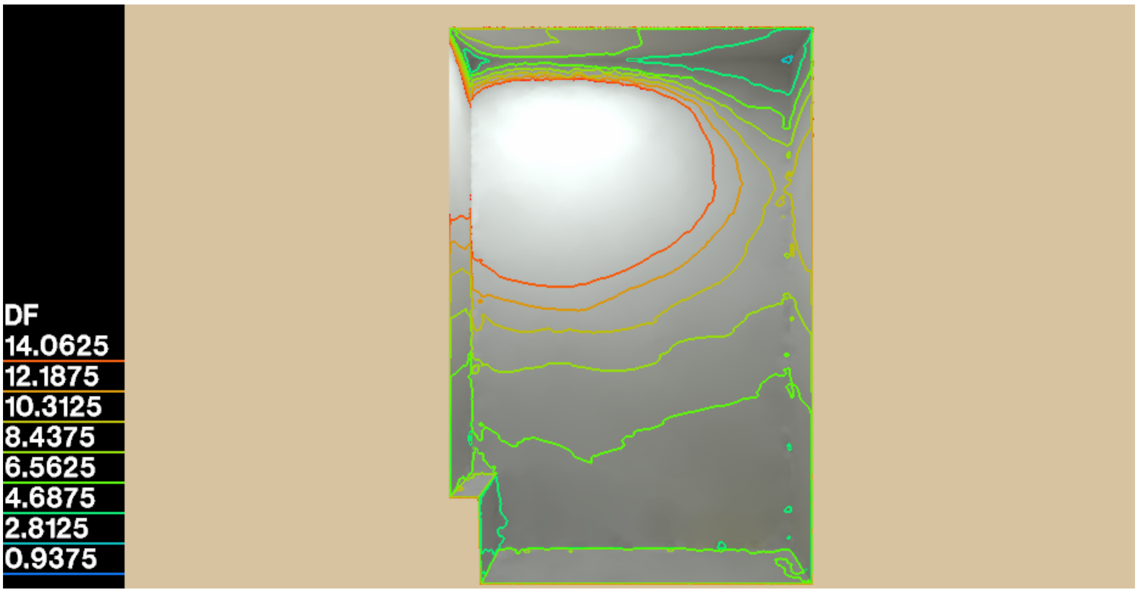
The results have clearly shown that the Daylight Factors (DFs) on the surfaces within these consulting rooms (C10 and C08), are above 2% indicating that the rooms will appear well lit. Although the results have presented sufficient daylighting in these rooms, in practice due to privacy, window blinds are mainly used and therefore artificial lighting is mostly in operation. This collides with the initial design principles (energy efficiency/environmentally friendly measures) and therefore is being compromised in practice, which also explains why Design Modifications are considered in this case study (see the following section).

Design Modifications

Covering the lower half of the window area with a non-transparent material (such as painted MDF board) in Consulting Rooms:
The Design Modification studies carried out in these consulting rooms by covering the lower half of the window area to find out if the rooms will still be well lit. Although the quality of natural light entered in this specific room (consulting room C10 is used as an example for this paper) was decreased by having a non-transparent cover, this consulting room appeared to be well lit. This is further demonstrated with the Daylight Factors on the working plane within this room, which is still above 2%, indicating that the room will appear well lit.

The following figures (see figures 17 and 18) show the overall change; between before and after covering the lower half of the window area, and provides the DFs obtained throughout these analyses.

Before



After

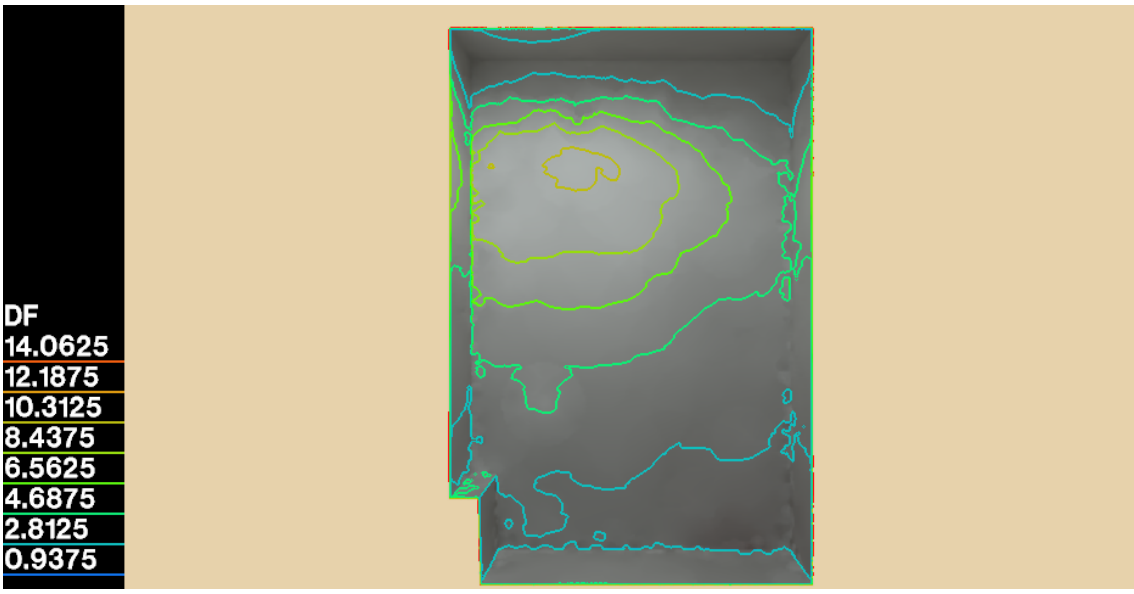


Figure 17: Daylight Factors in Consulting Room C10 - Before and After Covering Half of the Window Area

This is also verified in the Radiance Simulations as shown below:

Before

After

Figure 18: Radiance in Consulting Room C10 – Before and After Covering Half of the Window Area

The results of this Design Modification undertaken will support the use of daylighting (one of the initial design principles of energy efficiency/environmentally friendly measures) within the Student Health Building and also provide alternative solution to the privacy issue experienced in these consulting rooms in practice. In this paper, only one alternative design modification is suggested, however there are other solutions that could be also considered which would also be equally feasible in daily practice.

Conclusions

This paper has demonstrated evidently the benefits of using such improved strategies in refurbishment stages; however also stressed the importance of using such techniques for sustainable building design and development to forecast the dynamic response and performance of buildings. To make effective use of building simulation, it is vital that designers and developers adopt some common-sense practices, to overcome various problems that can easily be avoided at the early stages of the design, such as those issues experienced in this study.

In addition, with both building monitoring surveys and the integration of computer simulations, a better overall understanding of the impacts of overheating periods, thermal comfort levels, adequate daylighting and window shadings on the overall performance can be obtained. This overall understanding has resulted in modifications to the design, which further inputs the building performance.

Post-occupancy monitoring has shown that there are significant periods of overheating during summer season, especially in the east-facing rooms. This is also assisted by the building performance and simulation studies undertaken and the results has also presented that there are potential discomfort levels during summer months (June, July and August) in these specific rooms in the Student Health Building.

With regards to the design modification studies; it was very important to pay attention to both key factors in order to come up with alternative solutions such as exercised in this study, although other approaches could also be equally applicable (other than covering part of the window with MDF board - some different solar transmittances and solar heat gain coefficients could be explored by adding external shading devices, internal blinds, changing the type of glass, etc.).

In this case study, decisions were made by taking into consideration the use of daylighting (for building energy efficiency) as well as the privacy (for treating patients) within these consulting rooms. It was suggested that the consulting rooms were simulated with the lower half of the window covered with a non-transparent material. The results have indicated that although the daylight factors would decrease there was sufficient light to still allow the rooms to be adequately day lit, which expresses the whole purpose of this paper how an example of a good practice can be achieved.

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Operation Diagnostics – A Methodology for Enhanced Building Operation

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Abstract

Building automation systems (BAS) and building energy management systems (BEMS) have been used in modern edifices for the last 2 decades. These systems measure, process, and monitor a huge amount of data to operate the building and systems more or less properly. Often, the data is only used to signal failures or break-downs of systems or components. Further information of the data to analyze and diagnose the building operation is not used due to the lack of analysis methods and tools.

Within the *Operation Diagnostics*, different visualization techniques are applied to display the information that is hidden in the recorded operation data of buildings and systems. Different diagrams and plot types are used to visualize the data. Time series of large amounts of data can be realized and analyzed quickly, as well as the correlation between various operation values, the frequency of data, or other useful statistical information. This data visualization is qualified for evaluating the quality of operation and identifying optimization potential by comparing with *Operation Patterns*. Furthermore, the quantity of optimization potential can be estimated by additional visual or numerical analysis of the deviation between measured operation data and *Operation Patterns*.

A first numerical plausibility check gives a rough outline of the quality and the reliability of the data. The following visual diagnosis with *Carpet Plots* allows a quick check of large time series of the data. The visual method enables one to detect even slight indications of optimization potential. The visualization of the data in form of *Scatter Plots* and *Scatter Plot Matrices* allows a detailed analysis of the correlation of operation, even with complex strategies and dependencies. Further calculations profit by the brushing function implemented in the used visualization tool *Pia* to select data interactively in the diagram. Subsequently, numerical analysis gives the possibility to estimate optimization and saving potential.

Operation Prognostics uses expert knowledge from the design phase of systems and buildings to develop *Operation Patterns*, that describe the dynamic behavior in a visual way. These *Operation Patterns* contain operation data under optimal operation conditions to be compared with measured data from the BAS. Optimized operation data can be acquired from simulation models or test facilities. Even faulty operation of systems can be modeled to obtain clues how to interpret measured data and to identify reasons for ineffective operation and to define clear measures how to optimize it. The measures indicated by *Operation Diagnostics* and *Operation Prognostics* mainly focus on optimization in form of modified control strategies and changed parameter settings. Therefore, the measures are extremely cost-effective with pay-back times that are calculated with consulting fees only.

The methodologies of *Operation Diagnostics* and *Operation Prognostics* have been developed by *Ebert-Ingenieure München* within the R&D project *OASE – Optimierung der Automationsfunktionen betriebstechnischer Anlagen mit Hilfe der dynamischen Simulation als Energie-Management-System*. The project was partly funded by the *German Ministry of Economics and Labor* (*Bundesministerium für Wirtschaft und Arbeit – BMWA,* Förderkennzeichen 0327246D). *OASE* was also part of the *Annex 40 'Commissioning of HVAC Systems for Improved Energy Performance'*, a project covered by the *International Energy Agency* (*IEA*). The shown *carpet plots* and *scatter plot matrices* are realized with the *MATLAB* based tool *Pia*, developed by Per Isakson, *Royal Institute of Technology* (*KTH*) in Stockholm, Sweden.

Operation Diagnostics

Approach
Building automation systems (BAS) and building energy management systems (BEMS) measure, process, and monitor a huge amount of data to operate the building and systems more or less properly. Often, the data is only used to signal failures or break-downs of systems or components. Further information of the data to analyze and diagnose the building operation is not used due to the lack of analysis methods and tools. The BAS itself offers only poor means to analyze the data and to diagnose the dynamic operation of building and systems.

Operation Diagnostics is based on a visual methodology to analyze the dynamic operation of buildings and systems. Therefore, advanced statistical visualization forms are used to display the information that is hidden in the recorded operation data.

Advanced Visualization Techniques
The human brain is trained for transmitting information (in the form of sensory perception) into logical structures like groups or patterns, or classifying with logical structures like groups or patterns, respectively. That supports better understanding, analyzing, and valuating of the information. Recognition is a factor of importance as well. Information is easier to handle and to recall when filed into mental or real structures. The human brain uses this structuring of information fairly unconsciously, depending on talent or training. Numbers, for example, are much easier to remember by combining them in groups of two, three or four.

Different visualization forms have different abilities to support this structuring of information. Table 1 gives an overview about categories of information and adequate visualization forms. The higher the dimension of the visualization form, the more information can be obtained. The visualization forms mostly used within *Operation Diagnostics* are described in the following.

Table 1: Categories of information and their respective visualization forms.

Information / Visualization form	Dimension)
time series (temperatures, schedules)·	
- line plot·	2-dimensional
- ribbon plot	2-dimensional
- cluster plot·	2½-dimensional
- carpet plot	3-dimensional
correlations (dependant switching, characteristics)	
- scatter plot	2-dimensional
- matrix of dependent scatter plots	n-dimensional
quantities (energy consumption)	
- characteristic values	1-dimensional
- Sankey diagram	1-dimensional
- load duration curve	2-dimensional
- cumulated load duration curve	2-dimensional
statistical distribution (utilization, frequency)	
- histogram	1-dimensional
- pie chart	1-dimensional
states of operation	
- trend of demand	2-dimensional
- schematic with dynamic display	1-dimensional

Methodology

Valuation of Energy Consumption

The first step conducting *Operation Diagnostics* is the valuation of the energy consumption of buildings. Usually, energy and water meters are installed by the utility in any building. Therefore, at least the annual, or often monthly, energy consumption is available from the energy bills. Sometimes, the meters are connected to the BEMS. The more meters are installed within the building – for example for different tenants areas – the more information can be used for the valuation.

The absolute values for energy consumption are usually transferred into characteristic values, related to gross floor area, heated floor area, heated volume, number of persons, number of beds (hospitals), etc. This allows to compare energy consumption with benchmark data that is available from different sources (e.g. *VDI 3807*, *ages Studie*, etc.) or – roughly – with calculated demand values (e.g. from energy codes).

Energy consumption from different energy sources can be shown in form of pie charts. This visualization form allows to compare the ratios of each portion that is displayed. Since the complete 'pie' is the overall sum of all portions, and therefore the different ratios are reduced to percentage, this visualization form is suitable for the analysis of ratios only, where the absolute numbers are not the main focus. Otherwise, the absolute or characteristic values need to be added to the chart.

Sankey diagrams combine the ratio of energy consumption as well as their absolute values, regarding the width of the displayed arrows. Further more, the path of the energy flow can be displayed in the same diagram. Sankey diagrams are able to display energy flows within entire buildings or even complex technical systems (see Figure 1).

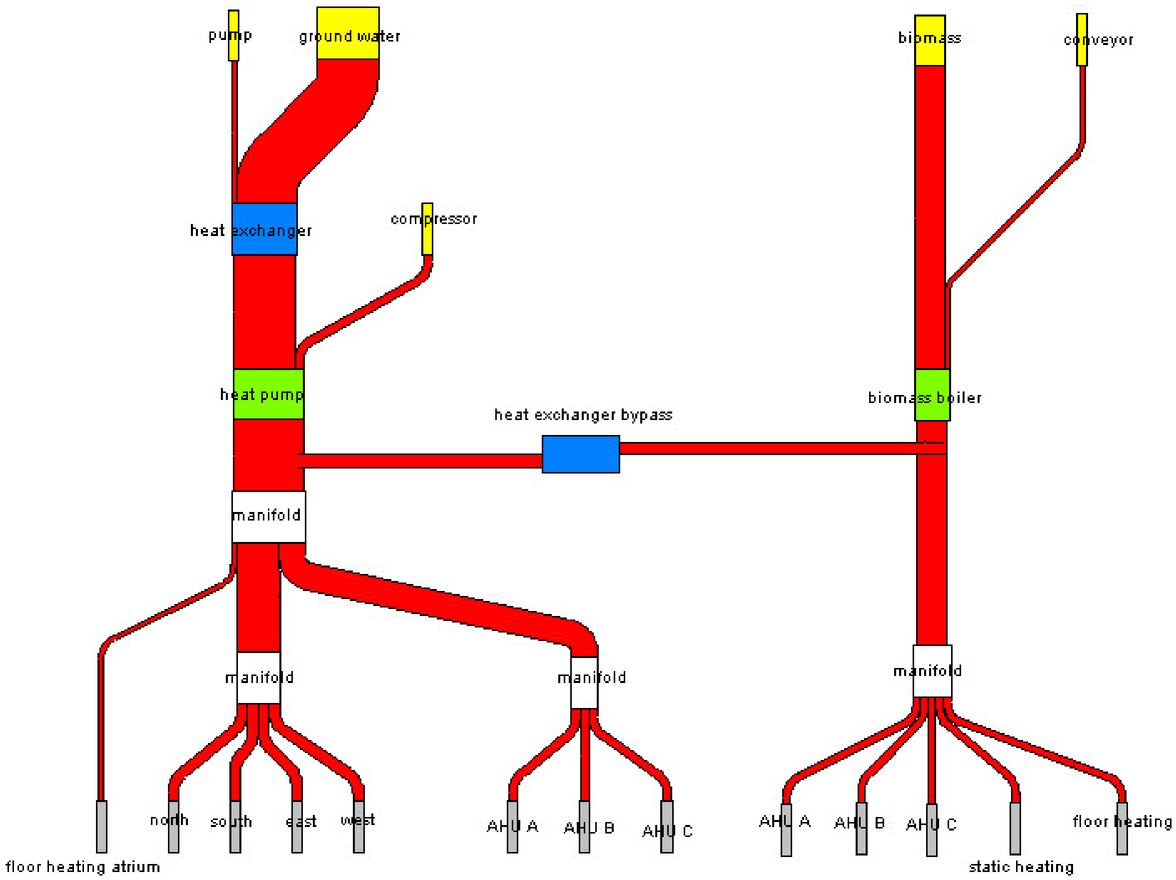

Figure 1: Energy distribution within a HVAC system from source energy (electricity, ground water, biomass) to end users (floor heating, AHU heating coils).

The main purpose of the valuation of the energy consumption is to estimate saving potential, and to define a baseline for future energy savings. Using the available information about energy consumption not only for characteristic values, but rather for displaying the energy flow within the building often reveals first hints for optimization measures already or at least where to look first.

Evaluation of Operation Schedules

The next step is to check operation schedules. Adjusting operation times of systems and components to the actual need is the most simple way and therefore the most efficient way to save energy. Rather than using line plots, time series should be displayed in form of carpet plots. In carpet plots the values of the data is displayed in different colors regarding a color scale. The data of each day is arranged in columns with the time of day from top down on the Y-axis (1 to 24 hours). The data of subsequent days is aligned in the next column on the right. Additionally to the ability to yield patterns that enable the viewer to recognize quickly time dependant processes, Carpet Plots allow to display large amounts of data in a single diagram. Figure 2 shows a carpet plot with 16 months of data with a sampling rate of 5 minutes

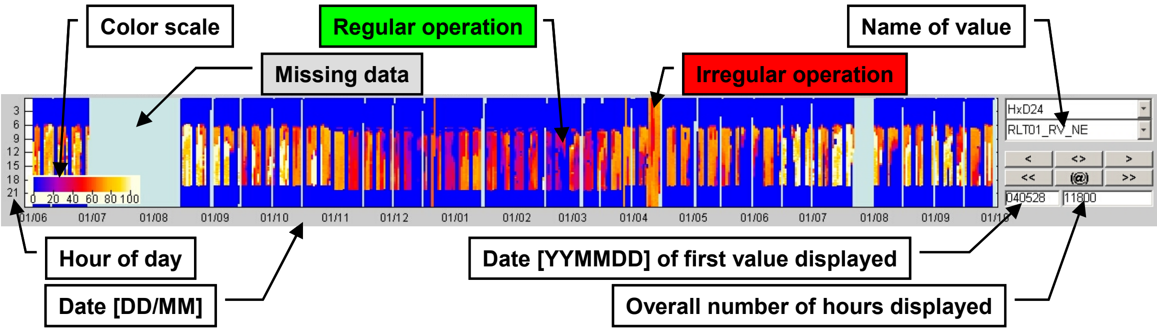

Figure 2: Carpet plot showing about 16 months of operation data from a control valve for a heating coil.

In the same manner, the thermal comfort in buildings or in single rooms can be evaluated. Using adequate limits for the color scale produces distinctive plots that show clearly deviations from required temperatures during given times of usage. A proper thermal comfort is a prerequisite for applying measures for energy savings. Otherwise, optimization measures to enhance thermal comfort have to be applied first.

Evaluation of Operation Conditions

As a third step, the operation conditions and interdependencies of operation are evaluated. Dependencies between two values can be shown in scatter plots. Figure 3 for example shows measured values of the heating supply temperature against the outdoor air temperature.

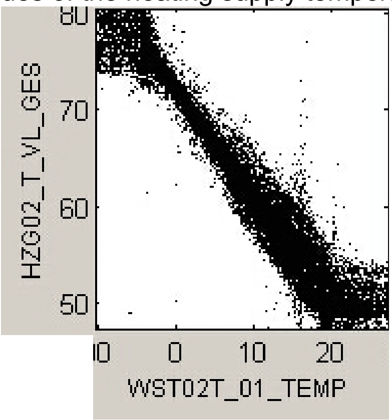

Figure 3: Scatter plot of supply temperature against outdoor air temperature

Scatter plot matrices enable to show the correlation of even more operation data. Figure 4 shows the data that describes the operation of two heating coils of an AHU. A brushing function allows to indicate operation data interactively in one of the scatter plots. The same data is then marked in all other plots of the matrix with the same color automatically. Additional scatter plots in the 3 most right columns of the matrix show the data against the time of the day, the day of the week, and the entire time range to bring about time relation.

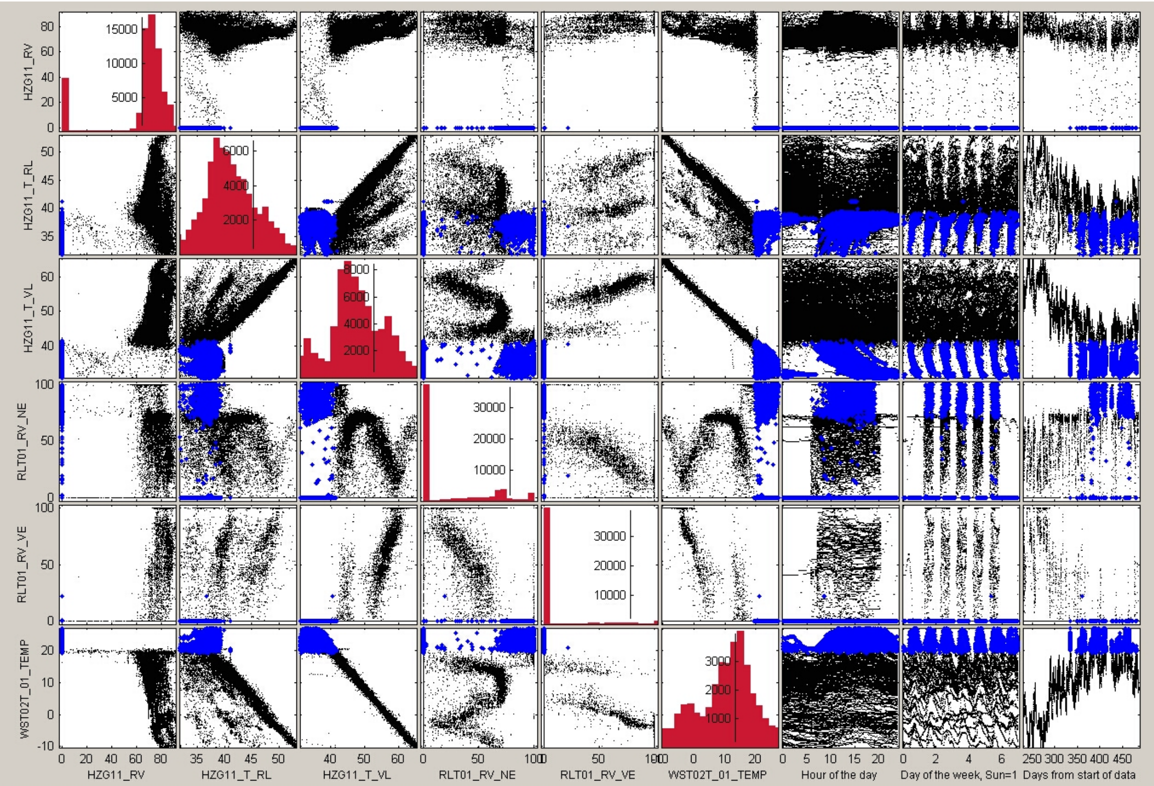

Figure 4: Scatter plot matrix with operation data of an AHU (from top down: control valve heating circuit, supply temperature, return temperature, control valve preheating coil, control valve heating coil, outdoor air temperature).

The histograms on the diagonal of the matrix proved to be most valuable, since the frequency of operation states contains important information about regular operation, the control characteristic of valves, fans and pumps, as well as the relevance of deviations from regular operation.

Findings
The performance of *Operation Diagnostics* lead to findings and recommendations that should be discussed with the client. Afterwards, most optimization measures can be applied directly. Some findings need further measurements or numerical analysis to get more detailed information to decide about adequate measures. Typical findings of *Operation Diagnostics* are:

- correction of operation times regarding schedules
- implementation of new or modified control strategies
- re-implementation of 'out ruled' control strategies
- adjusting of control settings

A significant distribution of *Operation Diagnostics* for enhanced building operation is the better understanding of the dynamic behavior and the control logics of systems and building by the operation personnel. The visual methodology helps to display and to examine large amounts of data and even complex correlations.

Operation Prognostics

Approach

The described methodology of *Operation Diagnostics* is mainly based on expert knowledge. Though deviations from given operation schedules and timing are recognizable quite obviously with carpet plots, the reading of scatter plot matrices requires considerable expertise. Therefore, the methodology of *Operation Prognostics* uses similar visualization techniques as described before. The dynamic operation and behavior of buildings and systems as well as their performance can be described using so called *Operation Patterns*. These patterns can then be used to evaluate the recorded BEMS data of the actual operation by simple and even visual comparison.

Operation Patterns

Operation patterns use visual forms to describe the quality and performance of dynamic operation already during the design phase of a building. Since the visual description with *Operation Patterns* is unmistakable and gives no room for interpretation, it is favorable regarding the usual verbal description of operation.

Figure 5 shows the operation pattern for the cooling coil of an AHU, depending on its use for cooling and dehumidification. The position of the cooling coil valve is used to define the operation pattern, since the signal is available on the BAS and indicates the intensity of operation. In the left diagram, the valve position is displayed against the outdoor air temperature. Also, to describe the operation due to dehumidification, the valve position is displayed against the outdoor air humidity ratio (right diagram). While the valve position is variable and depends on the outdoor air temperature for cooling only, it is completely open for dehumidification.

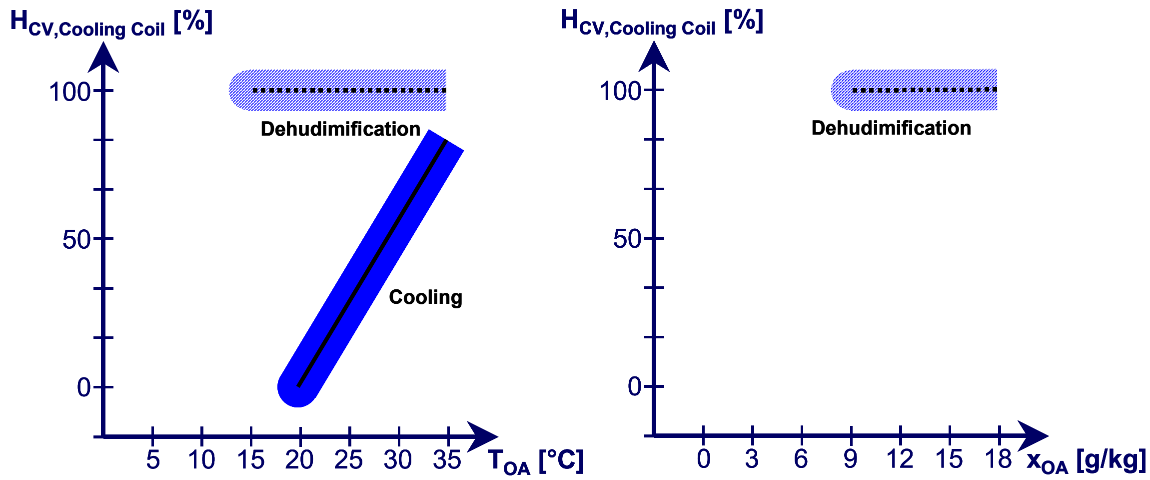

Figure 5: Operation pattern – Position of cooling coil valve for cooling and dehumidification.

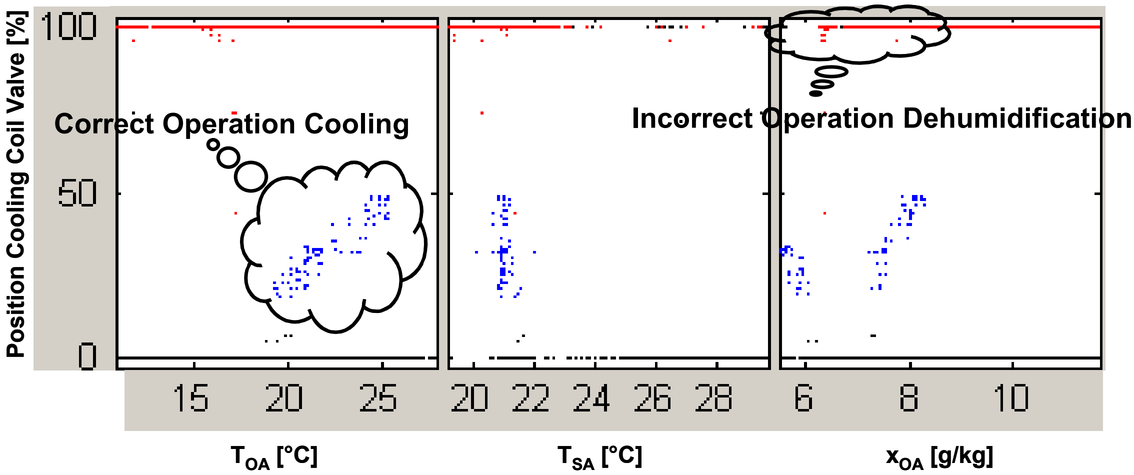

Figure 6: Date visualization – Verification position of cooling coil valve for cooling and dehumidification.

Figure 6 shows the corresponding operation data of the cooling coil valve against the outdoor air temperature (left diagram) and against the outdoor air humidity ratio (right diagram). Comparing the displayed operation data with the operation patterns from Figure 5 proves correct operation for cooling (variable valve position only at outdoor air temperatures above 20 °C), but incorrect operation for dehumidification (open valve at outdoor air humidity below 8 g/kg).

Methodology

Operation Prognostics uses expert knowledge from the design phase of systems and buildings to develop *Operation Patterns*, that describe the dynamic behavior in a visual way. Figure 7 shows a matrix with operation patterns that describe the operation of an air handling unit (AHU). These operation patterns can be used to compare measured operation data from the BAS with data under optimal operation conditions. Optimized operation data can be produced with calibrated simulation models. Even faulty operation of systems can be simulated to obtain clues how to interpret measured data and to identify reasons for ineffective operation and to define clear measures how to optimize it.

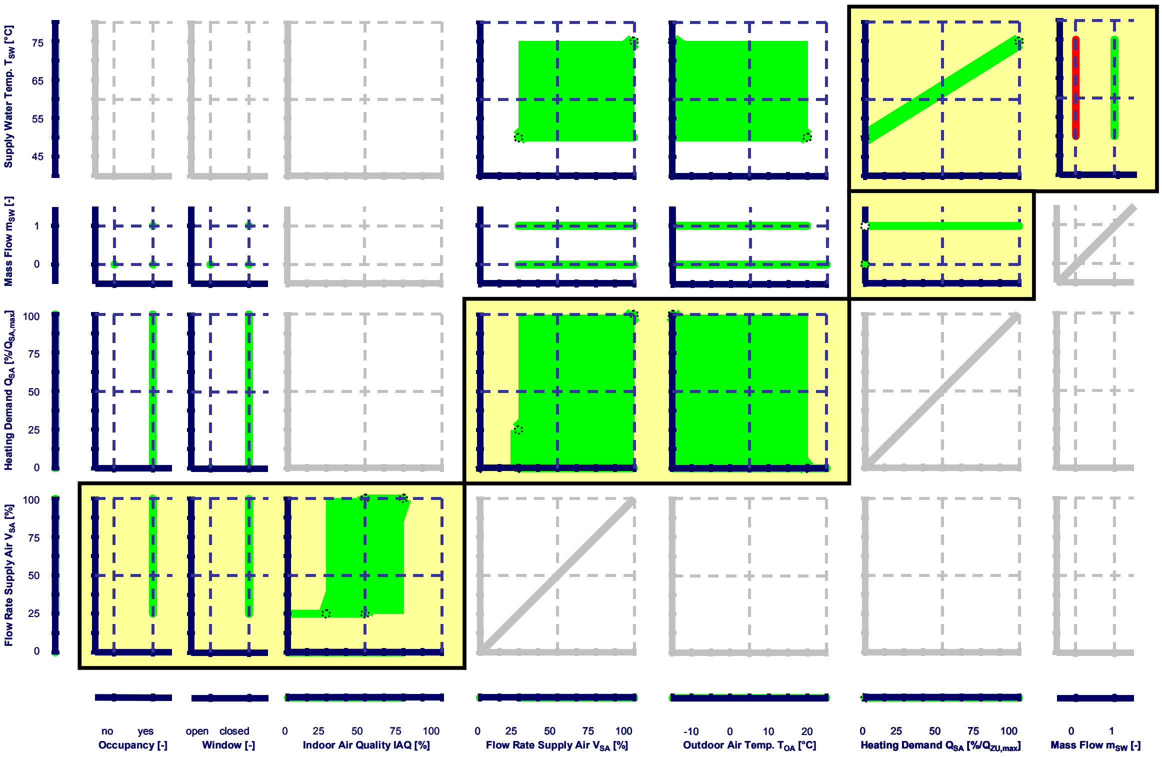

Figure 7: Example of operation patterns for an AHU.

Conclusions

Operation Patterns in fact are visible expert rules. Numerical expert rules, as known so far, are more or less black box models which give messages of whether the tested operation data is valid or not. The expert rules themselves cannot be tested easily. Thus, it is crucial to set up clear mathematically defined rules.

The approach of using operation patterns avoids this difficulty by using visual means. Even complex rules can be described by a set of a few operation patterns that are easily recognizable. By bringing recorded operation data into the form of operation patterns, the operation of buildings and systems can be checked and verified.

Operation patterns that have been created already in the design phase of systems can be used for initial commissioning. Within the approach of *Operation Diagnostics*, it is usually necessary to develop operation patterns based on available information from design documents, system and component descriptions, and knowledge from the operation personnel.

Initial optimization can be done by considering the general correlations of systems operation when setting up suitable sets of operation patterns. Further optimization can be carried out using simulation models. To do so, it is necessary to have exact models of the systems which are able to consider control systems and control strategies. To attain adequate results that can later be compared with operation data, it is recommended to use models that are calibrated with manufacturers' data.

One of the main difficulties when applying *Operation Diagnostics* is the limited performance of BAS. Even though the data that could be used for operation diagnostics is already processed and recorded in the BAS, the access to the data and the possibilities to get it out of the system in an adequate format is often extremely limited.

Within a new research project that started in September 2004, the approach of using *Operation Patterns* for *Operation Diagnostics* will be further developed and applied to several case studies. The objective of the research project is to develop sets of 'typicals' with operation patterns for common HVAC systems that can then be adjusted to the actual systems during the design phase. These operation patterns, together with schemes and short verbal description, give a clear description of the functionality and the performance of systems that can be used for bidding, testing and balancing, initial commissioning, hand over, and ongoing commissioning as well.

Acknowledgments

The project described in this paper is part of the research project *'OASE – Optimization of Automation Functionalities for HVAC Systems using Simulation and Energy Management Systems'*. The project was funded by the *German Ministry of Economics and Labor* (*BMWA*) within the research program *'EnSan – Energetische Sanierung von Gebäuden'* (Reference: 0327246D). [5]

The project was also used as a case study within the *Annex 40 'Commissioning of HVAC Systems for enhanced Building Operation'*, a research project covered by the *International Energy Agency* (*IEA*). The results of the Annex 40 are published on www.hvac-commissioning.org. [9]

Special thanks to Per Isakson from the *Royal Institute of Technology* (*KTH*) in Stockholm, Sweden for the free use of the visualization program *Pia* and countless hours for technical support. [6]

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building performance congress

Modelling Buildings for Energy Use: a Study of the Effects of Using Multiple Simulation Tools and Varying Levels of Input Detail

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Abstract:
Increasingly, legislation (including the imminent requirement for the energy labelling of buildings) is requiring the building industry to produce more accurate estimates of the energy performance of buildings and building services in use. This accuracy is unlikely to be met through means other than dynamic simulation models. However, in practice detailed information about important factors which affect the energy use of both new buildings during the design phase and existing buildings during operation can be very limited.
This paper considers the accuracy with which the existing dynamic simulation models EnergyPlus and ESP-r predict temperature in one existing commercial office building for which the authors have detailed information - including measurements of internal and external conditions at every 15min intervals over 1 year period. It examines the predicted temperatures produced using two different simulation tools with two different modelling strategies: single zoning and multiple zoning. The predictions of internal temperature for the office building are then compared with the physical measurement of temperature in the building to provide an indication of the accuracy with which the complexities of a real situation can be predicted.
The work forms part of the European project AUDITAC: "Field Benchmarking and Market Development for Audit Methods in Air Conditioning", and builds on a previous project undertaken by the Welsh School of Architecture – "AC Energy Use in Offices: Field Monitoring Study".
As part of the process, the paper discusses the strategy used to generate compatible input data for the two energy modelling software packages. The establishment of compatibility is important to enable valid comparisons to be drawn between the different simulation algorithms.
The paper ends by drawing preliminary conclusions as to the most important building modelling variables for the test building, and therefore which variables should have the most time spent on them when establishing values. Similar studies will be undertaken on a number of buildings in various typologies and European climatic conditions to ascertain how the relative importance of these variables changes. This information is particularly important for deciding which data must be provided to enable building modellers to produce the most accurate models possible for energy analysis.

Background
The recent BESTEST studies[1] have examined how closely various modelling tools agree with each other in modelling simple highly monitored enclosures. These studies show that, even for these simplified situations, the models can vary in their predictions of Temperature and Energy requirements for the buildings.

With these differences at the simple level it is not surprising that there are few independent objective studies which examine how closely modelling tools predict the actual performance of real buildings and building services. This lack of objective studies is worrying as we are rapidly moving towards a reliance on modelling to make major design and investment decisions about our buildings and services, including decisions on whether a design can be built or not.

The Welsh School of Architecture has recently completed a detailed monitoring study of the energy use in A/C systems in a number of UK Office Buildings. The outputs of this work are being used as part of the underpinning data to the AUDITAC project, as well as being used within the UK to help update relevant professional guidance and regulations.

To enable the results of the UK Office study to be applied more generally across Europe the Welsh School of Architecture is using E+ and ESP-r to model a selection of the buildings, usage and services of the monitored UK Office buildings. The aim is to establish how accurately the models predict the monitored conditions in the buildings, with all the uncertainties and inaccuracies that occur in modelling real buildings.

Clearly with only one building modelled then there will still be much uncertainty about how well the models can actually predict the real performance of other buildings and systems. This paper therefore is purely to establish that the range of parameters and their variations input into the models are capable of encompassing the measured temperatures in the real building modelled, and to establish which of the parameters are relatively the most important.

Future work will model a further 14 or so buildings from the study to establish a greater degree of confidence in the findings.

Simulation Tools – Issues and Details

Each of the tools has its own data input requirements, which means that to model exactly the same building in each tool is harder than it appears. Modelling limitations and equivalences referring to geometry, topology, shading and scheduling need to be listed for each tool.

In this comparison, most geometry issues refer to limitations determined by ESP-r such as the maximum number of vertices per zone and per surface, a maximum number of surfaces per zone, a limited number of windows per surface, etc. Most of the topology issues refer to compatibility not restrictions or limitations:

- Each surface cannot be adjacent to more than one surface,
- Surfaces adjacent to zones with similar conditions are assigned as adiabatic
- Voids are modelled in ESP-r as fictitious surfaces and in Energy Plus as internal windows allowing equivalent process of heat transfer between zones.

Shading issues are the most difficult ones to make compatible. In ESP-r they need to be modelled separately and linked to the zone they are going to affect. The geometry is restricted to rectangular shapes and there are no possibilities of rotation around the X or Y axis. There is also no account for interzonal shading or self shading. To allow comparisons to be made shading calculations were set to “off” in both ESP-r and EnergyPlus. This should not affect the calculations for this building greatly as the degree of external shading is minimal. ESP-r also shows limitations in schedule as weekdays are all grouped together.

The thermophysical properties of opaque and transparent materials, ventilation, infiltration and internal gains were also made compatible. Parameters common to both tools are: flow rates, specific heat, density, conductivity, thickness, absorptivity, emissivity, and transmittance.

Modelling Reality – The Case Study

The reality of the modelling of real buildings in use, and the accurate modelling of buildings in the design phase, is that, generally, qualitative but not quantitative data are available for many of the important modelling variables.

Qualitative information for buildings includes descriptions of what the building is made of, its materials, and how the building has been used (the number of people inside it, when they are generally there, and the amount of equipment and lights in its interior). Quantitative information for buildings includes geometry (floor plans, sections, etc.), thermophysical properties of materials, and the magnitude of internal gains, ventilation and infiltration.
Generally, only accurate information about geometry is available for most buildings and, sometimes, general data about occupancy patterns, lighting and small power as in this case study. In this context

buildings can only be modelled as best understood and assumptions from zoning to all other missing parameters need to be made.

Case study building description

The case study is a speculative office building in Cardiff (UK) built in 1992. It consists of 2 stories and is steel framed structured, with pre-cast concrete floor decks, masonry cavity walls and a wood frame pitched roof system. The glazing system is clear double and all windows are openable. Only the third floor was considered in this analysis. It is owner occupied with relatively intensive but normal office use, on a hot-desk management style. It is mainly open plan with some small conference rooms and individual offices. Normal occupancy is 8.00am to 6.00pm form Monday to Friday. A survey has been undertaken to establish occupancy numbers and patterns, equipment and lighting details and usage.

Zoning

The first point to be resolved in modelling reality is how to zone the building. There are many issues to be considered in choosing how to zone a building, from the purpose of the modelling itself to limitations of simulation engines and the position of the temperature sensors when the target is to compare to measured data. For this paper the target is to predict internal temperatures and compare them to measured data in a “freerun” period, therefore the zones do not necessarily need to be set based on the installed HVAC system. They need to be in accordance with the enclosure and the sensor location. In this building there is only one sensor and the building is mainly an open plan office. It is believed that a single zone model is more appropriate to simulate average internal temperatures whereas a multiple zone model, trying to reproduce the internal lay-out and occupancy patterns, would be more appropriate to show local temperatures.

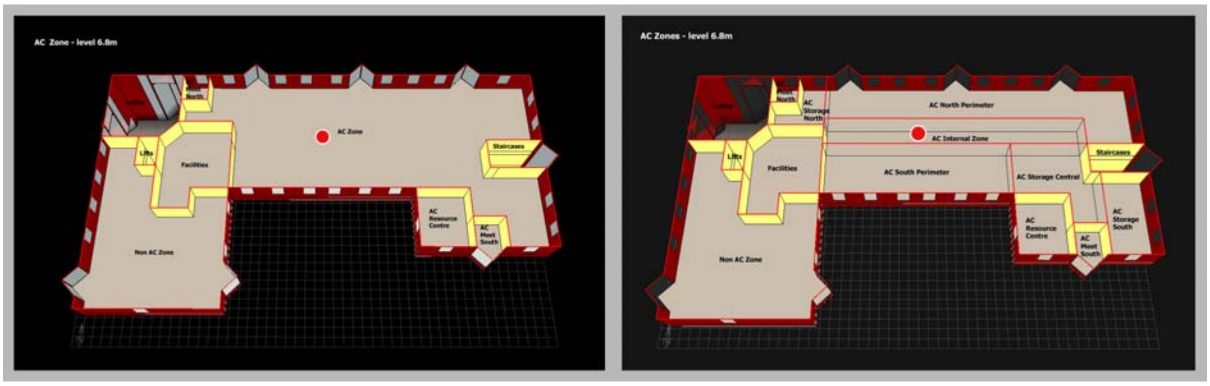

Figure 1 – Single zone and multiple zone models with the position of the temperature sensor

Figure 1 shows the single zone model and the multiple zone model both with the position of the temperature sensor – the red dot. The multiple zone model divides the open plan office into virtual zones according to the occupancy and the lay-out.

However, issues associated with limitations in the simulation engine, as well as the modelling itself, arise when a multiple zone model is to be created. The boundaries between zones are defined based on the internal lay-out and occupancy and are therefore virtual surfaces. Virtual, fictitious or void surfaces have limiting properties in all tools. They basically allow heat exchange through conduction and short wave radiation. No mass exchange and longwave radiation exchange between zones are accounted for. In this context, a simplification of mass exchange between the internal zone, where the sensor is located, and the adjacent ones is made. More complex simulations using CFD or COMIS were not used because of further compatibility issues.

Simulating Reality – The Case Study

The target of the simulation in this Case Study is to see how far predicted temperatures will be from measured temperatures and to check if the predicted temperatures from different sources “agree” with each other. Results will be compared for single and multiple zone models in ‘free run’ Spring and Summer period conditions. A ‘free run’ period is one during which no mechanical heating or cooling has been employed in the building and has been identified in this Case Study from measured data as lasting from the 27th of May to 16th of June (Spring season) and from 8th July to 28th July (Summer season) in the year of 2002. 'Free run' conditions are used to reduce the number of modelling variables to be addressed, as modelling a period when heating or cooling are provided would have also needed quantitative and qualitative data about the services, their setpoints and controls.

The simulation will start with a so-called "base" condition, with all the quantitative variables set to "average" values. Average values for thermophysical properties of materials are set according to various sources[2,3,4,5,6,7,8,9]. Air change rates are assigned according to MacDonald[2] and CIBSE[4], Internal Gains are set according to MacDonald[2], CIBSE[4], ASHRAE[10] and Knight[11] and schedules are based on UK data[12].

The values obtained by simulation are to be compared to each other and to the measured data.

Ventilation is assumed to be equally distributed over the floor area, because it is mechanically provided, and infiltration in the multiple zone model is calculated according to the amount of exposed area of each zone. The overall infiltration rate in m3/s is divided by the perimeter exposed area and multiplied by the percentage exposed area of each zone to provide the infiltration rates to each zone. The internal zones are assumed to receive air only from mechanical ventilation.

Mass exchange between the internal zones, using a simplified approach, was not addressed because in ESP-r air can be purchased from only one of the adjacent zones whereas in Energy Plus it can be purchased from as many zones as the user needs. A simplified solution to this problem was adopted by assuming equally distributed internal gains over the open plan office area.

Input values for the sensitivity analysis
Once the building is modelled as best understood with the information available, a probable range of values for each parametric variation is defined to enable a sensitivity analysis to be undertaken. These ranges are obtained from the same sources as the average values above. Parametric runs are divided into 3 groups as shown in Table 1.

Table 1 – Input values for the sensitivity analysis

Group		Minimum	Average	Maximum
Air changes				
	Ventilation Rates	8 l/s person	16 l/s person	36 l/s person
	Infiltration Rates	0.15 ach	0.35 ach	1.25 ach
Internal Gains				
	Activity levels	115 W/person	130 W/person	140 W/person
	Lighting levels	9.79 W/m2	-	11.5 W/m2
	Small power Rates	9.26 W/m2	21.38 W/m2	37.02 W/m2
Materials				
	Glass transmittance	0.228	0.565	0.901
	Glass conductivity	0.604 W/mK	1.294 W/mK	1.984 W/mK
	Wall insulation conductivity	0.025 W/mK	0.039 W/mK	0.053 W/mK
	Ceiling insulation conductivity	0.025 W/mK	0.039 W/mK	0.053 W/mK

Findings
Comparisons between measured data and predictions from single zone Energy Plus / single zone ESP-r, multiple zone Energy Plus / multiple zone ESP-r and single zone / multiple zone for both tools are primarily done to check which zoning strategy appears to best predict temperatures as close as possible to the measured values, as well as which assumptions would provide best agreement between the tools. The group of comparisons providing the best "match" are then further investigated through a parametric sensitivity analysis using the input values already described.

Single Zone Models

The graphs in Figures 2a and 2b for Spring and Summer periods show that, in general, both software tools "agree" with each other. ESP-r tends to predict slightly higher temperatures than Energy Plus but the shape of both predicted temperatures is very, very similar. Maximum differences between Energy Plus and ESP-r results vary from 0.8ºC, when the minimum Spring temperature occurs, to 0.7ºC, when the maximum Summer temperature occurs. On average temperatures vary 0.1ºC which indicates that even different algorithms provide very similar results once the input data is compatible.

The measured temperature values are shown in red to give an indication of how different the predicted values are from reality, especially in the Summer period. Average differences from predicted temperatures to real ones are shown in Table 2 confirming larger discrepancies in the summer period.

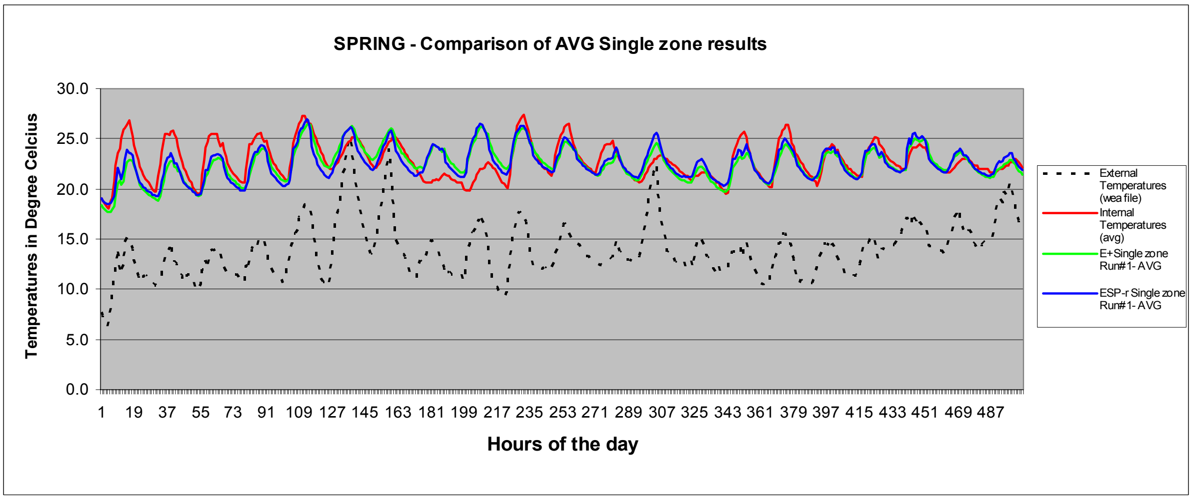

Figure 2a – Comparison of Single zone models in the Spring Season

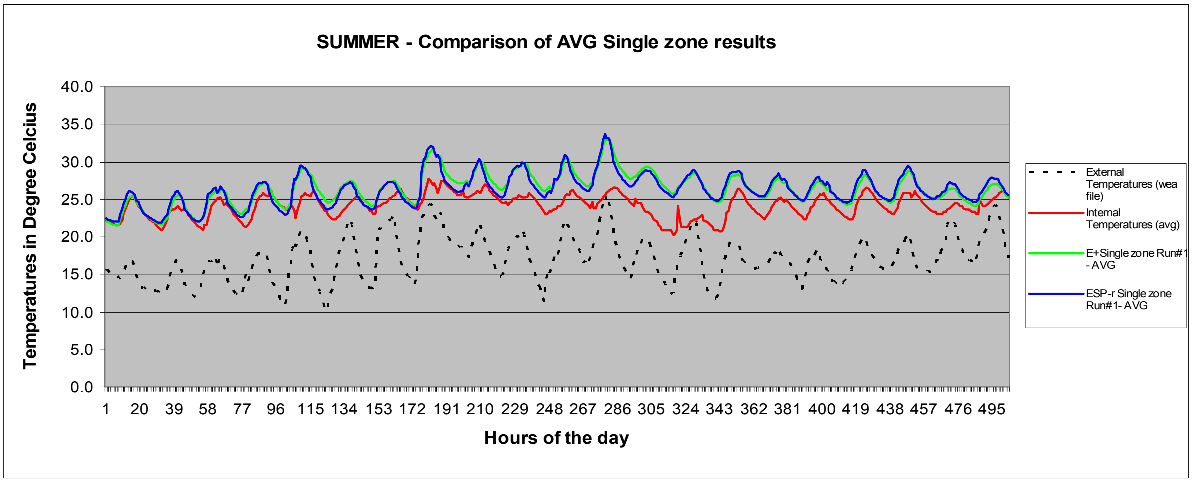

Figure 2b – Comparison of Single zone models in the Summer Season

Table 2 – Statistic analysis of the single zone model - Predicted temperatures

SPRING	Measured value	E+ - AVG	ESP-r - AVG	Range of agreement between the 2 software	Difference between the measured and simulated
Average	22.8ºC	22.5ºC	22.6ºC	0.1ºC	From 0.2ºC to 0.3ºC
Stand Dev	1.8ºC	1.7ºC	1.6ºC	0.1ºC	From 0.1ºC to 0.2ºC
Max	27.4ºC	26.5ºC	27ºC	0.5ºC	From 0.4ºC to 0.9ºC
Min	18.1ºC	17.7ºC	18.5ºC	0.8ºC	0.4ºC

SUMMER	Measured value	E+ - AVG	ESP-r - AVG	Range of agreement between the 2 software	Difference between the measured and simulated
Average	24.1ºC	26.4ºC	26.3ºC	0.1ºC	From 2.2ºC to 2.3ºC
Stand Dev	1.5ºC	2.1ºC	2.1ºC	0ºC	0.6ºC
Max	27.7ºC	33ºC	33.7ºC	0.7ºC	From 5.3ºC to 6ºC
Min	20.3ºC	21.5ºC	21.8ºC	0.3ºC	From 1.2ºC to 1.5ºC

Multiple Zone Models

In this case, the graphs in Figures 3a and 3b show that the software do not “agree” with each other as closely as they do in the single zone model. Differences between Energy Plus and ESP-r vary from 2.3ºC when the maximum Spring temperature occurs to 6.6ºC when the minimum Spring temperature occurs. In general, Energy Plus underestimates temperatures in Spring but is near the measured temperatures in Summer. ESP-r is near the measured temperatures in Spring but overestimates the temperatures in Summer.

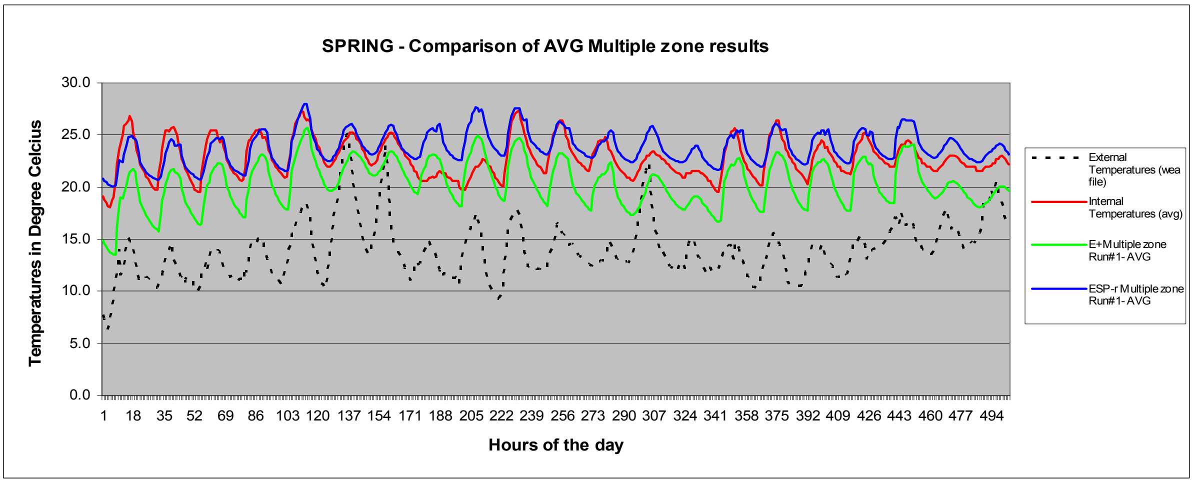

Figure 3a – Comparison of Multiple zone models in the Spring Season

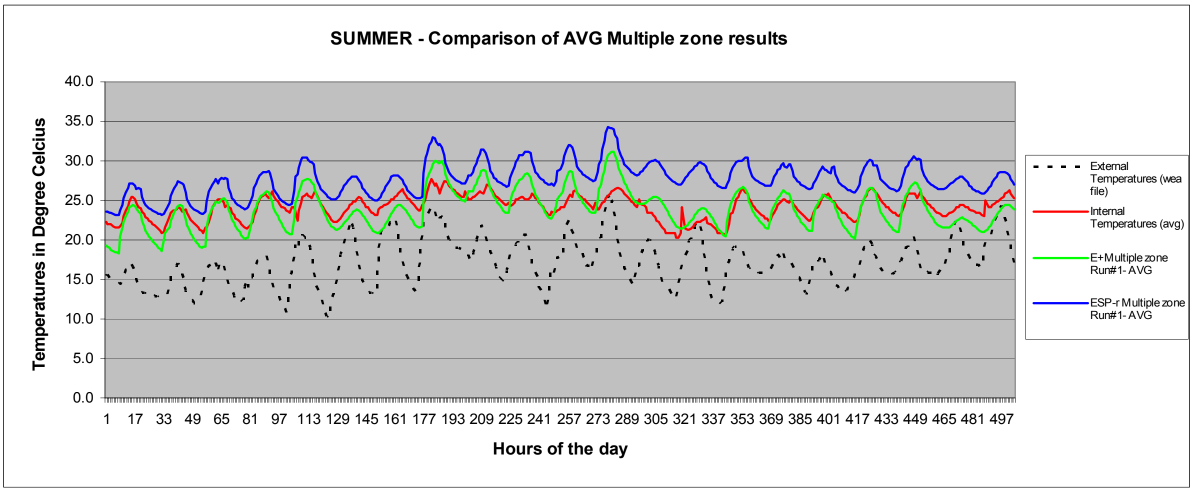

Figure 3b – Comparison of Multiple zone models in the Summer Season

Table 3 provides a simple statistic analysis on the measured and predicted temperatures and simplifies the understanding of the graph.

Table 3 – Statistic analysis of the multiple zone model - Predicted temperatures

SPRING	Measured value	E+ - AVG	ESP-r - AVG	Range of agreement between the 2 software	Difference between the measured and simulated
Average	22.8ºC	20.3ºC	23.8ºC	3.5ºC	From 1ºC to 2.5ºC
Stand Dev	1.8ºC	2.2ºC	1.6ºC	0.6ºC	From 0.2ºC to 0.4ºC
Max	27.4ºC	25.7ºC	28ºC	2.3ºC	From 1.7ºC to 0.6ºC
Min	18.1ºC	13.5ºC	20.1ºC	6.6 ºC	From 2ºC to 4.6ºC

SUMMER	Measured value	E+ - AVG	ESP-r - AVG	Range of agreement between the 2 software	Difference between the measured and simulated
Average	24.1ºC	23.9ºC	27.7ºC	3.8ºC	From 0.2ºC to 3.6ºC
Stand Dev	1.5ºC	2.5C	2.1ºC	0.4ºC	From 0.6ºC to 1ºC
Max	27.7ºC	31.2ºC	34.4ºC	3.2ºC	From 3.5ºC to 6.7ºC
Min	20.3ºC	18.3ºC	23.1ºC	4.8ºC	From 2ºC to 2.8ºC

Single zone models compared to multiple zone models
According to the graphs in Figures 4a and 4b, the most noticeable trend is that generally the single zone models appear more consistent with each other and the measured temperatures. Therefore whilst it is difficult to draw any firm conclusions about the use of single zone versus multiple zone models from this data, there do not appear to be any compelling reasons to undertake the greater complexity of multiple zone modelling.

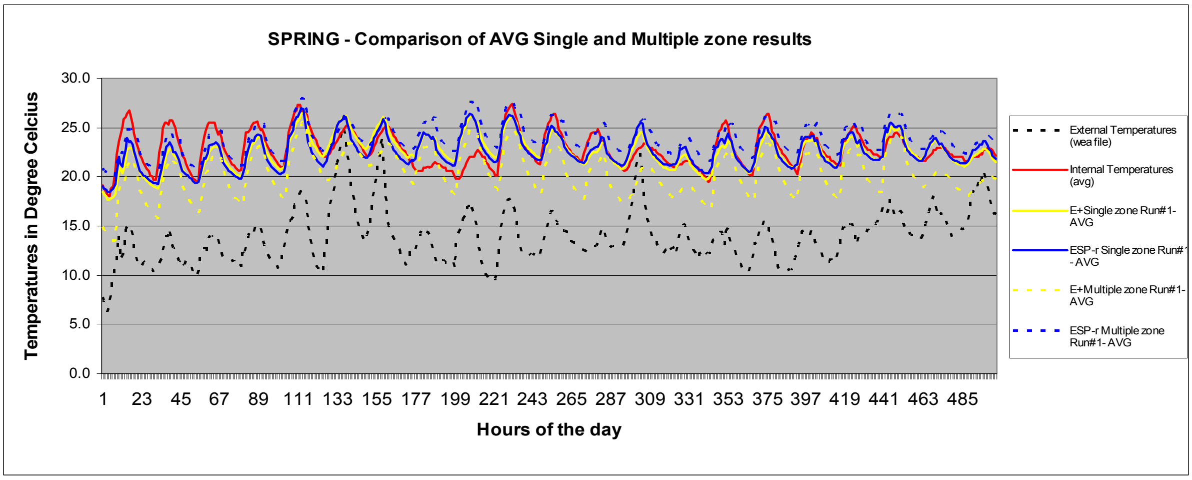

Figure 4a – Comparison of Single and Multiple zone models in the Spring Season

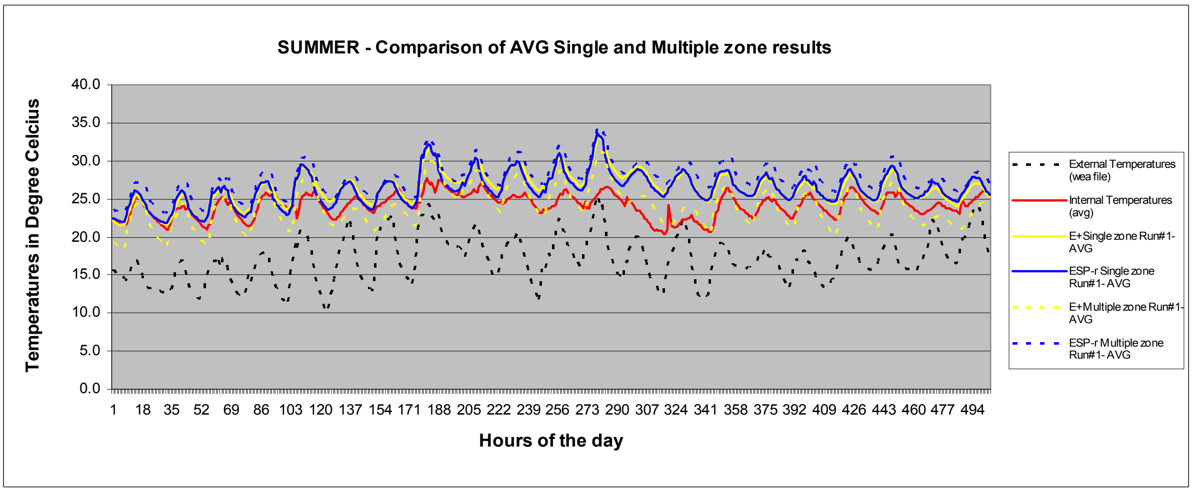

Figure 4b – Comparison of Single and Multiple zone models in the Summer Season

Sensitivity analysis of single zone models

As the single zone models are the ones that best “agree” with each other and show results very similar to the measured temperatures in this building, we chose to undertake the sensitivity analysis on these models.

Table 4 shows the range of agreement between the 2 software for all the runs that are part of the sensitivity analysis. Differences in predicted temperatures vary from 0.1ºC to 0.9ºC between Energy Plus and ESP-r data confirming the good degree of agreement in all the parametric runs. And in most of the cases measured temperature tends to fall within the predicted temperature ranges.

Table 4 – Statistic of the sensitivity analysis - Predicted temperatures

SPRING	Measured value	Air Exchange			Internal Gains			Materials		
		Range of agreement between the 2 software	Temperature variations	Range of variation	Range of agreement between the 2 software	Temperature variations	Range of variation	Range of agreement between the 2 software	Temperature variations	Range of variation
Average	22.8°C	Between 0.1°C and 0.2°C	From 19.3°C to 24.8°C	5.5°C	Between 0°C and 0.2°C	From 21°C to 24.4°C	3.4°C	Between 0°C and 0.2°C	From 21.4°C to 23.9°C	2.5°C
Stand Dev	1.8°C	Between 0.1°C and 0.3°C	From 1.4°C to 2.7°C	2.3°C	Between 0°C and 0.1°C	From 1.4°C to 2.2°C	0.8°C	Between 0°C and 0.1°C	From 1.6°C to 1.8°C	0.2°C
Max	27.4°C	Between 0.1°C and 0.6°C	From 24.6°C to 31.2°C	6.6°C	Between 0.1°C and 0.5°C	From 25.3°C to 30.3°C	5°C	Between 0.4°C and 0.6°C	From 26°C to 28.1°C	2.1°C
Min	18.1°C	Between 0.3°C and 0.8°C	From 12.9°C to 20.5°C	7.6°C	Between 0.7°C and 0.9°C	From 17°C to 19.4°C	2.4°C	Between 0.6°C and 0.8°C	From 16.6°C to 20°C	3.4°C

SUMMER	Measured value	Range of agreement between the 2 software	Temperature variations	Range of variation	Range of agreement between the 2 software	Temperature variations	Range of variation	Range of agreement between the 2 software	Temperature variations	Range of variation
Average	24.1°C	Between 0.1°C and 0.2°C	From 22.9°C to 28.7°C	5.8°C	Between 0°C and 0.2°C	From 26.2°C to 28.3°C	2.1°C	Between 0°C and 0.3°C	From 25.1°C to 27.8°C	2.7°C
Stand Dev	1.5°C	Between 0.1°C and 0.2°C	From 1.9°C to 2.7°C	0.8°C	Between 0°C and 0.2°C	From 1.9°C to 2.7°C	0.8°C	Between 0°C and 0.1°C	From 2°C to 2.3°C	0.3°C
Max	27.7°C	Between 0.5°C and 0.8°C	From 29.4°C to 37.5°C	8.1°C	Between 0.6°C and 0.7°C	From 30.5°C to 36.9°C	6.4°C	Between 0.2°C and 0.8°C	From 32.4°C to 34.2°C	1.8°C
Min	20.3°C	Between 0.1°C and 0.6°C	From 17.8°C to 23.2°C	5.4°C	Between 0.3°C and 0.6°C	From 20°C to 22.9°C	2.9°C	Between 0.1°C and 0.4°C	From 20.4°C to 23.1°C	2.7°C

A quick analysis of each individual statistic data for the parametric runs shows that in the air change runs the use of minimum ventilation rates will predict the highest internal temperatures in Summer and Spring; Maximum infiltration rates will predict the lowest internal temperatures in Summer and Spring and both ventilation and infiltration rates exert a strong influence on the predicted temperatures and therefore need to be as accurate as possible. In the internal gain runs, assuming that the number of people, lights and equipment are as accurate as possible, as well as information about the luminaires, small power loads are shown to be the most significant parameter influencing the temperatures. In the material runs minimum and maximum predicted temperatures are most affected by the transmittance of glass.

Figures 5a to 7b shows these results graphically, and also show how the predicted temperature varies with time for the most significant parameters of the sensitivity analysis.

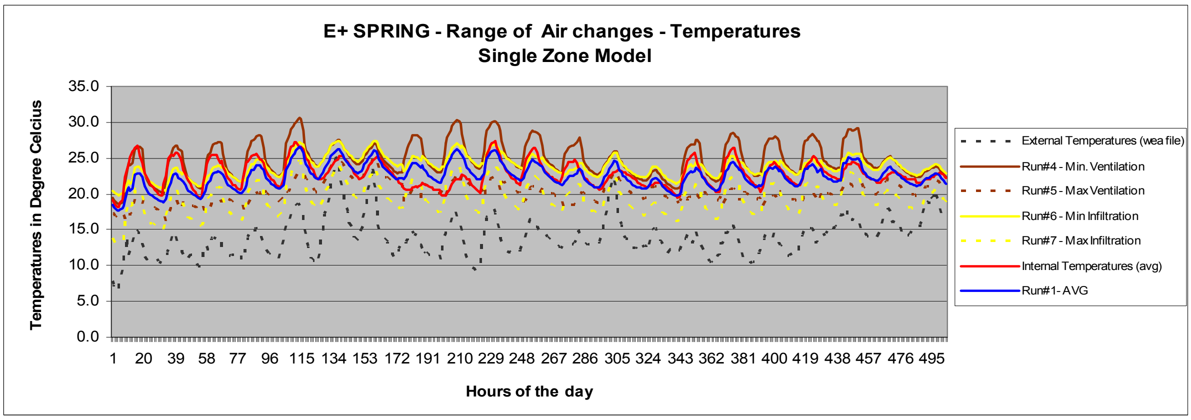

Figure 5a – Sensitivity analysis varying air change rates – Spring season

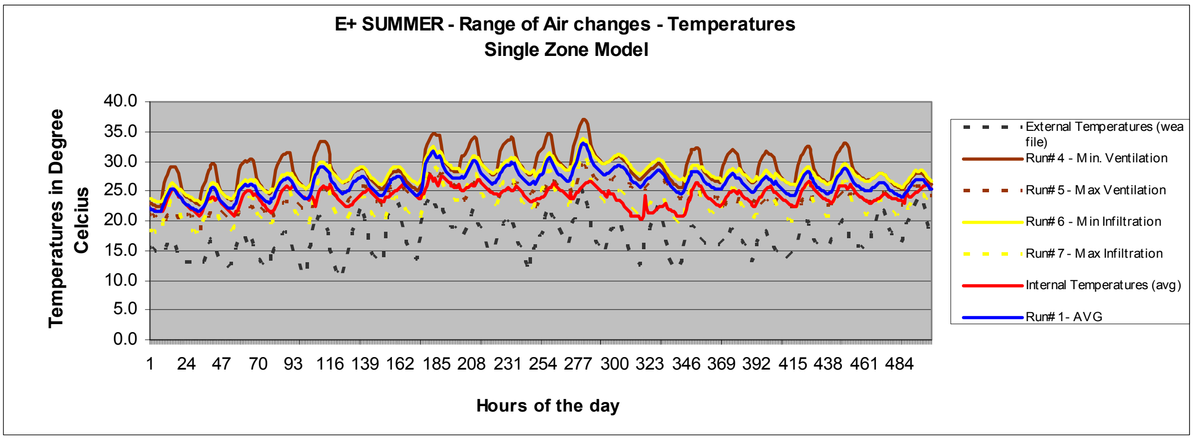

Figure 5b – Sensitivity analysis varying air change rates – Summer season

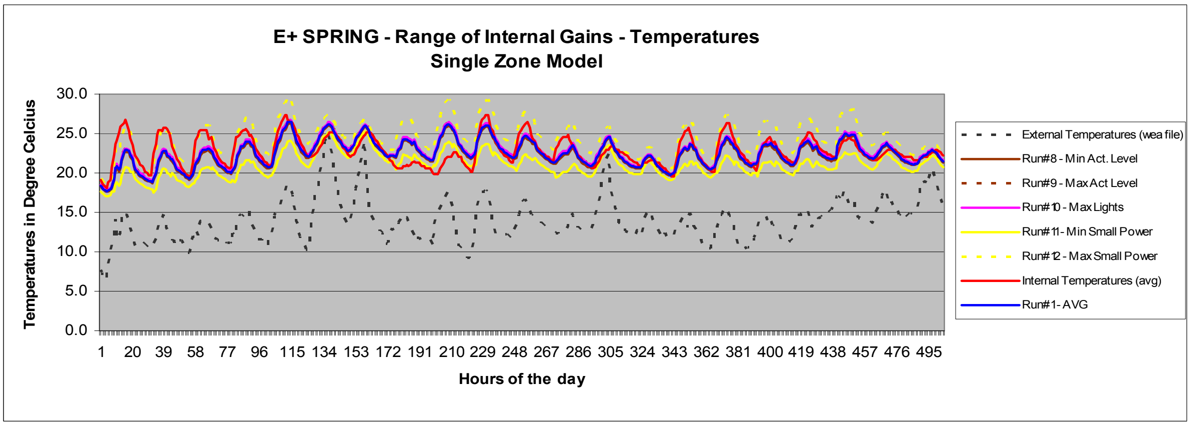

Figure 6a – Sensitivity analysis varying small power gains – Spring season

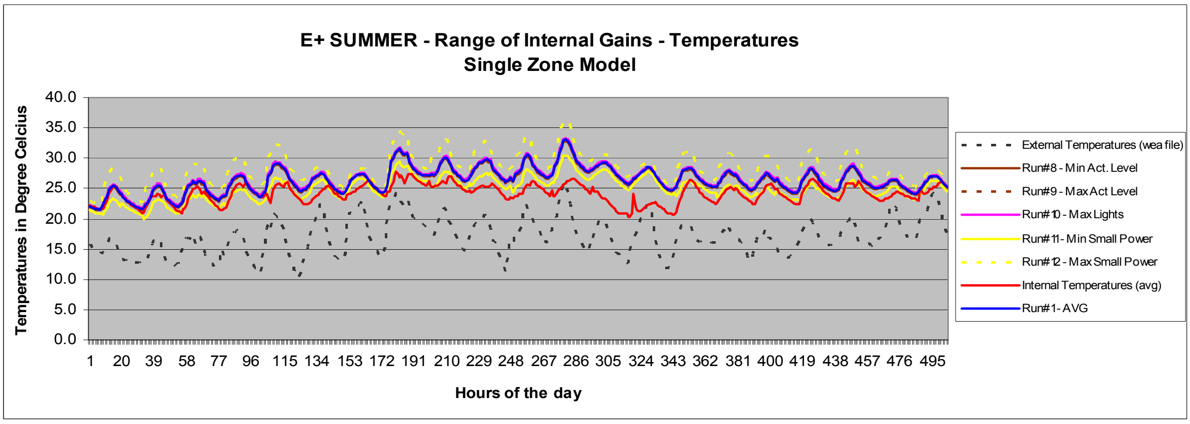

Figure 6a – Sensitivity analysis varying small power gains – Summer season

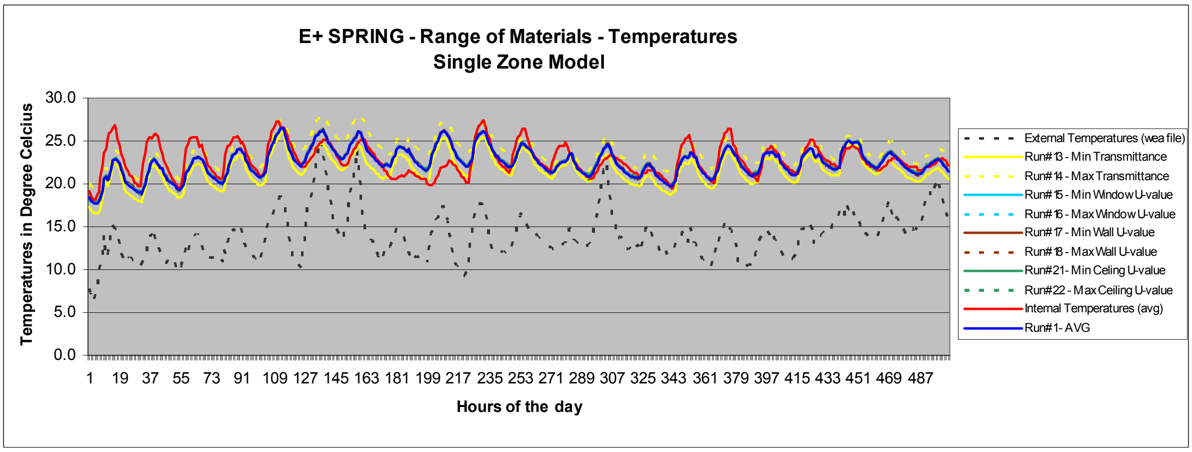

Figure 7a – Sensitivity analysis varying glass transmittance – Spring season

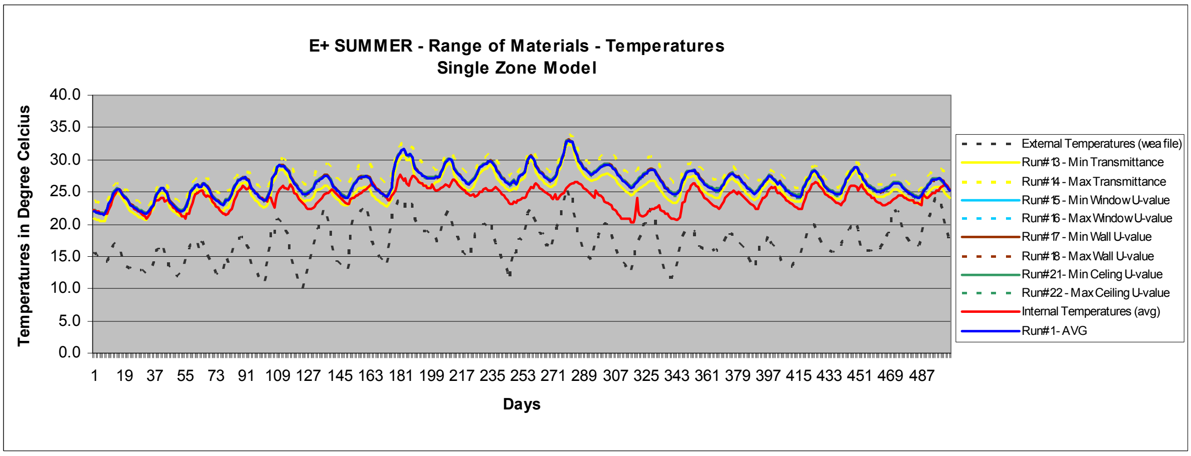

Figure 7b – Sensitivity analysis varying glass transmittance – Summer season

Conclusions

The results show that it is possible to model one building in 2 different tools with different input criteria and still obtain very similar predictions of performance running a single zone model analysis. But it is important to know what these input criteria must be to obtain this equivalence. A future paper will provide these parameters in detail.

It is also possible to conclude that for this building, in these weather conditions, assuming the sets of parameters based on the survey, the best option is to run a single zone model analysis. Zoning with virtual surfaces does not provide results that "agree" with each other using different simulation tools. Also the variations in these results when compared to the measured temperatures introduce even more uncertainty in the reliability of the predictions.

The parameters that appear to most affect the predicted internal temperatures when no mechanical heating or cooling is being provided, assuming that data about the people, lights and equipment are correct, are, in order of influence:

- Ventilation rates and infiltration rates
- Small power gains
- Transmittance of glass

Further investigations of the "match" between predicted and measured temperatures are still necessary as results in this paper were addressed using simple summary statistics and visual comparisons of graphs. A frequency distribution of the temperature differences would be recommended to see variations between predicted and simulated temperatures on a time varying basis.

The overall conclusion from this work is that it is possible to use different building simulation tools to predict the temperatures obtained in buildings with reasonable agreement between the tools and reality provided the input details and values are carefully researched.

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Results of research for innovative Eco-buildings in Austria, Slovenia and Uzbekistan

Anita Preisler

Arsenal research

Introduction

Energy efficiency and renewable energy sources play a major role in residential buildings in Austria and also in other European countries. In the last years low energy houses and passive houses as well as domestic hot water preparation and heating by solar thermal systems and heat pumps increased considerably. Now it is necessary to find replicable strategies to implement these future oriented technologies also in other types of buildings as office buildings, commercial buildings, industrial buildings and so on.
Therefore, national and international research framework programs focus on increasing the construction of sustainable buildings with a low energy demand and the use of renewable energy sources as well as the refurbishment of existent buildings with innovative Technologies and high energy saving goals.
The EC-framework program “Eco-building” and “Haus der Zukunft” in Austria make a technical and scientific steering of building projects possible and the following three examples are results of co-operations between research institutes and builders to set up Eco-buildings for different applications:

- **Office building**: Sunny research! – New concept for a commercial building with offices and halls in Vienna (Austria)
  Research project in the framework program “Haus der Zukunft”

- **Supermarket**: Mercator center – New concept for a supermarket and department store in Ljubljana (Slovenia)
  Research project in the EC-framework program “Eco-building” (‘SARA)

- **School**: Medersa Rachid – Refurbishment of training centre in Bukhara (Uzbekistan)
  Research project in the EC-framework program “Eco-building” (SARA)

These three buildings have been selected as future oriented non-residential demonstration site because these applications (offices, supermarkets, schools) presently have a huge amount of energy demand and the replicability of sustainable and cost effective concept is very high.

Example “Sunny research!”

Typology: commercial building with offices and halls
Location: Vienna (Austria)
Project type: research project financed in the framework programme “Haus der Zukunft” (Austria)

Figure 1: Sunny research – commercial building with offices and halls (source: pos architekten)

Objectives
Commercial buildings of basic to medium standard are hardly ever designed by a high quality of innovative building services engineering. In the research project Sunny research! a sustainable building design with high energy performance was developed. The aim was to adapt the aspects of Renewable Energy, thermal comfort and wellness in work by the development of a sustainable over-all building concept with following **key aspects**:

- Merge of building design and energy performance
- Wellness in work with high flexibility
- Low energy-demand for heating, cooling and lighting
- Use of renewable energy sources to supply energy-demand

Results
Right from the beginning, architectural aspects as well as building services engineering were integrated into the process. Transient thermal simulation [TRNSYS, 2001] and computational fluid dynamic simulation [FLUENT, 2005] were used for performance tests and technical improvement.

North/south orientation of the building:

- Active and passive use of solar gains by south façade
- High-standard offices in the north space
- Open, flexible useable south space with greenhouse-puffer rooms

Innovative ventilation concept:

- Air handling unit provides north offices with high quality fresh air, natural overflow to south space
- Natural air flow on the south façade by thermal lift
- Ecological air humidification by light controlled plants in greenhouse-puffer rooms

Energy performance:

- Activation of thermal mass for comfortable radiant heating and cooling
- Configuration of south façade makes high solar gains by Photovoltaics and high comfort conditions possible without outside shading

- Heating and cooling demand will be provided with ground water heat pump and ground water heat exchanger

Compared to a current standard commercial building the primary energy use per m² useful area decreases by 80% from 245 kWh/a to 54 kWh/a.

Project team: arsenal research (project management, CFD-simulations), pos architekten (architecture), ib hausladen (building services engineering), Technical University of Graz (TRNSYS-simulations), pokorny lichtarchitektur (lighting and daylight-simulations), quiring consultants (room acoustics and noise protection)

Example "Mercator center"

Typology: supermarket and department store
Location: Ljubljana (Slovenia)
Project type: Demonstration site in the EU-project
SARA (6th Framework programme/Eco-building)

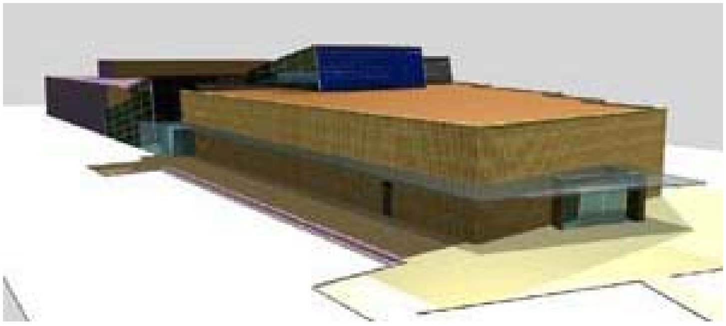

Figure 2: Mercator center – supermarket and department store (source: Mercator Group)

Objectives
Mercator Group is planning an innovative Mercator center used for a supermarket and department stores with the following objectives:

- Up to 40% overall saving on energy costs
- High comfort level
- Integration of renewable energy sources

Results
The energy savings will be achieved by taking the following steps:

- Reduction of electric energy for artificial lighting by implementation of a daylight controlled system in skylights and use on sunpipes
- Reduction of thermal energy by low energy and energy protecting building envelope
- Heat recovery system of heating and food refrigeration system

The highest energy demand of a supermarket is electric power, so the integrated renewable energy technology will be a building integrated Photovoltaic system with around 2 kWp installed power.
The main goal of the BMS is establishment of real time control system in the framework of global information control system of the building for performance control and direction. An online presentation of selected data for public of the following energy systems will be foreseen:

- Heating: building will be supplied with several heat meters connected to the BMS. They will enable metering of heating/cooling consumption of the whole building and selected zones.
- Electricity: several conventional electricity meters will enable metering of electricity consumption of the whole building, cooling device, ventilation and lighting for selected zones.

- Indoor Comfort: For selected zones indoor air temperature, CO2 concentration and indoor air humidity will be registered.

Project team: Mercator Group (builder), University of Ljubljana (thermal and light simulations), ETAS – Expert Technical Advice Service of SARA (technical advice), FH-Stuttgart (BMS and intelligent control)

Example "Medersa Rachid"

Typology: Training centre
Location: Bukhara (Uzbekistan)
Project type: Demonstration site in the EU-project SARA (6th Framework programme/Eco-building)

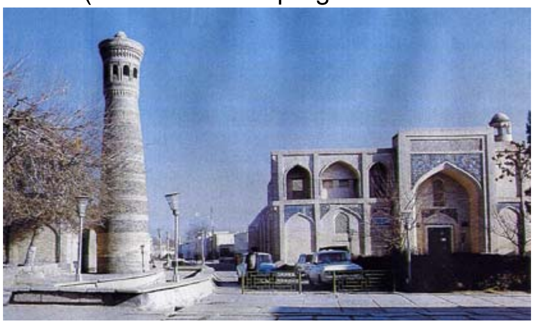

Figure 3: Medersa Rachid – training centre (source: Association Tessellatus)

Objectives
The architectural refurbishment concept and the heating, cooling and ventilation system for the refurbishment of Medersa Rachid should be implemented in a way that the original building appearance can be conserved and local conditions are used.

Results
Refurbishment of the façade:

- Use of local and traditional building materials like clay to reduce the environmental impact of the renovation
- Use of traditional construction methods such as against humidity and salts coming from the ground

Energy performance:

- Heating: Solar thermal collectors will support the gas driven heating system of the building
- Cooling: The solar thermal collectors will also be used for a solar cooling system in the classrooms
- Ventilation: Pre-heating and pre-cooling of the supply air by earth collectors
- Rainwater usage: Rainwater storage in the courtyard

The integration of 60 m² solar thermal collectors and 50 m² of Photovoltaics are foreseen by using new wooden constructions on the top of the building.

Project team: Mayor of Bukhara (builder), Association Tessellatus (architecture), ETAS – Expert Technical Advice Service of SARA (technical advice)

Conclusion

The main focus of all of these examples was to use the advantages of low energy buildings and renewable energy sources to set up replicable building concepts for different applications. The requirements on a modern building envelope go from thermal protection, solar protection, noise protection and daylight control to ventilation needs and reflect of outside conditions. A high inside comfort level needs controlled fresh air ventilation and humidity control as well as the use of radiant heating and cooling systems.

To fulfil all of these requirements and achieve the expected energy savings the implementation of the used technologies must be well designed and measured. Transient thermal simulations and computational fluid dynamic simulations are good instruments to get answers for very specific questions concerning heating and cooling demand of different façade concepts, expected inside temperatures, usable energy output of solar thermal collectors, heat pumps and Photovoltaics depending on the climate conditions and the building concept.

The architectural design of these buildings also have energy protecting functions, the existent building in Uzbekistan is also very well designed for the climatic conditions which has a positive effect on the energy demand, which only cause about 5% - 10% of additional costs compared to “standard” modern buildings. The energy supply by alternative, renewable technologies compared to fossil heating or electrical driven cooling technologies still cause between 10% - 30% additional costs (Photovotlaics beyond it) and yet have to be funded by the government to invest in a fewer fossil source dependency and a cleaner environment.

The three building concepts have shown, that compared to residential buildings, the electrical demand has a much more important factor than thermal energy. Therefore, in all of the three buildings the reduction of electrical demand by natural lighting strategies and sunpipes as well as an efficient energy distribution (efficient pumps, ventilator,…) to reduce the auxiliary electricity demand have been foreseen. Furthermore, in all of the three buildings Photovoltaics have been integrated as renewable energy technologies to support with electrical production.

The possibilities of energy efficiency and renewable energy sources in the building sector are very numerous and are in many fields as “solar cooling” still in a development and demonstration phase. Measurements of realised Eco-buildings will increase reliability in these innovative concepts to give more builder and planner reasons to build Eco-buildings.

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building
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congress

Integrated Evaluation of Buildings for Energy Efficiency: A Case Study in Office Buildings

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Abstract
Within the framework of EPBD and as a part of a wider initiative to reduce energy consumption a holistic and more complete approach is required for buildings' evaluation. The case study discussed in this paper is based on the development of an integrated analysis model, which implies, apart of the energy aspect, the environmental and economic evaluation of buildings. The Life Cycle Thinking concept is applied to buildings' management and is supported by several methodologies. This case study analyses and compares two separate methodologies "Life Cycle Analysis" (LCA) and "Life Cycle Cost Analysis" (LCCA) which cooperate in order to evaluate, with the most efficient and comprehensive way, buildings. The decision making tools used have major methodological differences and evaluate buildings adopting different approaches.

The software tool used for the methodologies' support and implementation is ENVEST® which simplifies the otherwise very complex process of managing buildings with low and controlled environmental impact and whole life costs' estimation. The analysis model depicted in this case study allows both environmental and financial evaluation of buildings in the general framework of energy labeling and certification.

1. Introduction
This case study aims at the comprehensive building's approach by developing an integrated analysis model, which implies, apart of the energy aspect, a complete environmental and economic evaluation of buildings. Therefore the Life Cycle Concept is adopted and supported by several methodologies. The Life Cycle Concept reflects the consideration of "cradle to grave" implication of any action and process. The basic criteria for choosing tools during the decision process are the final goal set and the quality of data required or, in more cases than thought of, available. In order to evaluate environmentally a process or a product and hence accomplish sustainability, there are several methods and tools to choose amongst. It depends on the resources available, the supportive technical elements supplied and the analysis' depth required. The decision process is an interactive process where the results produced from one type of analysis are used as an input for another methodology.

More specific, this case study analyses and compares two separate methodologies "Life Cycle Analysis" (LCA) and "Life Cycle Cost Analysis" (LCCA) which cooperate in order to evaluate, in the most efficient and comprehensive way, buildings. The decision making tools used have major methodological differences and evaluate buildings adopting different approaches. The software tool used for the methodologies' support and implementation is ENVEST® which simplifies the otherwise very complex process of managing buildings with low and controlled environmental impact and whole life costs' estimation. The analysis model depicted in this case study allows both environmental and financial evaluation of buildings in the general framework of energy labeling and certification.

2. LCA AND LCCA METHODOLOGIES TOWARDS INTEGRATE BUILDINGS' COMPREHENSIVE EVALUATION
The development of LCA in the building sector has been an accelerating one over the last decade. Much effort, by researchers and designers, by the building industry and independent institutions, and

not least by governments is being directed into LCA-projects worldwide. The importance of environment-related product information by means of LCA is in that sense broadly recognised and LCA is considered as one of the tools to help achieving sustainable building practices. LCA as such offers a comprehensive analysis which links actions with environmental impacts. At the same time it provides quantitative or qualitative results and taking into consideration the link between system's functions and environmental impacts it is easy to identify the issues which need improvement.

Applying LCA to the building sector has become a distinct working area within the general LCA practice. This is not only due to the complexity of buildings and constructions. LCA aims at specifying the environmental consequences of products or services from cradle – to – grave. Buildings and constructions have an extremely long lifetime, often exceeding the conventional period of 50 years. Therefore it is difficult to predict the life cycle "from cradle to grave" as a lot of data are required. During this life span the building or construction may undergo many changes in its form and function. These changes can be as significant, or even more significant, than the original construction. Many of the environmental impacts of a building occur during its use, for instance energy and water consumption. Proper design and material selection are critical to minimise the environmental loads during the use phase.

Therefore within the framework of implementing LCA to institutional and public buildings, several fundamental points have to be examined and defined in order to accomplish a realistic environmental evaluation, more specific:

- Goal and scope definition: the scope is to achieve comprehensive environmental evaluation during the building's life cycle.
- Inventory analysis: this stage deals with the input and output flows of all the procedures concerning building's life cycle. The inputs and outputs flows contain data of materials and energy consumption.
- Impact assessment: at this phase the environmental load calculated from the inventory analysis is transformed to environmental impacts.
- Use and application of results: at this phase and after analysing the system the crucial points are identified in order to focus on the procedures which need to be improved.
- Relation to other tools: this case study focus on the collaboration of two comprehensive tools which target the one to the environmental evaluation (LCA) and the other to the financial evaluation (LCCA).

LCCA is a method to analyze [3] the total cost of acquisition, operation, maintenance, and support of a product/system/service throughout its useful life, and including the cost of its disposal. This LCCA analysis can provide important inputs to the decision making process, for example in the fields of:

- evaluation and comparison of alternative design approaches,
- assessment of economic viability of projects/products,
- identification of cost drivers and cost effective improvements,
- evaluation and comparison of alternative strategies for product use, operation, test, inspection, maintenance, etc.,
- evaluation and comparison of different approaches for replacement, rehabilitation/life extension or retirement of ageing facilities,
- allocation of available funds among the competing priorities for product development/improvement and
- assessment of product assurance criteria through verification tests and its trade-off.

Life Cycle Assessment and Life Cycle (or Whole Life) Costing Analysis (LCCA) share common features and aims, that is they seek to assess impacts over the whole life of a building or structure and present the information in a manner which supports decision-making processes. The purpose of a life cycle costing exercise is usually to aggregate the total capital and operating costs of building systems and components over extended periods of time and then present the figures as relative values, which can be easily compared and assessed against alternatives. LCCA does not explicitly deal with environmental impacts, although it can frequently be used to support environmentally sensitive construction solutions, especially in cases where operating and/or maintenance costs are significant.

The most typical approaches to LCCA are those of net present values (NPV) and payback periods. There are numerous costs associated with acquiring, operating, maintaining, and disposing of a building or building system. Building-related costs usually fall into the following categories: initial costs—purchase, acquisition, construction costs, fuel costs, operation, maintenance, and repair costs, replacement costs, residual values—resale or salvage values or disposal costs, finance charges—loan interest payments, non-monetary benefits or costs, environmental costs and benefits.

Only those costs within each category that are relevant to the decision and significant in amount are needed to make a valid investment decision. Costs are relevant when they are different for one alternative compared with another; costs are significant when they are large enough to make a credible difference in the LCCA of a project alternative.

3. MEASURING THE ENVIRONMENTAL IMPACT

One of the ways in which the environmental impact of a building can be measured is by applying the method of ecopoints. This can be done in a series of ways considering the main building's structural and operational data, combined with the location specific parameters like climate and geomorphology.

The evaluation begins with the input of the main architectural features of the building (height, number of storeys, floor area, opaque elements' area, window area, etc) and the details of the structural elements (external walls, glazings, roof elements etc). Then comes the description of the entire HVAC system and all other building services.

Table 1. Main differences between LCA and LCCA

	LIFE CYCLE ANALYSIS	**LIFE CYCLE COSTING**
Goal	System's environmental management. Compares relative environmental performance of alternative systems taking into consideration the entire system's life cycle (cradle – to grave analysis).	Determine cost effectiveness of alternative investments and business decisions from the economic perspective. It also includes eco-costs, therefore leads indirectly to eco-efficiency.
Scope	System's comprehensive environmental evaluation.	Cost effectiveness.
Object of Analysis	Product or service.	Product, service, process or activity.
Spatial characteristics	Global to regional and non site specific.	Global to regional and non site specific.
Level of detail	Covers wide range of analysis' types from qualitative flow charts to comprehensive quantitative analysis.	From narrow to broad analysis.
Activities included to the "Life Cycle" system	All processes connected to the system analysed including the entire pre-usage supply chain, use and end of life processes.	Activities causing costs to the system analysed.
Flows considered	Materials. energy, pollutants, resources flows.	Cost and benefit monetary flows directly impacting the system analysed.
Units used for the analysis	Mass, energy, occasionally volume, other physical units.	Monetary units.
Time treatment and scope	The timing of processes and their release or consumption flows is traditionally ignored.	Time is critical. Present valuing of costs or benefits. Specific time horizon scope is adopted.
Formal recognition	ISO, UNEP and SETAC.	No single standard or protocol.
Tool's strengths	Comprehensive with respect to environmental impact connected to the system analysed.	Evaluates external and internal costs. Provides one single indicator.
Tool's weakness	Complex because it considers a comprehensive chain of processes and therefore data intensive. It doesn't consider directly future changes. Only known and measurable environmental impacts are considered.	No comprehensive model available, data intensive, the valuation of environmental costs not always trustworthy, uncertainty.

By using an appropriate software package, in the case of this study the Envest 2, the designer can identify those elements with the strongest influence on the building's environmental impact and its whole life cost and demonstrate the effects of selecting alternative construction techniques and materials. He can also predict the basic environmental and cost impact of various strategies for heating, cooling and operating a building. The environmental impact of the building's life cycle encompasses a wide range of issues, including climate change, mineral extraction, ozone depletion and waste generation. Each environmental issue is measured using its own unit. Using the characterised impacts it is easier to compare and come up to conclusions. The ecopoints are based on this concept base and express the impacts of a typical UK citizen calculated by dividing the impacts of the UK by its population. Therefore it is rather arbitrary to use these British data for other parts of Europe. Still, this approach gives a safe qualitative and quantitative estimation of the system's environmental and financial identity, particularly when considering the fact that one evaluates in a comparative way. Furthermore, this methodology has been widely accepted over the last years, enabling a Europe-wide LCA of building (BRE, Centre for Sustainable Construction). Costs are measured in £Sterling according to Net Present Value, discounted at 2002 Treasury rates or a discounted rate set by the user.

So the UK ecopoints is a measure of the overall environmental impact of a particular product or process covering the following environmental impacts BRE, Centre for Sustainable Construction):

- Climate change, 38%
- Fossil fuel depletion, 12%
- Ozone depletion, 8%
- Human toxicity to air, 7%
- Human toxicity to water, 3%
- Waste disposal, 6%
- Water extraction, 5,5%
- Minerals extraction, 3,5%
- Acid deposition, 5%
- Ecotoxicity, 4%
- Eutrofication, 4%
- Smog, 4%

The weightening factors show the importance of the environmental impact according to defined criteria which conclude not only scientific parameters but also social priorities and prospects. Assessing such different issues in combination requires subjective judgements about their relative importance. For instance, a product or a material with high global warming impact that does not pollute water resources can, under given circumstances, have a smaller overall environmental impact, but produce significant water pollution. Therefore giving ecopoints for the various forms of impact can assist the comparison between different operations and materials during building's life cycle. Ecopoints can be given to each one of them, or with a single Ecopoint score, for the sake of easier apprehension, especially in multiple comparative studies, including economic factors. Having made the comparisons between different buildings and their specifications, designers can graphically demonstrate the environmental and financial credentials of different designs to clients. In that sense, both environmental and financial tradeoffs can be explicitly understood during the design process, allowing the designer, but also the client, to optimise the concept of best value according to their own priorities.

4. THE CASE STUDY OF AN OFFICE BUILDING

4.1 LCA IMPLEMENTATION

Building's description

The building studied is a 9 storeyed institutional building, with a unique architectural structure, as it comprises a cylindrical shape, glazed facades and partially aluminum cladding on its walls, over a life span of 20 years. The building is located in the campus of the Aristotle University of Thessaloniki, in the city center of Thessaloniki, Greece. The building was commissioned in 1999, it features 9 floors and a ground floor, and houses a number of offices, auditoriums and assembly halls. The total volume of the conditioned spaces is approximately 11,000 m^3 whilst the volume of conditioned space of a typical floor is 1,050 m^3. The height of the building is 35 metres.

The analysis required several data such as shape and orientation of the building, structural elements, floors' formation, data for exterior, interior walls, windows, roofs, insulation, ceilings, lighting, heating and cooling systems. Moreover operation characteristics collected such as occupancy details, energy, materials and water consumption.

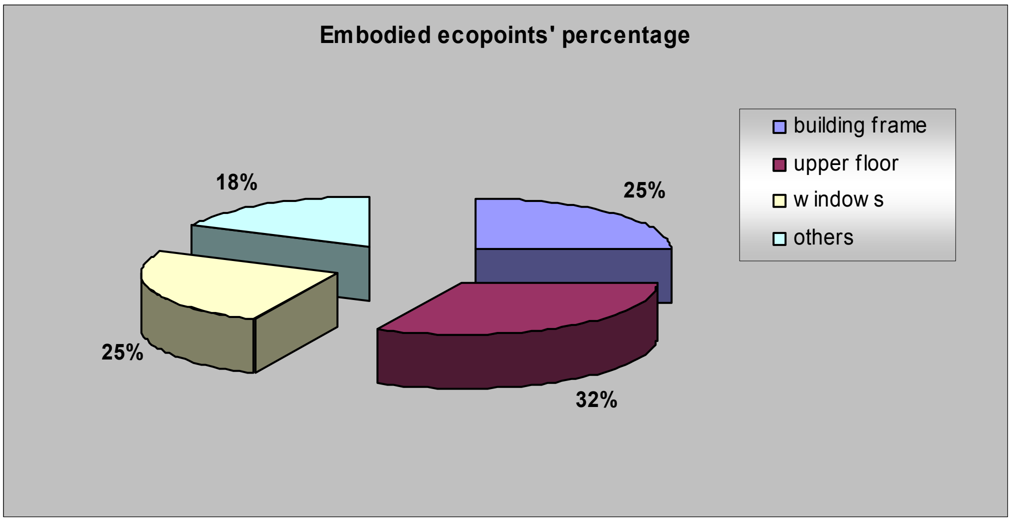

Figure 1. Environmental evaluation based on material use – embodied ecopoints

The LCA implementation and the inputs and outputs flows' processing with envest software gave the embodied ecopoints from building's life cycle. The embodied ecopoints take mostly into consideration the materials' use while the operation ecopoints that are analysed at the following paragraph the operations during building's life cycle.

The embodied ecopoints are influenced basically from two parameters:

- the type of materials used at the construction stage or at the operation or maintenance phase
- and the materials' consumption quantity.

The total embodied ecopoints from building's life cycle are 31909. For the environmental load caused by these ecopoints mostly responsible is building's frame construction at about 25%, the upper floor's construction at about 32%, windows at 25% and the other structural building's elements at about 18%. The term "others" is referring to constitutional data concerning foundation, external and internal walls, insulation materials consumption, ground floor's construction, ceiling, roof, e.t.c.

In correspondence the operational ecopoints focus on building's services. The total operational ecopoints' quantity is 298.253. Before analysing the total operational ecopoints to building's services it is important to notice that operational ecopoints and consequently services are about 90% more responsible for the building's environmental load during its life cycle in comparison to embodied ecopoints. In detail, the services analysed at the LCA procedure were: heating, ventilation, water consumption operations, ventilation, cooling, lifts' and office equipment's operation.

As it was already analysed for the embodied ecopoints the total operational ecopoints from building's life cycle are 298.253. For the environmental load caused by these ecopoints mostly responsible is the office equipment's operation at about 55% it is essential to mention that the air conditioning operation is also included in the office equipment and that is the main reason for the operational ecopoints' increase. Moreover cooling operation contributes at about 12% while heating contributes at about 15%. Finally lighting is responsible at 11% to the total operational ecopoints amount.

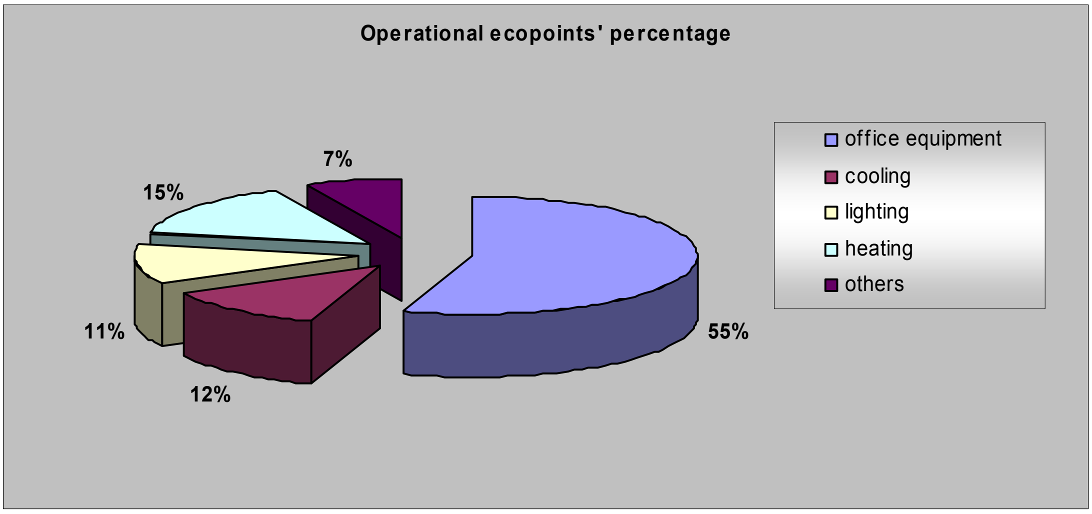

Figure 2. Environmental evaluation based on services – operational ecopoints

At this point it is important to translate the ecopoints into environmental impacts in order to detect the most significant environmental impact caused by building's life cycle. The above diagram depicts that the most crucial environmental impacts which are:

- climate change
- fosil fuel depletion
- acid deposition
- and eutrophication.

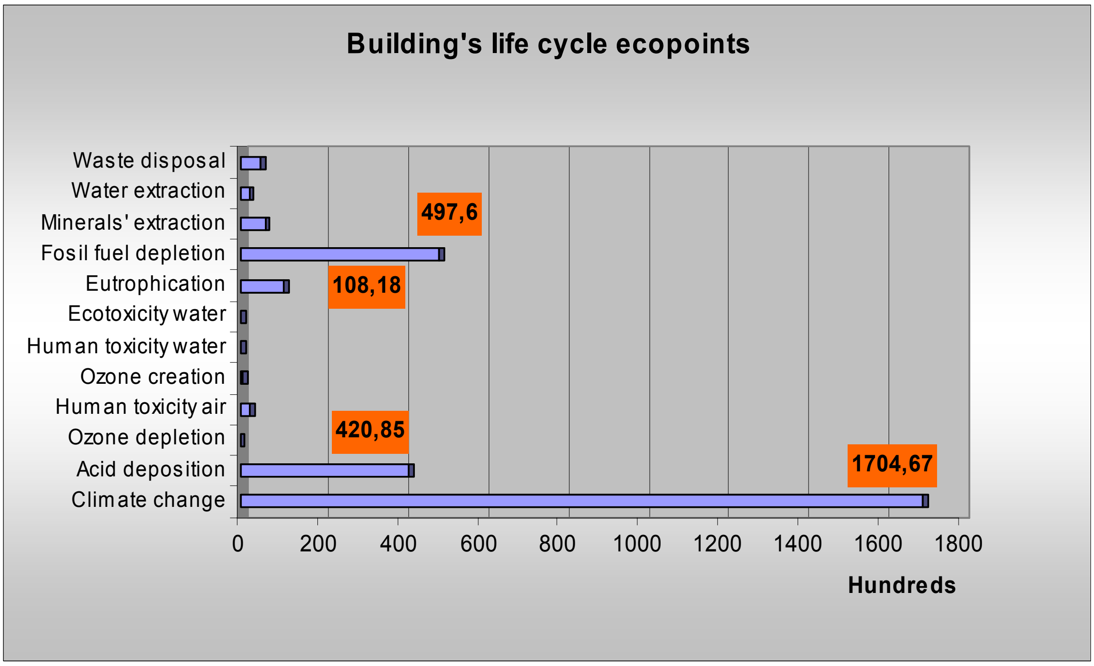

Figure 3. Environmental evaluation based on total ecopoints during building's life cycle

The environmental impacts derived as a result of adding the entire amount of total operational ecopoints to total embodied. It was expected that climate change would be one of the most aggravated environmental impacts because the operational ecopoints are increased comparing to embodied ecopoints and as operational ecopoints are more related to energy consumption it was quite easy to predict that fosil fuel depletion and climate change would be rather increased comparing to other environmental impacts.

4.2 LCCA IMPLEMENTATION

The results from Life Cycle Costing Analysis follow the same concept as the LCA's results. More detailed the results deriving from the analysis are measured on sterlines and then transformed to euros. Moreover the disaggregation of LCCAs' results are:

- Embodied life cycle costs in correspondence to embodied ecopoints
- and operational life cycle costs in correspondence to operational ecopoints.

The embodied life cycle costs coming up by multiplying costs and quantities from materials' consumption. The same concept is followed for services too. All costs were considered and in case the data were not adequate especially on maintenance circumstances and replacements elements for envest database were taking into consideration in order to achieve a more comprehensive and realistic situation even if uncertainties arising from estimations. Costs are measured in £Sterling according to Net Present Value, discounted at 2002.

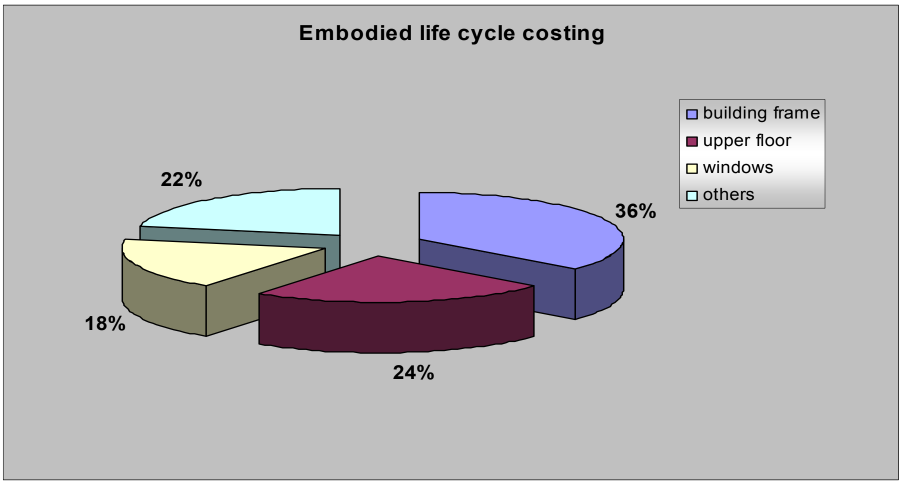

Figure 4. Embodied life cycle costing

The embodied life cycle costs refers to the structural elements of the building rather than operations in correspondence to embodied ecopoints. The total embodied life cycle costs in euros is coming up to 2.631.516. Building's frame is responsible at about 36% for the cost, the upper floor at 24%, windows 18% and other structural elements approximately 22%.

In correspondence operational life cycle costs are 3.492.177. Office equipment, including air conditioning which contributes approximately 30% to the total cost, lighting 18%, heating 22%, cooling 11% and other services 19%.

It is important to notice that although the environmental contribution of operational ecopoints is approximately the 90% of the total amount of ecopoints deriving from LCA methodology the correspondence percentage for the total life cycle cost is the 44%.

5. CONCLUSIONS

The decision making tools used have major methodological differences and evaluate buildings adopting different approaches. More specific LCA gives quantified data for the environmental impacts caused, during building's life cycle and LCCA evaluates building from an economic perspective.

The software tool used for the methodologies' support and implementation is ENVEST® which simplifies the otherwise very complex process of managing buildings with low and controlled environmental impact and whole life costs' estimation. The analysis model depicted in this case study allows both environmental and financial evaluation of buildings in the general framework of energy labeling and certification.

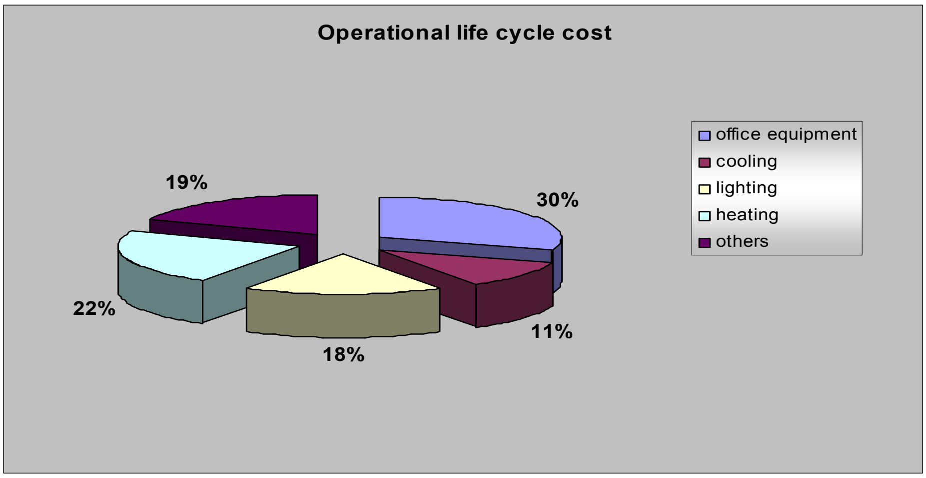

Figure 5. Operational life cycle costing

Some of the most useful results concluded from the analysis are:

- The total embodied ecopoints from building's life cycle are 31909. For the environmental load caused by these ecopoints mostly responsible is building's frame construction at about 25%, the upper floor's construction at about 32%, windows at 25% and the other structural building's elements at about 18%.

- The total operational ecopoints' quantity is 298.253. For the environmental load caused by these ecopoints mostly responsible is the office equipment's operation at about 55% it is essential to mention that the air conditioning operation is also included in the office equipment and that is the main reason for the operational ecopoints' increase. Moreover cooling operation contributes at about 12% while heating contributes at about 15%. Finally lighting is responsible at 11% to the total operational ecopoints amount.

The operational ecopoints and consequently services are about 90% more responsible for the building's environmental load during its life cycle in comparison to embodied ecopoints.

The total embodied life cycle costs in euros is coming up to 2.631.516. Building's frame is responsible at about 36% for the cost, the upper floor at 24%, windows 18% and other structural elements approximately 22%.

- The operational life cycle costs are 3.492.177. Office equipment, including air conditioning which contributes approximately 30% to the total cost, lighting 18%, heating 22%, cooling 11% and other services 19%.
- The operational ecopoints is approximately the 90% of the total amount of ecopoints deriving from LCA methodology the correspondence percentage for the total life cycle cost is the 44%.

6. ACKNOWLEDGEMENTS

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“Reality Check” organized by the Competence Network Innovative Building Services Engineering (KinG): the case UNIQA Tower Vienna

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Arsenal research / business unit Sustainable Energy Systems

1. Introduction

The Reality Check: Uniqa Tower was the first object of the series: „Reality Check - Innovative Building Services Engineering" organized by KinG, the competence network for innovative building services engineering. This network has been initiated and developed by arsenal research for the building services engineers to facilitate the integration of innovative building service technologies into the planning process.

2. Competence Network Innovative Building Services Engineering "KinG"

Motivation

Due to the service-oriented economy in the industrial nations, the demand for electricity, transport and heat from households and the tertiary sector has been increasing, while the industrial energy demand has been relatively stable. Hence, households and the tertiary sector are the biggest users, accounting more than 40% of the final energy demand within the EU.

By now, more than one third of final energy consumption in Austria is used for heating and cooling, warm water consumption, lighting and energy use of appliances in the building sector.[1] Due to the high energy savings and energy efficiency potentials it seems reasonable to take more effort in reducing the energy consumption of the buildings sector by meaningfully planned new buildings and optimally refurbished buildings.
The benefit for the customer shall result in the reduction of operating costs but also increased indoor comfort. At the same time, the possibility for a personal contribution to the climatic protection is offered by avoiding $C0_2$-emission.

Now, there are many possibilities to optimize the energy efficiency in buildings, like e.g. research activities in energy efficient systems and renewable energy technologies, legal and political actions to set up a framework for supporting energy efficiency activities, tax reliefs and subsidies. The know-how transfer of latest research results to the market actors and to the customers as well as the know-how exchange amongst the professional are further chances to increase the awareness for energy efficient buildings and to provide a more highly competent work force.

However, practice in Austria shows that barriers in developing innovative and energy efficient buildings are rather rooted in high investment costs, lack of knowledge by professionals, inadequate know-how transfer of innovative methods as well as in the notable lack of cooperation within the building branch. Innovative systems are often limited to few best practice examples, due to the fact that usually any innovation needs a long implementation period to be launched into the building market.

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[1] "Geschäftsfeld Gebäude & Raumwärme", by Klemens Leutöb, in: energy - Zeitschrift der Energieverwertungsagentur, Nr1/2005

One possibility to implement promising strategies for energy savings and to overcome these barriers is the development of a network collaboration with the aim to transfer innovative know-how and to overcome the existing lacks.

Targeting the building services engineering for network development
One practicable approach is the focusing on one of these branches, the building services engineering. As a high-tech branch they play a key role for developing innovative buildings. The building services engineers are inevitable partners for architects, planners and real estate developers to design sophisticated solutions for high performance buildings. Solar cooling technology, concrete core activation, etc. are subject to the competences of the building services engineers and synonyms of innovative technologies. The future of innovative building services engineering depends on a successful implementation, which requires an integrated planning approach and collaboration of all partners in the building sector.

Today's intensified legal regulations, high demand for energy-saving technologies and the use of regenerative energy systems, ecological building materials and constructions as well as intelligent architectural designs make it increasingly necessary to create "ideas ahead".
Hence, architecture offices, planning offices, operating companies, building services companies, suppliers, manufacturers of innovative components, economists and many more need to get involved in the right time at the right place to provide innovative projects. The critical point is to assure all partners the lead in their core competence on one hand, but to establish a working environment which supports all of them to offer innovative solutions and services on the other hand. Integrated planning demands the equalization of all partners within a common framework.

However, in Austria this early cooperation among the various building actors is mostly inevitable. Due to the lack of information and cooperation, it is difficult to fully tap potentials in increasing comfort and decreasing energy consumption of buildings. Depending on the specific user requirements, building specifications and flexibility of the client and planning team, just a few good examples of optimized concepts have been developed until now.

To strengthen the integrated planning method and to support the positioning of the building services engineers (see figure 1) as well as to develop more awareness for the integrated planning, a network for innovative building technologies has being developed in the Vienna Region.

Source: arsenal research, 2005
Figure 1: Integrated Planning demands the involvement of the building services engineers

The Vienna Region as a Starting Point for the Network on Innovative Building Technologies
The tasks for refurbishment of buildings and for new buildings in the urban areas of the Vienna Region are setting up quite different challenges in realisation, although the principles are similar. Complex requirements on buildings are growing as functionality, smart structures and designs, high comfort, ecology and economy issues are more demanded.

Being a network hub in the new Europe, the region Vienna counts as a culmination point of innovative projects and services in the field of energy efficiency. Also the vicinity to the neighbouring countries and youngest member of the EU, who are expecting increasing energy consumption and therefore higher energy rates, strengthens the need of Vienna as an environmental active city. Constitutive on these facts and on the existing potency of the Viennese economy, the development of a competence network can also function as a stimulus for the RE activities in the Central European Region.

To resume the decision of focusing on the building services engineering in the Vienna Region has been made from following reasons:

- Continuous increasing importance of building services
- Key role in energy saving technologies and RES
- Key role in optimization of building quality
- Negative experiences in efforts to establish network activities for the whole building sector
- Strengthening of the regional economic power and in the Central European Region

KinG Kompetenznetzwerk innovative Gebäudetechnik

The “Competence Network for Innovative Building Services Engineering”
KinG is being established to facilitate the integration of innovative building service technologies into the planning process, thus substantially improving comfort and energy efficiency. The network is focusing on crossing activities of specific interest in the field of building services engineering as well as initiating and accompanying of innovative projects in co-operation with other branches and clients.

KinG is a project- and client-orientated initiative, focussing on the clients and market needs. Information, development and know-how exchange relating to innovative products and system in the building services branch are the incentives of the activities.

The aims of the network KinG are:

- Focusing on core competences of the branch (RE indoor quality and building ecology)
- Innovation and co-operation enhancement, specifically in the field of renewable energy
- Establishing a strong common identity - strong representation of interests
- More qualified and trained personnel
- Establishing a critical mass of innovative companies for competition on European level
- Co-operation with other (inter)national network activities in this field
- Encouragement of applied research activities for components and systems in the building services sector
- Consolidation of architecture, building services and energy efficiency - reduction of distrust within the branches (win – win situation)

There have been two strategic directions defined which are complementing each other:

- **Strategy of stabilization:** Fortification of the existing network of the building services branch and of the research activities, technology development and production in the Vienna Region
- **Strategy of expansion**: Export of innovative services, technologies and systems to other market actors in the building sector and further on to other regions

The establishment of a competence network between enterprises, associations and research institutions in the field of building services engineering is specifically attractive for SME's, which are presenting the main economic fraction in the Vienna Region.

To support these strategies, arsenal research provides their innovative knowledge and infrastructure (R&D activities, training and standardisation) to achieve an optimal transfer of new research results in the RES and energy efficiency systems within the competence network.

3. Development of the Competence Network KinG

KinG is linked with the EU-project CER2[2] - www.cer2.net - a transnational INTERREG III B funded project of 14 partners from 7 different countries, supporting energy efficiency and renewable energy sources. Both, CER2 and KinG are leaded by arsenal research, business unit Sustainable Energy Systems.[3] Within this project, the initial steps for KinG were set as competence network in the area of the Vienna Region in 2004.
KinG will further benefit from the CER2 network during the transfrontier movement to neighboring regions.

Source: arsenal research, 2004
Figure 2: KinG is linked to the EU project CER²

First steps
Due to the restraints along with the implementation of innovative projects in this field, first steps were already made in 2003 to initiate a building competence network aiming the reduction of established barriers. Hence a workshop with different experts has been held, to discuss the potential of a competence network.

arsenal research enhanced this mission and conducted studies as well as a master thesis[4] concerning the possibilities of an establishment of a competence network in the building sector of the Vienna Region.
The competence network is based on these works and on a feasibility study, investigating the needs of the building services engineering branch.

Interviews with key actors in Vienna were conducted in autumn 2004/2005 by arsenal research on the current situation in the building technology branch.

Statements like the following were compiled and provided the basis for developing KinG:
"Somebody should clarify master conditions and support project initiatives, so that it is easier to apply for funds …"
"We don't know what's available and can't assess what we know; consumption data and objective assessment in a databank would make sense."
"… to collect results developed in the renewable energy branch and to display them - a lot of single initiatives exist, but there is a lack of networking."
"… pilot projects, which provide some operational experience, should be accessible."

In regard to these facts and further studies[5] a network concept has been developed, which has been finalised and agreed together with representatives of the branch on a workshop in spring 2004.

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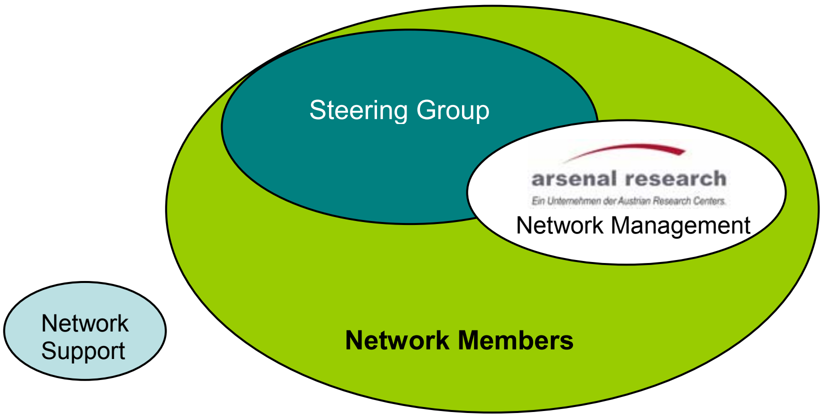
[2] Project duration started with 1st of January 2004 and lasts until 31th October 2006. Lead partner is arsenal research / business unit „Sustainable Energy Systems“. The target of CER² is to create new perspectives for the regional economy and energy supply sector, as well as support of sustainable development in RES. CER² delivers vocational trainings in the field of RE, activities in quality assurance of systems and products, support for business start-ups and preparation of regional energy concepts and last but not least support for the development of regional competence networks.
[3] arsenal research is an Enterprise of the Austrian Research Centers.
[4] Fichtinger, J. (2004): Vorstudie zu einem Gebäudecluster in der Vienna Region. Diplomarbeit zur Erlangung eines Magistergrades an der Wirtschaftsuniversität Wien. Betreuung: Mag. Christoph Chorherr

Interviews with active companies in this field have been carried out and discussions with representatives of the City of Vienna have been held.
The development process has been initiated by experts from arsenal research, and carried out in cooperation with the City of Vienna MA27, raum & kommunikation and representatives of the branch who participated in the Kick-off workshop, as well as accompanied by the experienced network coach DI Alexander Schmidt[6].

4. The network system of KinG

To achieve the aims of KinG and to keep the structure of the competence network clear stated benefits for members had to be defined as well as a well-organized management (small, efficient, professional).
KinG is characterized by the formative bottom-up-approach. Active members of the building services engineering branch shape in so called impulse-meetings the network's fields of activities and therefore steer demand driven strategies and actions. This provides for an optimal textual alignment of workshops and seminars, strengthens the network's underlying immanent team play and vitalizes innovations in this branch.
Moreover, the Competence Network Innovative Building Services Engineering provides knowledge transfer, better access to the results of the latest research activities and competent support at project development by qualified experts.



Source: arsenal research, 2005

Figure 3: Composition of the competence network KinG

The steering committee **(“Impulsgeber”)** meets twice a year to evaluate the past activities, create an action plan on the basis of the feedback of the members and develop the activities for the next term. The member of the committee also acts as observers hence they provide exterior views and establish contacts to stakeholder, key players and lobbies, guilds, funding, etc. They introduce their expert knowledge to support the competence network and the ongoing progress. The committee consists of active members of the competence network. At this stage these are the founders of the competence networks.
The network management ("**Netzwerkmanagement**"), remaining at arsenal research, is responsible for the administrative tasks of the competence network, like the implementation and realisation of the action plan, organisation of the activities (meetings, workshops, seminars, etc.), post processing of the activities, finances and documentation. They also hold the function as a clearing board in intensive cooperation with the steering committee. The management is leaded by arsenal research, one of the founders of the competence network.
The network support group ("**Netzwerksupport**") is not a member of the network but provides their expertise and support on demand. This group is not limited to the building services, but rather these

[5] Korab, R. (2001): Kompetenzzentrum Bau, KBAU, Proposal, unpublished; Korab, R. (2002): Impulskompass für Bau- und Immobilienbranche Bau.Werk.Zukunft, Research project in the framework of „Haus der Zukunft“, unpublished.

[6] Accompaning of the network developments TecNetCluster Niederösterreich, ecoplus. NÖ Wirtschaftsagentur GmbH, 2001/2002, Accompaning of several cooperation groups like e.g.: CAD connect (20019, Kleinholzhaus im Tourismus (2004), Müll EX (2003), ARGE Holzfenster (2004), Designinitiative Niederösterreich (2002) and many more

experts will be invited according to the needs (moderation, legal advice, etc.). With their expertise background coming from the real estate sector, architecture, the legislation and financial sector, research institutions, consultation in energy efficiency, but also in submission of research proposals, and many more. Regular members of this group will be representatives of funding institutions, moderation and coaching and research centres.

5. Services of KinG

Since spring 2005 KinG started to organise workshops, reality checks and presentation platforms. As a starting point the following services have been established for the network members:

- "**Reality Check Innovative Gebäudetechnik**": Innovative Building Services Engineering: surveys of innovative reference buildings / projects together with the responsible engineers, in combination with the analysis of planning data compared with operational data.
- Yearly changing **Specials – "Series of expert workshops"**: Events focusing on clients, partners in the building sector, 2006 the target group will be real estate developers, and architects focusing on integrated planning.
- **Expert seminars** ("**Fachseminare**"): Positioning of building services engineering as a high-tech branch, through solution and market oriented workshops with clients (real estate developers, building owners, architects, etc.).
- **"Future Corner"**: Processing of latest results of research and development results within the world of building services engineering.
- **"Communication platform"** for knowledge transfer as a basis for successful (inter)national networking
- Innovative **Support** in project development by a competent project team.

"**Reality Checks**" for building service engineers and clients	**Series of expert workshops** for clients	**Expert seminars** for building service engineers and clients	**Future Corner**
Commercial building & large size heat pump: The case Uniqa Tower Passive Housing & controlled comfort ventilation: The case Students Home Molkereistrasse	Added value for real estate developers – What is needed?	Building Directive & energy performance certificate Use of simulation for Building service engineers and architects	Subjects: LCC-Modells Comfort
Communication platform	Services on www.king-network.at: Presentation of KinG, Information platform, event calendar, newsletter, Expert forums, members area for research projects and information, …		

Source: arsenal research, 2005

Figure 4: Activity services of KinG plus the past and coming activities

6. Past activities

Following events were organized:

30th June 2005	1st steering committee meeting setting up the first activities within the network and the schedule for the second term 2005
19. October 2005	**"Reality Check" Innovative Building Services Engineering: Uniqa Tower**
22. November 2005	Workshop with building services engineers and real estate developers: "Contribution of high-tech building services engineering to the market value of commercial buildings and long-term maintenance of value."
28. November 2005	2nd steering committee meeting evaluating the first workshops and preparing the next steps for 2006
19. January 2006	Information event "energy performance certificate" – Implementation of the Building Directive in Austria

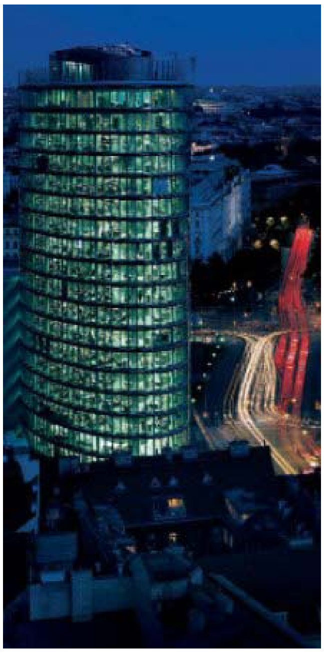
7. Reality Check: The case UNIQA Tower in Vienna

In this "Reality Check" the successful system integration of a renewable energy source (heat pump) in a commercial building to minimize energy consumption has been focused.

Large sized heat pump application for sustainable heating and cooling of the Uniqa Tower, Vienna, Austria
Uniqa Tower is an office building with double glass cladding using geothermal energy for energy supply. With a heat output of 880 kW and a cooling capacity of 620 kW it represents an innovative use in the heat pump sector. The large sized heat pump provides about one third of thermal requirements of the building and contributes to an environmentally friendly operation of the building. Due to the integrated planning and close cooperation between the architect, the building services engineers and other key players, the building demonstrates an optimized solution for an energy efficient implementation.

New challenges had to be overcome. The complexity of the heat-pump system which is fully fused by a back-up unit is relatively high and the precise adjustment of measurement and control technique were challenging.

"The indoor climate plays an important role in the work environment. Due to the continuous glazing façade, particular attention has to be put on the indoor comfort of the work stations. This includes temperature, fresh air ventilation and lighting (day light situation)."[7]



Source: http://tower.uniqa.at
Figure 5: UNIQA Tower: First "Reality Check" of KinG

[7] by Mr. Hans Haugeneder, Altherm Engineering GmbH, presentation at Reality Check, 19.10.2005

Source: Article: "UNIQA Tower - Modernste Gebäudetechnik Europas" in HLK, 2005
Figure 6: Uniqa Tower: Skylobby, Reception area, double glass cladding

The system is being monitored since the implementation. The results show that an integrative approach from the very beginning can lead to optimal thermal shifting between internal-, external air and the soil, energy is saved and around 84 tons of yearly CO2-emissions can be avoided.[8]

The results of the monitoring were also presented by the responsible engineer on the Reality Check.

"Reality Check Innovative Building Services Engineering"
With the start of the “Reality Check Innovative Building Services Engineering” series, the Competence Network Innovative Building Services Engineering (KinG) introduced a new approach of site visits focusing on direct knowledge transfer within the building services branch. The site visits to innovative energy efficient buildings are carried out by the responsible building services engineers, who present the system and the comparison of planning data with operating data, in order to exchange their lessons learned and experiences.
Being available for questions while guiding through the building, a deepened and informative knowledge exchange can be provided for the participants. Besides focusing on the application itself, useful information around the shown technology and latest research activities are presented and discussed as well.
The „Reality Check Innovative Building Services Engineering" Uniqa Tower was held on 19th of October 2005 and highlighted the starting of the Competence Network KinG. This "Reality Check" focused on the successful system integration of a large sized heat pump application in a commercial building to minimize energy consumption for sustainable heating and cooling purposes.

About 40 interested participants were facing a comprehensive program of information and presentation. Analyzing as well as discussing the chances and risks of implementations of large heat pump applications, the participants gained specific and innovative benefit.

The frame of the event has been composed by the introduction of general issues regarding the competence network and by a short lecture about the technology. Being in Austria the only research and development centre for heat pump technology, arsenal research presented their range of activities, such as the laboratory with the test bench, development, simulation and monitoring for heat pumps and last but not least training activities.
In the key presentation the responsible building services engineer demonstrated the complex planning process of the project. Furthermore, focusing on the monitoring methods, the comparison of the planned data and with the first results of the operating data showed the functioning of the system and necessary trouble shooting. Finally, the experiences and lessons learned closed the informative presentation.
This presentation and the preceding information set up a discussion basis for the workshop, at which all participants were asked to summarize their ideas to the following questions like:
What has been unclear/open?
Which heat pump projects have been realized successfully?
What would be needed to force more applications of heat pumps?

The outcome and the questions asked during the guide through the building showed clearly the needs of the branch and validated the need of this interactive event.

[8] article from: HLK (Heizung Lüftung Klimatechnik) magazine, 04/2005

8. Conclusion

Lessons Learned from the Reality Check

By exchanging their knowledge and experiences and presenting some more projects within a comprehensive framework of experts, the Reality Check achieved the planned purpose.
The motivation by the presenters to exchange experiences made in through the installation and testing of the system provided an open discussion platform. In the workshop comprehensive results have been elaborated, with deeper discussions on e.g. economical conditions (investment costs, subsidies, motivation), electricity demand and system performances (measurement differences in planning and operating data, automatic control technique), cooling and heating, integrated planning and combination and chances with double glazing.
The outcome demonstrated clearly the advantages but also problematic interfaces of large scale heat pumps. It also proved the concept of the Reality Check of the network.
The next Reality Check will be on 14th of March 2006 presenting a students residential refurbishment in passive house technology with the integration of comfort ventilation technology.

Outcome of the Competence Network Innovative Building Services Engineering

Integrated planning and cooperating interactions between different branches in the building sector isn't a vision any more. Further on, the trend of validation of buildings with the focus on more indoor comfort, energy efficiency and life cycle building quality puts the building services engineering in an essential competition position.
Hence, the competence network KinG, specifically designed of and for the needs of the building services engineering branch, is meeting this increasing demand in future absolutely.

Since the first preparatory activities in spring 2005, the network activities are running with a very positive feedback from the building services branch and their clients. In another workshop in November 2005, the building services engineers and real estate developers were discussing the subject "Contribution of high-tech building services engineering to the market value of commercial buildings and long-term maintenance of value." An expert seminar in January 2006 with the title: “Implementation of the building directive & energy performance certificate” demonstrate the innovative interdisciplinary approach of the network. The “Reality Check” series will have a next event in March 2006. The considerable participation on the events and the very positive feedback from all sides are proving that KinG has been established at the right time with the right ideas.

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UNIQA Tower	http://tower.uniqa.at, download 2005

building
performance
congress

Incorporating energy in facility management; experiences of the Dutch Ministry of Defence

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Abstract
The Ministry of Defence in the Netherlands anticipated on the general objectives on CO_2 reduction set out by the Government through formulating energy targets for their building stock. All buildings over 1.000 m^2 floor area, using fossil fuel should be subject to an energy advice and if appropriate energy measures with a pay-back time of less than eight years should be taken.
This is a major operation, since the defence building stock consists of over 14.000 buildings with a large variety in user types. In order to create a real impact it is of great importance to define the energy issue as an integral part of building management processes instead of a separate issue that is an addition to the process. An important advantage of this integrated approach is that the many non-energy benefits related to energy saving are becoming more explicit. EBM-consult was contracted to set-up an Energy Performance Advice method for Defence buildings and develop the tools (EPA-DEF). The incorporation of the energy aspect into the building management processes was designed in close co-operation with representatives of the organisation. The obligations resulting from the Energy Performance of Buildings Directive (EPBD) can easily be incorporated in this approach.

The EPA-DEF method consists of a manual describing the process with responsibilities, competences and data structures together with tools like calculation software, protocols and checklists. The outcome of the assessment is a technical report together with a management report on the level of the building as well as the level of the compound.
After a pilot phase the method is being used since the beginning of 2005 and the first results are available. The experiences up to now are positive and the method creates a solid basis for the actual implementation of energy saving measures.

Energy policy of the Ministry of Defence in the Netherlands
The Dutch Government set out general objectives on CO_2 reduction and incorporated targets in the environmental regulations for existing non-residential buildings (*Wet Milieubeheer*). The Ministry of Defence in the Netherlands anticipated on these objectives by formulating energy targets for their building stock:

- Gain insight in the energy performance of all buildings using fossil fuel over 1000 m^2 useful floor area by the end of 2006
- 15% improvement of energy efficiency for heating in 2008 compared to 1999
- Energy assessment with recommendations for the cost-effective improvement of the energy performance of the buildings
- Carry out all measures that are technically, functionally and economically feasible. Appropriate measures with a pay-back time of less than eight years should be taken. This is a more strict approach where official regulations are aiming at measures with a pay-back time of 5 years.
- 75% electricity supply from renewable energy sources
- 20 MW wind turbine installed on Ministry of Defence property in 2010

These targets formulated in 2003 are in line with the Energy Performance of Buildings Directive (EPBD) issued by the European Commission in 2002. In order to achieve these targets efficiently the energy saving measures should preferably be combined with maintenance activities, thus reducing the investment. This also implies that the energy performance assessment of the building can be integrated in the common real estate management processes. Energy saving organised in such a way is not an additional activity and requires therefor less effort in the organisation. Including the additional benefits of energy saving (e.g. increased comfort, a better indoor air quality, less moisture problems) makes energy saving even more feasable. In fact this all comes down to a full integration of the energy issue in real estate management processes in order to minimise the burden of this major energy saving effort.

Energy saving and building performance

In general Corporate Real Estate Management (CREM) deals with the performance of buildings related to cost. The performance can be defined for the fields functionality, safety, comfort and appearance of the building. This performance is related to costs subdivided in investments, running costs, rent (in case of renting out a building) and property value. In economic terms an investment is effective if there are sufficient benefits from the reduction of running costs, the increase of rent or property value. This main playing field of CREM is shown in figure 1.

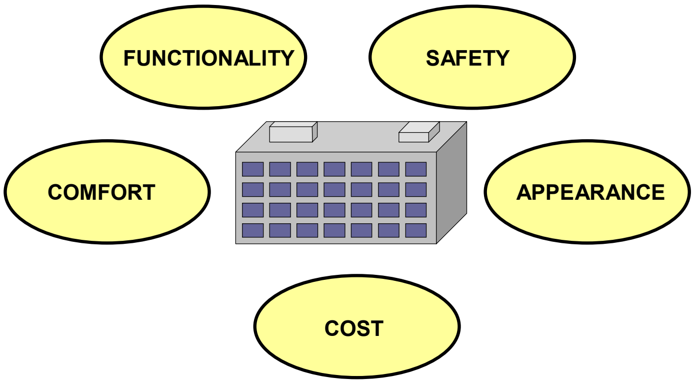


Figure 1: Performance fields of Corporate Real Estate Management

Improving the Energy Performance of a building is mostly defined in terms of investment and reduction of energy costs. Executing energy saving measures is considered to be an additional process that is experienced as a burden. This is a far too limited approach. In many cases energy saving has important non-energy benefits. Taking these into account substantially reduces the pay-back time of the measures.

Some examples from practice:

- The necessity of improving comfort (like draught problems near windows) can often be achieved by applying energy saving measures.
- Improving the functionality by spatially separating back office and front office functions may alow differentiation in the climate control and subsequently reduce the energy consumption.
- Also fire safety can lead to subdivision of the building in zones combined with a more efficient climate control.
- Overheating during summer on a top floor can be caused by solar radiation on a poorly insulated flat roof. Adding sufficient insulation to the roof can solve the problem partly or completely. This approach avoids or reduces the investment in cooling equipment and the resulting extra energy costs, while at the same time energy cost are reduced during the heating season.

In these cases the added investment for energy saving is very limited and taking energy saving measures is easily justified.

Apart from these additional benefits of energy saving it is very profitable to combine energy saving with maintenance and retrofitting activities. In this way energy saving fits in to the ordinary CREM processes and the extra costs for energy saving are reduced. The most convincing example is adding roof insulation when the roof cover has to be renewed.

These positive interactions on an operational level (additional benefits and more efficient execution through combination with maintenance and renovation) show that energy saving should be incorporated more often. This means that there also are opportunities for embeddiment in CREM processes.

Energy saving and real estate management processes

Real estate management processes are taking place on strategic, tactical and operational level.
On **strategic level** policy objectives concerning the building stock are set together with financial boundary conditions and criteria. On this level portfolio analyses are being made and performance goals for the building stock are formulated. The strategic level determines the activities on tactical level. The strategic decisions are based on information of the market/clients and adequate characteristics of the building stock. This implies that high quality data should be generated on tactical and operational level in order to feed the higher management level. It is also crucial for the strategic level to monitor and evaluate the activities initiated. On this level the energy performance can be dealt with by translating it into building performance indicators. Also policy targets concerning energy saving are set on this level.
On **tactical level** driven by the decisions of the strategic level management plans for maintenance, renovation, demolition and new buildings are being developed; globally for a few year period and more in detail for the ongoing year. On this level the execution of the plans will be monitored and quality control on the execution is initiated. Energy can easily be incorporated in these maintenance plans by using the results from energy advices.
Finally, on the **operational level** the plans are being executed and the status is reported to the higher management levels. This is the level where energy saving measures are being taken and EP-certificates are being produced. This is depicted in figure 2.

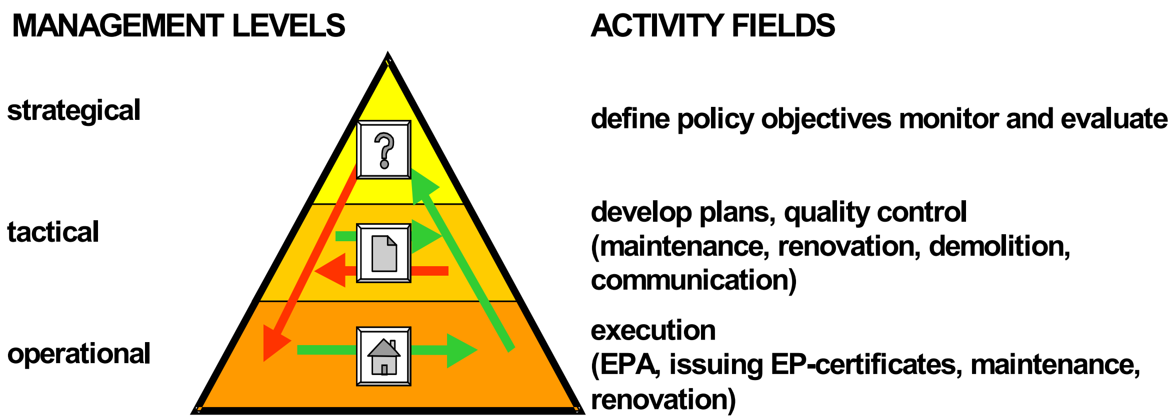


Figure 2: Management organisation pyramid

Energy saving and data management

Important aspects in this pyramid are data flows and communication presented by the arrows (red from top to bottom and green vice versa). For large professional organisations data management is becoming a more and more important issue. It can be beneficial to link the energy performance assessment to data structures already available. First of all building data are needed for energy advice and it is efficient to use the already existing data for instance generated for maintenance planning. At the other hand the data resulting from large-scale energy saving advice can be incorporated in the data structure and may be of use for maintenance and renovation plans. There is a clear synergy concerning data management. A sound data structure provides suitable information for each management level of the pyramid. On strategic level EP-indicators for parts of the building stock can be presented in an aggregated EP-label. These EP-indicators are also a very effective means of benchmarking the building stock and setting targets. On tactical level the energy quality can be expressed for one building or a group of buildings also using the same labelling scheme (figure 3).

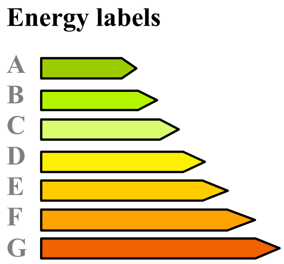


Figure 3: Example of energy labelling

On the operational level it is worthwhile considering an integral building inspection and to harmonise the definitions of the different parameters to inspect (e.g. use the same surface area definitions).

The structure of real estate management at the Ministry of Defence

In case of the Ministry of Defence there is a complex organisation. The forces themselves consist of several divisions (like armed forces, air forces, naval forces and military police). They are the owner and the user of the buildings. Real estate management is taken care of by the organisation MOD/Infra. In fact they are in charge of the performance of the hardware (being the buildings). Both organisations within the Ministry of Defence are structured more or less similar in three main management layers. On top the staff on national level including subdivision in the separate forces dealing with strategic issues. The second management layer is subdivided in regions and acting on a tactical level. The operational level is situated in military compounds throughout the country. Both organisations (the forces and MOD/infra) work together horizontally on each level. The Ministry formulated the overall objective on the energy saving target and MOD/Infra is the organisation to execute this policy in co-operation with the forces. Their aim was to relate these activities to CREM and the building data structure. MOD/Infra translated the energy saving targets into a plan for execution. Part of this plan was the development of a method for determining an energy saving advice on the level of the building and on the aggregated level of a compound. This method has been developed by EBM-consult in co-makership with MOD/Infra. The aim was to use the available building data effectively and to incorporate the energy data gained from the advice into the data structure of the buildings. The execution should be possible by personnel from MOD/Infra after they received a training and in addition external consultants could be contracted to take a share in the activities.

The EPA-DEF method and its tools

The EPA-DEF method had to be effective and efficient for the specific task.

Effective is defined primarily as:
- sufficiently accurate to be the basis for the investment decision on energy saving measures
- giving insight in the energy performance of the building stock and providing a benchmark
- embed the energy performance information into the CREM organisation
- provide consistently high quality results by using a standard method and assessment process.

Given the large volume of the building stock efficiency is of great importance; this is reflected in:
- minimising the effort of data-acquisition by using already available knowledge of the buildings
- making data-acquisition and building inspection an efficient process separated from energy calculation and analyses. In this way the skills of the building inspector and the consultant are efficiently directed
- providing task directed training of personnel accompanied by support from EBM-consult
- embedding energy data into the building data structure enables an easy update function when energy saving measures are executed
- building inspection activities for energy, maintenance or safety checks can be combined.

Taking this into account the following implementation process was defined (see figure 4). First of all the required results were defined. The next step was a preliminary study of the characteristics of the building stock in order to efficiently design the assessment method with a special focus on data-acquisition. Parallel quality control was addressed. The next stage was testing the prototype approach in pilot studies. After evaluation the EPA-DEF method was finalised, personnel was trained and large-scale execution started and results were incorporated in the CREM process.

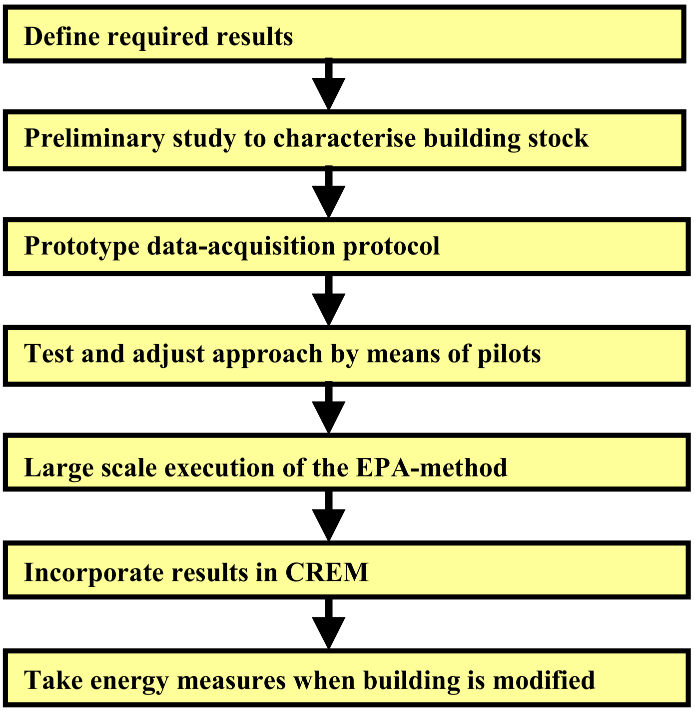


Figure 4: The implementation process

Attuned to the CREM process the EPA-DEF method and the tools are developed. They are presented in figure 5. The heart is of course the EPA-DEF software and the data base. The energy calculation is a multi-zone stationary model based on monthly mean values. The thermal dynamics is taken into account by means of correlation coefficients. The software is positively validated against a formal Dutch test set for energy simulation software. A handbook on the method and a data-acquisition protocol are the basis for executing the work. In order to achieve high quality results a training course was set up together with support for the personnel in the field. Quality control has to assure adequate and consistent results.

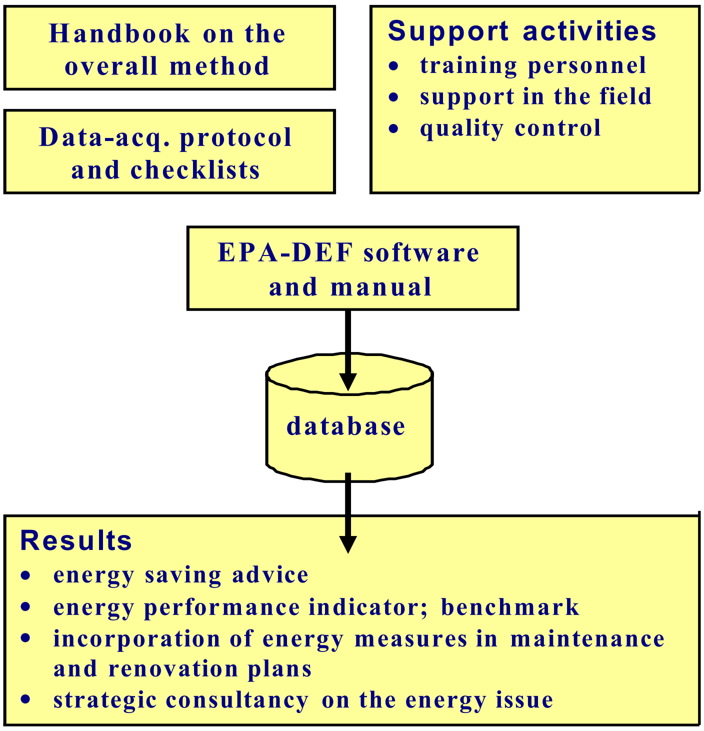


Figure 5: The EPA-DEF tools

Implementation in practice

After developing the method and the tools as a prototype they were tested in three military compounds. The size of the three pilots is listed in the table.

Compound	**A**	**B**	**C**	**Total**
Division	Armed force	Air force	Armed force	
Buildings addressed	15	26	16	57
Total floor area	16.000 m^2	43.000 m^2	25.000 m^2	84.000 m^2

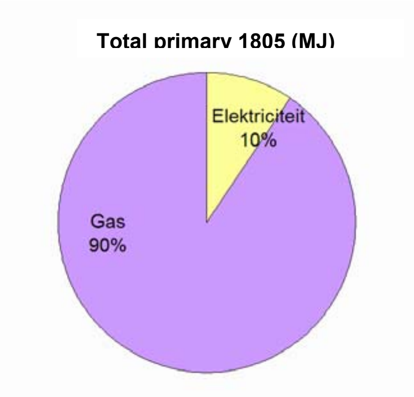
The evaluation results were positive. Data-acquisition was experienced as easy to perform. Buildings with a more complex geometry were more difficult to assess. The total time consumption for applying the method was registered. For data-acquisition this was on average 7 to 9 hours per 1000 m^2 floor area. Using the software and creating the report took 4 to 8 hours per 1000 m^2 floor area. The total effort was 11 to 17 hours per 1000 m^2 floor area. The people involved in the pilots estimated that the time consumption in the future would be 9 to 15 hours per 1000 m^2 floor area. The building data already available in the existing data structure could be applied in two of the pilot projects. In the third one they were partially useful. Building data needed for planning maintenance are not satisfactory compatible with the data needed for energy analyses. Further tuning is needed on this aspect. Inconveniences in the software concerning generating an advice were reported to be irritating.

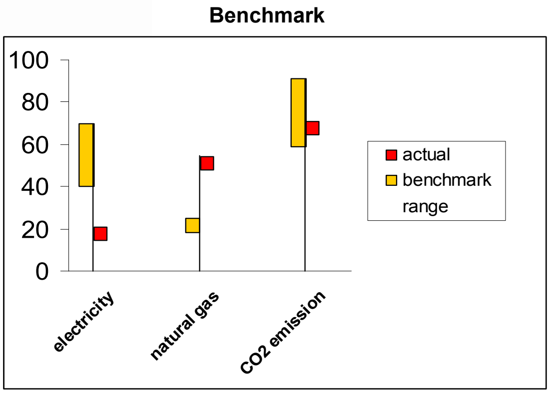
The pilot studies were considered a success and after improvement of the tools the EPA-DEF method was put into practice. EPA-DEF is the official method used by the experts of MOD/Infra and contracted external consultants. An example of a project is shown in the frame.

Some typical EPA-DEF results:
barrack building; 4300 m^2 floor area built in 1952

Energy use present situation

Energy use/CO_2 emission	Actual use/emission	Use/emission per m^2	Standard use/emission (benchmark per m^2)
Electricity (kWh)	80.294	19	40 - 70
Natural gas under standard climate conditions (m^3 gas)	199.106	46	18 - 25
Primary energy consumption (MJ)	7.743.744	1.805	1.001 - 1.523
CO_2 emission (kg)	287.956	67	59 - 91





From the figures it is clear that the electricity use is relatively low. This is caused by the limited number of appliances in the building. The gas consumption at the other hand is very high due to the poor insulation of this old building. The building is connected to the central heating system of the compound.

Energy saving measures with a pay-back time of less than eight years

Measure	Savings electricity (kWh/year)	Savings gas (m^3/year)	Savings cost (€/year)	Additional investment (€)	Pay-back time (years)
Insulation wall	0	4.020	1326	7.160	5
Insulation roof	0	57.081	18.837	82.883	4
Super glazing	0	25.754	8.499	42.039*	5
Efficient lights	16.157	0	1241	7.437*	6
Total	**16.157**	**86.855**	**29.903**	**84.966***	**3**

* These investments are partly covered by regular maintenance budgets

Advice

Execute the listed measures. Combine the measures roof insulation and super glazing with maintenance activities; wall insulation and installing efficient lights can be executed separately.

Status of the implementation of the policy targets

The EPA-DEF method is considered to be a valuable approach enabling an effective and efficient assessment of the energy performance of the building stock of the Ministry of Defence. So far the focus was more on performing energy saving advices and therefore the use of the results on tactical and strategic management levels is not yet fully explored. This is due to the fact that there is a great time pressure on producing the advice for all the buildings by the end of 2007. Further use of the data is foreseen in the near future.

Referring to the policy targets formulated in the second paragraph the conclusions are:

- The objective of expressing the energy performance of all buildings using fossil fuel over 1000 m^2 useful floor area by the end of 2007 is expected to be realised within time. This really is a major achievement.
- Recommendations for the cost-effective improvement of the energy performance of the buildings are produced in parallel and will also be available by the end of 2007
- Carrying out all measures that are technically, functionally and economically feasible. Appropriate measures with a pay-back time of less than eight years should be taken as a future step. Based on the EPA-DEF results incorporation of energy saving measures in maintenance and renovation plans is already in progress.
- This approach will lead to a 15% improvement of energy efficiency for heating in 2008 compared to 1999.
- 75% electricity supply from renewable energy sources is not directly related to the EPA-DEF method. Nevertheless almost 55% of the electricity supply is derived from renewable energy sources.
- 20 MW wind turbine installed on Ministry of Defence property in 2010 is not yet realised, a 15 MW turbine will be contracted in the fall of 2006.

Overall conclusion:

The Ministry of Defence and especially MOD/Infra is on track implementing the energy targets in the organisation and the EPA-DEF has proven to be an effective an efficient approach to perform large scale energy performance assessments.

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How to raise the efficiency of commercial buildings in Upper Austria

Christiane Egger, Christine Öhlinger

O.Ö. Energiesparverband

Abstract

Based on the Upper Austrian energy strategy and implemented by O.Ö. Energiesparverband, the regional energy agency, a commercial buildings programme is implemented in Upper Austria. Based on the successful existing building programmes (30 % energy reduction in 95 % of all new one-family houses since 1993), the new programme features especially innovative commercial buildings and includes a number of support activities ranging from energy and auditing services, information and awareness raising activities and a regional third party financing programme to special supports for industry & companies and a regional R&D programme.

Introduction

Basis of all activities is the Upper Austrian energy strategy & action plan. It started in 1994, when the first Energy Plan was passed which defined concrete goals to reduce fossil fuel consumption by increasing both energy efficiency (EE) and the use of renewable energy sources (RES) by the year 2000. A comprehensive energy action plan was developed and implemented, which led to the significant market development of RES:

- increase of RES from 25% in 1993 to more than 30% in the year 2004
- reduction of energy consumption in new single-family buildings by more than 30% since 1993
- in total, renewable energy sources provide or secure employment for 15,000 people.

In the year 2000, the Upper Austrian Government passed the "Energy 21" strategy, continuing the strategy of the successful first energy plan (1994-2000) into the 21st century. Concrete goals were defined to be reached by 2010, including for example:

- doubling biomass and solar thermal installations
- increasing energy efficiency by 1 % annually

Upper Austria is also among the first European regions to implement the "European Energy Services Directive" with its "Energy Efficiency Programme". It is aimed to increase energy efficiency by 1% annually, 1.5% for the public sector respectively.

Based on this strong political commitment to sustainable energy production and use, a comprehensive action plan was developed and is now being implemented which includes a mix of measures in the legal, financial, institutional field as well as with a strong focus on information and communication. O.Ö. Energiesparverband is responsible for the implementation of most of the activities laid down in the action plan. One central activity within the energy strategy and action plan is the new commercial buildings programme.

Upper Austria's Commercial Buildings Programme

The Upper Austrian commercial buildings programme includes the following support activities:

Energy and auditing service

Energy advice given at the moment when investment decisions are made is an important tool for the promotion of energy efficiency and renewable energy sources. O.Ö. Energiesparverband offers therefore a broad energy advice service programme offering energy advice for households,

companies & public bodies. For companies, the service has was recently extended, offering 2 days energy advice for businesses, 75% of the costs are covered by the regional government. So far about for 900 companies (300 of them only in 2005) of different sectors and size have received such an energy advice. In order to improve this service, a continuous evaluation is done.
In order to promote RES applications in companies, together with energy experts, energy strategies for four sectors (metal, wood, hotels, real estate) were developed. Based on these guidelines, individual energy advice sessions for the companies were held, leading to concrete RES installations.

Information & awareness raising activities
A number of information and awareness raising activities are carried out including publications and events. Presently for example a series of events targeting at companies is being carried out, where businesses are informed about "energy efficient company buildings". So far 8 events in different Upper Austrian district have been held.
One main part of the information activities is the promotion of large scale solar thermal installations. In order to overcome the barrier of lack of know-how, a planning manual ("solar guide") was developed and training courses for the planning and installation of large solar thermal systems were organised.
In order to trigger solar thermal installations, a solar campaign was carried out in summer 2005. More than 100 installers were partners of the campaign and a solar-hotline was operated by O.Ö. Energiesparverband which was frequently used.
Additionally an information campaign targeting at companies in "objective 2 areas" is carried out, where these companies are especially informed on the implementation of innovative energy projects and third party financing.

Training & education
For all these activities, a lot of skilled personnel are needed, that is why a number of training programmes for energy advisers are carried out.
The "general energy advisers" training course comprises a basic (50 lectures) and a advanced training course (120 lectures). So far more, 800 advisers passed these courses.
In order to train energy experts for the energy advice service targeting at companies, a new training course was developed and implemented for the first time in autumn 2005. The training course (7 days plus field trip) covers mainly training on energy technologies and building construction for non-residential buildings. An important aspect of the training is also the energy certification of non-residential buildings. So far, more than 25 participants have successfully completed the training.
As energy efficient cooling is of major importance, a new training course for "Cooling advisers" was started. 50 experts in field of building technologies, planers and people responsible for energy matters in companies and institutions attended the training.

Additionally 2 new educational programmes for more jobs in the field of energy efficiency and renewable energy sources were started:
- a new university course at the Fachhochschule Wels from which "Sustainable Energy Engineers" graduate" and
- a vocational training, called "Ökoenergie-Installateure", training installers especially in solar and biomass.

Supporting industry & companies:
Another main part of the commercial buildings programme is the support for industry and companies. In order to support business development, the "Ökoenergie-Cluster" (OEC), a network of green energy businesses was established. Presently 140 companies are partner of the network, employing more than 2,700 people and achieving a turn-over of around 393 M€. The network is managed by O.Ö. Energiesparverband.
The aim of the Ökoenergie-Cluster network is to foster co-operation between the partners by common training & information, research and export activities. Among the very successful activities within the network were a co-operation project to improve the quality of user manuals of biomass heating systems for domestic customers, the development of energy concepts for different sectors of commerce and industry, a promotion programme for triggering large scale solar thermal installations and an information folder on the technical requirements for pellets heating installations.

Research & Development
The regional programme "ETP" (energy technology programme) supports R&D projects in the fields of energy efficiency and RES in Upper Austria. So far 103 R&D projects have been supported, including several of the developing, testing & demonstration innovations in commercial buildings (especially regarding to "passive house buildings"). The programme is highly efficient in terms of triggering local investment: with 6.5 mio € support, 41.6 mio € investment were triggered.

Additionally an R&D centre (ASiC - Austrian Solar Innovation Centre) has been established to support the local solar companies in their research activities and a solar R&D laboratory was recently opened.

Innovative Financing Mechanisms
In order to support innovative financing mechanisms, such as third party financing (TPF), a regional TPF programme is managed by O.Ö. Energiesparverband. The successful programme has so far supported 55 energy performance contracting projects. Throughout the whole process, the programme provides detailed information, advice and guidance to local authorities and companies interested in TPF. It supports the innovative financing scheme and can be used to finance the retrofitting of buildings, street lighting etc. within the municipalities.
The programme covers both municipalities and companies, as well as investments in energy efficiency and in the construction or retrofitting of installations. Under the current energy price situation, it is expected that the programme will give a strong boost to retrofitting large buildings and installations, and that it will trigger new (larger) RES installations.

In order to trigger the implementation of TPF projects in companies, an information campaign was started in 2005. Companies were informed by mailings and a free advice session on the issues was offered to them. A focus of the campaign was put on institutions, which were additionally informed in a special event.
Especially attractive is also the financial support for renewable energy installations in companies, which amounts up to 44 % support for solar thermal installations in companies for an example.

Examples of Innovative Commercial Buildings

- "Christophorus Building":
  Innovative 3 floor passive house office building in timber construction using only environmentally friendly building materials and including a 10 kWp PV plant.

- "Supermarkt Pfeiffer":
  First passive house supermarket with a 7 kWp facade integrated and a 20 kWp roof mounted PV system. The energy efficient cooling appliances consume 30 % less energy.

- "Biohof Achleitner":
  The "biohof" is an innovative farmer's building including an organic restaurant and a supermarket in passive house standard. The construction materials are among others wood, clay and straw. An innovative cooling system using plants was developed and plant oil is used for transport.

- "Office & residential building Schlager":
  The office building of Mr. Schlager, which serves also as residential building meets passive house standard. The innovative building concept uses phase change materials to increase the heat storage ability of construction parts. The results are monitored and compared with other buildings.

Barriers & success factors

The commercial buildings sector was for a long time a neglected one and the main focus in recent years was put on the residential sector. After having achieved about 30% energy reduction for heating in private new homes, it was decided to extend this successful development also to the commercial buildings sector. However, in the commercial sector the focus so far was only put on energy efficient production neglecting the efficiency of company buildings.

When carrying out the commercial buildings programme, the following problems were encountered and could be overcome by the following measures:

Problems encountered	Measures implemented to overcome barriers
-> company owners are only interested in production issues and neglect building issues	-> promotion of best practice examples to create a positive image of leading company buildings
-> lack of know-how in companies	-> energy advice service for companies -> publications, e.g. sector concepts
-> lack of awareness	-> events: series of events in all Upper Austrian districts targeting at companies and informing them about innovative building issues -> campaigns to draw a focus on building issues: e.g. for efficient and solar cooling, for "objective 2 areas"
-> lack of investment (money is mainly used for production, R&D, etc. and not for building investment)	-> information campaign on the Upper Austrian third party financing programme to inform about TPF and the available financial support
-> only few consultants available and/or not known by companies	-> training programmes for energy advisers carried out, new training course started to train advisers for companies and "cooling advisers", new professions
-> lack of supplying companies	-> supporting green energy company development with different measures, e.g. OEC – network of green energy businesses, regional R&D programme

O.Ö. Energiesparverband

The commercial buildings programme is carried out by O.Ö. Energiesparverband. O.Ö. Energiesparverband is the regional energy agency of Upper Austria and was established in 1991 by the regional government. Aim of the agency is the promotion of energy efficiency, RES and innovative energy technologies. O.Ö. Energiesparverband is a central institution for energy information and one of Europe's largest energy advice and information providers. Services to different target groups, from private households to SME's and public bodies are offered.

The main services of O.Ö. Energiesparverband include:

- energy information and awareness raising activities
- energy advice for private households and industry: 15,000 energy advice sessions annually
- international co-operation & European projects: vice-presidency of FEDARENE, member of EUFORES, co-ordinator of the European RES-e network
- management of a sustainable buildings programme which includes energy certification for buildings and the calculation of an energy index for every new single family house (> 50,000 calculations carried out)
- a great number of different training activities (for energy advisors, for installers etc.)
- organisation of conferences, workshops, seminars, competitions
- management of the OEC, the network of green energy businesses.

Conclusions

The example of O.Ö. Energiesparverband and Upper Austria clearly demonstrates that a lot can be done at a regional level, provided the necessary political backing is given and a comprehensive action plan including information and promotion programmes is carried out.

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Will the Energy Performance of Buildings Directive make any difference to commercial sector emissions?

Jacky Pett

Association for the Conservation of Energy

Abstract

As the plans for implementation of the Energy Performance of Buildings Directive (EPBD) take shape, we ask whether certification will have the effect on the commercial sector that has been proposed. Business is still resistant to all but minimum compliance, yet research has shown that there are benefits to investors as well as owner-occupiers to have more energy efficient buildings.

The two topics causing most discussion in the dialogue on the implementation of the EPBD are the need for energy certificates and for raised and regularly reviewed minimum standards for buildings. The UK proposals for "buildings that are not dwellings" are expected to produce a 5% improvement in energy performance of the building. New buildings and refurbishments will be required to achieve at least the new minimum standard of energy performance. However, the consultation on the new standards suggests that only major refurbishments would require improved energy performance and these are carried out only every 20-25 years.

This paper examines a model developed to identify how quickly the certificates will infiltrate the marketplace provided that their introduction goes smoothly. As part of an independent project addressing the motivation of investors to adopt low energy buildings as part of their investment strategy, the market diffusion curve for energy performance certificates for the UK commercial office sector has been addressed. This model assumes that certificates are produced at the first change of lease, and at the refurbishment of owner-occupied buildings on the basis of a seven-year refurbishment cycle.

The paper then explores the results of the introduction of certificates and the potential impact on carbon dioxide emissions from the sector under different conditions and levels of action adopted by investors. It shows the effect of minimum compliance and compares it with the achievement possible with quite modest acceptance of the arguments in favour of investment in low energy property. Those who wish to minimise their investment portfolio risk exposure and who prefer to take a responsible approach to their property portfolio need to be encouraged to take the necessary steps to achieve the substantial difference in carbon savings.

Introduction

The Energy Performance of Buildings Directive (EPBD) entered into force in January 2003 and Member States were due to implement it from January 2006. In all states, plans for implementation have taken firmer shape, but although setting minimum and regularly reviewed building standards, and inspection of boilers has been relatively easy for most, the question of how to implement energy performance certification has been largely unanswered. Although governments have made much progress in assessment of domestic property, commercial methodologies for energy performance analysis have proved more difficult, with solutions proposed varying from extremely simple, leading to criticism that it is too simplistic to be worthwhile, to highly complex, resulting in criticism of expected cost of the assessment and value of the resultant information. Governments are addressed from all sides by conflicting messages from those who see energy performance as an opportunity and those businesses that seem to see it as a threat to their profitability. In this paper we concentrate on the commercial sector and ask whether certification will have the effect on energy use or carbon emissions that has been proposed. In the UK, influential organisations such as the Confederation of British Industry, the CBI, has encouraged its members to resist all but minimum compliance. This is despite the proven benefits of good energy performance. Why, when more efficient working practices, products and services are the goals of so many businesses, does opposition to energy efficient workspace persist? It appears to be a burden, not a benefit.

In this paper the situation in the UK is reviewed, outlining the proposals for implementing the Directive as it applies in the commercial (office) sector, and investigating the possible impact on that sector. Research carried out to determine whether there was a business benefit to investors in commercial property (Pett et al 2004a) identified the significance of recognised energy performance measurement to the demand from tenants and purchasers of commercial office space. As a result, attention was turned to the effects of the EPBD. This in turn led to the development of a model to identify how quickly energy performance certification might penetrate a market where uncertainties exist as to precise numbers of key factors such as the percentage of owner-occupiers (who have a different incentive for energy efficiency of their buildings) versus tenants. As a result, it was realised that by testing different levels of the impact of increased standards and the demand for better energy performance from tenants, the amount of carbon savings delivered by the Directive might be varied. The results of this work are presented here, and lead to some questions that need to be raised as to the type of promotion programmes that might be worthwhile if carbon saving from the commercial sector is to be optimised.

Summary of the EPBD for the commercial sector

The requirements of the Directive can be summarised as:

- measurement and production of a certificate of the energy performance of buildings
- regular inspection of boilers above 20 kW
- regular inspection of air conditioning systems above 12 kW
- raised and regularly reviewed minimum standards for new buildings and refurbishments

Proper servicing of a company car fleet, servicing of manufacturing equipment and similar measures are appropriate to maintain equipment in cost-effective and safe working order. Therefore this paper does not address the issues of inspection of boilers and air conditioning systems as the same concern for maintenance is assumed to exist, and therefore the performance expected from efficient plant is assumed to be delivered..

In the UK, the Building Regulations are well established, although standards for existing buildings are relatively new. The Regulations were already reviewed regularly and consultation on the proposed changes to bring certain elements in line with the EPBD have been carried out, and continue to be carried out on some more controversial elements. The original proposals for “buildings that are not dwellings” were expected to produce a 5% improvement in energy performance of the building (ODPM 2004). However, this consultation on the new standards suggested that major refurbishments that would require improved energy performance are only carried out every 20-25 years. New buildings would be required to achieve at least the new minimum standard of energy performance but standards for refurbishments are subject to further consultation in 2005.

The more controversial issue is the implementation of energy performance certification, where every building will have to be inspected and a certificate issued, initially when it is built, sold or on the first change of lease (whichever occurs first), and then at least every ten years. There is no requirement for these certificates to reach any particular standard, although the design of the certificates, methods of rating, and how energy performance can be calculated are the subject of much research and discussion.

Modelling the impact of energy performance certificates

As part of an independent project addressing the motivation of investors to adopt low energy buildings as part of their investment strategy (Pett et al, op cit), the market diffusion curve for energy certificates has been addressed for the commercial office sector. This model starts by identifying the numbers of offices in the UK, groups them by lease length bands (5, 10, 15 & 25 years being the most common) assumes that certificates are produced at the first change of lease, and at the refurbishment of owner-occupied buildings on the basis of a seven-year refurbishment cycle. As data on the number of owner-occupied offices and on distribution of lease lengths are the subject of considerable disagreement between actors in this area, the model allows for assumptions to be made about the proportion of offices under different lease lengths and the numbers switching to shorter lengths at the time of lease renewals, to demonstrate certificate diffusion into the market under different conditions. It is also possible to vary new build and demolition rates (demolition is assumed to be at the same level across all lease types including owner-occupied). The model took 2006 as the starting point for certification, which is now known not to be the case, so all timescales in this papers should be considered to be delayed by the time of certification commencement after 2006.

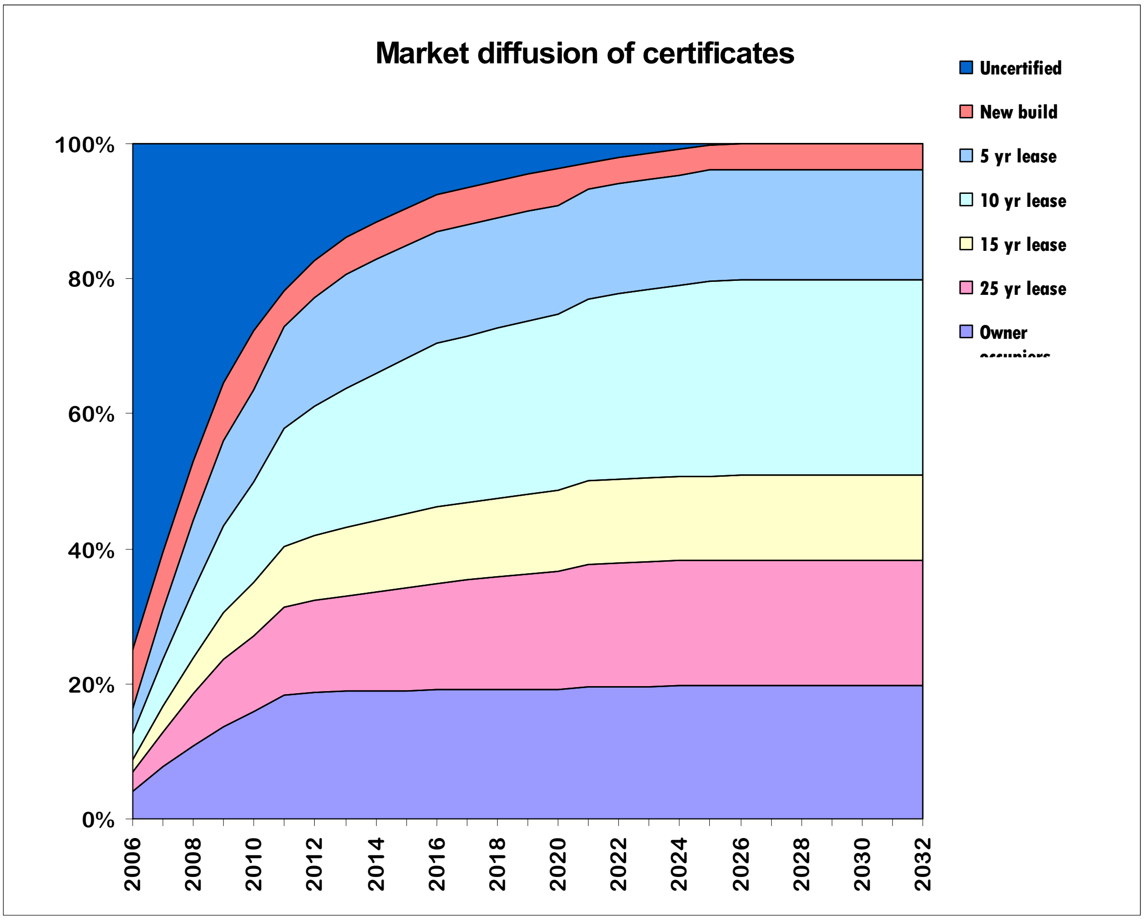

Figure 1: Market diffusion curve for given scenario (see text)

The results of this model show that for the most realistic options tested, 80% of offices will have certificates by 2010 to 2015. The key issues affecting this rate are the number of short leases and the rate of demolition or replacement, i.e. the current net growth of 6% achieved with all new build and no demolition means that market diffusion is much slower than that achieved with 16% new build and 10% demolition. Figure 1 shows the market diffusion curve for a market with 20% owner-occupied, 30% with 25 year lease lengths and the rest shorter, with 10% new build until 2010 (reducing to 6 and then 4% at 5 year intervals) and 4% demolition rate. In this scenario, 80% market diffusion is achieved in 2011, with full certification in 2025.

Combining the effects of Building Regulations and certification

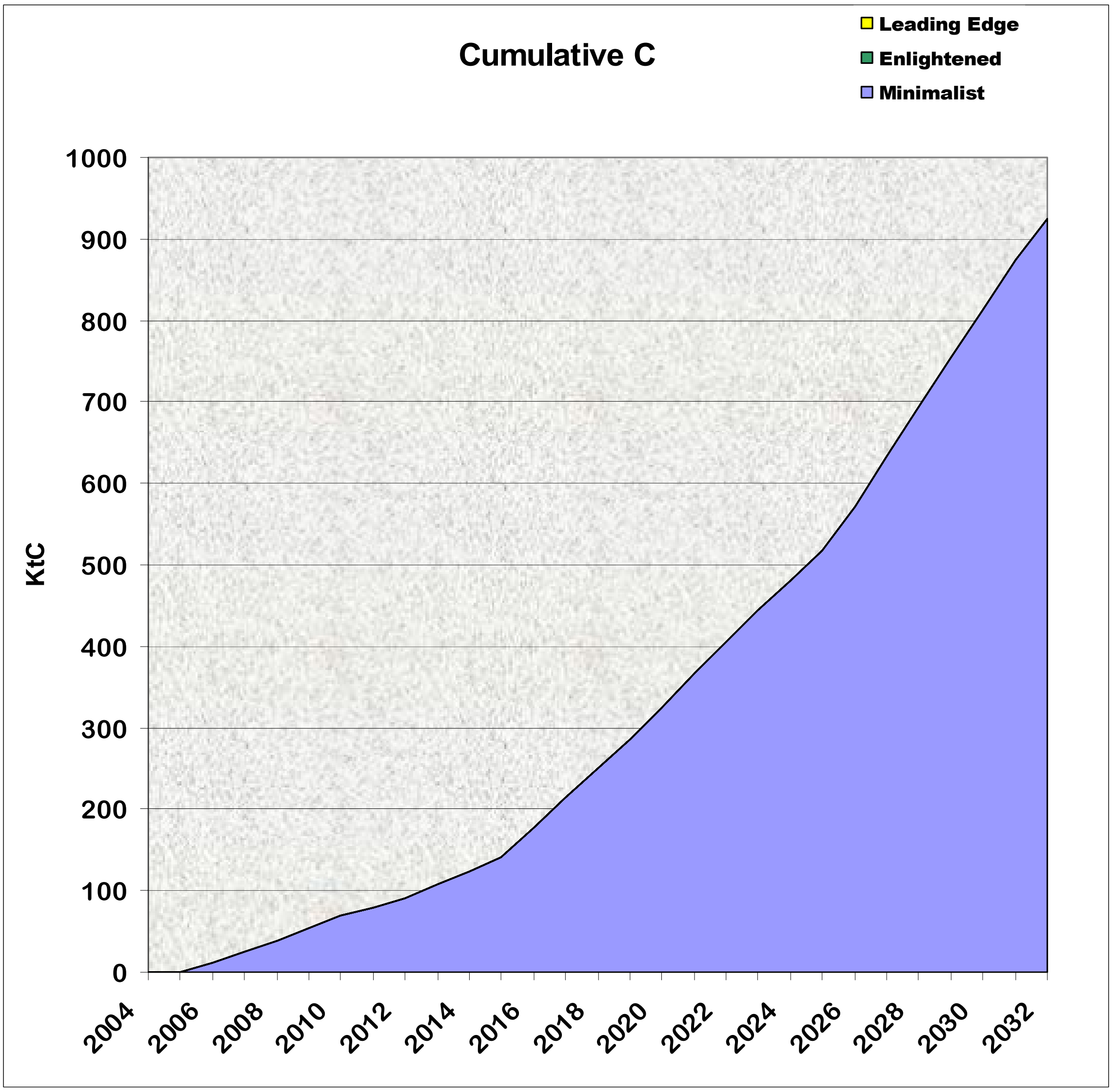

Figure 2: Cumulative carbon saving from commercial offices

There is no requirement for any improvement in energy efficiency as a result of a low energy performance rating, but assuming that when a building is refurbished it is brought up to the minimum standards of efficiency in the 'regularly reviewed' building standards required under the Directive, an estimate of carbon saving can be modelled. In Figure 2 the saving that accrues to the certificate diffusion scenario used earlier, with new build and refurbishment gaining energy efficiency improvements of 4% at every review of the regulations, is shown in graphical form. Carbon saving is cumulative as savings made this year are made again next, along with the new savings from new buildings. This scenario shows that by 2020, the total carbon saved in the year from the commercial offices sector, provided there is no increase in use inside the buildings themselves, is 320 ktC or 12% of the total commercial office carbon emissions in 2000 (Pout in Wade et al, 2002a). The figure on this graph for 2010 is slightly higher than the ODPM's own estimate of carbon savings in 2010 from the proposed Building Regulation changes (ODPM op. cit), but the assumptions on refurbishment are more optimistic in the model that those used by ODPM. Estimating the value of this carbon saving under conditions such as emissions trading is fraught with danger, as estimates range from 10 to 50 euros/tCO_2. At the lower end the carbon saving would be worth just under 12 million euros.

A number of scenarios can be tested with the model, and a few combinations are shown in Table 1. These show the assumptions made for market composition, indicators for certificate diffusion at 80% and total certification, and the total carbon saved from 2006 to key years with refurbishment to Building Regulations standards (assuming a 4% improvement with each review).

Table 1: Reference scenarios, certificate diffusion and carbon saving

Ref	Lease length/type					Lease switch		New build rate (year from 2006)			Demolition rate		Certificates		MtC saved from 2006 to		
	25	15	10	5	owned	10	5	'10-	'11-'20	'21+	'15-	'16+	80%	100%	'10	'20	'30
A	30	20	20	10	20	80	80	10	6	4	4	4	2010	2025	.20	2.00	7.67
B	20	20	20	20	20	100	100	10	8	6	8	8	2011	2020	.17	1.74	6.22
C	0	0	0	0	100	0	0	10	8	6	8	8	2010	2012	.17	2.18	8.04
D	20	20	20	10	30	10	10	8	8	4	6	6	2012	2022	.09	1.27	4.90
E	30	20	20	10	20	100	100	12	4	0	8	5	2011	2016	.22	1.77	5.57

The range of scenarios reflects both uncertainty and extremes; no-one suggests that owner-occupancy is 100% but scenario C does provide for rapid diffusion of certificates (based on a seven year refurbishment cycle) and robust carbon savings if refurbishment conforms to the new Building Regulations requirements each time. Options A, B and E offer a rapid transition to short leases, which might represent the current trend for short leases, although neither the percentage of switching nor the likely duration of the trend are known. The main difference in the carbon saving is achieved from the differences in the replacement rates assumed; option A provides an example with quite low demolition rates and option E expects a static or declining market. Indeed in A the number of commercial offices stabilises at around double the current number in the mid 2010s, and in E the number reaches current plus 50% then declines; both situations in tune with other work on scenarios carried out as part of this project (Pett et al 2004b).

The questions remain as to how much effort is likely to be put into improvements at refurbishment, and whether anyone is likely to exceed the minimum requirements.

The value of good energy performance

Our research has focused on the argument for investors that good energy performance provides a lower risk to return on investment (ROI) than equivalent property with poor energy performance. The reasons for this are twofold:

1. when energy certificates are available, then poor energy performance provides an opportunity for prospective tenants to negotiate reduced rental terms
2. in future market scenarios, poor energy performance is likely to be at high risk of obsolescence, as a result of both legislative and social factors

For the risk-averse investor, this identifiable risk needs to be compared with the more intangible global risks for long-term investment including terrorism, political upheaval and equity price collapses. For the speculative investor, there arises an opportunity to identify those properties that positively embrace a low energy future. An example might be through energy independence using building integrated renewables or fuel cell technologies in a low energy use building.

For the 'energy intelligent' investor, therefore, the opportunity arises to seek property with good energy performance and to drive forward refurbishment to improve initial energy certificates at the next refurbishment opportunity.

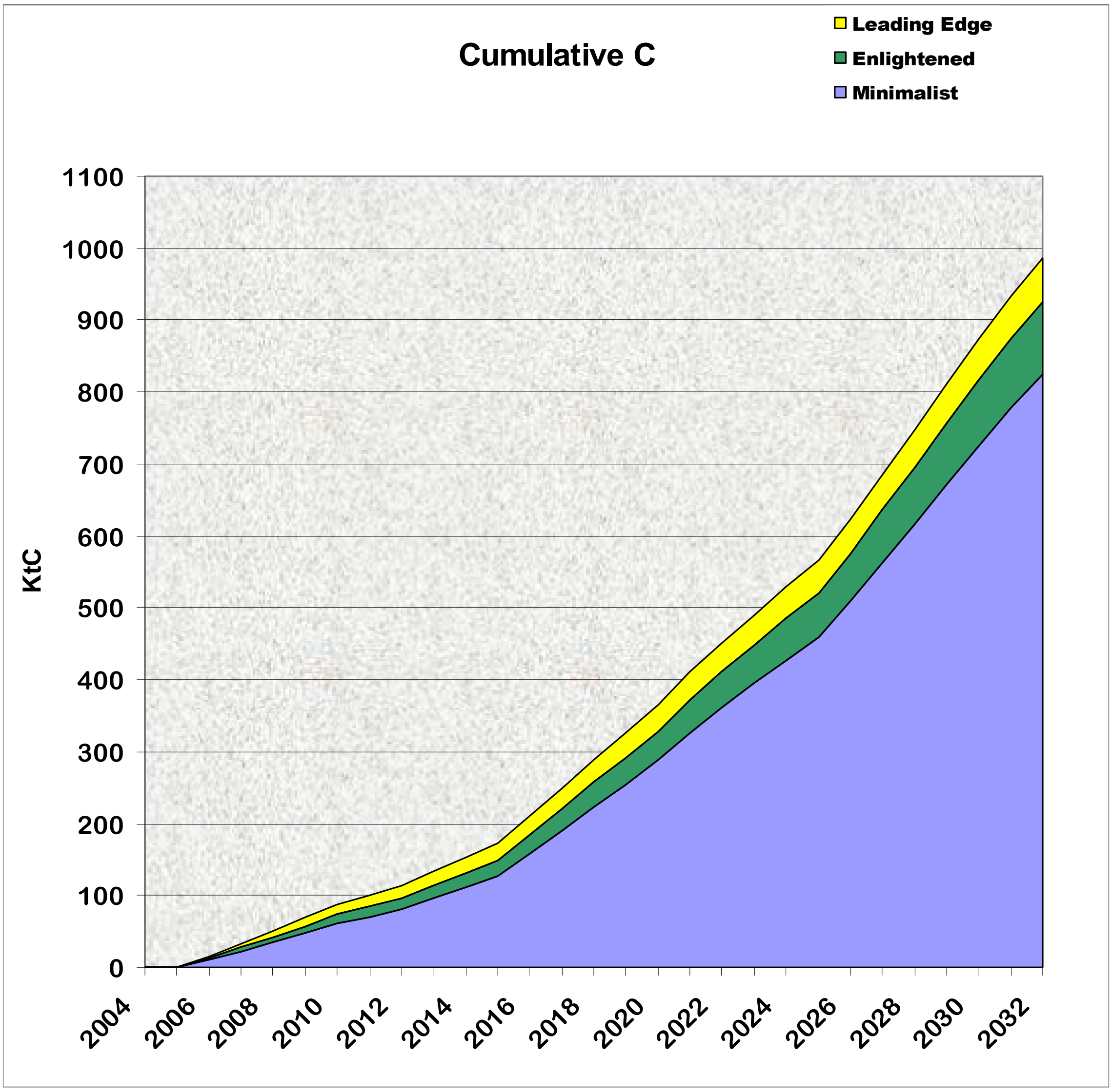

Figure 3: Carbon savings for investor driven property improvements

Figure 3 carbon savings are shown for 10% of 'enlightened' property investors that carry out improvements to the level of all cost-effective improvements at the stage of renewing the energy certificates, plus 1% of 'leading edge' investors where refurbishment or improvement is carried out at best practice and demonstration of technologies level. Cost-effective improvements are those that have been demonstrated by substantial research and implementation projects and can be identified through public programmes. Best practice and demonstration technologies may be cost effective under certain conditions, including whole life costing approaches, or may require the user to justify additional expenditure based on their own approach to calculation of worth, or for reputation reasons.

Under these conditions (using scenario A), the carbon saved in the year 2020 is 365 ktC, 14% more than the minimum approach shown in Figure 2, and worth an additional 2 million euros.

Are the benefits to be gained from properties with good energy performance likely to lead to wider take up of greater improvements? A wide range of possibilities can be tested using these models (which are available at www.ukace.org/research/commercial).

The five scenarios shown in Table 1 are addressed again in Table 2, this time with different levels of take up for 'enlightened' (En) and 'leading edge' (LE) adopters of energy improvements.

Table 2: Scenarios with different levels of take up for energy improvements

Ref	Lease length/type					Lease switch		New build rate (year from 2006)			Demolition rate		Energy Intelligent %		MtC saved from 2006 to		
	25	15	10	5	owned	10	5	'10-	'11-'20	'21+	'15-	'16+	En	LE	'10	'20	'30
A1	30	20	20	10	20	20	10	10	8	4	8	6	0	0	.20	2.00	7.67
A2	30	20	20	10	20	20	10	10	8	4	8	6	10	1	.26	2.37	8.56
A3	30	20	20	10	20	20	10	10	8	4	8	6	20	10	.64	5.01	15.03
B1	20	20	20	20	20	100	100	10	8	6	8	8	0	0	.17	1.74	6.22
B2	20	20	20	20	20	100	100	10	8	6	8	8	10	1	.22	2.07	6.96
B3	20	20	20	20	20	100	100	10	8	6	8	8	20	10	.57	4.35	12.51
C1	0	0	0	0	100	0	0	10	8	6	8	8	0	0	.17	2.18	8.04
C2	0	0	0	0	100	0	0	10	8	6	8	8	10	1	.23	2.57	8.95
C3	0	0	0	0	100	0	0	10	8	6	8	8	20	10	.63	5.37	15.86
D1	20	20	20	10	30	10	10	8	8	4	6	6	0	0	.09	1.27	4.90
D2	20	20	20	10	30	10	10	8	8	4	6	6	10	1	.14	1.55	5.55
D3	20	20	20	10	30	10	10	8	8	4	6	6	20	10	.39	3.42	10.17
E1	30	20	20	10	20	100	100	12	4	0	10	15	0	0	.22	1.77	5.57
E2	30	20	20	10	20	100	100	12	4	0	10	15	10	1	.28	2.10	6.29
E3	30	20	20	10	20	100	100	12	4	0	10	15	20	10	.66	4.42	11.66

These versions of the scenarios show that substantially greater savings could be made if owners and investors were prompted to make greater investment in energy efficiency. The levels of adoption are arbitrary, but indicative of the results of the survey of attitudes to certification carried out as part of our research (Kaplan 2004). The interesting point here is the projected carbon saving for the scenarios version 2 (A2, B2 etc). The carbon saving achieved over and above the version 1 approach is achievable with cost-effective measures. The owners or investors need to be convinced that the effort involved in saving energy is worth more than the simple payback in terms of cost-effectiveness. The argument for this has been made earlier in the discussion of risk, but incentives, as discussed later, would have more of an impact..

The effect on overall emissions from the sector

The savings indicated in the tables above do not fully paint the picture of the effect of the change in the size of the market developed by the scenarios. This was indicated in the text concerning the differences in market size between scenarios A and E. This issue of the overall size of the market, and hence the potential total unchecked emissions from commercial offices can also be addressed by the model. There is no limit to the growth in the number of offices in the model, so the saving suggested above might be wholly outweighed by unconstrained growth in the availability (and use) of offices. One can compare the total emissions for a scenario for a Business As Usual (the same average carbon emissions per office as 2001) case as well as the minimum take up (EPBD response only) and the response by Enlightened and Leading Edge (Enlightened +) in Figure 4 below, which uses Scenario A3. This shows that the optimism of the carbon saving is outweighed by the growth in the overall emissions from the market, which goes from around 3 MtC in 2006 to over 5 MtC from 2021 onwards. Clearly, barely constrained growth in the market leads to the same problems that have been highlighted through efficiency gains in societal use of cars and other engines; efficiency gains are outweighed by the increase in emissions from overall growth in usage.

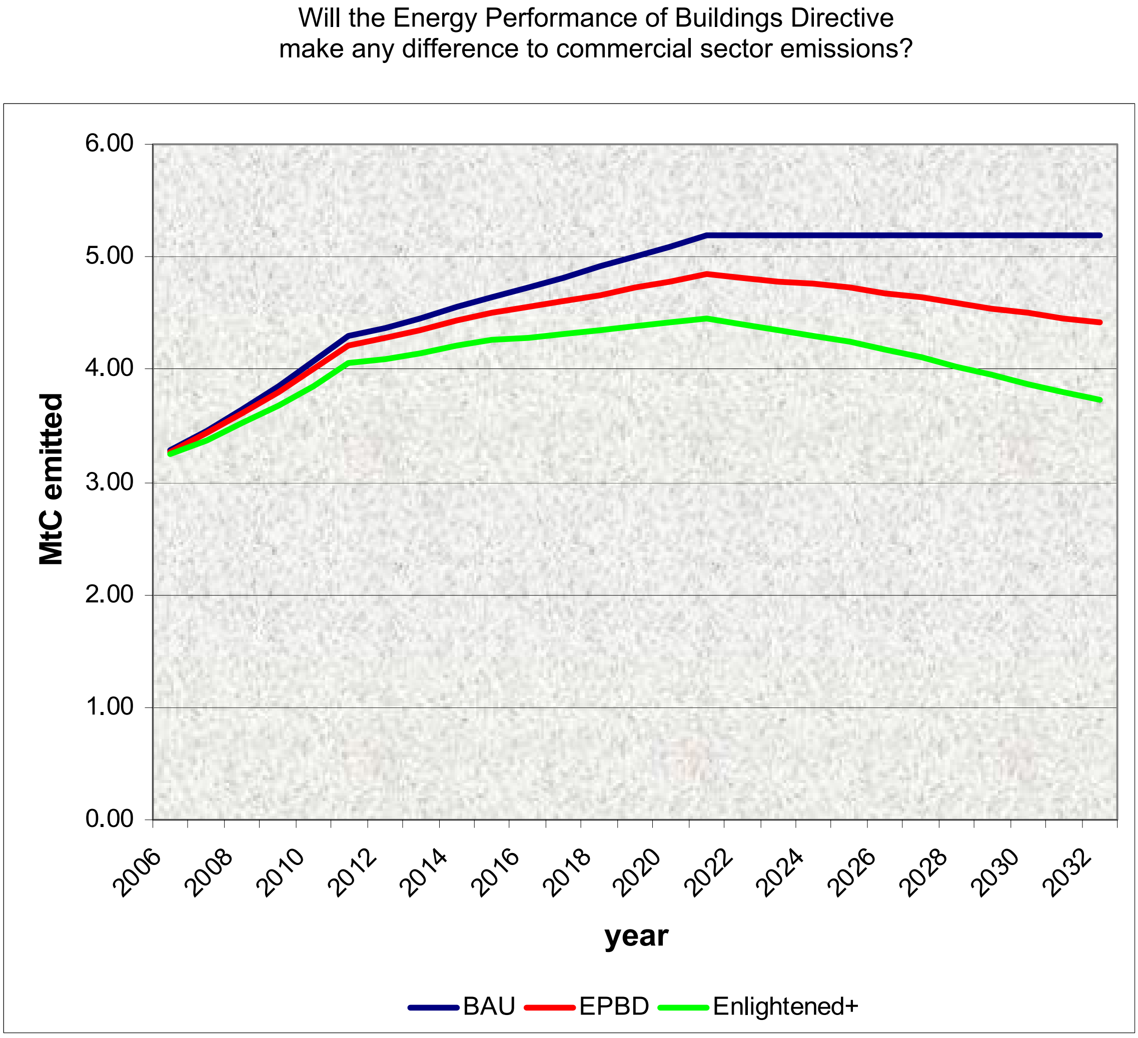

Figure 4: Total emissions for BAU versus other options, scenario A3

Option A3, suggests there is a saturation of the market at about double the number of properties in 2001. However, whilst with the basic regulation provided by the EPBD there is an actual downturn in the emissions from offices from a peak at about 5 MtC, the growth in the sector never reduces carbon emissions to the present day levels. Indeed it is only with substantial numbers creating the demand for lower energy property and refurbishments that a significant saving is made over business as usual.

Scenario E deliberately attempts to limit the number of offices to only a 50% increase by 2015 and a decline from then, returning to 2001 levels in 2025; it reflects the research scenario where the population has replaced travelling to central offices with local hubs, networks and home office type working. Under this scenario the number of offices as such has reduced, although this does not take account of different forms of building energy use (to which the required energy services have presumably been displaced).

The effects of energy intelligent investors taking every opportunity to make their property attractive to an energy conscious public leads to a very different picture for carbon emissions, as shown in Figure 5.

Fully half the emissions reduction is obtained from leading edge investors, but the downward trend in the numbers of buildings is a key factor in what would suggest is the route towards a low carbon economy. However, even just considering this graph to 2025 when current levels of buildings are in use, the energy use on basic EPBD alone has reduced due to the demolition of old, inefficient buildings, and the influence of investors could have reduced energy consumption by one-third of current figures.

This would suggest that a radical approach needs to be taken to new development if any control over emissions from commercial property is to be effective.

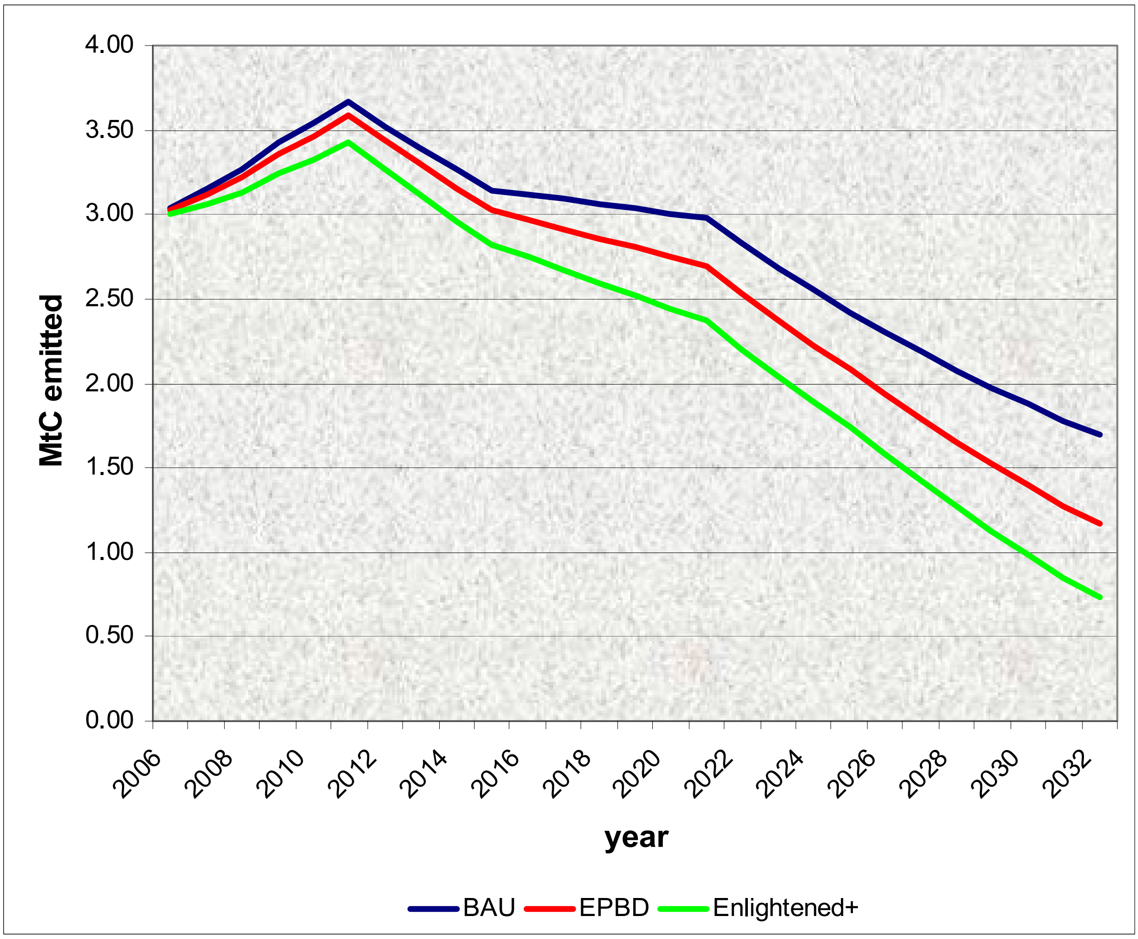

Figure 5: Limited growth and modelled emissions from offices: Scenario E3

Limitations of the Model

Although the inputs for the model can be manipulated to a certain extent, there are some embedded issues that users should be aware of when interpreting the outputs.

- There is no limit to growth of the commercial office sector. Scenarios to 2020 explored as part of the project (Pett et al 2004b) suggest it is likely that there will be a reduction in the demand for commercial property in the UK alongside the stabilisation of the population. This means that for some of the reference scenarios indicated above, the growth in the market allowed and the associated long-term carbon savings are overstated. Scenario A has a purposefully chosen limit to growth – to about twice the current number of offices, and E is restricted to 2015 then declines. These figures are consistent with the sector's growth over the last 30 years (Wade et al, 2002a) and with public sector modelling (link to RIIA). Anyone using the model should be aware of this and choose new build and demolition rate parameters accordingly.
- Date ranges in the model have some method but do not harmonise easily. Changes to the Building Regulations are applied every 5 years from 2005. 2016 has been selected as a break point where changes to the EPBD might be introduced. The reporting points 2010, 2020 and

2030 have been selected to resonate with targets for carbon emissions reduction commitments (under Kyoto, Climate Change Strategy or other).

- Carbon savings from energy improvements have been extrapolated from estimates for 2000 (Pout in Wade et al, 2002a). On the one hand building fabric improvements may become more difficult so that no further improvement to some types of building may be possible; on the other, innovation may have a major effect on building energy use. Initial rates have been embedded but its possible to choose variations in later periods depending on assumptions for new low carbon systems (e.g. fuel cells)
- Refurbishment of owner-occupied premises is assumed to take place every seven years. The assumption made by the ODPM is that energy efficiency refurbishments would only be part of a major refurbishment taking place every 25 years. If this is the case we suggest that incentives (including legislation) are necessary for owner-occupiers to take up cost effective improvements at the earliest opportunity. 25 year refurbishment would lead to a very minor impact of the EPBD on overall carbon savings.

Will ‘energy intelligent’ investors come forward?

Would the energy intelligent investors be spurred on to the level that 30% are convinced of the value of ‘better than regulatory’ improvement? The drivers indicated in earlier research (Wade et al, 2002b) suggest that sufficient incentive could be found for ‘enlightened’ investors from certification, CSR and investment risk. However, the market needs to demonstrate the benefit and/or that further financial incentive is needed to overcome inertia and narrow focus.

In order to promote the initial market move that would lead to greater realisation of the benefits, we suggest that incentives are needed. For investors, such an incentive needs to impact directly on their own financial benefits. For direct owners, who bear the premises costs and pass them on to tenants, incentives such as reduction in business rates or local taxation would be relevant. It is important to recognise that neither of these types of owners receive any benefit in the cost-effectiveness of the energy saving measures themselves as they pay the capital cost whilst the tenant uses the (saved) energy. This is the case even for absent landlords of multi-tenanted buildings, where the property manager could benefit from providing energy services at lower cost but maintain the same service charges. This any incentive on the cost of measures would have little effect on the up take of such installations and would not guarantee that isolated measures were correctly used (for examples of this see Eijadi et al 2005 and Vaidya et al, 2005). The barriers in the property market are such that a major and very visible incentive is needed to promote the value of energy efficient properties as entities. The energy performance certificate provides the evidence of the building’s worth as a whole, without the surveyor having to determine whether technologies are in themselves energy efficient..

The incentive needs to be at the point of sale, so that low energy properties carry a carrot ‘up front’. In stakeholder consultation, it emerged that the single incentive that would provide the greatest stimulus to the UK commercial property market would be a reduction in or restructuring of stamp duty (a property purchase levy) for energy efficient property, based on achieving specific ratings for their energy performance. Further research is necessary to identify indicative costs and benefits of this and other fiscal approaches.

Conclusions

It appears that the certification of buildings will take a considerable time to be completed even without delays caused by slow implementation through lack of leadership from governments. Without a market and incentives to improve building performance above the minimum requirements of Building Regulations (assuming that no radical changes are made, e.g. to require 50% of the energy needs of a development to be produced by building integrated renewables), it is likely that the effect of the EPBD will be negligible compared with increased emissions due to market growth. And this does not take into account energy use within offices for computing and telecommunications.

However the EPBD can have an impact, and moreover it can provide the stimulus for the investor who understands the interest generated by poor performing property when rental terms are negotiated. Enlightened investors will lead the market and once the market for low energy buildings is recognised, developers will have less resistance to building them. This in turn would remove one of the major obstacles to radical change in the Building Regulations for new “non-dwellings”.

Much depends on the nature of the property sector itself; the global scenarios examined for this project suggest that there may be a much more radical change in the nature and use of buildings, so that office property growth could be slowed considerably, with current investment portfolios considering how to adapt their buildings to other uses entirely. Sustainable property investment takes on a range of alternative approaches, including the value of the building to the community and its conversion to other types of use (Sayce et al 2004). If the number of office properties stabilises at a much lower level, then the impact of the EPBD could be considerable, and yet maintain a healthy economy for the construction industry. Indeed, the best option for the industry might be to have the strictest possible agenda for reducing carbon emissions, to provide plenty of refurbishment, re-development and renewal to more radical standards. Implementing the Energy Performance of Buildings Directive is only the first step, and it needs support and incentives to help more leading edge investors become aware of and demonstrate the market benefits.

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B.E.A. (Building Energy Analysis) a methodology for energy certification in buildings. A practical example of a small hospital.

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Abstract

The building sector is one of the fastest growing in terms of energy consumption. The European Directive of Energy Performance of Buildings will require a major effort to improve building energy performance and will bring the energy performance of the buildings to the forefront of building market operators.
The implementation of the Directive of Energy Performance of Buildings has as its primary aim the establishment and application of energy certification programs.
The aim of energy certification programs is to guarantee energy saving and to reduce CO_2 emission as a consequence of the EU commitment to comply with the Kyoto protocols.
Obtaining energy effectiveness labelling means the achievement of energy quality, allowing a decrease in the CO_2 kilograms emitted as a consequence of lighting, heating and cooling buildings without any loss in terms of comfort.
This work proposes a new methodology called BEA (Building Energy Analysis) that allows the implementation of European Directive about energy certification of buildings.
We show the different steps of BEA methodology (heat and cooling load, energy demand, energy consumption and CO_2 emission.) The program ends with energy labelling of the building.
As well as this, we present a practical study, in our case we chose a small hospital that is studied with BEA methodology and compare it with other energy simulation programs like HAP (Hourly Analysis Program) and PowerDOE.
The results of energy labelling are very similar for both programs.

Introduction.

Developed countries need a high rate of energy consumption to maintain their standard of living and comfort. Nowadays, the challenge is to look for sustainable development, keeping the activity, transformation and progress levels but adequating the needs to the existing resources and therefore achieving an energy saving.

This increasing concern about the preservation of the environment and particularly about climate change has led the European Union to establish some definite commitments, with the Kyoto protocol as an example.

The fomentation of energy efficiency constitutes an important part of the package of policies and measures needed to comply with the Kyoto protocol.

The building sector in the EU accounts for more than 40% of the final energy consumption and is expanding, and so the adoption of measures involving the improvement of energy efficiency is justified. These aspects have determined the adoption of directive 2002/91 on energy performance in buildings whose objectives are:

- Establish a methodology of calculation of the integrated energy performance of buildings.
- Application of minimum requirements on the energy performance of new buildings.
- Energy Certification of buildings.
- Energy audits in big buildings.

- Regular inspection of boilers and air conditioning systems.

The energy certificate of a building shall include reference values based on the current guidelines and comparative assessments, so that the final users can compare and evaluate the building energy efficiency.

Calculation methodology for energy certification shall include aspects such as thermal characteristics, building shell, air tightness, thermal equipment, lighting, orientation, renewable energy, ventilation and indoor climate conditions.

For calculation purposes, two categories of buildings will be established:

- Residential buildings: single-family houses and apartment blocks;
- Non-residential buildings or service buildings: office buildings, education buildings, hospitals, and so on.

Energy certification in Spain is still not compulsory, and the current computer programs to evaluate energy certification are PEEV, CEV and CALENER.

The goal of this work is to propose a new energy certification method called BEA (Building Energy Analysis), valid for any non-residential building with heating and/or cooling, based on a methodology which fits with the European Directive 2001/91 and whose calculation method has a proper balance between accuracy and complexity.

This new method has been applied to a small hospital and the results compared to these obtained with two internationally accepted energy simulation programs: HAP (Hourly Analysis Program) and PowerDoe, the differences being very small, as we shall see.

BEA (Building Energy Analysis) methodology.

The parameters determining the energy demand of a building, known as “Demand Factors”, are those which affect the load curve and the running schedule, and weather conditions, building envelope and occupation and functional characteristics are included among them.

Once the building energy demands are obtained, we deduce the energy consumption through the use of the concept of seasonal performance, which will depend on the chosen thermal system (heating/cooling).

Afterwards, from the energy consumption obtained, carbon dioxide emissions to the atmosphere are calculated, evaluating the environmental impact.

With the electric and thermal rates the operation costs are deduced, as well as the economic evaluation by means of the installation investment costs.

Adding lighting energy use, the total building energy consumption is finally obtained, which will allow us to compare with reference buildings (UK evaluation) and thus obtain the energy qualification of the building.

The steps for the development of BEA methodology are shown in figure 1.

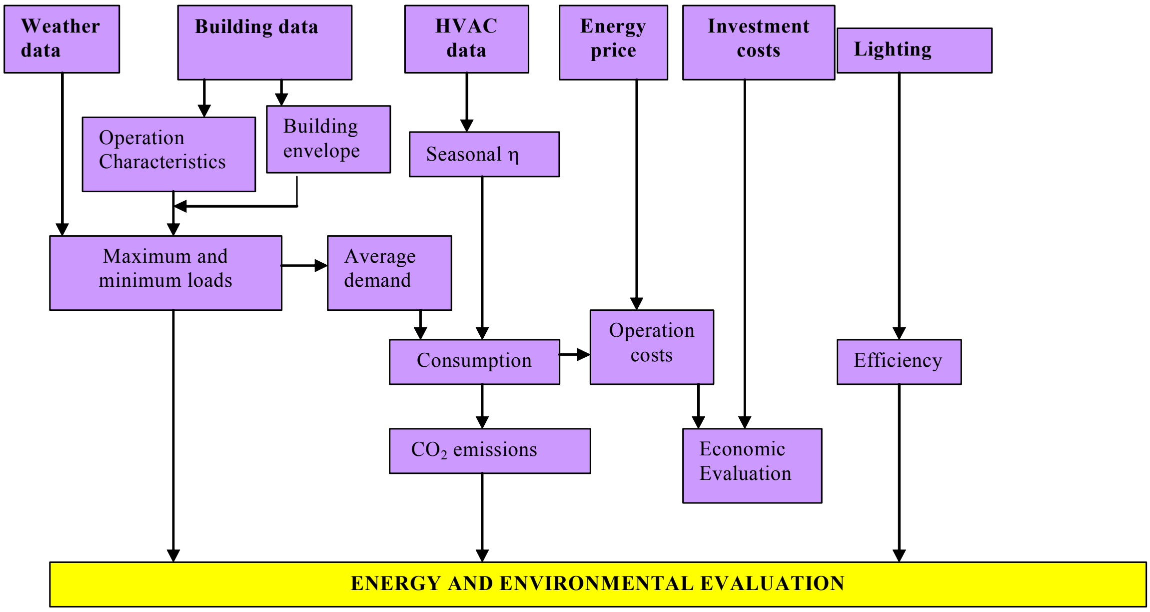

Figure 1. Steps for the development of BEA methodology.

Weather data.
In this section the weather data of the climatic zone where the building is situated are specified. Data from UNE 100001-2001 (Spanish Standard) are used, and include percentile dry bulb temperatures, this percentile being the temperature for which the defined annual percentage of the hours of the year have a temperature above it.

The percentile level chosen will be 99% in winter conditions and 1% in summer conditions, winter conditions those in which heating is needed, and summer conditions those in which cooling is needed.

Winter data are given monthly by the coldest day of the month, with a percentile of 99%, and summer data are refer to the warmest day of the month with a percentile of 1%.
The chosen climatic data will be dry bulb temperature, humidity ratio and solar radiation. In figure 2, summer climate evolution is shown, while in figure 3 variation for winter climate is presented, both for the city of Madrid.

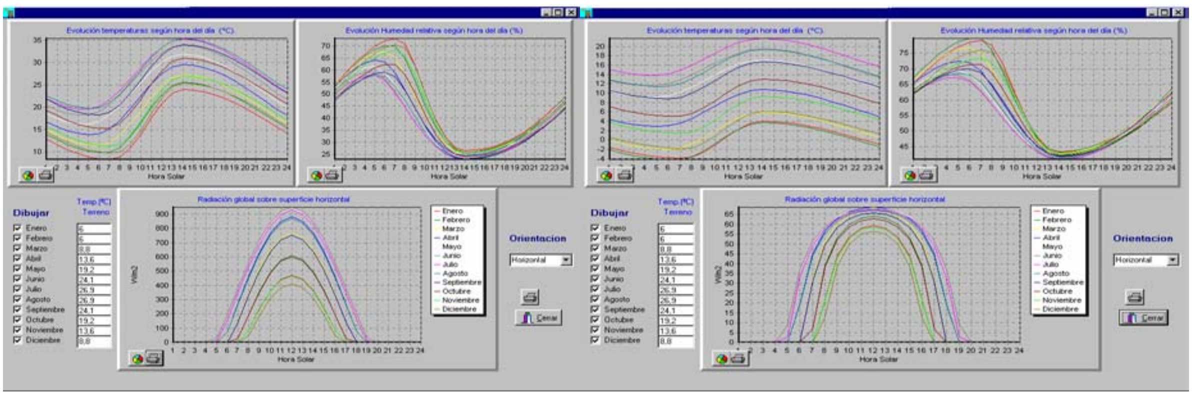

Figure 2. **Figure3.**
Evolution of temperature, relative humidity and solar radiation in a summer day and a winter day in Madrid.

Building data.
In order to perform the load calculation, we will use a software program which implements a transfer function load calculation method.

Thermal zones, spaces, as well as building constructive data corresponding to each space (windows, exterior walls, roofs, ceilings,...) are introduced into the program through its user interface. Also running schedules corresponding to lighting and equipment are introduced, as well as occupation schedules.
As we are in the case of non-residential buildings, working days and holidays must be distinguished. We will consider working days the weekdays (Monday to Friday) and holidays weekends and non-working days.

Thus, for each zone, occupation, lighting and other loads schedules are defined for weekdays and holidays separately. In figure 4 the window corresponding to weekdays is shown.

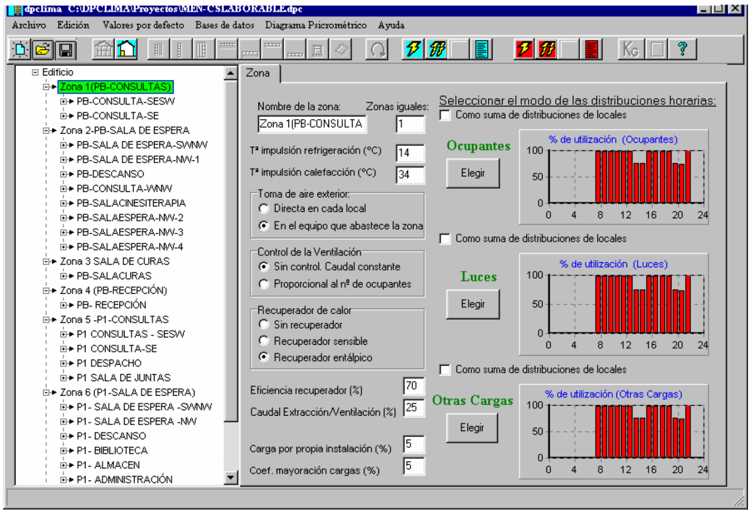

Figure 4. Working day schedule.

Heating and cooling load calculation.
Once the needed data are introduced, the program proceeds to the calculation of heating and cooling loads. This calculation program is designed for dimensioning purposes, so loads are calculated in extreme meteorological conditions. That is to say, it obtains the building load in the coolest and warmest day of each month.

For winter months, the *Maximum Load Curve* is defined as the building load curve in the coolest day of the month, ie, where winter climate data have been used to dimension the heating installation. On the contrary, the *Minimum Load Curve* is defined as the building load curve in the warmest day of the month, ie, where summer climate data have been used to dimension the cooling installation. The *Medium Load Curve* is obtained from both as the arithmetic media, and this is the curve used for energy demand calculation purposes.

Consumption calculation.
In order to estimate the energy consumption for each month of the year, the previously calculated energy demands are used. The equation which relates both of them is the following:

$$C = \int_{t_1}^{t_2} C(t)dt = \int_{t_1}^{t_2} \frac{D(t)}{\eta(t)}dt = \frac{D}{\eta_{season}} \qquad (1)$$

Where $C(t)$, $D(t)$ and $\eta(t)$ are the instantaneous consumption, energy demand and HVAC performance respectively, and C, D and η_{season} are the consumption, energy demand and average performance of the HVAC installation in the period $[t_1, t_2]$.

The development of this methodology requires the adoption of an average value of the seasonal performance, considered constant, and different in heating and cooling.

The energy consumed depends on the energy demand and the HVAC system. The BEA methodology allows energy consumption to be obtained from the energy demand, using the expression (1).

The seasonal performance is a parameter which depends, among other factors, on the climate data. In this case, the data of seasonal performances for different systems are taken from the databases of the Instituto Cerdá. The running periods associated to these seasonal performances are: winter months, for heating installation, and summer months for cooling installation. Seasonal performance is the product of three factors: generation performance (η_g), distribution performance (η_d) and regulation performance (η_r).

Energy Evaluation.

In order to establish energy evaluation, studies developed in the United Kingdom (DETR 2000b) are taken as a reference. In these studies, buildings are evaluated according to the kWh/m^2 consumed and we will adapt these consumptions to acceptable, good and excellent in the final qualification. The limit values considered are shown in table 1, in which the points which affect the qualification can be seen. Among other aspects, DHW consumption, fans, pumps, humidifiers and electric loads are considered. Although English tables are designed for office buildings, they can be used to evaluate every other kind of non-residential building. So as to apply this table to the results obtained for the building studied, the total area of the mentioned building must be considered, deducting the non-conditioned spaces.

To obtain the energy evaluation, first we must establish what kind of building we are evaluating, among the four predefined kinds (1,2,3 or 4). Afterwards, energy consumption obtained is compared to that found in table 1 corresponding to the kind of building studied. Finally, by observing the limit values, we will obtain the qualification of the building.

Table 1. Energy consumption in U.K. Based on DETR (2000b)

	kWh/m^2 net area							
	Type 1		**Type 2**		**Type 3**		**Type 4**	
	Efficient	**Typical**	**Effic.**	**Typ.**	**Effic.**	**Typ.**	**Effic.**	**Typ**
Heating and DHW	79	151	79	151	97	178	07	201
Cooling	0	0	1	2	14	31	21	41
Fans, pumps and control	2	6	4	8	30	60	36	67
Humidifiers	0	0	0	0	8	18	12	23
Lighting	14	23	22	38	27	54	29	60
Office equipment	12	18	20	27	23	31	23	32
Catering	2	3	3	5	5	6	20	24
Other electric uses	3	4	4	5	7	8	13	15
Computer equipment	0	0	0	0	14	18	87	105
TOTAL	**112**	**205**	**133**	**236**	**225**	**404**	**348**	**568**

Note: Type 1: Natural ventilation, Type 2: Mechanical ventilation, Type 3: Standard Air Conditioned, Type 4: Efficient Air Conditioned.

Building Studied: Small Hospital

The building studied is a small hospital located in Madrid. It has two floors of 939 and 679 m^2 in the ground floor and first floor, respectively.

In figure 5 the location map of the building is shown, where the front façade faces south-west while the rear one faces north-east.

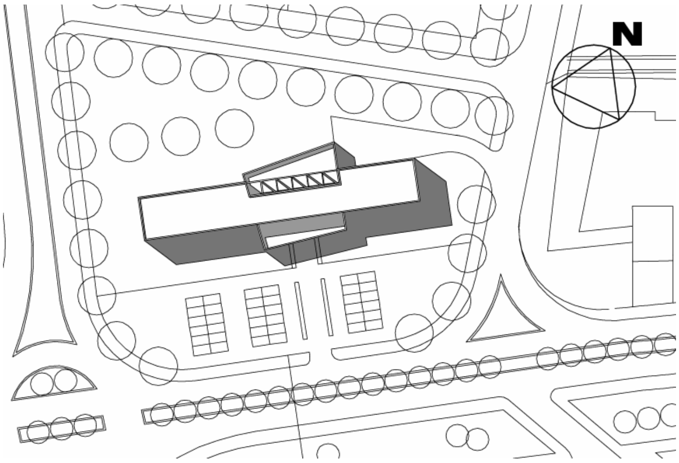

Figure 5. Site map of the building

Temperature in summer conditions will be 24ºC and relative humidity 50% in the occupied area and winter conditions will be 22ºC and 50%. Thermal conditions in unoccupied areas in summer will be 27ºC and in winter 14ºC.

With regard to the outdoor air ventilation, the RITE (Spanish *Code for Thermal Installations in Buildings*) standards will be adopted and the air flow for each space of the hospital will be different depending on its use, the maximum being in operating theaters (15 l/sp) and minimum in waiting rooms (8 l/sp).

In order to perform the study, the building is divided into several thermal zones so as to make simulation easier.

The ground floor is divided into four thermal zones while the first floor is divided into three. Each thermal zone is divided in turn into spaces. Building materials of walls, floors, roofs, ceilings, windows are defined in the architectural project.

The spaces within the building are illuminated with fluorescent lighting and a simultaneity coefficient of 0.9 is assumed, which means that 90% of the lights are on at the same time. Other electric equipment like computers or refrigerators is also considered.

To obtain the heat gain due to occupation, a number of people in each space and their activity are defined.

Ground floor schedule is from 8:00h to 21:00h on weekdays and from 9:00h to 17:00h on holidays. In the first floor, the same schedule is considered on weekdays and on holidays the building is considered closed.

The HVAC system is an air/air heat pump as terminal unit with ducts and supply and return fans. Heat recovery is also included in the system.

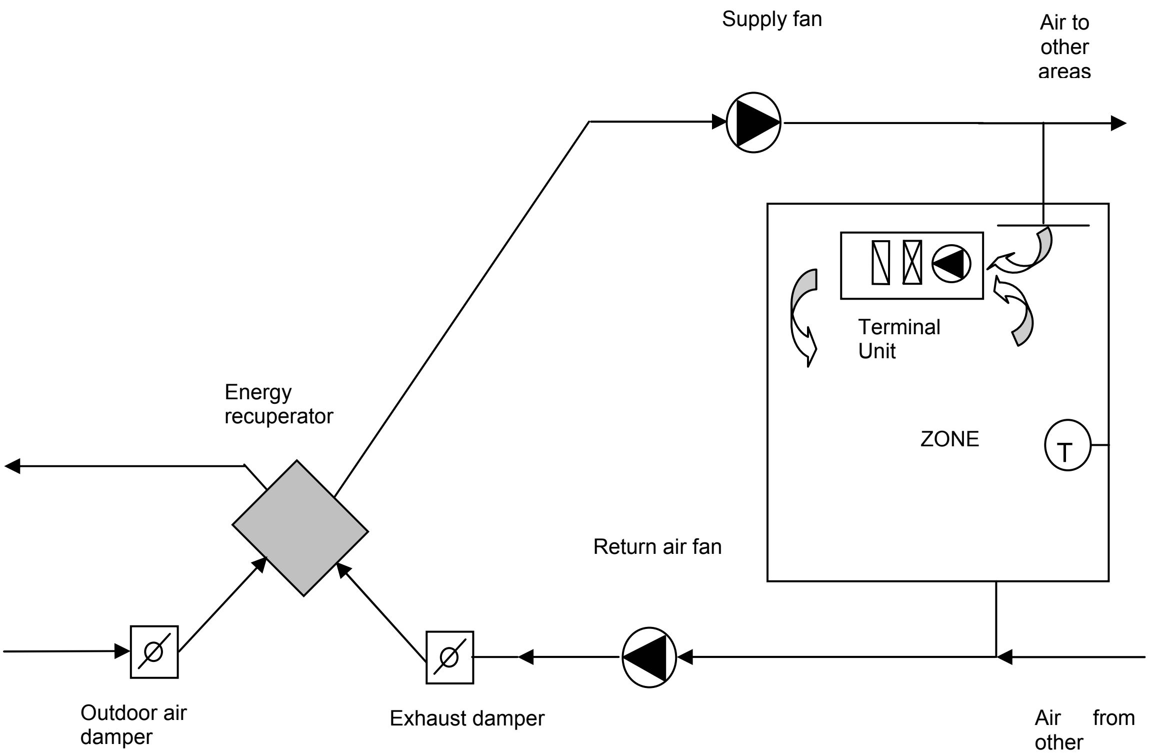

Figure 6. Scheme of the energy recuperator included in the system.

4. Analysis of the Results

According to the BEA methodology, maximum thermal loads are obtained for a typical day of each month. These thermal loads are valid for the design of the HVAC systems which are to be included in the building.

In the following figures, the heating and cooling thermal loads throughout the year are shown.

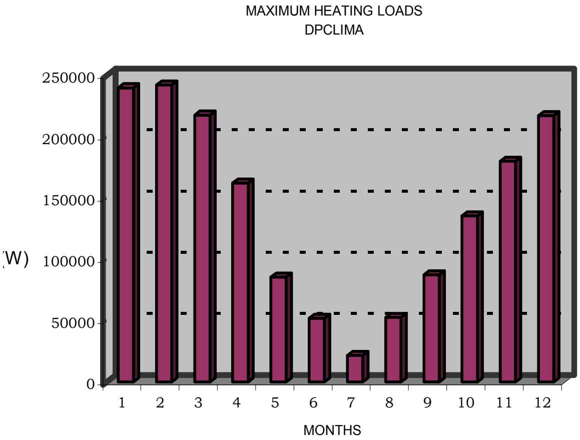

Figure 7. Maximum heating loads.

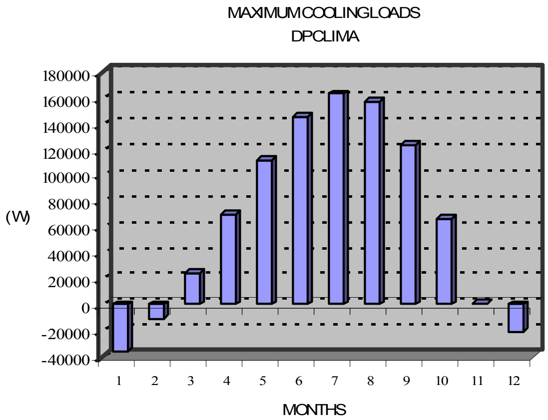

Figure 8. Minimum heating loads

Figures 9 and 10 show the heating and cooling energy demands for each month of the year.

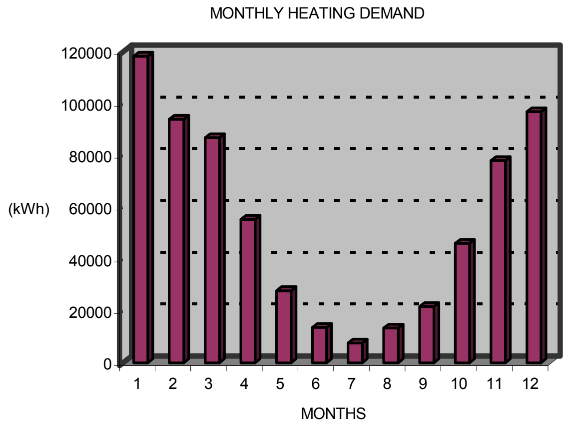

Figure 9. Monthly heating demand

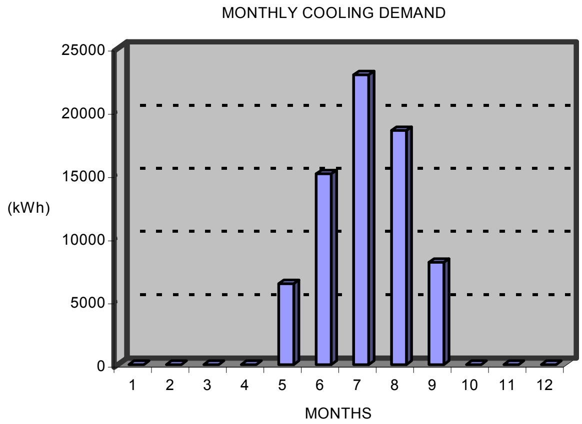

Figure 10. Monthly cooling demand

By means of the BEA methodology energy consumption can be obtained, and these results are shown in figures 11 and 12.

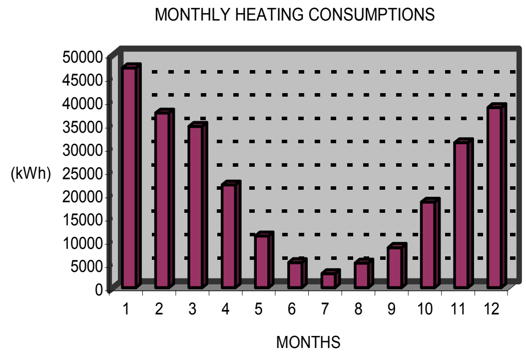

Figure 11. Monthly heating consumption

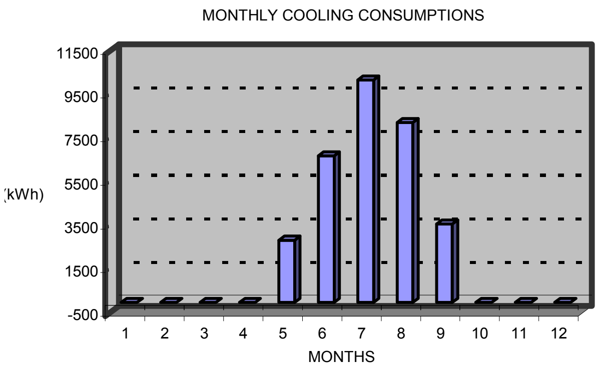

Figure 12. Monthly cooling consumption

In table 2, the energy consumption in every case is shown, together with CO_2 emissions and energy qualification.

Table 2. Consumption, emissions and qualification.

Methodology	Consumption kWh/m^2	Environmental impact kg CO_2/m^2	Qualification
BEA	227.19	125.15	VERY GOOD
HAP	240.16	130.88	VERY GOOD
POWERDOE	275.31	151.01	GOOD

As can be seen through the comparison of the monthly energy consumption of the three methods, BEA differs from the other two. This is logical since we are talking about a statistical model compared to two detailed hourly simulation tools. However, the trend of the three methods is very similar, but the most important thing to point out is that when the time interval is expanded into the whole year, these values are much closer, the difference between BEA and HAP being around 5% and between BEA and POWERDOE of about 17%. If the goal of energy consumption estimation is energy qualification, this qualification coincides in the three methods.

The environmental impact caused by the CO_2 emissions produced by the building throughout a year, taking into account that the only source is electricity, amounts to 125.189 kg CO_2/m^2.

Finally, the energy evaluation according to BEA methodology is obtained adding the monthly energy consumptions of the building and dividing it by the useful area. In our case, this consumption is 227.19 kW/m^2.

Comparing this obtained value with the table DETR (2000) for a building type 3, we obtain an energy qualification of “Very efficient”.

In order to test the BEA method, two different energy simulations have been performed in the same building, both carried out with two internationally well known software tools: HAP and POWERDOE. The comparison of the results of monthly energy consumption are shown in figure 13.

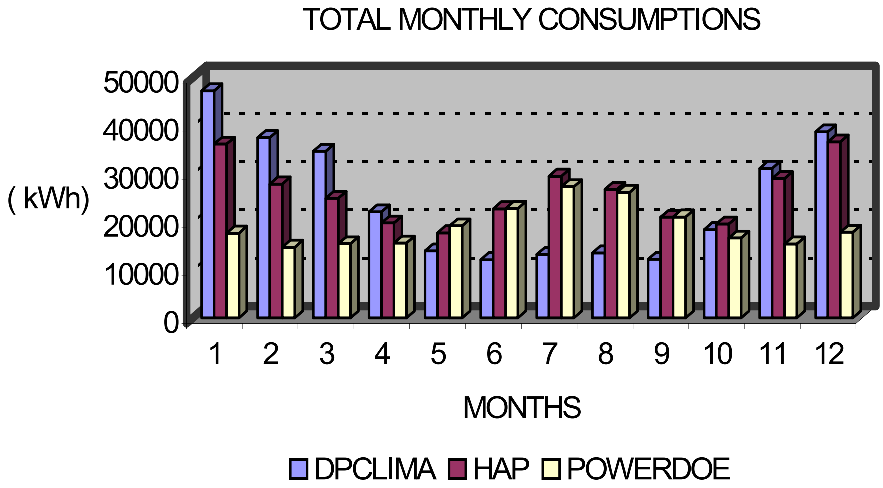

Figure 13. Comparison of monthly energy consumptions.

Conclusions.

1. The BEA, a methodology of energy certification has been developed, applicable to every kind of non-residential buildings, the main stages of which are shown in figure 14.

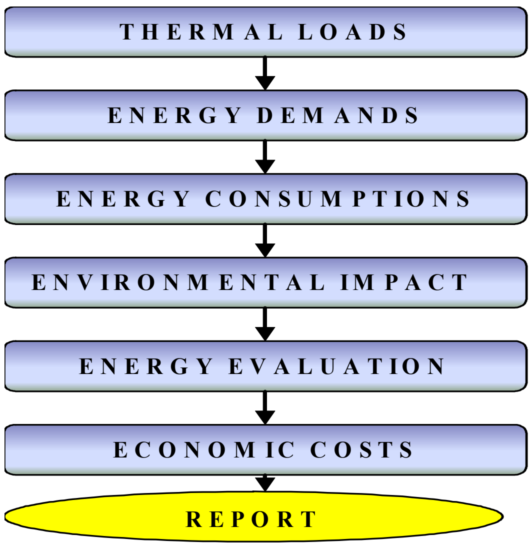

Figure 14. Stages of the BEA methodology.

2. The objectives in the European Directive 2002/91/CE on energy performance in buildings, and the features offered by the developed method, BEA, are shown in table 3.

Table 3. Comparison Directive objectives vs. BEA features.

1. Reduction of CO_2 emissions through an improvement in energy performance	1.Evaluation of energy consumption including final energy and CO_2 emissions
2. Applicable to any kind of buildings	2. Applicable to any kind of new buildings. Adaptable to existing buildings
3. Thermoeconomical and environmental study for buildings over 1000m^2	3. Allows energy and environmental analysis, as well as an economic feasibility study.
4. Encourages investments in energy saving	4. BEA evaluates energy savings achieved in each of the considered alternatives
5. Introduces transparency for prospective owners or users with regard to the energy performance in the EU property market.	5. BEA provides the results in a simple and straightforward way.
6. Characterize the building in terms of energy.	6. BEA provides the building energy characteristics and specifies its energy performance.
7. Offer energy improvements and analyse renewable energy systems (solar)	7. Allows the improvement of the building energy features analysing different systems

3. The BEA methodology has been applied to a small hospital located in Madrid (Spain) showing a very simple method of energy qualification.
4. The comparison between BEA method and two other internationally well known energy simulation tools (HAP and POWERDOE), in a time interval of a year, shows an acceptable margin of error.

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Energy Certification for non-residential buildings: Results of dena field-test on procedures and user-acceptance

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Background

The European Energy Performance of Buildings Directive (EPBD) requires the implementation of energy certificates for all building types starting in 2006 in all EU-Member States. This not only applies for residential buildings but also for non-residential buildings, e.g. buildings for services, trade and public buildings. Major goal of the European Parliament and the Council of the EU when formulating the requirements of the Directive was to strengthen the public consciousness on energy efficiency of buildings and to trigger energy savings measures and investments. The necessity to enforce energy efficiency measures in the building sector is a long known fact. Appropriate technologies and materials are available and tested, nevertheless only thirty percent of the cost-effective measures are taken in practice. The Directive therefore recommends the certificate to be accompanied by recommendations for the cost-effective improvement of the energy performance.

The EPBD poses significant challenges for EU Member States in terms of the practical details of the transposition. The requirements of the EU Directive, though clear and objective, allow a degree of freedom in their implementation. This flexibility, which is much welcomed in terms of the principle of subsidiary, carries with it an increased challenge, as all the details to the transposition must be prepared and adopted by each Member State in an appropriate way.

Situation in Germany

In German Legislation the requirements of the EU Directive for residential buildings are already widely covered by the existing Energy Savings Ordinance of 2004 and the German standards DIN V 4108-6 (EN 832), and DIN V 4701-10/12 that the Ordinance refers to as calculation method. Since 2002 energy certification is mandatory for all new buildings in Germany. The certificate is part of the documents for the application for a building permit and has not reached much public acknowledgement since then. Nevertheless the calculation procedures are implemented into daily practice and served as procedural basis for extending the certification of buildings also to existing residential buildings on a voluntary basis. Dena tested the energy certificate for residential buildings in a large field test study in 2004 on more than 4.000 issued certificates. Within this field-test many questions concerning the label, efforts for data acquisition, costs and end-user acceptance could be answered and lead to an improved strategy for a national energy certificate in accordance to the Directive.

The procedures and calculation tools for the certification of non-residential buildings still had to be developed to fulfill the requirements of the EPBD, since the calculation method for the residential buildings does not include the energy consumption for cooling and lighting. In a concerted effort different German standard committees developed a new holistic calculation procedure to fulfill all the Directives requirements also for the non-residential buildings. The new German standard draft DIN V 18599 which was released in July 2005 contains a holistic calculation method to cover all aspects of building related energy consumption including air-conditioning and lighting. The standard contains ten parts that cover the different aspects of the building system. The parts can be applied independently to a certain extent. That way less complex building will need a less complex calculation procedure. The amendment of the Energy Savings Ordinance of 2006 will refer to this standard as a calculation procedure. Additionally the Ordinance will have to cover topics like the setting of reference values and minimum requirements. For residential building the maximum values for primary energy consumption were defined dependant on the buildings' form factor. This relationship could not simply be transferred

to the non-residential sector since the usage of the building has a much larger impact on the energy consumption than the form-factor in most cases.
The Energy Savings Ordinance of 2006 will therefore introduce a new procedure to determinate the legal reference values. With a so called “reference building method” the actual building is calculated including the actual geometry and usage profile but with standardized default values for the quality of the building envelope and technical systems. The default values represent the state-of-the-art and the minimum legal requirements for new buildings. In a second step the building is calculated with the actually planned or collected building data. To facilitate the data acquisition for existing buildings the Ordinance will include simplification rules and default values that issuers may use if they lack equivalent information. The content and layout of the future energy certificate will also be regulated in the new Energy Savings Ordinance.

German field-test on non-residential buildings

In July 2005 dena was mandated by the Federal Ministry of Transport, Housing and Urban Development to initiate a field test on the planned boundary conditions for energy certification of non-residential buildings. At that state the amendment of the Energy Savings Ordinance of 2006 was under way and the Ministry wanted to include experiences of the first practical certification results in the amendment procedure until the end of the year.

During the late summer 45 existing non-residential buildings were selected for the field-test from the applications by dena and the Ministry. Most applications came from interested engineering and energy consultant companies, who had big interest in getting familiar with the new procedure. But also building owners and municipalities showed great interest in the field test. The main goal at selecting the buildings was to cover a wide allocation of the existing building-stock in the non-residential building sector and include as many German regions as possible. Since not only the asset rating procedure was going to be tested but also a method to use operational data for certification, only older existing buildings were considered for the field test. The issuers were mostly building service engineering companies and energy consultants but also a corporation between an architect and an engineer and members of building authorities participated in the field test.

Participants
In the field test the following distribution of building types and usages were represented in the 37 until December issued certificates:

- Twelve office and administration buildings
- Four city halls
- Two libraries
- One museum
- Seven school and university buildings
- One hotel
- Four recreational and sporting facilities
- Three Congress Centers
- One church with kindergarten and community centre
- One hospital and one elderly-home
- One Fire Department

On 26th of August dena and the Ministry of Housing started the field-test with an opening session in Berlin where the goals and methods were discussed with the participants.

The main goals of the field test were:

- Test of the practicability of the new standard DIN V 18599
- Test of the simplified methods, the reference building method and the operational method
- Test of the user-acceptance of publicly displayed certificates

Energy Certification for non-residential buildings:
Results of dena field-test on procedures and user-acceptance

On September 14th and 15th the issuers were trained on the new calculation standard and the boundary conditions for energy certification of non-residential buildings in a two-day seminar. During these two days it showed that the complexity of the calculation method by far exceeds the known standards for the residential buildings. The workshop character of the seminar already offered room for intense discussion. For the field test the issuers could use an excel-based calculation tool provided by the Fraunhofer Institute for Building Physics that was developed by order of the Federal Ministry of Transport, Housing and Urban Development.

Results
On November 7th all participants met again for an evaluation workshop in Berlin to discuss the final results and experiences made during the field-test. At that time the work on the calculation tool and the certificates should have been completed to a large extent. But it showed that many issuers underestimated the necessary effort for on-site data acquisition and the handling of the calculation tool.

The discussion of the evaluation workshop was structured in five parts:
1. DIN V 18599
2. Simplified methods
3. Reference building method
4. Operational rating method
5. Certificate

The first three points can be summarized under the topic “Technical Basics”. It showed that not many issuers studied the standard intensely; most issuers focused on the necessary input data of the calculation tool and only consulted the printed standard when major problems or questions occurred. The standardized user profiles were regarded too strict in some cases, e.g. the standardized indoor air temperature of 21°C was regarded too high for some typical usages. Some other user-profiles were missing in the standard so that the issuers had to find the closest match to their requirements from the given profiles. Most issuers considered the zoning of the building the most elaborate part of the calculation and in regard to simplified methods expressed that simplified zoning rules would lower the necessary time and effort for certification significantly.

The simplified methods were regarded helpful by most issuers. The linkage between the simplified default values and the correlating parts of the standard should be improved to facilitate the procedure. Also discussed was the political decision to not give a reference value for cooling for the calculation of the reference building. This means that cooled buildings have to be a lot more energy efficient on the heating and lighting balance than comparable buildings without cooling. The idea behind this decision is the assumption that most non-residential buildings in German climate not necessarily need cooling systems if there are no special usages in the building and the architecture reflects the climatic situation.

Regarding the experiences with operational data the issuers encountered some difficulties in getting correct and reliable data from the existing meters and energy bills. Except some few cases where the building had been intensely monitored over several years the issuers often missed the appropriate background information on the data on hand. Secondly it showed that the available reference values did not reflect the issuer’s experiences in some cases. A regular update of the benchmarks is planned by the Ministry.

The certificate form reached a large degree of acceptance among the issuers. Some details regarding the color gradient of the certificate which placed too many buildings in a yellow/red sector will be updated until the release of the Ordinance.

To summarize and specify the information of the evaluation workshop the Fraunhofer Institute for Buildings Physics (IBP) developed a questionnaire to be sent out to the issuers based on the central topics discussed during the workshop. Additionally the building owners receive a short questionnaire for public display to get an end-user feedback on the displayed certificates.

Energy Certification for non-residential buildings:
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The standard DIN V 18599 as well as the reference building method and the simplifications are applicable tools for the holistic calculation of non-residential buildings and the certification according to the EPBD. Some issues such as reliable software tools that implement some of the tasks that had to be performed by the issuers in the field test will help to put the procedure into practice. In total the results of the energy performance calculation, summarized in the primary energy characteristic of the building, proved to be better than expected by many issuers. The template for the certificate and the public display of the certificate were judged positively by most owners and issuers. The displayed certificates are understood as sign of high energy awareness of owners by the public.

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The Seasonal Efficiency of Multi-Boiler and Multi-Chiller Installations

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Abstract

The Energy Performance Certification requirements of the Energy Performance of Buildings Directive highlight the need to have repeatable, robust, but easy to use methods of assessing the annual efficiency of HVAC systems. This is also an important issue for energy-efficient system design in general. System efficiency depends on the efficiency of heat generators (usually boilers) and cold generators (often chillers) - as well as many other heat distribution and control factors. This paper focuses on the calculation of the annual heat (or cold) generator efficiency of multi-boiler (or multi-chiller) systems.

Standardised methods exist for estimating the annual efficiency of boilers (or chillers) in systems with only one heat (or cold) generator: The UK SEDBUK rating for boilers, and the American IPLV rating and the proposed European ESEER value for chillers are examples of such rating systems. These produce *product* ratings for operation under standardised conditions. However, many larger systems have multiple boilers or chillers, and these product ratings are of limited value in these circumstances. In addition, the standardised assumptions of sizing and climate may not apply in every situation. Detailed energy simulations provide one means of estimating annual performance, but are too complex for many buildings, or for the early stages of design.

This paper describes a simpler procedure for calculating the seasonal performance of multi-boiler or multi-chiller heat or cold generation systems, taking account of the part-load characteristics of the individual heat or cold generators, their sizing, and the load distribution of the building. It inevitably requires some information about the part-load performance of the heat or cold generators, but is sufficiently flexible to accommodate different levels of data. For example, it can be used with the boiler part-load tests required for compliance with the European Boiler Efficiency Directive or the chiller part-load tests proposed by Eurovent for their certification system. The individual heat or cold generators do not need to be identical. Building load information can be specific to a particular design and climate, if this is available: alternatively standard distributions can be defined for regulatory purposes.

Introduction

Estimates of HVAC system seasonal efficiency are required whenever annual energy consumption is calculated – notably within the requirements of the European EPBD . (1)

An important part of the calculation of seasonal *system* efficiency is the specific issue of the seasonal efficiency of heat generators (usually boilers) and cold generators (commonly chillers). This paper offers a framework for carrying out such calculations and discusses its practical application.

Much of the content has been developed within three activities:

- the development of draft European standards to support the EPBD (2)
- the development of application tools for UK implementation of Article 3 of the Directive (11)
- a multi-partner study of part-load issues relating to HVAC plant (3)

This paper first describes the theoretical background and then discusses different implementation options, depending on the extent of data availability. Finally a short worked example is presented.

For clarity the paper will focus on chillers, though the principles are equally applicable to boilers and to room air-conditioners. For boilers some of the issues that arise with chillers are absent. The general principles could also be applied to other situations where performance depends non-linearly on weather conditions – for example, to heat recovery systems.

1. Basic Principles

The ratio between the annual cooling load placed on a chiller and its corresponding energy consumption is its "seasonal efficiency" or, more accurately, "seasonal energy efficiency ratio" (SEER). However, this ratio is not constant for a given chiller, but depends on a number of other factors that vary with the application. Furthermore, the nominal EER of a chiller may not be a good guide to its SEER – see table 1 below.

In particular, the efficiency of a chiller varies significantly with the load placed on it and with the temperature to which heat is rejected. For many chillers, the efficiency at part-load is less than at full load – though for others, the opposite is true. Generally, efficiency increases as heat rejection temperature falls. The two effects are usually of comparable size. For air-cooled equipment, the heat rejection temperature is closely linked to ambient air temperature but, for liquid-cooled equipment the temperature variations clearly depend on the source of the cooling fluid.

Table 1. Examples of part load values: (taken from German standards) German weather, space cooling application in offices. (SEER = nominal EER x part-load value)

Chiller type	Part load Value
Water-cooled piston or scroll compressor, with on/off control and dry recooler	0.92
Water-cooled piston or scroll compressor, with multi-stage control and dry recooler	1.26
Water-cooled piston compressor with individual cylinder shut down and dry recooler	0.79
Water-cooled piston compressor with hot-gas bypass control and dry recooler	0.56
Water-cooled screw compressor with valve control and dry recooler	0.97
Air-cooled piston or scroll compressor with on/off control and buffer storage	1.32
Air-cooled piston or scroll compressor with multi-stage control and buffer storage	1.43
Air-cooled screw compressor with multi-stage control	1.14

Seasonal performance indices for single chillers exist in the form of the American Integrated Part Load Value (IPLV) (4) and the proposed European Seasonal Energy Efficiency Ratio (ESEER) (5). Each of these is a weighted average of several efficiencies measured under different part-load conditions and heat rejection temperatures – see Table 2. The primary purpose of these indices is for product labeling – to allow the easy identification of chillers of differing seasonal efficiency. For this reason, they need to be product- rather than application- specific and therefore to use a fixed set of weightings of the different part-load EERs. For building energy calculations this can be misleading when the load patterns or climate of the application are substantially different from those that underlie the standard weightings (6). For example, the implications of the application of the ESEER ratings in the UK were discussed at a previous IEECB conference (7).

Table 2

Comparison of IPLV and proposed ESEER for air-cooled chillers				
	ESEER		IPLV	
% part load	**Temperature C**	**Weighting**	**Temperature C**	**Weighting**
100	35	0.03	35	0.01
75	30	0.33	26.7	0.42
50	25	0.41	18.3	0.45
25	19	0.23	12.8	0.12

IPLV and ESEER implicitly assume the use a of a single chiller, carefully sized to match the peak cooling load of a building. In practice, larger systems will commonly contain more than one chiller (or boiler) and the total installed capacity is rarely an exact match to the building load.

The section below describes the basic theory that underlies these indices and shows how the same principles can be extended to energy calculations that reflect building characteristics and use, climate, and the number and sizing of chillers installed.

2. Theory

2.1. The Objective

To calculate the energy consumption of a chiller or a set of chillers in an air-conditioning system, given knowledge of:

- the cooling demands placed on it (or them)
- the energy efficiency under a number of part-load conditions.

The same processes can also be applied to complete cooling systems and to heating systems. [1]

2.2. Combination of Load Frequencies and Part-load Performance Measurements

Over some period of time the cooling demand on a chiller is L (kWh). During this period, energy C (kWh) is used to meet this demand.

Efficiency is defined as L/C. The inverse, Energy Input Ratio EIR is often more convenient to use.

Then C = EIR.L

Clearly, over some longer period of time the total consumption is simply the sum of the consumption during different time periods. [2]

$\sum C = \sum (EIR.L)$

and we can define an overall EIR as $\sum C / \sum L = \sum (EIR.L) / \sum L$

Note that, if we express the equation in terms of efficiency instead of EIR, the overall efficiency is the harmonic mean of the individual efficiencies. (That is the reciprocal of the sum of the reciprocals)

More generally, when L is zero, there may still be an energy consumption. In this case EIR is infinite and efficiency zero (irrespective of the size of the no-load consumption). Denote such zero-load consumption as C_o .

$\sum C = \sum (EIR.L) + \sum C_o$

and overall EIR is $((\sum EIR.L) + \sum (C_o)) / \sum L$

EIR is a function of L and of heat rejection temperature: for air-cooled chillers outdoor temperature.

This calculation can, in principle, be carried out for each individual time step (say each hour) within the calculation period of interest. It can be simplified by determining the frequency of occurrence of each level of demand (and temperature) during the period of concern. This is the basis of “bin analysis”. For example a “bin” might be defined as containing the number of hourly occurrences of a cooling load between 35% and 40% of the design cooling load of the building that are coincident with ambient air temperature between 24 C and 26 C.

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[1] For many boilers, efficiency at 30% and 100% of rated output is known in order to comply with the Boiler Efficiency Directive. Ambient temperature is not an issue.

[2] For simplicity subscripts denoting the range over which summations are made are not shown

Denote the frequency with which each condition occurs as F, and associate a value of EIR with each bin. Then (noting that the summation is now over frequency classes rather than hours)

$\sum C = \sum (F.EIR.L) + F_o.C_o$

The frequencies and the demands may be further combined to generate *demand weightings*, W = F.L

$\sum C = \sum (W.EIR) + \tilde{F_o}.C_o$

2.3 Seasonal performance indices

Seasonal performance indices can be calculated in the form of an ***overall EIR***, for the period, that is:

$(\sum (F.EIR.L) + \tilde{F_o}.C_o) / \sum L$

or

$(\sum W.EIR) + \tilde{F_0}.C_o) / \sum L$

The overall seasonal EER is the reciprocal of this overall EIR

A “mean partial-load factor” can be defined as

PLV_{av} = SEER/EER

This approach, combined with standardized part-load EIRs for different types of chiller, and for single-chiller systems where the chiller is carefully matched to the peak load, is used in reference (10)

2.4 Calculation of Representative EIRs

Each bin has to have an associated EIR value. However, each bin has a finite size (for example, from 45% load to 55% load) within which there may be significant variations of EIR – especially if the bin size is large.

Strictly speaking, the EIR for each bin should be calculated from the distribution of loads within the bin in the same way as the seasonal figure is calculated from the bin data. Pragmatically, it is rarely possible to do this, and it is necessary to estimate EIR by, for example, taking a value that represents the mid-point of the bin range, or the average of the values at the two bounding conditions for the bin.

2.5 Multiple Chillers

For systems with multiple chillers, a combined EIR value must be calculated for each bin, representing a combined EIR of all the operating chillers (and the load conditions on each – for example, one chiller at full output and a second one at 50% of full output). Note that this is *not* obtained by averaging EERs (unless the harmonic average is used) but by adding consumptions and determining the combined total consumption. The later worked example illustrates this.

2.6 Calculations for systems

The same theory may be applied to complete systems. In this case, it is convenient to subdivide the energy into two classes: auxiliary energy A (kWh) that is used principally for energy transfer (fans and pumps) and for controls; and direct consumption, C (kWh) (used for the generation of heating or cooling by chillers, boilers and their ancillary equipment). For system calculations, direct consumption depends not only on the on the efficiency of conversion of fuel or electricity to heat (or cold) but also on the efficiency of distribution of heat (or cold).

System EIR may be defined as the ratio between the total cooling (or heating) demands in the spaces being conditioned and the energy consumed by chillers or boilers. Auxiliary energy will be calculated separately (for example as a multiple of installed fan power and operating hours). [3]

[3] Alternatively, EIR could be defined to include both direct and auxiliary energy consumption.

Some distribution systems alter the frequency distribution of loads placed on chillers – for example by switching to full fresh air and no chiller operation when outdoor air temperatures are sufficiently low.

3. Practical Application

3.1 Background

Ideally the theory would be applied to data that are specific to the building and system under consideration, to the actual or expected pattern of use, and to the local climate. This requires detailed information on chiller performance [4] over a wide range of conditions, and detailed estimates of building cooling demand – from detailed simulation, for example. Such detailed information is rarely available, and simplifications have to be made. This section describes how this may be done in ways that are consistent with various levels of available data.

Simplifications fall into two related areas: chiller information and bin definitions.
Simplifications inevitably reduce the resolution of the calculation. However, the basic data will always be uncertain to some degree, and high theoretical resolution does not necessarily mean more precise or reliable results. For many applications, consistency of approach will be more important than fine degrees of apparent accuracy. For energy performance certification purposes, standardized assumptions will be necessary.
Figure 1 summarises the suggested hierarchy of decisions and simplifications.

3.2 Simplification of Load Frequency Data

Draft CEN standards (2) distinguish between dynamic building energy calculations, typically at hourly intervals, and simplified methods than generally work with monthly time intervals.

When building cooling demands are calculated on an hourly basis, the production of hourly bins (of joint demand and ambient temperature) is straightforward. Alternatively the calculated hourly loads can be used directly with chiller performance data if this is available. For standardised energy calculations, standardised weather data are obviously required.

When cooling demands are calculated monthly or annually a standardised set of load frequencies (or demand weightings) can be used. These could be generated in several ways, of which computer simulations of characteristic buildings under standardised weather conditions are perhaps the most satisfactory. Clearly, these standardised demand frequencies will best match those of the building under consideration if the simulations are for a similar building with a similar air-conditioning system, similar pattern of use and located in a similar climate.

Since the efficiency of air-cooled chillers depends on ambient air temperature, the demand frequencies should ideally be accompanied by associated ambient air temperatures. Failing this, it may be possible to estimate ambient temperatures from the demand figures – the two variables are usually correlated, though imperfectly. The implications of inappropriate temperatures are discussed in the section dealing with chiller performance simplifications.

The EECCAC project (6) derived load frequency distributions from building energy simulations for a wide range of system types at three sites: London, Milan and Seville. As (7) points out, the loads placed on the chiller system can vary with the type of cooling system installed, as well as with weather and building design and use. Similar building energy simulations (using a different simulation tool) have been carried out for a wider range of building designs (though all offices) and locations, but for fewer systems, in the UK (3).

Figure 2 shows a sample distribution for an office in London, with a 4-pipe fan-coil cooling system.

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[4] Either from manufacturers' data or by detailed modelling. The characteristic time constants of chillers and packaged air-conditioners are usually such that it is difficult to define efficiency meaningfully for periods much less than, say ten minutes, while for some equipment, the variations of performance with load can be difficult to represent over periods much in excess of an hour.

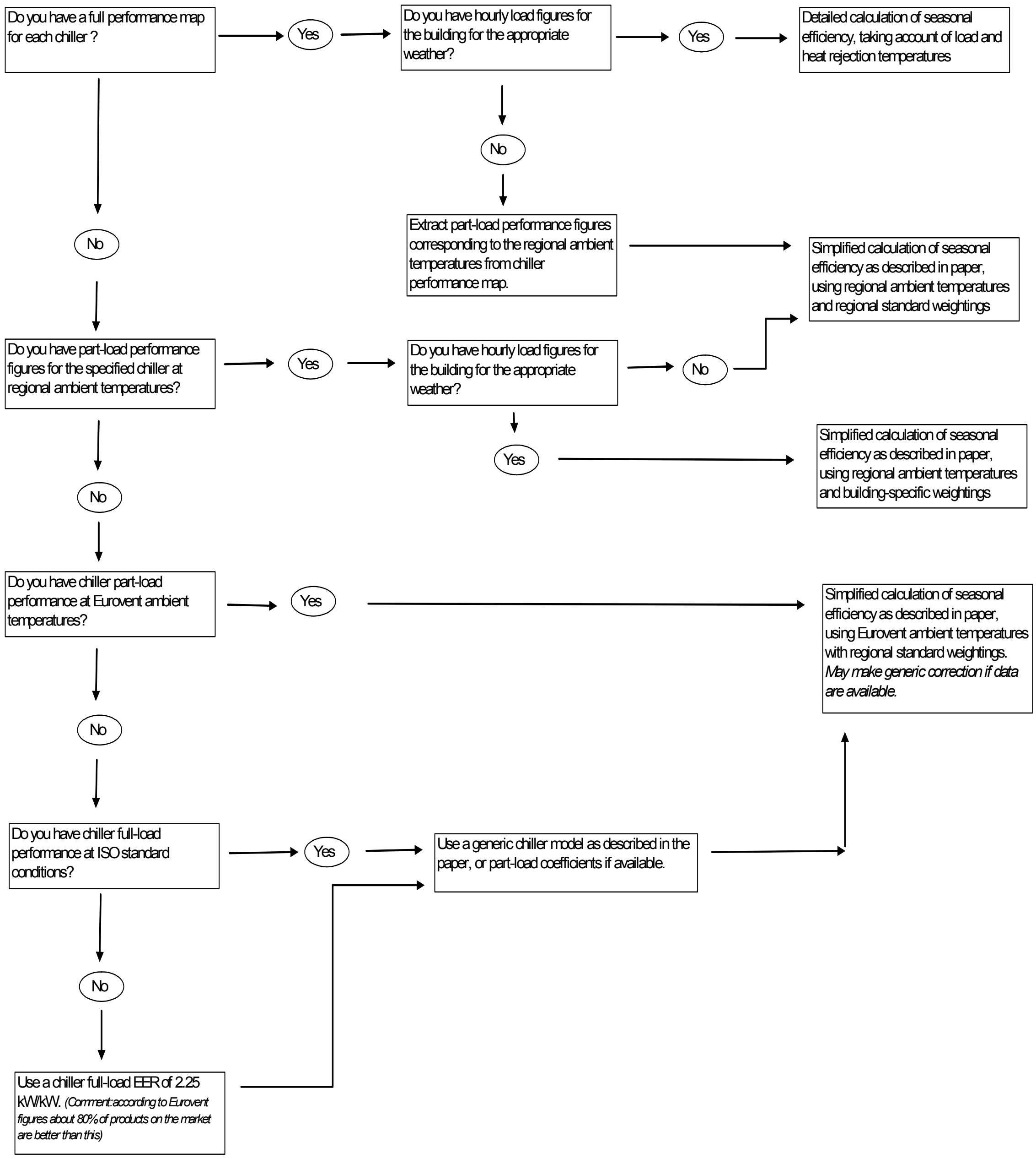

Figure 1. Hierarchy of simplification decisions (the default value shown is for air-cooled chillers)

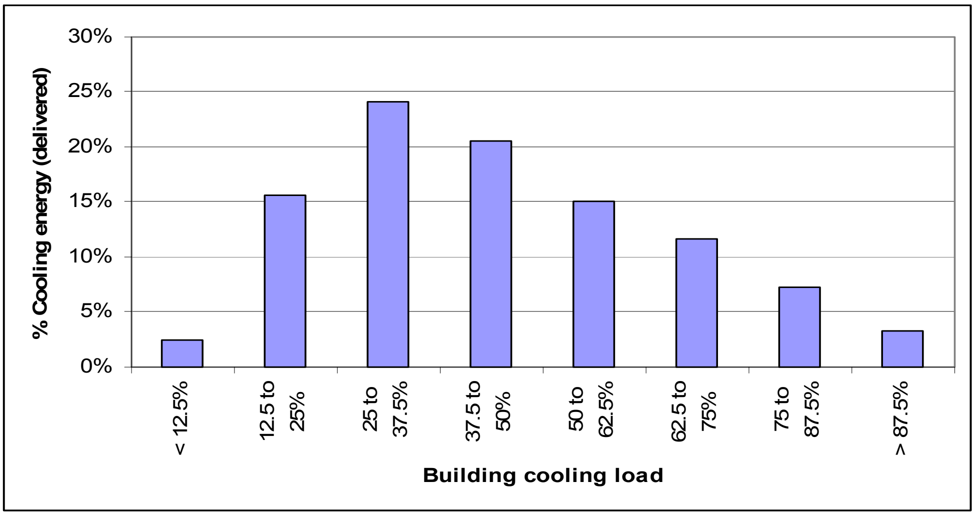

Figure 2. Example building load distribution.

3.3 Approximation of Chiller Performance Data

Ideally the chiller performance should be evaluated at each time step of the cooling demand calculation. This requires a full (and reliable) performance map for the chiller(s) that are installed or proposed. Some manufacturers are able to provide this information, but it is not always publicly available nor independently verified.

If a full chiller performance map does not exist, measurements under standard "full-load" conditions and some part-load conditions may be available.

The EECCAC project concluded that a minimum of four demand weightings (each associated with an ambient temperature representing the mean value associated with these load conditions) was necessary to distinguish between chillers of differing performance. The US IPLV rating (4) also uses four part-load conditions. Values were determined by the EECAC project for a range of climates and systems. For a fan-coil system located in London, they were:

Table 3 Example Demand Ratings

Relative frequency of occurrence (% of operating hours)	Cooling demand as percentage of design load	Relative demand weighting (frequency of occurrence x proportional demand)	Mean ambient temperature associated with demand
60.8%	25%	42.3 %	16.1
34.9%	50%	48.5 %	20.1
4.2%	75%	8.7 %	24.6
0.2%	100%	0.5 %	27.6

There are several existing and proposed sources of chiller performance information under conditions other than full load standard test conditions. For example Eurovent is proposing to include part-load tests into its certification programme (5). Draft CEN standard prCEN/TS 14825 describes part-load tests, as does Italian standard UNI 10963. ARI standard 550.590 defines four part-load tests required for the ARI IPLV rating; and the SAVE project EECCAC (12) proposes European tests equivalent to the ARI tests.

The particular temperature conditions prescribed for the part-load tests will not be appropriate for all climates (7) and cannot apply to each individual chiller in a multi-chiller installation with the chillers operating in sequence. Manufacturers may be able to provide sufficient information to interpolate to appropriate national or regional temperatures, where these are known. If this is not possible, data relating to the "wrong" temperatures has to be accepted. A limited number of calculations on the impact of using ESEER temperatures – which reflect Southern European conditions – in the UK suggests that the error will be of the order of 5% to 10%. As it will always be in the same direction (in the UK, better efficiencies, reflecting the lower summer temperatures), the impact on equipment selection choices is probably not great. (With the caveat that chillers with free-cooling capability might be under-valued in cooler climates).

Sometimes only full-load performance under standard test conditions is known. For many new and older chillers this information is available from the Eurovent Certification website (www.eurovent-cecomaf.org). In this case, part-load performance values have to be estimated using generic models. For example using the procedure previously used in ARI standards (8) (current ARI standards require part-load testing), or that proposed by Bettani et al (9). Reference (10) contains standardized part load performance factors for several types of chiller and room conditioner.

When no information is known about the chiller (for example in existing systems or in the initial stages of design), it will be necessary to use a default value for full-load performance, and apply the generic part-load estimates mentioned above. From Eurovent certification data the EER of the average European air-cooled air-conditioning chiller is about 2.5. Approximately 80% of chillers have values above 2.25, so this could be a suitable default assumption

3.4 Suggested Data Sources
This section summarises key points from figure 1 and from the preceding discussion.

EER values: in order of preference:

1. Part (and full-) load EERs measured under climatic conditions appropriate to the application. For example, suitable ambient temperatures have been defined for London, Seville and Milan by the SAVE project EECCAC. Some manufacturers have full performance maps of equipment that includes this level of detail, but this information is not always publicly available or independently verified.
2. Part (and full-) load EERs measured under standardised conditions, even though these are not an ideal match for the local climate. Eurovent intends to require such measurements at 25%, 50%, 75% 100% rated output for standardised European conditions for its certification scheme. (5)
3. Measured full load EER in accordance with CEN (and ISO) standards, with default assumptions for part-load performance.

Load frequency distributions: in order of preference

1. Building and system-specific distributions calculated typically from hourly values.
2. Standard national or regional values. For example, the weightings derived for London, Seville and Milan by the SAVE project EECCAC.

4. Illustrative Example of Estimation of Seasonal EER

This example illustrates the processes of:

- determining load frequency distributions
- determining multi-chiller EER from data for single chillers
- mapping the chiller rating data onto the load frequency distribution
- estimating seasonal EER

The general principles illustrated here are applicable to any set of chiller or boiler part-load conditions and sizing. In practice it may be convenient to build the process into software such as a spreadsheet. Suggestions for data sources are made at the end of this section.

4.1 Load frequency distributions
Either from load calculations for a specific building, or a standard national or regional assumption, we have a *frequency* distribution of different fractional cooling loads (where 1 = the peak load). For energy calculations, we need to convert this into an energy demand distribution, by multiplying the frequency by the part-load fraction. This generates a *load-weighted* distribution. In the chart below,

the frequency distribution for an office in the UK is shown as a broken line, and the load-weighted distribution as a solid line.

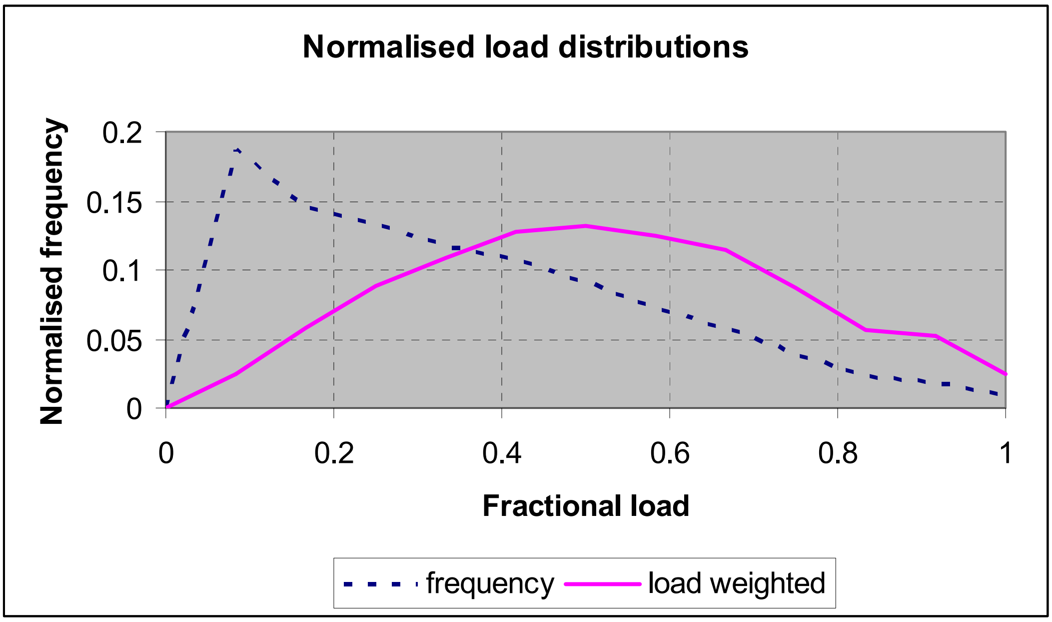

Figure 3: Normalised Load Distribution

For later stages in the calculation, it is convenient to convert the load-weighted distribution into a cumulative distribution as shown below.

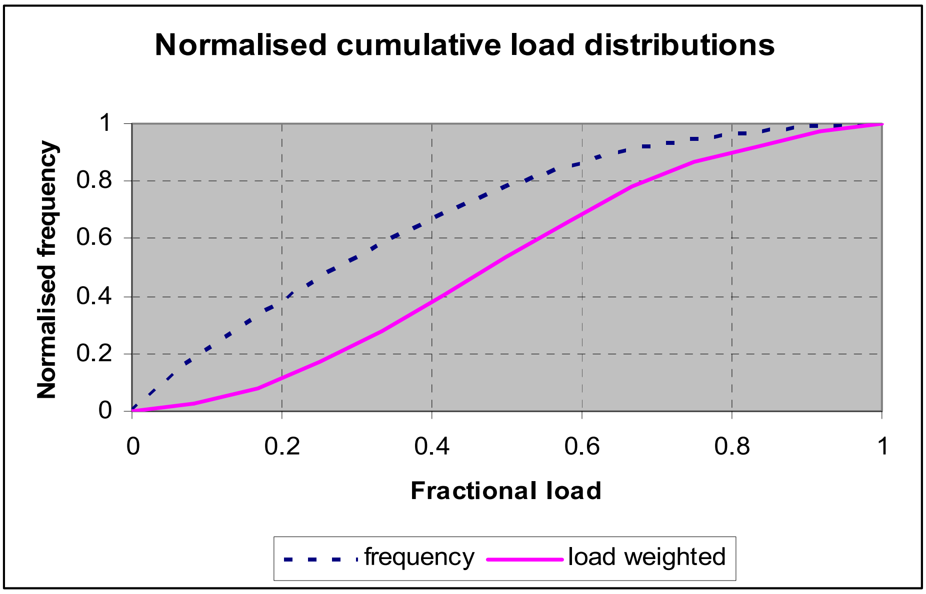

Figure 4: Normalised Cumulative Load Distributions

4.2 Combined chiller performance
In the example, we assume two identical chillers, each capable of providing 75% of the peak load, operating in sequence, each with part-load performance values of

Table 4:

% part-load	EER
100	2.8
75	2.7
50	2.5
25	2.0

With two chillers we therefore have eight combinations for which we can calculate an EER. [5] These are shown in the table below . Because the example system is oversized, three of the conditions are for loads in excess of the peak load.

When both chillers are operating, the combined EER is determined by dividing the relative demand on each chiller by the appropriate EER, summing the total consumption and dividing the result by the total demand.
Thus with 1 chiller operating at 100% output and the other at 25%, we have
Chiller 1 consumption = 1/2.8 = 0.357
Chiller 2 consumption = 0.25/2 = 0.125
Total consumption = 0.482   Combined EER = 1.25/0.482 = 2.59

Table 5:

Chiller 1 fractional load	Chiller 2 fractional load	Chiller 1 EER	Chiller 2 EER	Combined EER
0	0	N/A	N/A	N/A
0.25	0	2.0	N/A	2.00
0.5	0	2.5	N/A	2.50
0.75	0	2.7	N/A	2.70
1	0	2.8	N/A	2.80
1	0.25	2.8	2.0	2.59
1	0.5	2.8	2.5	2.69
1	0.75	2.8	2.7	2.76
1	1	2.8	2.8	2.80

4.3 Mapping the chiller ratings on to the load frequency

Each of these chiller rating points maps onto the building's load frequency distribution, as shown in Figure 5 as solid vertical lines:

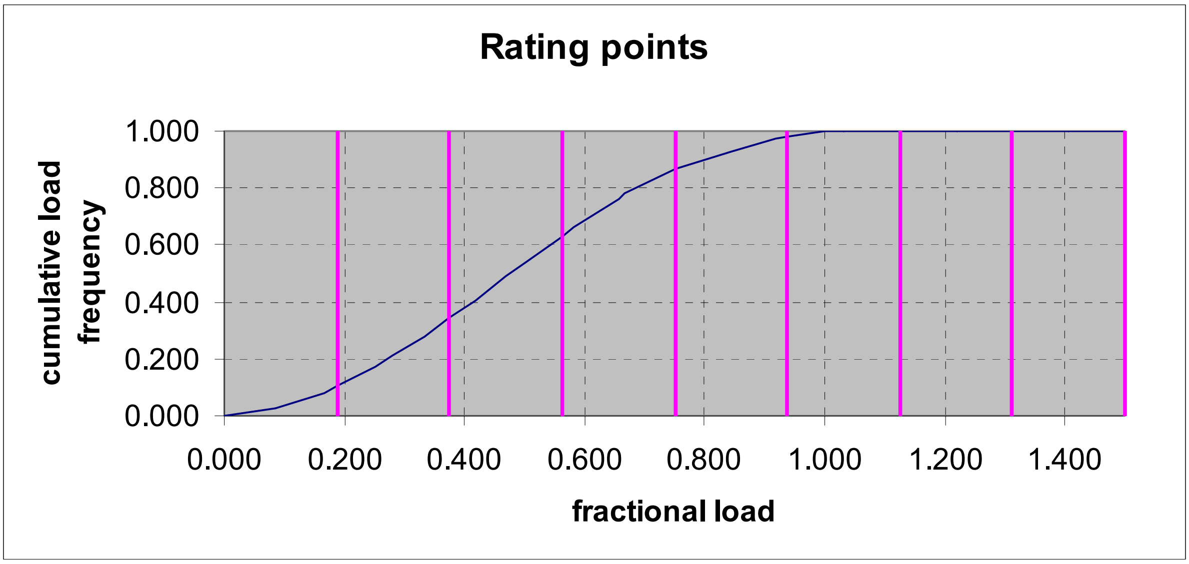

Figure 5

[5] If the chillers do not operate in sequence, the procedure has to be modified accordingly.

We need to associate each rating point with some proportion of the cooling energy demand. We do this by first finding the *building* fractional load that is midway between each chiller rating point. This divides the frequency distribution into a number of bands, each of which contains one chiller rating point. (The lowest band has a lower limit of zero building load). This is illustrated in Figure 6, where the band boundaries are shown as broken vertical lines.

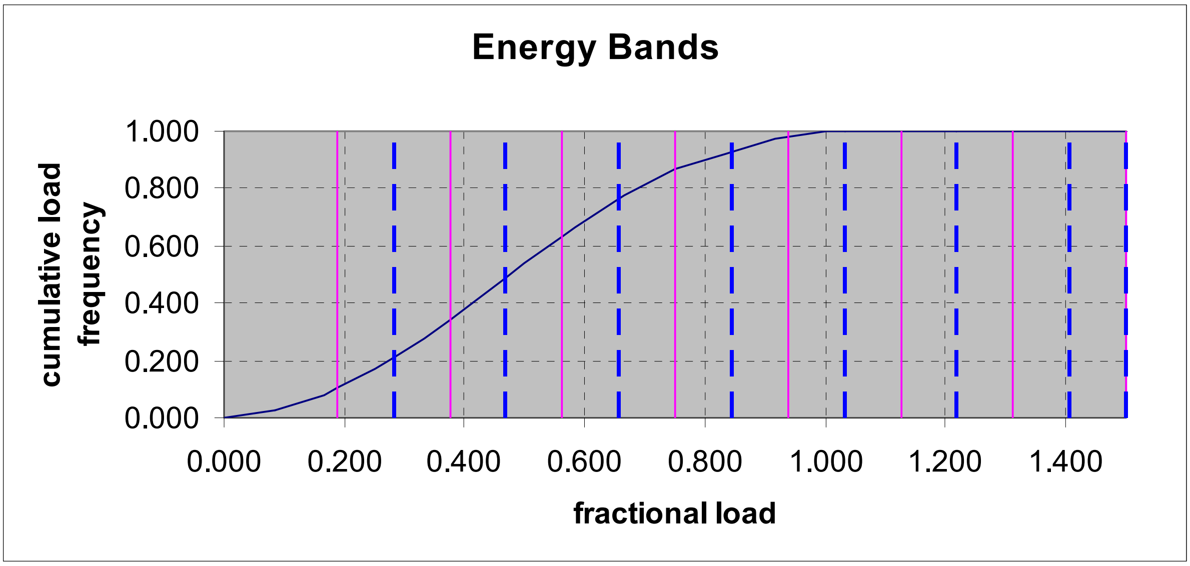

Figure 6

The weighting for each rating point is the difference of the cumulative loads at each of the two boundary conditions. (It may be necessary to interpolate between known values of the load frequency distribution to determine these values).

We then have to divide each demand weighting by the appropriate EER to calculate the total consumption and can then derive the seasonal EER.
The process is illustrated in the table below.

Table 6:

Chiller 1 fractional load	Chiller 2 fractional load	Building fractional demand	Demand weighting for the demand level	Combined EER	Energy consumption
0	0	0	0	N/A	0
0.25	0	0.188	0.104	2.00	0.0520
0.5	0	0.375	0.238	2.50	0.0952
0.75	0	0.563	0.290	2.70	0.1074
1	0	0.750	0.234	2.80	0.0836
1	0.25	0.938	0.115	2.59	0.0444
1	0.5	1.125	0.019	2.69	0.0071
1	0.75	1.313	N/A	2.76	N/A
1	1	1.500	N/A	2.80	N/A

Total (normalised) energy consumption = 0.3897
Combined seasonal EER = 1/0.3897 = 2.57

5. Conclusions

The estimation of the seasonal efficiency of heat and cold generation systems comprising several heat or cold generators is an important component of energy-efficient design and building energy performance certification.

This paper has set out a procedure for doing this calculation. Although the availability of data is improving, in many practical situations, only incomplete data will be available. The paper shows how the procedure may be applied in these circumstances.

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building
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Applying LEED® Internationally: Progress and Lessons Learned

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Overview

Formed in 1993, the U.S. Green Building Council (USGBC®) has as its goal the transformation of the U.S. market to promote buildings that are environmentally responsible, profitable and healthy places to live and work. The primary tool for this transformation has been a national green building standard. In 1998, the USGBC launched Version 1 of its Leadership in Energy and Environmental Design (LEED) Green Building Rating System for new commercial construction. In 2000, the Council launched the revised and updated LEED for New Construction Version 2.0. Now, the LEED program has expanded to a family of products that touch on the many types of construction in the U.S. marketplace. LEED has grown to Version 2.2 of LEED for New Commercial Construction and Major Renovations (LEED-NC), LEED for Existing Buildings, LEED for Commercial Interiors (LEED-CI), LEED for Core and Shell (LEED-CS) currently in pilot, LEED for Homes (LEED-H) also in its pilot program, and LEED-Neighborhood Developments (LEED-ND) currently in development.

LEED-NC, the first and largest of the programs, has had the biggest impact on the U.S. market. The LEED-NC Rating System, while developed for the U.S. market, can be easily applied and adapted for use in other countries. There are several registered and certified international projects in China, Mexico, India, and Canada using USGBC LEED Products. Countries also have the option to license LEED for adaptation to their national/local standards and market. The USGBC is willing to license LEED to organizations in other countries with similar missions and ethos and that are committed to protecting and enhancing the LEED brand. Typically these organizations might be the Green Building Councils of other countries. When LEED is adapted and licensed in this way, the other organization takes on responsibility for liaising with local stakeholders, adapting the standard to local climate, code and practice, promoting and implementing the standard within the Country and keeping the standard up-to-date.

Once the USGBC approves the licensing of LEED to an organization for implementation in their country, support frameworks and organizational structures need to be in place to begin the adaptation process. Often a committee is formed that includes stakeholders representative of the building market to help with the adaptation. Some areas addressed during the adaptation process can include:

- structure of the market
- capabilities and available resources
- climate
- national/local polices, codes, laws, treaties, regulations and other requirements
- design/building practices and traditions
- environmental, social, and economic priorities
- environmental opportunities and challenges
- cultural and historical norms and expectations
- regulatory vs. voluntary traditions
- translation to one or more languages

Any changes to the LEED Rating System during the adaptation have to meet or exceed the performance standards referenced in the USGBC LEED Rating System. After the adaptation is drafted, it must be reviewed and approved by the USGBC.

Once LEED is approved by the USGBC and launched, there needs to be an organizational structure in place to support the implementation in to the market place. This includes procedures and staff or contractors for reviewing projects and issuing certifications, as well as providing support to project teams through workshops and reference materials. The organization licensing LEED also needs to have staff and committees in place to support ongoing refinement and development of future versions.

We have seen the success of the adaptation of LEED-NC in Canada with the launch of the LEED Canada–NC Pilot Program in 2004 by the Canada Green Building Council that offers a Rating System in both English and French. In addition, the India Green Building Council is currently in the process of adapting the LEED-NC Rating System for use in India.

LEED in Canada

The Canada Green Building Council (CaGBC) was formed in December 2002 and Canada's LEED for New Construction and Major Renovations (LEED-NC) 1.0 was launched in December 2004. As of November 2005, there were more than 170 registered projects and 19 certified projects.

Background

Canada had an active green building market prior to the formation of the CaGBC and launch of Canada LEED-NC. In fact, Canada was one of the early leaders in the development of green building assessment systems. The Building Environmental Performance Assessment Criteria (BEPAC) system was published in 1993 by the University of British Columbia, one of the first green building assessment systems worldwide. Canadians Ray Cole, one of BEPAC's developers, and Nils Larsson developed the Green Building Challenge program and its GBTool for building assessment in concert with an international committee, beginning in 1996. GBTool was not intended for use in Canada specifically, but instead was designed as an international framework that could be adapted to any country or region. The UK's BREEAM system was adapted for use in Canada and eventually evolved into Green Globes. Green Globes for Existing Buildings was adopted by the Building Owners and Manufacturers Association of Canada and re-titled BOMA Go Green Comprehensive. At the same time, project teams in Canada have been using the U.S. version of LEED for their projects, with 21 Canadian projects certified by the USGBC.

With this background as a foundation, Canada undertook an analysis of various options and opportunities for developing and implementing a national system for building ratings. This study led to the decision to adapt LEED for use in Canada.

Adaptation

Numerous similarities between the U.S. and Canada facilitated adaptation of LEED. These include the proximity of the two countries, extensive trade across the border, similarities in many industries, architects and engineers with practices in both countries, and similarities in economies and governments. Many people were already familiar with LEED and had used it for projects in the U.S. or in Canada.

On the other hand, differences existed that indicated a need for tailoring of LEED to meet specific Canadian needs or conditions. These differences include[1]

- Geography and population – Canada is very urbanized, with 60% of the population located within less than 3% of the total land area. Most populated areas are near the U.S. border.
- Water resources – Canada has abundant fresh water supplies and relatively low cost for water.
- Climate – Canada has a cold climate in which heating energy is more important.
- Kyoto Accord – Canada has signed the Kyoto Accord and this initiative enjoys widespread support.

[1] Alex Zimmerman, Cross-cultural Lessons from LEED Adaptation for Canada, pages 3-8

- Natural resources and land claims – Some natural resources are covered by outstanding land claims by first nations peoples in British Columbia; long-standing disputes affect resource-based credits, such as wood.
- Manufacturing and supply chains – There are few large manufacturing operations in Canada for building materials, and most that require a large investment are imported from the U.S. and other countries.
- Electric utilities – Hydro is the dominant fuel for electricity generation although there are regional variations.
- Incentives programs – The government's Commercial Buildings Incentive Program provides cash for anticipated energy savings.
- Trade among provinces – An Agreement on Internal Trade requires that goods and services be treated equally, irrespective of where they originate in Canada.
- Standards – Canada has different national and local standards and codes which were favored as references to replace US standards.

These differences led to changes in credits for water efficiency, energy and atmosphere, and materials and resources. Examples of changes included the following:

- Water efficiency
    - Changed to delete references to the U.S. Energy Policy Act.
- Energy and atmosphere
    - Raised the performance level in the minimum performance prerequisite to address the importance of energy efficiency in Canada's severe climate. This prerequisite was also aligned with the Commercial Buildings Incentive Program through an alternative compliance path. The CaGBC contracted for an analysis comparing the Canadian standard with the ASHRAE standard referenced in the U.S. LEED.
- Materials and resources
    - Added a credit for building durability due to severity of winter climate.
    - Deleted the credit for regional materials due to constraints of the Agreement on Internal Trade governing trade among provinces.

Some issues could not be dealt with in this adaptation. First, Canada wanted to use reduction in Greenhouse Gas emissions as the basis for energy credits. During the public comments, however, the issue of regional differences in fuel sources for the electricity grid, which would affect the cost of obtaining the credit and its value, was raised. Since LEED does not currently have a mechanism for handling regional differences, CaGBC could not undertake the restructuring of credits that would be needed. Another issue that could not be resolved was wood certification. Obtaining FSC certification for some forestry operations in British Columbia on lands owned by first nations peoples is not currently feasible, so this materials credit has become almost a "show stopper" for endorsement of LEED by the government.

The CaGBC took about 6 months to complete its first draft adaptation of LEED; it then took the USGBC 8 months to approve the draft. There was considerable discussion between the CaGBC and the USGBC Technical Advisory Groups on several credits. The TAGs are charged with maintaining the rigor of LEED in adaptations and they reviewed carefully several of the proposed changes. Since this was the first licensing process, there were also policy questions within the USGBC that had to be resolved, such as the issue of adding a credit (on durability).

Ongoing Development

The CaGBC recognizes that an effort to adapt all U.S. LEED products (such as LEED for Existing Buildings and LEED for Commercial Interiors, which are now available; LEED for Homes, Neighborhood Development, and Core and Shell, which are in development; as well as Application Guides for Schools, Labs, Retail, and Healthcare, which are also in development) would be enormous and probably prohibitive in its resource requirements. In addition, from its outside perspective, the CaGBC is able to learn from the USGBC experience. As a result, the CaGBC is going through a process of considering various options for its future work. It has developed an Application Guide for Multi-Family Residential buildings and is working on an adaptation of LEED for Commercial Interiors that involves minor changes and translation into French. It does not plan to duplicate the suite of products found in the US and it is open to considering systems other than LEED. Currently, the CaGBC is looking toward developing a framework that is adaptable to different building types, scales, life cycles, and climates – a database of credits.

LEED in India

The India Green Building Council (IGBC) was formed in 2001 with LEED licensed in 2003. India's LEED for New Construction and Major Renovations (LEED-NC) v2.1 Rating System will launch in January 2006.

Background

The CII-Sohrabji Godrej Green Business Centre, home to the India Green Building Council, is India's first USGBC LEED-NC registered project (in 2001) and is also India's first certified project earning LEED-NC v2 Platinum on October 2003. The process of working with LEED allowed for a "rediscovery of the Indian ethos" according to a representative of the India GBC. These five elements of nature (Panchabhutas) are:

Five Elements:	Five Sections of LEED:
Prithvi (Earth)	Sustainable Sites
Jal (Water)	Water Efficiency
Agni (Energy)	Energy Efficiency
Vayu (Air)	Indoor Environmental Quality
Akash (Sky)	Daylight, Night Sky Pollution

As the number of USGBC LEED registered and certified projects in India grew from 2003 to 2005, a doubling of projects, the understanding and experience of working with LEED grew and the India GBC realized that most of LEED was applicable in the Indian context. For example, USGBC's LEED-NC Rating System references ASHRAE 90.1-1999 for the energy standard. The Indian building community also follows the ASHRAE standard for designing energy systems; therefore there was no need to change this standard. Despite the many similarities, the India GBC felt that the U.S version of LEED-NC needed to be fine-tuned to meet National priorities like water conservation, easing the load on infrastructure in urban areas, and safety aspects in a building, so they decided to license LEED.

Adaptation

With so many LEED points applicable in India, there was little change to the LEED-NC Rating System resulting in a fairly easy adaptation process. Four of the five sections of LEED had changes. They are:

- Sustainable Sites: the Urban Redevelopment and Alternative Transportation, Bicycle Storage and Changing Room credits were deleted.
    - Urban Redevelopment was deleted because the national priority is to divert development away from urban areas which are already saturated.
    - Alternative Transportation, Bicycle Storage & Changing Room was deleted because bicycle storage is already required in buildings.
- Water Efficiency: a credit was added for Water Efficiency in Air-conditioning System, Reduce by 50% and Reduce by 75%.
    - The new credit intent is intended to limit or eliminate the use of potable water for air-conditioning make-up.
    - The requirement is to use captured or recycled site water to reduce potable water consumption for air conditioning make up by 50% and 75%.
- Energy and Atmosphere: Modified Green Power Credit
    - All of the credits in the Energy and Atmosphere section of LEED are directly relevant in the Indian context. However, a green power mechanism is not in place. Hence this credit has been modified so that investments by a company anywhere in the country will be

recognized. Projects are encouraged to invest in off-site renewable energy technologies to be exported to the grid.

- Indoor Environmental Quality: Two new prerequisites
    - Building Safety: the intent is to protect both the construction employees and building occupants from any safety hazards and provide a better place to live.
    - Emission Reduction in Captive Power Plants: the intent is to protect the environment from emissions from captive power generators in the building and provide a better environment for the building occupants.
        - Most buildings in India have their own captive generation. Hence emission levels from captive generators need to be limited with in the prescribe limits of the National Pollution Control Board.

With the adaptation process complete, 2006 is the year of implementation. The India GBC will spend 2006 accepting registrations for India LEED, developing the support structure for handling project reviews and certification, developing workshops, and developing the technical structure for India LEED projects online and supporting databases. During this 2006 transition the USGBC will support the India GBC with help on technical issues, project reviews and certifications, and training of Workshop faculty and India GBC project reviewers. By 2007 the India LEED will be 100% supported by the India GBC.

Ongoing Development

The LEED rating system in India has created tremendous enthusiasm amongst the stakeholders. From 20,000 square feet of LEED rated buildings in the year 2003 to about 5 million square feet of buildings to date registered for the USGBC LEED rating. After the full implementation of India LEED, the India GBC will look to license other LEED products to accommodate the growing green building market and demand.

LEED in Other Countries

There are several countries currently using USGBC's LEED products. Mexico has one certified and two registered projects with LEED-NC. China has projects using LEED-NC and LEED-CS with two certified and four registered LEED-NC projects and one certified and three registered LEED-CS projects. In addition, Brazil has two registered projects, one using LEED-NC and one using LEED-EB, Spain has one registered project using LEED-NC, and Japan has one registered project using LEED-NC.

International projects can register with USGBC LEED and use the experience of applying one of USGBC's LEED Rating Systems to a project to help make the decision as to whether or not LEED is a good fit and whether or not to pursue the license of LEED or to adapt one of the other green building rating/assessing tools such as Green Star in Australia, CASBEE in Japan, BREEAM in the UK, or others.

Lessons Learned

Experience gained in adapting LEED provides useful lessons. There are many benefits from adapting an existing system, such as LEED. There are also cautions, however, and pitfalls to be avoided.

1. Adaptation of LEED, or another existing rating system, enables countries to implement a rating system without investing the enormous resources needed to develop the system itself and its associated supporting materials (reference guides, workshops, communications tools) from the ground up – most do not have the financial or volunteer human resources needed. Although significant effort is required to perform a careful analysis and adaptation, it is far less than starting with nothing. This approach enables most countries to take the first step.
2. Adaptation allows countries to take advantage of the experience of others in testing and revision of the system and its credits – using the lessons learned elsewhere. In the US, LEED has evolved through significant changes since the first version was introduced, based on testing and feedback on what was working and what could be improved. This process has supported ongoing refinement of the system and validation of its prerequisites and credits.
3. It is difficult if not impossible to adapt some credits to meet conditions of another country. In some cases, these inapplicable credits might be deleted from the system; in other cases, the USGBC has insisted that they be retained to support the structure or rigor of the LEED system. This can

limit the adaptability of the system and result in a mix of credits that is not optimal for local conditions.

4. Adaptation is not only about technical issues – the cultural, organizational and social context as well as market factors are also important and cannot be ignored. LEED was developed for the specific market in the US; in other markets with different characteristics, this foundation might not be as appropriate.
5. The LEED "brand" lends credibility to a rating system and some people might try to minimize adaptation to retain that brand credibility rather than optimizing the system for their context. The USGBC's rules for adaptation do not encourage large-scale changes, which supports this approach.
6. LEED is not always the best fit for a country, using different assessing/rating tools is important when deciding what to develop for your country. Some countries are now developing systems that take the "best" from various available approaches. It will be interesting to explore the lessons that will be learned from these resulting hybrid systems.

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EPLabel: a graduated response procedure for producing a building energy certificate based on an operational rating

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Abstract
Governments are sensitive to accusations of creating unnecessary red tape and "gold plating" European Directives. However, in practice a minimum implementation of the Energy Performance of Buildings Directive (EPBD) could be more disruptive than a well-integrated one: some annoying hurdles to jump, instead of an integrated driver of continuous improvement.

This paper describes the key steps in the procedure for the energy certification of non-residential buildings on the basis of their actual annual energy use – the Operational Rating. It proposes robust and pragmatic ways to implement the steps, with sufficient flexibility to accommodate national diversity whilst seeking the harmonisation the EC desires. It indicates how energy reporting and assessment might be approached in a series of Levels: each Level adding more detail, providing more insight and potentially superseding the Level below, but requiring more stringent verification procedures. For example, building energy benchmarks might be at three unified levels of sophistication: simple (derived from stock statistics), corrected (for special energy uses not included in the simple benchmarks) or customised to take into account the building's schedule of accommodation, activities and use.

Such a 'graduated response' allows a progressive introduction of EPBD Article 7.3 to suit the knowledge available in each country/region for each building sector and the level of resources an organisation is able to apply: an easy entry level is proposed for cases where detailed information is hard to get or may be less rewarding, whilst more detailed assessment is suggested where the need and scope for improvement is greater, all within a cohesive framework which makes assessments at different levels as mutually consistent as possible.

Project background
The EPLabel project addresses the EU Energy Performance of Buildings Directive (EPBD) Article 7.3: the requirement for 'Public Buildings' over 1,000 m² to display an Energy Certificate prominently, OJEC (2003) and is supported by the EC's Intelligent Energy for Europe (EIE) SAVE programme. It started in January 2005 and finishes in early 2007 and involves nineteen countries, ten with full Partners[1], See www.eplabel.org for further details.
The project's main technical objective is to develop a methodology for energy benchmarking and certification based on Operational Ratings (actual annual energy consumption), offering sufficient flexibility to accommodate national diversity whilst seeking the harmonisation the EC desires. It covers the following six sectors:

- Public administration offices,
- Higher education (Universities, Colleges),
- Schools,

[1] The project Co-ordinator is the UK Partner, Energy for Sustainable Development Ltd, who are supported by sub-contractors Target Energy Services, William Bordass Associates and the Association for the Conservation of Energy. The project is part funded in the UK by a Government Ministry (ODPM) and Constructing Excellence. The other partners are BBRI (Belgium), Energiereferat Frankfurt (Germany), Esbensen (Denmark), CSTB (France), NKUA (Greece), NUID (Ireland), DHV (Netherlands), Enerma (Sweden) and Motiva (Finland).

- Sports facilities,
- Hospitals and other health facilities,
- Hotels and restaurants (to take account of residential and catering facilities in the public sector).

In 2002-04, EPLabel's predecessor Europrosper (see www.europrosper.org) reviewed the potential for Operational Ratings, developed a prototype procedure for offices, and contributed to draft CEN standards. EPLabel intends to demonstrate a robust, pragmatic procedure which can assist Member States to phase in Operational Ratings over the three years from 4 January 2006, permitted by the Directive.

Energy certification based on operational ratings

There are five key steps to energy certification based on an Operational Rating:
1. Collect quality data and calculate the building's Energy Performance Indicator (EPI).
2. Identify appropriate benchmarks with which the EPI can be compared.
3. Grade the energy efficiency of the building by comparing the EPI with the benchmarks.
4. Identify cost-effective energy saving measures.
5. Collate all the relevant information onto an energy certificate, possibly of several pages with the first page being on display to the public.

Each of these steps can be undertaken with different degrees of rigour. Following a review for the UK's Sustainability Forum, Bordass (2005), the project is developing a graduated response which permits a progressive introduction, to suit both the knowledge available for each building sector and the resources an organisation is able to apply. For example, there can be an easy entry level for cases where few if any benchmarks are currently in use, plus more detailed assessments where current knowledge is more advanced, including customised benchmarks based on schedules of accommodation and usage. The opportunity to work at different levels of sophistication even applies to the mundane task of measuring annual energy consumption (must the value be metered over precisely 365 days?) or a building's floor area (should it be professionally measured on site, calculated off plans, or estimated by some other means?).

Energy reporting and assessment can be undertaken in a series of Levels: each Level adding more detail, providing more insight and potentially superseding the Level below, but requiring more stringent verification procedures. Figure 1 shows how different Levels of benchmarking might be introduced progressively in different sectors in one country, within a single integrated system. Efficiency would be improved by collecting only the information essential to an effective evaluation, allowing its adequacy to be reviewed continuously, and including provision for accredited persons to sign-off critical data. Information collected could also go into a database; and the statistics could be used to drive the continuous improvement of the system and the associated benchmark data.

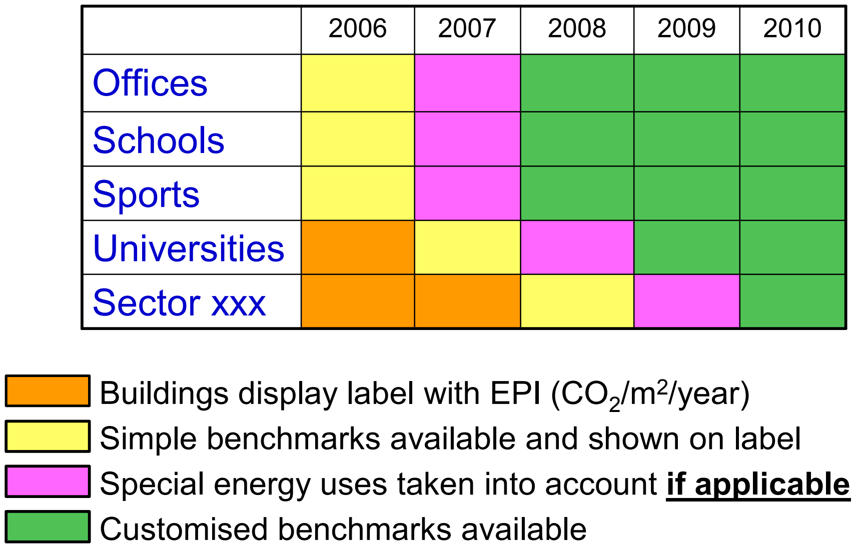


Figure 1 Notional illustration of the graduated response across different building sectors

Step 1. Determining the EPI

The measured Energy Performance Indicator (EPI) is defined by a draft CEN Standard (CEN prEN 15203, 2005) as the weighted sum of the actual annual consumption of all energywares (also called the Operational Energy Rating) divided by the building's total conditioned floor area. Both the rating, representing the absolute total impact of the building's energy use and the indicator, representing the building's energy intensity, should be reported.

A large amount of the time and effort in energy surveys can often be taken up by the tedious task of getting hold of reliable annual fuel consumption data. Frequently meter readings are estimated (and may not even be available for "new" buildings[2]), bills are never seen on site, accounts are aggregated for corporate customers, and records are kept in money - not classified by energy source. In a streamlined certification procedure, such data collection overheads will be completely unacceptable. Instead, we recommend a statutory requirement that energy suppliers make records readily available, e.g. with annual statements of each energyware[3] delivered to each supply point, where possible based on actual readings a year apart, with automatic estimation of 365-day requirements otherwise.

Article 13 of the forthcoming Energy End Use Efficiency and Energy Services Directive (ESD), contains a general requirement about the information energy suppliers collect from their energy meters and provide to their customers. The Article could easily be used to create the legislation necessary to mandate annual energy statements. This information also needs to be readily accessible to accredited energy assessors, ideally electronically, or perhaps from a log book kept on site.

Each country's energy certification scheme would need to include weightings for each energyware, in order to allow for their carbon dioxide emissions, primary energy, cost, or other parameters defined by national energy policy. Guidelines given in CEN Standard (CEN prEN 15217, 2005) recommend taking into account the 'upstream' overheads (e.g. extraction, processing and transport) in delivering energy to a building. They also suggest ways to handle multi-plant generation systems (e.g. grid

[2] In the Probe post occupancy studies undertaken by the authors in the UK from 1995 to 2002 and in some office case studies before them, verified fuel bills were not always available from the suppliers two or three years after the completion of a building. Anecdotal evidence suggests that the situation has not improved since.
[3] Energywares are tradable commodities used mainly to produce mechanical work or heat, or to operate chemical or physical processes, and listed in Annex A of ISO 13600. Examples are oil, gas, coal, grid electricity, and district heating.

electricity and district heating) where the weightings might represent the annual average for the system or the marginal value (e.g. in electricity grids where the demand from buildings is not likely to affect the operation of base-load stations (often nuclear)). This marginal value may even be specific to different building energy end uses where these are more likely to occur at specific times of day or seasons of the year.

There will be sufficient flexibility in the EPLabel method to cater for a wide range of weighting permutations. As well as a choice of different weighting parameters, to assist comparisons there will be the option for weights to represent average EU values, national or regional values (ideally the 'official' ones) or local values, specific to the energy supplies for the building being assessed.

For buildings with active renewable energy systems[4], the same CEN Standard also recommends reporting the net weighted delivered energy that would be used if the renewable energy systems were not present. The result, the Building Energy Use (BEU – see Figure 2), is more useful when considering the scope for energy saving measures. In calculating the BEU, the weighting factors applied to any renewable energy supplied should be those of the non-renewable sources that are being displaced, for example, grid electricity in the case of renewable electricity. To illustrate the calculation of BEU under various circumstances, Table 1 illustrates four cases for an office building:

1. Supplied by mains gas and grid electricity;
2. With a pv system displacing some of the grid electricity;
3. With a wind turbine, from which surplus electricity is exported from time to time;
4. With some of the mains gas displaced by solar thermal heat.

In each case the BEU remains the same, whereas the EPI (and Operational Rating) are markedly different.

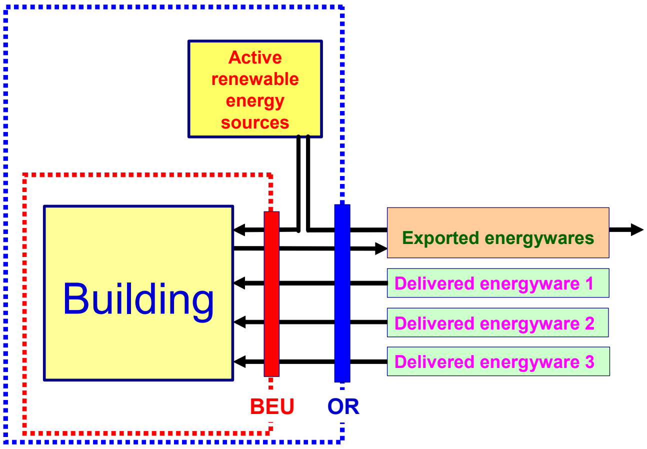


Figure 2 Energy performance indicator and building energy use

Table 1 Example calculations of the EPI and the BEU

Case 1: office building with gas and electricity supply	Units	Fuel Gas	Grid electricity Imports	Grid electricity Exports	Renewables Solar PV	Total weighted energy
Total delivered quantity	kWh/m^2/year	178	226		0	
Exported quantity	kWh/m^2/year	0		0		
Quantity used in building	kWh/m^2/year	178	226			
Weighting factor for EPI	kgCO2/kWh	0.194	0.422			
Energy Performance Indicator	**kgCO2/m2/yr**	**34.5**	**95.4**			**129.9**
Weighting factor for BEU	kgCO2/kWh	0.194	0.422			
Building Energy Use	**kgCO2/m2/yr**	**34.5**	**95.4**			**129.9**

Case 2: as Case 1 but with a PV system	Units	Fuel Gas	Grid electricity Imports	Grid electricity Exports	Renewables Solar PV	Total weighted energy

[4] Sometimes these renewable sources are not physically attached to (or owned by) the building: a wind turbine might be a kilometre away, connected by a 'private wire'. Similarly, a building may use (or be sold) the electricity produced from a PV array on an adjacent building or car park (which does not need the electricity).

Total delivered quantity	kWh/m^2year	178	190		36	
Exported quantity	kWh/m^2year	0		0		
Quantity used in building	kWh/m^2year	178	190		36	
Weighting factor for EPI	kgCO2/kWh	0.194	0.422		0.000	
Energy Performance Indicator	**kgCO2/m2/yr**	**34.5**	**80.2**		**0.0**	**114.7**
Weighting factor for BEU	kgCO2/kWh	0.194	0.422		0.422	
Building Energy Use	**kgCO2/m2/yr**	**34.5**	**80.2**		**15.2**	**129.9**

Case 3: as Case 1 but with a large wind turbine	Units	Fuel	Grid electricity		Renewables	Total weighted energy
		Gas	Imports	Exports	Wind	
Total delivered quantity	kWh/m^2year	178	40		336	
Exported quantity	kWh/m^2year	0		150		
Quantity used in building	kWh/m^2year	178	40	-150	336	
Weighting factor for EPI	kgCO2/kWh	0.194	0.422	0.422	0.000	
Energy Performance Indicator	**kgCO2/m2/yr**	**34.5**	**16.9**	**-63.3**	**0.0**	**-11.9**
Weighting factor for BEU	kgCO2/kWh	0.194	0.422	0.422	0.422	
Building Energy Use	**kgCO2/m2/yr**	**34.5**	**16.9**	**-63.3**	**141.8**	**129.9**

Case 4: as Case 1 but with a solar thermal system	Units	Fuel	Grid electricity		Renewables	Total weighted energy
		Gas	Imports	Exports	Solar thermal	
Total delivered quantity	kWh/m^2year	148	226		24	
Exported quantity	kWh/m^2year	0		0		
Quantity used in building	kWh/m^2year	148	226		24	
Weighting factor for EPI	kgCO2/kWh	0.194	0.422		0.000	
Energy Performance Indicator	**kgCO2/m2/yr**	**28.7**	**95.4**		**0.0**	**124.1**
Weighting factor for BEU	kgCO2/kWh	0.194	0.422		0.2425	
Building Energy Use	**kgCO2/m2/yr**	**28.7**	**95.4**		**34.5**	**129.9**

Step 2. Identifying benchmarks

In order to judge whether or not a building's energy performance indicator represents good energy efficiency, the EPI needs to be compared with something. Measured or Operational Ratings, being based on the (weighted) energy a building actually uses are normally compared with *benchmarks,* usually derived from the measured performance of the building stock. There are two primary mechanisms for generating benchmarks:

- Using statistics: the 'population' is divided into bands containing equal numbers of buildings e.g. quartiles. For example, the US Energy Star rating is awarded to buildings in the top (lowest energy) quartile of the distribution of all assessed buildings. Many UK publications for benchmarking buildings have also used quartiles. Performance in the best quartile is often termed Good Practice, and the worst quartile is regarded as Poor. Others use the top and bottom 15th percentiles to define Best and Worst Practice; though in our experience many records near both ends of the distribution include faulty data. Other problems with statistical benchmarks are:
    - Getting started. Few countries[5] have reliably measured energy data available for more than a very small sample of a sector's building stock.
    - Getting the contextual data right, in terms of the classification of the building, its systems and its use. This is a big problem even for the large raw statistical databases, though this is eased where the stock is relatively homogeneous in its purpose and use (e.g. primary schools). For example, benchmarks tend to divide annual energy use by floor area – for good practical reasons. However, areas are not always accurately measured. In addition, modern commercial buildings tend to use their floorspace more efficiently and intensively: so a high energy use in relation to a benchmark based on historic statistical data may not necessarily mean inefficient.
- On a parametric basis, the system used by "ECON 19" in the UK (Action Energy, 2003) which sets Good Practice[6] and Typical benchmarks for four types of office building based on standards

[5] Denmark and Finland are exceptions.

for the energy efficiency of each energy end use. Parametric benchmarking is powerful because in the absence of stock statistics, you can still create a benchmark. The benchmarking process can also begin to tell you not only whether a building is efficient, but also what components of its energy performance are likely to need attention.

The component-based values used in parametric benchmarking are related to iconic descriptions of stereotypical buildings in a sector: the building's schedule of accommodation (often simplified to principal "activity areas", e.g. cellular offices, open-plan offices, restaurants), typical levels of occupancy and equipment and the hours of use. The principal parameters in this method can be summarised using the energy tree diagram (Figure 3), which goes down to the roots of consumption – separating out the asset (standards and efficiencies), and operational (use, control and management) elements of energy use (CIBSE 1999). Benchmark values can then be reported not just for the building as a whole, but also for each energy end-use (e.g. lighting), and their components. This allows benchmarks to be re-computed if necessary to suit genuine differences, e.g. a building with a different set of activity areas or energy end-uses; or a higher intensity of use. The tree diagram description also suits "what-if" calculations, e.g. estimating the likely savings if the installed power density of the lighting was halved.

The example in Figure 4 illustrates the components of the published annual electric lighting energy use benchmarks for a standard "Type 3" air-conditioned office in the UK (ECON 19). Typical and Good Practice criteria are provided not just for the annual electricity consumption, but for each contributory element i.e. the light level, the efficiency of the lamps and luminaires, the hours of use and the control and management factor (which includes assumptions about the availability of daylight).

We can combine together similar analysis for each end use in each area of this typical building to produce total energy benchmarks assuming performance at Typical or Good Practice level.

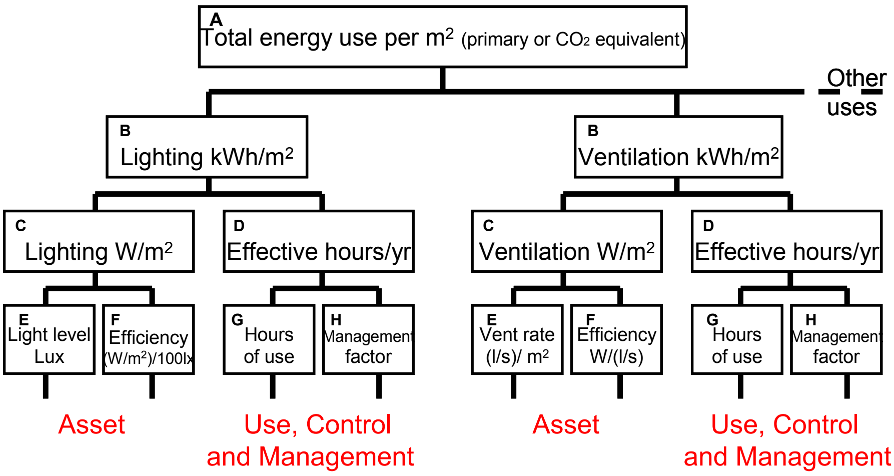
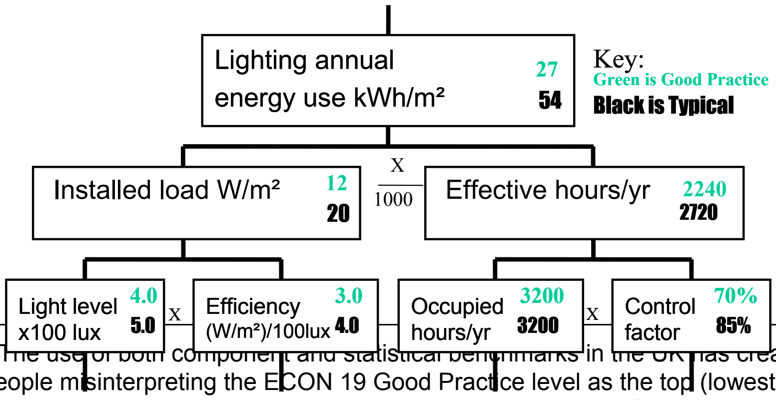


Figure 3 The Tree Diagram description of a building's annual energy use



6 The use of both component and statistical benchmarks in the UK has created some confusion, with many people misinterpreting the ECON 19 Good Practice level as the top (lowest energy) quartile. In fact ECON 19 Good Practice is a parameter based benchmark achieved by few buildings (less than 5 to 10%) because the criteria apply to all energy end uses and not many buildings are Good on all fronts.

Figure 4 Using the tree diagram to summarise the benchmarks for lighting in an office

Bringing statistical and parametric benchmarks together

Parametric benchmarks allow one to get going on a useful system without having all the statistics, whilst statistical benchmarking is practical where good quality bulk data are available, but parametric components have yet to be defined. As mandatory energy certification becomes required across so many sectors; and where there are large variations in knowledge about energy performance (both by building type and by country), we need to combine the insight achieved by using the parametric approach and the practicalities of the statistical one. In fact, the two approaches can complement each other as shown below. If the data collected during energy certification are also stored and managed well, the whole system can become self-improving.

Statistical and parametric benchmarks can be directly linked at the median, as illustrated in Figure 5. One can associate and then reconcile the tree diagram breakdown of typical energy consumption for the stereotypical building with the energy performance of the stock median. Ideally the stock statistics will either exclude buildings with ‘special’ substantial energy uses (e.g. a swimming pool at a school), or the sample size will be sufficiently large and the incidence of these specials relatively low, so that their influence on the median will be negligible.

Once the parametric benchmark Typical performance has been aligned with the statistical median, one can then define good (and poor) energy efficiency values for each tree diagram element – for a building with identical facilities in identical use, but with proven good (or poor) practice technical and management features. For the UK office benchmarks (ECON 19), Good Practice criteria were related to proven outcomes in case studies of energy efficient offices (EEO, 1995) using simple, available and cost-effective technical and management techniques. The result is Good (and Poor) Practice benchmarks for the total energy use of this building type. These values can then be compared with the statistical distribution for the stock’s energy performance, if this is available, as shown in Figure 5, to identify the corresponding percentiles. The UK Good Practice values in ECON 19 proved to be considerably more stringent than the lower energy quartiles, because although verified by actual energy use in case study buildings which performed even better, few buildings are good in all departments at the same time. However, in our view this does not mean that Good Practice criteria should be loosened, it merely demonstrates the major potential for reducing energy use and carbon dioxide emissions; and the need to challenge people to achieve them.

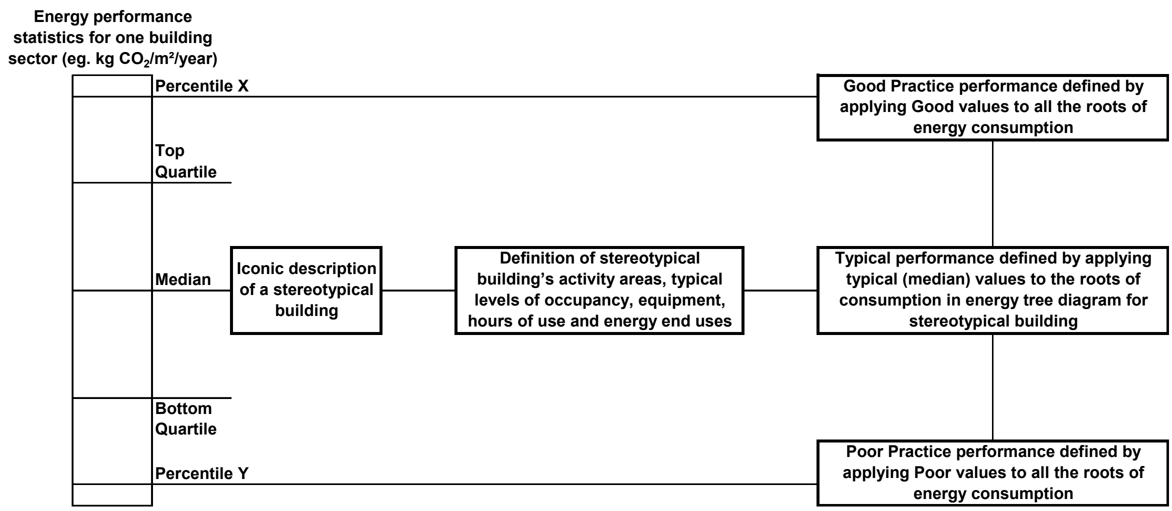


Figure 5 Bringing together the statistical and parametric approaches

For building sectors or sub-types where reliable statistics are not available, appropriate parametric descriptions and benchmarks can still be created *ab initio,* by professional judgement of what constitutes an iconic building type, and what parameter values should apply for both Typical and Good Practice performance. Ideally such judgments will be supported by good quality empirical data on annual energy consumption by end use from energy surveys and case studies. The EPLabel project is planning to build benchmark generators which can assist with this approach. The more the theoretical description can be calibrated against real-world data, the more robust it can become.

Once parametric descriptions have been established, it is also straightforward to apply the same benchmark generator that produced the Typical and Good Practice benchmarks for the iconic buildings to a customised description of an individual building (i.e. using its specific activity areas, occupancy, etc.) and hence produce benchmarks customised to this building (see Figure 6). This approach was demonstrated for offices in the SAVE-Europrosper project, see www.europrosper.org .

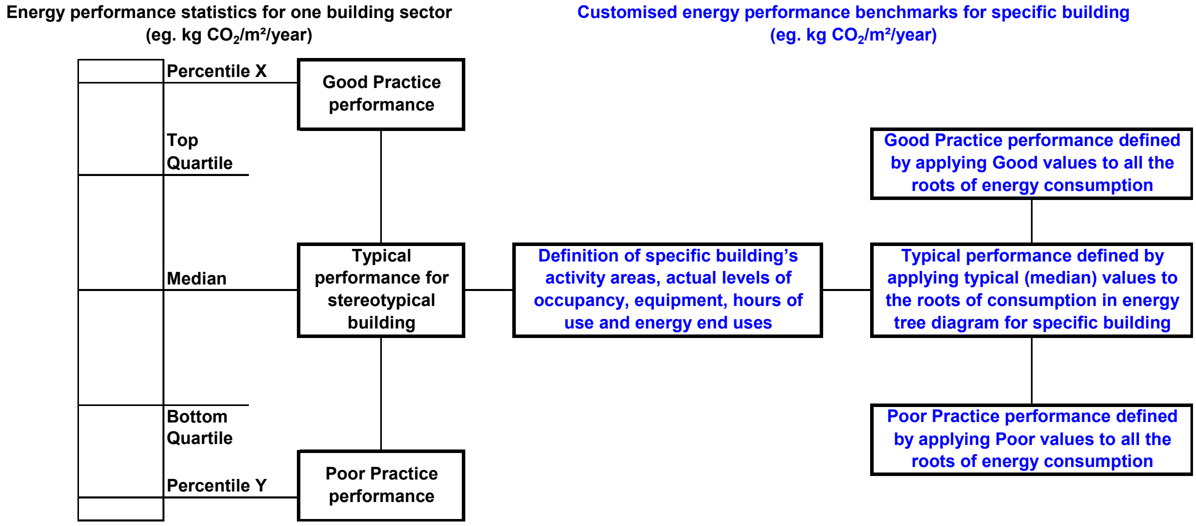
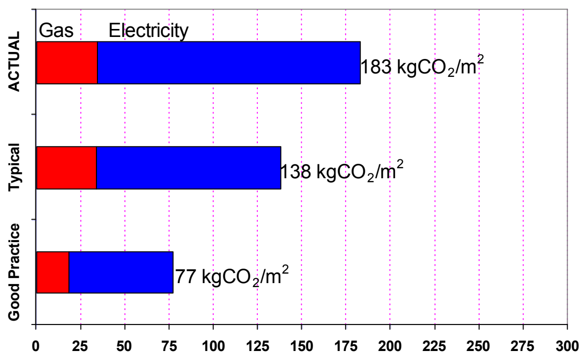
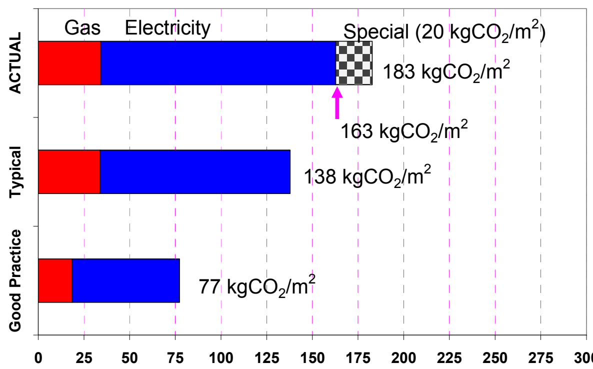


Figure 6 The linkage between statistical and parametric component-based benchmarks

EPLabel plans to apply the above analysis in a unified scheme for the benchmarking of Operational Ratings at three levels of sophistication, as illustrated in Figure 7.



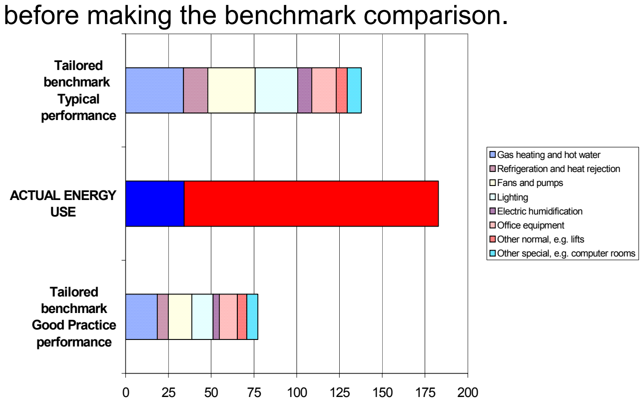
Level 1: simple, usually reconciled with stock statistics for the type of building concerned.



Level 2: corrected, taking account of special energy uses not included in the Level 1 benchmarks.

The above charts show a building's actual carbon dioxide emissions in comparison with fixed Typical and Good Practice benchmarks appropriate to the building. With the level 2 approach, the emissions from a special energy use (not included in the benchmark reference) are identified by measurement (e.g. survey or sub-metering) and deducted from the total emissions before making the benchmark comparison.

Level 3: customised, taking more detailed account of the building's schedule of accommodation, activities and use.
The chart on the right includes benchmarks built



up from each of the energy end uses occurring in the different activity areas in the building concerned, calculated separately assuming Typical and Good Practice energy efficiency for the fabric, plant, management and controls involved for the actual occupancy of the building (hours and densities of use).

Figure 7 Three levels of benchmarking for a measured EPI

Level 1 fixed benchmarks
The UK has a detailed set of mostly statistical benchmarks, developed in various government programmes since the 1970s and now available from the Carbon Trust (www.carbontrust.org.uk). Other countries have fewer benchmarks, and some none. Closer examination of UK benchmarks reveals underlying inconsistencies, for example:

- most are split into fossil fuel and electricity, some aren't;
- most show typical and good practice levels, some don't, and a few show a third level;
- climate and exposure corrections may be applied in different ways, or not at all;
- benchmarks in different publications can vary, probably owing to age or sampling method;
- sometimes there are inexplicable variations, for example data on ostensibly similar buildings can be very different, and some benchmarking documents have internal inconsistencies.

In summary, existing fixed benchmarks are a good starting point but could benefit from a shakedown, in both numerical values (especially by reconciliation with tree diagram descriptions) and in the range of building types covered. This would also allow countries which do not have benchmarks already to get going more quickly. More detail could be added at Level 2 and this could also make Level 1 simpler, as outlined below.

Level 2 corrected benchmarks
In the UK at present, more complex buildings (e.g. a secondary school with a swimming pool) tend to be given different benchmarks from the basic versions. However, while school pools can differ widely in size, there is just one benchmark. Similarly, while the UK's benchmark (in ECON 19) for a "prestige" air-conditioned office includes allowances for a restaurant and computer room, the other three Types of office don't. And although the energy use by computer rooms is highly variable, many people just use the quoted value regardless. Meanwhile, some offices have swimming pools but no benchmarks for them. At Level 2 one can examine such unusual areas and energy end-uses (e.g. a pottery kiln in a school) explicitly, and take account of what is actually there, particularly if it can be sub-metered for easy verification. With Level 2 available to deal with the exceptions, benchmarking could become more realistic, while Level 1 benchmarks could be made simpler and fewer in number.

Level 3 customised benchmarks
At Level 3 one can get into more detail, looking at individual areas or energy end-uses. With rigorous verification, one can also take account of densities of occupation and hours of use (unverified, these "soft" variables can easily be used to mask poor performance). Such procedures can be very powerful but are at present rare, with methods available in the UK for only a few sectors. However, once principles are defined and numerical values agreed, the thinking can be developed and applied more widely, as has already been illustrated for offices in Europrosper.

The Level 3 benchmarking approach will allow the most meaningful and fairest assessments of a building's energy use and CO_2 emissions. However, the simpler Level 1 and 2 assessments may well be adopted in initial statutory implementations of Article 7.3, and may well suit the vast majority of buildings by number – which are both small and relatively simple. In due course, the Level 3 approach might become verified and accredited as an alternative to the Level 2 correction. The goal of ultimate unification of all three levels in a single system which provides a "graduated response" from simple to more detailed assessments depending on what is appropriate for the size and complexity of the building concerned provides a powerful link between the levels and a compelling logic for their progressive use.

For benchmarking to be effective, it must make performance visible and actionable and become a spur to real improvement; not a ritual bureaucratic exercise which absorbs valuable time and money which would be better spent on other things - not least technical and management measures to improve energy efficiency and cut CO_2 emissions. The entry level should therefore be at the lowest possible cost, subject to acceptable quality. Ideally, moves to higher levels would be driven by market need (e.g. to understand what is going on, to demonstrate proven performance, to plan improvements, or to respond to customer and stakeholder pressures) and be seen as necessary and affordable by building owners, occupiers and managers, not more red tape. If energy certification begins to interest the property market and creates a demand for higher Grades, then the extra assessment and improvement measures would become economically viable business propositions.

Step 3. Grading the Building energy performance

The third step in the energy certification process is to place the EPI on a relevant scale and/or to calculate a *Grade* or energy *class* in order to derive a headline indicator of the building's energy efficiency. A fundamental question is the degree of resolution the grading will have i.e. the total number of possible grades. Precedents include:

- the Danish ELO system, with 13 grades (A to M) calculated by statistical grading
- the Australian ABGR, which allocates up to 5 stars calculated by component based parametric grading
- the EU labelling scheme for electrical appliances such as light bulbs, fridges and washing machines which have their energy efficiency labelled in 7 grades, from A to G[7].

CEN Standard prEN 15217 recommends (in an informative annex) the 7 grade A to G classification, (and the option of sub-classes, like A*, A** or A1, A2, B1, B2, etc.), with boundaries as follows:

Class A if	$EPI < 0.5 R_r$
Class B if	$0.5 R_r \leq EPI < R_r$
Class C if	$R_r \leq EPI < 0.5(R_r + R_s)$
Class D if	$0.5(R_r + R_s) \leq EPI < R_s$
Class E if	$Rs \leq EPI < 1.25 Rs$
Class F if	$1.25. Rs \leq EPI < 1.5.Rs$
Class G if	$1.5 \leq Rs$

where the boundaries are defined by two anchor points:

- R_r, a component based parametric benchmark achieved by a building compliant with the national regulation level when the EPBD is implemented in a country. Alternative definitions can be adopted for R_r (possibilities might be Good Practice or Best Practice), until sufficient data on the operational performance of buildings completed according to the new regulations become available.
- R_s, a statistically-based benchmark representing the median level for the building stock in that sector. In a mixed use building this can be an area weighted average. As described above, this value can also be equated with a component-based parametric model.

If this classification scheme is used, then the below-average half of the building stock will be in classes E, F and G, and the above-average half in classes A to D (in fact initially nearly all will be in C or D as few existing buildings will surpass the level required for new buildings).

As an alternative, the CEN Standard shows how building energy performance might be presented using a numeric scale, but without a letter classification, as illustrated in Figure 8.

[7] Although there is now an A+ grade at the top end of the scale.

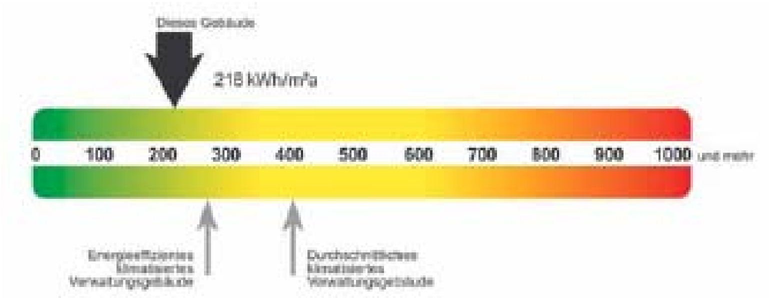


Figure 8 Presentation of the EPI (bold arrow) and benchmarks (for energy-efficient and average performance) on a relevant scale using Germany's DIN 18599

Examples of how grading might be applied
To illustrate the use of the CEN grading scheme, Figure 9 shows the energy performance statistics for the 2,019 secondary schools in England (out of a total of 3,436) which have provided the government with full energy and area data (DfES 2005). Superimposed on the cumulative distribution are the grade boundaries and the corresponding percentage of the stock better than that boundary. Figure 10 shows the percentage of schools which would fall in each class. The reasonably uniform distribution suggests that the boundaries proposed by CEN are appropriately designated, at least for this relatively homogenous building sector.

Another interesting example is provided by the Display Campaign[8] project which put in place a grading scale for schools before the CEN standards had been written. On the basis of existing data, they selected to use class boundaries with equal band widths of 12 kg CO_2/m². The A band covers 0 to 12 kg CO_2/m², B covers 12 to 24 kg CO_2/m², etc. The D/E boundary is therefore at 48 kg CO_2/m², which, presumably by chance, coincides almost exactly with the median for secondary schools in England which was 48.4 kg CO_2/m² in 2002-03. The Display scale can therefore be mapped directly onto the CEN scale if it is assumed R_s = 48 kg CO_2/m² and R_r = 24 kg CO_2/m² (see table 2). It is noteworthy that any CEN-compliant scale will also have exactly equal band widths if the anchor points are set with $R_r = 0.5\ R_s$.

Table 2 Grade boundaries used by Display for schools and their CEN equivalents

Class	Grade Boundaries used by Display for schools (kg CO_2/m²)	Equivalent CEN boundaries:	
		as stated in CEN standard	when $R_r = 0.5R_s$ ie $2R_r = R_s$
A	EPI ≤ 12	EPI < 0.5 R_r	EPI < 0.5 R_r
B	12 < EPI ≤ 24	0.5 R_r ≤ EPI < R_r	0.5 R_r ≤ EPI < R_r
C	24 < EPI ≤ 36	R_r ≤ EPI < 0.5 (R_r + R_s)	R_r ≤ EPI < 1.5 R_r
D	36 < EPI ≤ 48	0.5 (R_r + R_s) ≤ EPI < R_s	1.5 R_r ≤ EPI < 2 R_r
E	48 < EPI ≤ 60	R_s ≤ EPI < 2.5 R_s	2 R_r ≤ EPI < 2.5 R_r
F	60 < EPI ≤ 72	1.25 R_s ≤ EPI < 1.5 R_s	2.5 R_r ≤ EPI < 3 R_r
G	EPI > 72	EPI > 1.5 R_s	EPI > 3 R_r

The latest results for 1,334 educational buildings participating in the Display Campaign, recently published by Display (Towards Class A newsletter 2005), are shown in Figure 11. The median for this sample is not at the D/E boundary but within the E class, demonstrating (unsurprisingly) that schools in England are not representative of this sample from across the EU. The bias towards higher CO_2 is perhaps caused by the scheme's methodology of not normalising for the differences in climate across the EU nor for the differences in the CO_2 intensity of electricity in different countries.

[8] The European **Display™ Campaign** is a voluntary scheme funded by the EC and designed by energy experts from 20 European towns and cities. It is aimed at encouraging local authorities to publicly display the energy and environmental performances of their public buildings using the same energy label that is used for household appliances – see http://www.display-campaign.org/

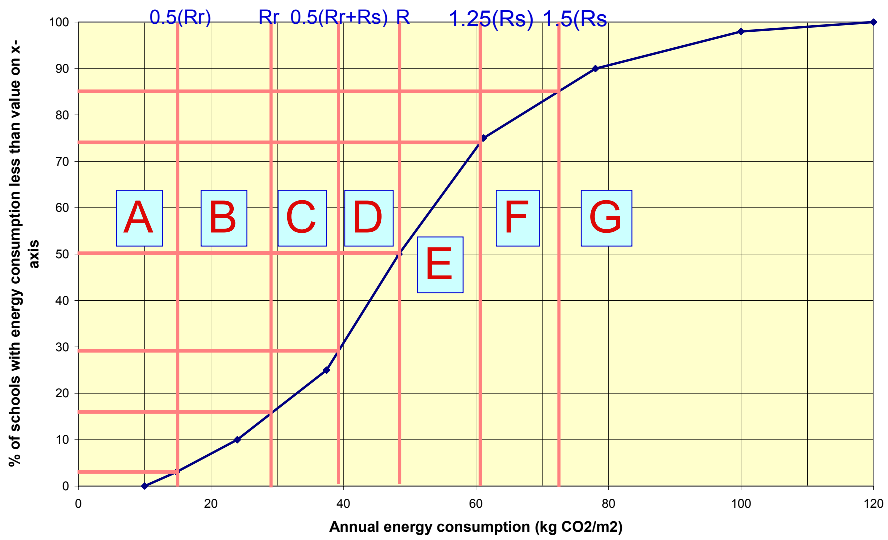


Figure 9 Cumulative distribution of the energy performance of secondary schools in England in 2002-03 and the grading scheme proposed by the draft CEN standard.

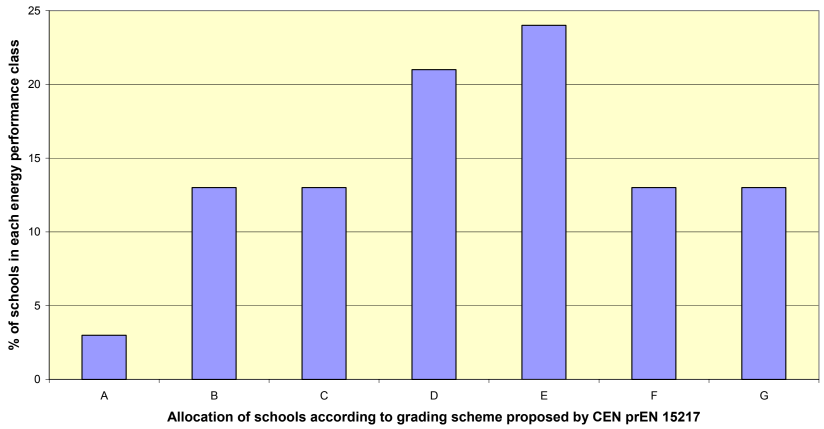


Figure 10 Data for secondary schools in England 2002-03

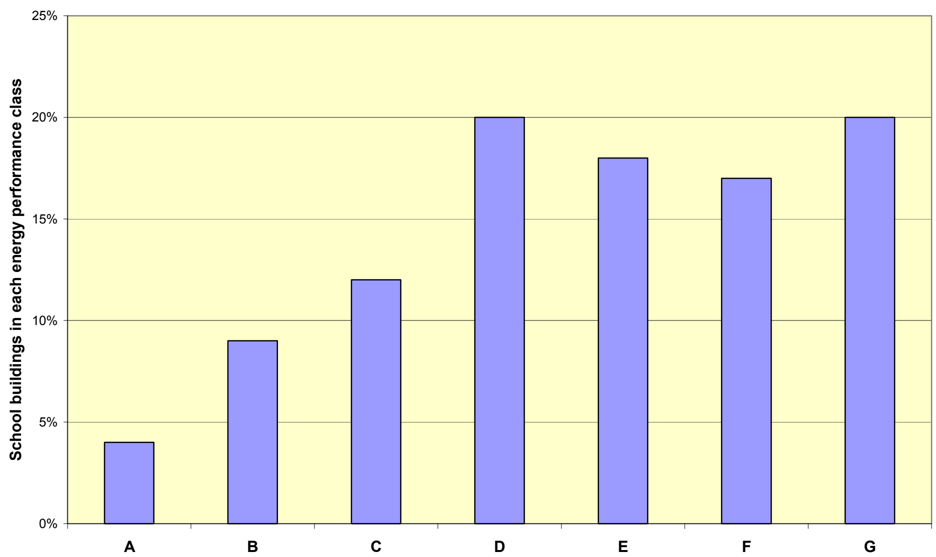


Figure 11 Latest results for educational buildings from the Display Campaign

Where and how the grade boundaries will in fact be set for each sector will ultimately be a political decision for each country and sector. However, the purpose of the CEN Standard is to encourage a uniform presentation across sectors and across Europe, whilst allowing for local differences.

Evolution of benchmarks and grades with time
The values of Rr and Rs when the EPBD is first implemented will change as the stock improves, with significant movement after ten or twenty years, for example as in Figure 12. Should the classification scale then be realigned?

Keeping a fixed scale has the advantage that the classes on all existing certificates remain valid and comparable with the classes appearing on newly issued certificates – which would be good for public perception. However, the new reference values will be out of alignment with their recommended positions with respect to the classes i.e. having the regulation level at the B/C border etc. But does this matter? The main problem is likely to be crowding of the A-grade, as has happened with domestic appliances, with the possible need to introduce A* and so on. Given the inertia in improving the energy performance of existing buildings, it could be several decades before such a grading strategy would suffer the problems of overcrowding in the top grades now experienced by the grading of white goods. Nevertheless, to provide continued incentives, we would recommend subdivision of the A-grade immediately.

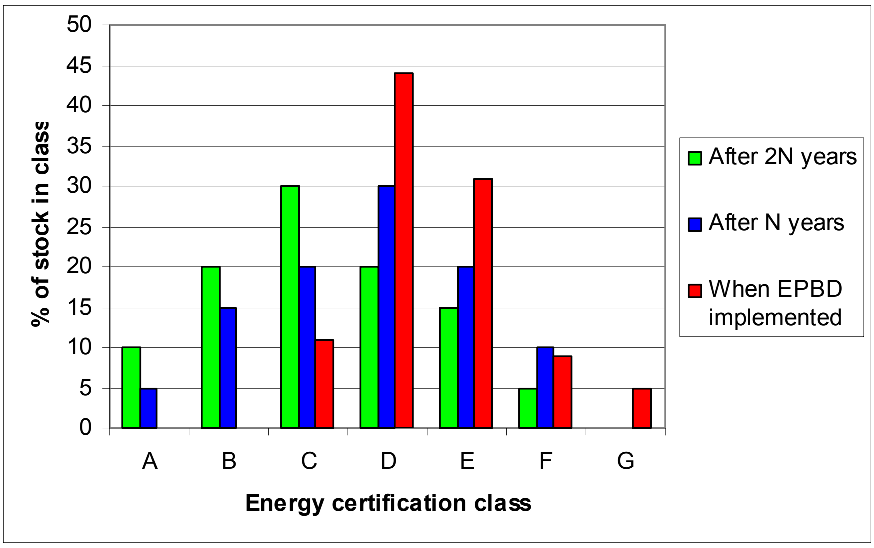


Figure 12 Illustrative evolution of sector energy performance profile against a fixed scale

Step 4. Identifying energy saving measures

The measurement of energy use, its benchmarking and classification are but a precursor to the main goal of the EPBD which is to reduce CO_2 emissions by implementing energy saving measures, whether through better management and control or by investing in more efficient plant or fabric. While the assessment needs to be fair and consistent, it is important that it is quick, efficient, and well-suited to the task in hand. The three-level approach to benchmarking permits this. By incorporating pessimistic assumptions at Levels 1 and 2 – in particular with the Level 1 benchmarks being based on relatively lightly-used buildings with a minimum of exceptional end-uses, one can provide an incentive to move to a higher level of assessment. It is then more likely than not that a detailed assessment will improve the assessment and possibly even the Grade, and the additional analysis will also create more insights into energy performance and the cost-effective opportunities for improvement.

The EPBD's Article 7.2 requires an energy certificate to be accompanied by recommendations for cost-effective improvement of the building's energy performance. It appears to allow a broad spectrum of ways to comply. Within a graduated response, we suggest there are three main levels for delivering such a list of recommendations:

1. A standard (national) list of measures generally applicable to the building's sector. Further customisation and analysis of these measures would be left to a separate exercise, outside the basic energy certification process;
2. Requiring the certification process to identify the applicability of each measure to the specific building, with some estimation of their cost effectiveness and the likely impact on the building's performance if all such measures were implemented. A semi-automated version of this approach was demonstrated by the Europrosper project for office buildings and is also a central part of the UK's method for energy labelling of dwellings. The robustness of the results will depend on the assessor's ability to quantify the applicability and likely cost of each measure. They are likely to be more a guide to what might reasonably be done, than a list which could be acted upon without further technical investigation and costing;
3. Making the list as definitive as possible by detailed appraisal of the technical and financial viability of each measure. This approach is understood to be required in Denmark, where there will also be a legal requirement for the cost-effective measures to be undertaken by the building owner within five years, when the building will be subject to its next certification.

In the UK, neither energy use, energy costs, CO_2 emissions, nor even energy security are yet strong market drivers: the energy demand of non-domestic buildings is relatively inelastic to fuel prices. For the price mechanism to overcome the inertia constraining implementation of energy efficiency measures (even those with attractive pay back periods), energy prices would need to rise to a socially and economically unacceptable level. To break this economic logjam, carrots are needed as well as sticks, for example with tax incentives to assist the implementation of building energy efficiency measures and reward buildings with better than average energy efficiency and, if the arrangements need to be fiscally neutral, penalising buildings with worse than average energy efficiency. However, a stronger driver than costs is reputational risk, and with the growing interest in Corporate Responsibility, to have energy labels on display could really set the market moving.

Step 5. Collation of information on an energy certificate

An energy certificate will need to give the information required by the EPBD; and:
a) be easy for the public to understand the rating at a glance;
b) show measures which can be acted upon effectively by the building owner, occupier or manager;
c) provide background information on the building, and on the techniques and values used to produce a certificate.

We think a certificate should include:
a) Page 1. Headline information, with a graphic suitable for public display. This may well be of a similar format to the label used on electrical appliances in Europe, as the public is familiar with it.
b) Page 2. A summary of the recommended energy-saving measures and the associated improvements in energy performance.

The main pages above may be the only two normally be seen by the public, or be of much interest to them. However, we see the need for supporting information - the small print, which should include:
a) Section 3, with information supporting a calculated 'asset' rating (or the design rating) including the appropriate reference values; and
b) Section 4, with information supporting the measured operational rating, including the appropriate benchmarks as required by the EPBD.
c) Both the supporting sections may well need to be more than one page each, but cover pages in a standard format may prove to be useful, depending on the precise needs that evolve.

Figure 13 is an example of a possible first page developed by the Europrosper project. It shows:
a) The familiar A to G scale (which might be sub-divided, for example into A1, A2, B1, B2, etc)
b) Twin "sliders", one for the Asset (or Design) Rating and one for the Operational Rating.

Additional detail is shown, above the scales showing:
a) the type of certificate,
b) the building type (here an office but it could include sub-types or mixed uses), and
c) whether the certificate is for the whole building, part of it (e.g. an individual tenancy), or perhaps for Landlord's Services only.

Below the scales, there is further information:

a) First on the methods and units used.
b) Then on key assumptions (for predictions) or indicators (from operational ratings).
c) Finally on the energy efficiency grades for subsystems and management.
d) Page 1 also has space for an indicator of internal environmental quality.

Information on other pages will require detailed development in relation to the systems finally adopted. However, the general approach should be driven by the needs of the methods and the users and not arbitrarily imposed beforehand. Both the Grade, representing the benchmark comparison of the building's energy use and the indicator, representing the building's energy intensity (e.g. in $kgCO_2/m^2$), should be reported.

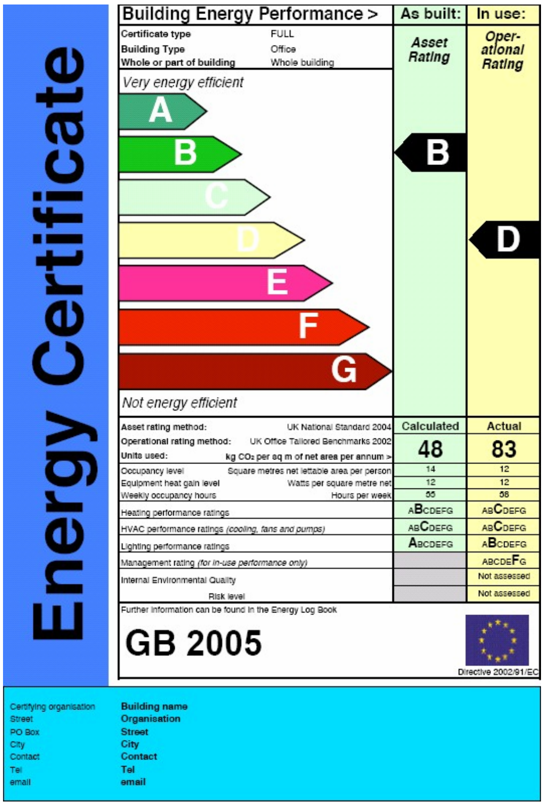


Figure 13 Design of front page of energy certificate proposed by the Europrosper project

Conclusions

This paper has described the key steps in the procedure for building energy certification based on an Operational Rating and proposes a clear, robust and pragmatic way for Member States to implement these steps, offering sufficient flexibility to accommodate national diversity whilst seeking the harmonisation the EC desires. Implementation of EPBD Article 7.3 in many countries may start with an Operational Rating approach requiring eligible buildings to provide a summary of their energy use, weight the different fuels used (e.g. by primary energy or by kg CO_2), report energy performance per m² of floor area (probably of gross internal area, though there are other choices) and compare it with simple benchmarks, where these are available. Where there are no benchmarks, then even the process of calculating the weighted energy use will be informative.

The paper proposes categorising building energy benchmarks at three levels of sophistication: 1) simple (e.g. derived from stock statistics), 2) corrected (for special energy uses not included in the simple benchmarks) and 3) customised (to take closer account of what the building is like and what is happening inside). The Level 1 and 2 assessments may well be sufficient for smaller, simpler and more standard buildings and be adopted in initial statutory implementations of Article 7.3. For more complex buildings, the Level 3 benchmarking approach will be available to allow more meaningful and fairer assessments of a building's energy use and CO_2 emissions. Level 3 may first be introduced by sector or sub-sector as a voluntary good practice procedure, allowing experience and confidence to be gained before it becomes part of a national system. The paper illustrates how all three levels can be unified, so providing a powerful link between them and a compelling logic for their progressive use.

Obliging building owners and occupiers to examine their energy performance and to reward good results (and perhaps to penalise bad ones) will establish a fertile environment for reductions in energy demand and CO_2 emissions, through investment, purchasing, improvement and management measures and by individual efforts. Such policies can be implemented naturally and cheaply once building energy certification is established and are explicitly encouraged by Recital 16 of the EPBD: “The [energy certification] schemes adopted should be supervised and followed up by Member States, which should also facilitate the use of incentive systems.”

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building
performance
congress

Empirical Benchmarking of Building Performance

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Introduction

In the past decade there has been increased attention toward understanding the energy performance of buildings, with particular interest being paid to the potential to significantly reduce building energy consumption. In a variety of regulatory drivers around the globe, including the introduction of the European Building Performance Directive, the question of how to assess the performance of commercial buildings has become a critical issue.

There are several initiatives for the assessment of actual building performance internationally, including in particular US Energy Star Buildings rating tools and the Australian Building Greenhouse Rating scheme. These schemes seek to assess building performance on the basis of actual achieved result, which takes into account not only the theory of how well a design works but also the quality and fidelity of delivery, commissioning, operation and maintenance. It has been shown that in virtually identical buildings, with very similar systems, equipment, and space usage patterns, small differences in control, operation and maintenance can generate dramatic impacts on the energy performance of the building.

Given the known dissonances between theoretical performance and actual performance – such as documented in the PROBE studies (e.g. Bordass et al 1996, Bordass 2004) - true operational performance-based assessment is essential if policy initiatives are to be assured of delivering actual benefits. Such assessment also has the strong benefit of being somewhat cheaper than design based approaches. However, there are also areas of difficulty associated with this approach.
In this paper, some empirical benchmarking schemes around the world and in development are identified and briefly scoped. The benefits and problems of empirical benchmarking are discussed, and solutions and examples drawn from existing schemes are presented. A future development path is proposed.

What is an Empirical Benchmark?

Empirical benchmarking, as relevant to this paper, is comparison of actual building performance – typically applied to energy – against the broader building market to achieve a view as to the performance of the building.

In creating such a benchmark, one has to be sure of the comparability of the building to the data set. This typically requires that a range of normalization factors are required to bring both back to a common basis for comparison. By this method, differences in climate, building size and hours of operation can typically be eliminated from the comparison.

Significantly, empirical benchmarking approaches characterize performance outcomes, but do not seek to characterize how that performance is achieved.

A number of the key known empirical benchmarking systems are summarized in Table 1 at the end of this paper.

The Relationship Between Empirical and Design Based Assessments

There are two basic ways in which a building's performance can be assessed. These are:

- **Design:** identifying the presence or otherwise of features that are deemed to be associated with efficiency. This may be done via a checklist and/or via the use of computer simulation, and although it most typically applies to new buildings, may be applied to existing buildings as well. Examples of this type of approach are LEED, BREEAM, ASHRAE 90.1 and other building codes.

- **Empirical Performance:** looking at actual building performance and determining efficiency on that basis. This is typically applied to existing buildings but can also be applied to new construction. Examples of this approach are Energy Star in the US and the Australian Building Greenhouse Rating scheme.

It is significant to note that the design-based systems have generally arisen out of a desire to assess efficiency during design. The assessment of design features is simple methodology for achieving this. However, such approaches carry a number of disadvantages:

1. There is no guarantee that the efficiency result will occur. The pivotal study in this area was undertaken by the PROBE team in the 1990s (e.g. Bordass et al 1996, Bordass 2004). In the US, a review of a large data set of commercial buildings found substantial differences between simulated design intent and as-built performance (New Buildings Institute 2003).
2. The limitation to those factors which can be readily assessed may mean that other, critical but difficult to characterize or monitor issues are ignored. For example, while design assessment systems may make reference to the need for good commissioning, the ability to assess this stops short of actually determining whether the scope and execution of the commissioning and subsequent rectifications have actually resolved the issues affecting efficiency.
3. Design approaches can also be expensive. An ABGR assessment costs typically in the region of $A1,500-$2,500 (€1,000-1,500). Design assessments appear to typically cost several times this figure.

If a design-based approach is extended to the environment of existing buildings, further issues appear:

4. The required design information may not be available (for instance, getting detailed information on glazing is difficult without actually sending a pane off for laboratory testing)
5. Key factors determining existing building performance may not be practically assessable from design information only – particularly in relation to operation and maintenance.

One of the key factors that arises in the review of design based rating systems is that most have been developed specifically to assess the design independently of operational factors. This approach makes good sense for building codes and other areas where there are distinct limits to what can be included within the scope of an assessment. However, if one is interested in changing the performance-based outcomes of the design, a broader approach is required.

By contrast, empirical performance based approaches have arisen largely out of the existing buildings sector. Such approaches have focused on available data – energy bills, floor area, hours of operation, etc. This is simple data for existing buildings but is problematic for new buildings, for which such data need to be estimated or simulated.

The key benefit of empirical approaches is that by focusing on actual measured building energy performance, one is working with actual performance outcomes. This means that all of the various factors that may have contributed to building performance – design, commissioning, operation, maintenance – are captured in one relatively simply obtained figure. In an environment where there is a need to manage actual building performance for cost or environmental reasons, this is hard to substitute with design based assessments, which provide only what we *think* will work, as opposed to what *does* work.

The key disadvantage of an empirical performance approach is that the assessment provides no information on what is or is not working, unless a further and deeper analysis is performed. This means that a poor empirical performance has to be followed up by additional investigations before causes can be ascribed and resolved.

The value of empirical benchmarking is becoming more widely accepted as a result of the voluntary initiatives described in this paper. In the State of California, an Executive Order was issued in 2004 requiring a plan "to accomplish benchmarking of all commercial and public buildings in California, including benchmarking at the time of sale, as well as a system by which benchmarking ratings can be disclosed to tenants, buyers and lenders to advise them in making decisions" (CEC Benchmarking White Paper 2005). In Australia, studies are underway to consider the possibility of a compulsory building labeling system, with one of the options being performance based. Several Australian State Governments are already requiring minimum ABGR performance levels for buildings that they lease.

It would be fair to say that there is some tension between the design assessment and performance benchmarking approaches, particularly as designers do not wish to be held responsible for in-practice performance that includes many factors outside their control. However, with the proliferation of "Green" or "High Performance" building design around the world, serious work is required and in some cases underway to rationalize the actual performance of many of these buildings. Much more work is needed to understand the reasons for disappointing performance of "well-designed" buildings.

Irrespective, it is important to emphasize that design and empirical performance assessment should not be viewed as being in conflict. Design assessment provides an important role in systematizing our understanding of good design, while performance assessment provides feedback on what works. The ideal operation of these two systems is for the knowledge gained through the use of performance assessment to be passed back and incorporated into the design assessment systems. In this way, the differences between these two systems will be minimized via the delivery of better buildings.

General Characteristics of Empirical Benchmarks

An empirical benchmark is a target performance level (or levels) generated by reference to the performance of the building population in general, that is used to assess the performance of a building relative to the balance of the building population.

The Statistics of Building Populations

The nature of most commercial building types is that a range of core services are provided in all buildings, with the result that the general distribution type is normal but with a high energy use tail. This reflects the reality that the provision of those core services takes a finite amount of energy, and there are technological limitations as to how efficiently the broad building market is capable of providing those services. This is illustrated in Figure 1.

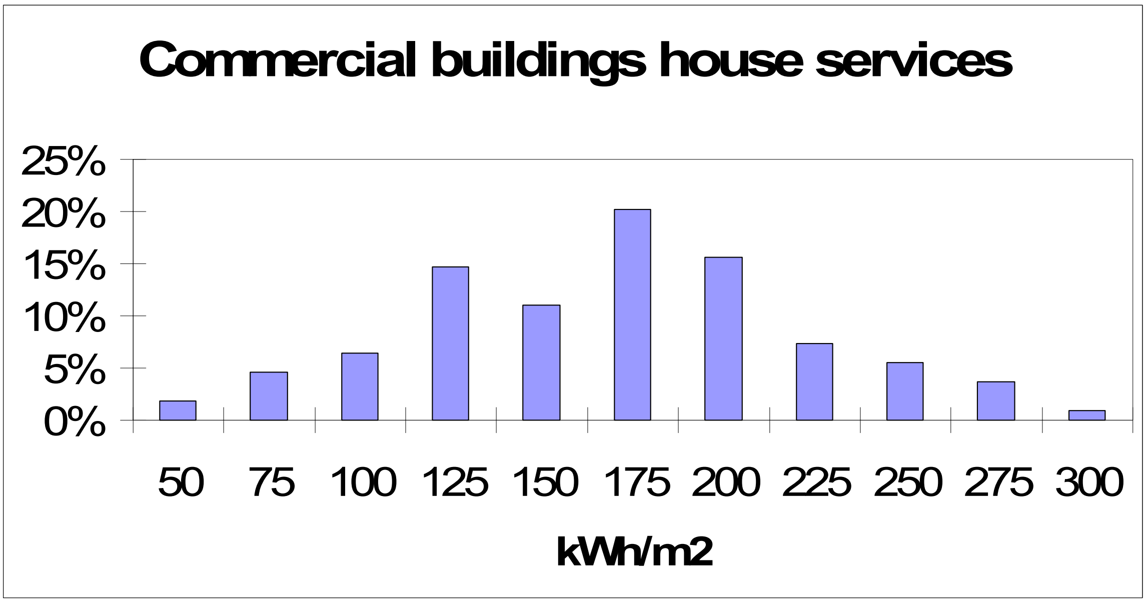

Figure 1: Commercial base building energy consumption (land lord services in 213 buildings in Sydney and Melbourne, Australia)

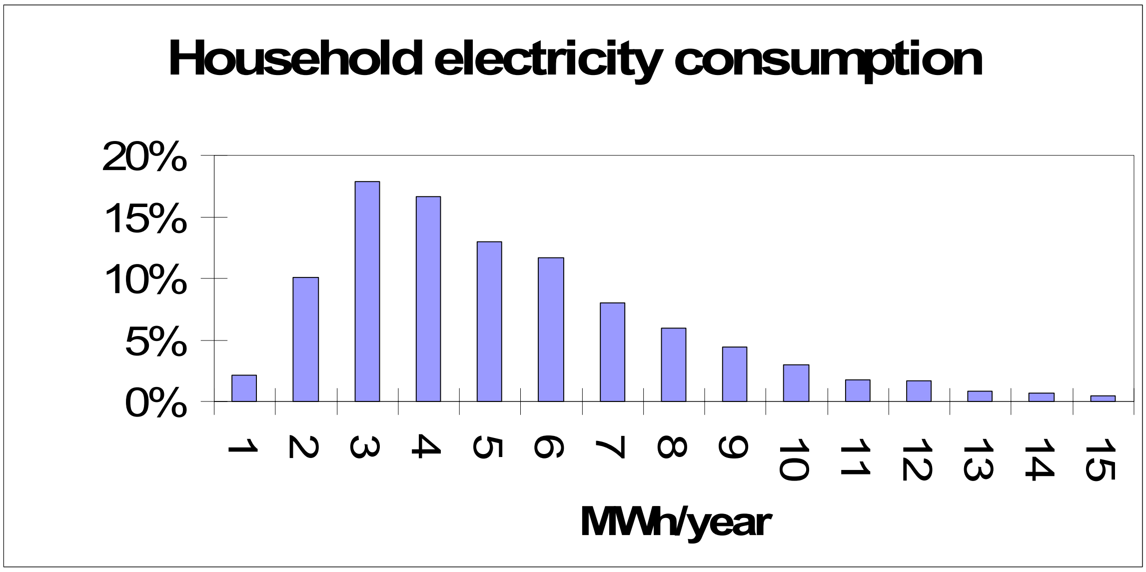

Figure 2: Household electricity consumption (1675 homes in Australian houses in Victoria and NSW).

However, where behavioural factors are significant, the distribution tends to take a somewhat more Poisson shaped distribution. This is illustrated in Figure 2. The distribution shape can be explained in terms of the fact that some sites approach nil energy consumption of the basis of seeking lower levels of service, which is feasible in the mild climate zone from which the data were taken.

In both cases, however, a significant “tail” of high energy use is present, which means that the average energy use is typically higher than the median. As the average can be heavily affected by a relatively small number of high energy samples, it is generally preferable to use the median to characterize the midpoint of the distribution.

A further feature of any real data set is the presence of erroneous data. These data are particularly prevalent at the extremes of the population, so that any methodology based on real data needs to recognize the potentially flawed nature of such data. In particular, the data at the extremes of the performance spectrum should be treated as untrustworthy, as experience shows that this is often the case. This however makes the definition of “high efficiency” relative to the market more challenging. A good review of statistical issues related to benchmarking is contained in the recent report “Review of California and National Benchmarking Methods” (Matson & Piette 2005).

Normalization Factors

In order to make a meaningful comparison of a building against the broader population, it is essential to define a common basis of comparison that allows the efficiency-related issues (such as poor plant, maintenance or operation) to be differentiated from primary factors (such as building size) or operational factors (such as hours of servicing). This requires the introduction of normalization factors that are used to correct a building back to a reference case of “normal” operation. Thus an office building can be characterized in terms of an energy per m² figure that has been corrected to a standard climate and operating hours. This then permits that building to be compared reasonably against other buildings.

When normalizing for the issue of size, it is important to normalize back to a relevant variable that is closely linked with the productive function of the building. Thus for instance, normalization to net lettable area in an office provides a better recognition of the productive variable for the office, whereas gross conditioned space may include significant areas of the building that are not lettable and thus not productive. Similarly, hotels and hospitals are arguably better characterized in terms of beds rather than floor area, as it is the beds in both cases that are associated with production, rather than the floor space.

Creation of Normalization Factors
There are two basic methodologies for producing normalization factors:

1. Empirical derivation, via the identification of trends in the building population correlated to individual normalization factors; and
2. Theoretical derivation, via the identification of trends predicted from simulation modeling or other such theoretical approach.

Each of these approaches has advantages and disadvantages, and the selection of the most appropriate methodology needs to be pragmatic.

An empirically derived normalization approach has the key benefit that the results are based on actual performance data. However, the validity of such an approach is dependent upon whether the data set has sufficient data with independent variation across each of the variables. Thus for instance, it is difficult to get a large sample of data across the full range of operating hours for office buildings, as the number of office buildings with more than 70 hours per week operation is small by comparison with the balance of the population. Similarly, there has been little evidence of empirical correlation between climate and building performance in most of the studies that have been performed.

In an interesting aside, although energy use typically fails to correlate with climate to any significant extent, recent work in Australia (Bannister, 2005) has identified a significant correlation between the climate and water consumption. Indeed, water consumption in buildings between Melbourne (a mild temperate climate) and Brisbane (a sub-tropical climate) doubles. Furthermore, extrapolation to UK climates via cooling degree days brings reasonable comparability to UK benchmarks. This climate correlation is believed to be the result of increased cooling tower water consumption, creating the interesting possibility that it may be realistic to derive a climate correction for cooling energy on the basis of water consumption.

A further point of note on the issue of climate correction is that studies in Australia have repeatably shown that dry-bulb cooling degree days are inappropriate as a basis for climate comparison. Cooling loads are far more strongly correlated to wet-bulb temperatures, with the result that wet-bulb cooling degree day data is a better basis for normalization. However, such data is not routinely available and there are issues with the consistency of calculation.

In general, however, the reliance on statistics alone to generate normalizations is flawed in that the normalizations identify the behaviour of the overall population rather than that of an individual building. Where correlations are strong these two items may be coincident, in which case the empirical normalization is the best methodology; however, for weaker correlations the other changes in the underlying data set may be more important in determining the correlation than the changes in the individual buildings. In this instance the derived normalization typically under-corrects.

Theoretically derived normalizations have the advantage of being derived on an individual basis but the disadvantage of being theoretical and thus potentially wrong. In particular, it is generally necessary to make a specific decision as to whether a theoretical normalization is going to correct for “best practice” or “normal” behaviour. This is not only a value judgment but is also a potential source of error as neither of these is necessarily well defined.

Benchmarking or Rating?
The traditional benchmark approach sets a single figure that is considered, typically either as “average” or “best-practice” performance. This process is utilized in the US Energy Star scheme, which sets a single “pass” mark on the basis of the 75th percentile of the building population. This has the advantage of providing a clear signal of good practice, but has the disadvantage of alienating those parts of the population for whom the achievement of the benchmark appears remote.

The alterative approach is to establish a rating, which provides most buildings with a place on a scale. This approach is adopted in the Australian Building Greenhouse Rating scheme, which places buildings on a nine point scale (one to five stars, with half stars), and in Hong Kong, which places buildings in the relevant decile of the population. This approach has the advantage of being more inclusive, such that poorly rating buildings can still use the scale to identify and promote performance without necessarily being best practice. However, it requires some care in informing the market place as to the meaning of the ratings.

Is Good Performance the Same as Efficiency?
A key issue for any performance benchmark is the question of what the results mean. All benchmarking systems reviewed in this paper assess performance solely in terms of utility consumption without necessarily assessing the level of service. This creates the possibility that a building achieves well by failing to provide service. The various schemes available display a range of responses to this:

- **Categorization.** This approach is used in the UK Econ 19 (Energy Efficiency Best Practice Programme 2000), which provides different benchmarks for different levels of building "quality", as indexed by the level of amenities in very broad terms.
- **Normalization.** An alternative approach would be to physically measure or otherwise characterize service on a scale and normalize for it on a mathematically continuous basis, as one might for hours of occupancy. However, the authors are not aware of any schemes that provide any form of continuous correction for service. This is at least in part because there is no necessary agreement internationally on the boundary between necessary service – which would merit normalization - and excessive service – which would not.
- **Limitation.** The approach used by the US Energy Star scheme is to require a minimum level of service. This provides an assurance that a building does not achieve well on the basis of service deprivation. However, there may still be disagreement about what constitutes a reasonable minimum level of service.
- **Avoidance.** The final approach is to clearly identify that all the rating does is rate energy, and let the relevant markets decide on this issues of servicing. This approach is used by the Australian Building Greenhouse Rating scheme and the Hong Kong Benchmarking Tools (EMSD 2006). This methodology is most readily applicable where there are relatively uniform expectations in the market place as to the level of service expected. This is the case in Australia, where basically all commercial buildings are air-conditioned, but would be more problematic in the UK, where the presence or otherwise of air-conditioning is a significant differentiator. However, even here this is strongly dependent upon the nature of what the rating is trying to promote.

From a purist perspective, the avoidance approach works well, if the function of the rating is to encourage people to use less resources.

Overall, it would appear that the resolution of this issue is somewhat dependent on the nature of the specific rating and market under consideration.

Value of Empirical Benchmarking Schemes in the Market Place

Empirical benchmarking has a number of roles in the market place:

Market Transformation
In an ideal world, we would all make choices based on perfect information, and one of the factors we might choose to use in sourcing a building could be efficiency. Benchmarking systems have a potentially critical role to play in this area, by providing information that enables a common language of comparison to be used throughout the market. However, if market transformation is to be successful, it is important to be able to break the rating into components that can be managed by individual market participants and then used reasonably to broker their relation with other market participants.

The principal benchmarking systems in use to date differ in whether they benchmark "whole building performance", looking at all of the energy uses in the given building, or break the energy use benchmark into the portions controlled by different decision makers. The US Energy Star system uses the whole building approach, while other regions have found it necessary to have two separate ratings – one for the building owner and the other for the tenant. Ideally, this then enables building owners to advertise the performance of their building to potential tenants, without the concern that their rating is significantly affected by tenants.

This latter approach is used in the Australian Building Greenhouse Rating scheme, which provides two separate ratings as listed in Table 1. The base building rating has been set to reflect a relatively frequent metering configuration whereby the "landlord services" – air-conditioning, lifts, common area lighting and tenant car parks are captured by one electricity meter and sometimes grossed at a fixed rate into the rent. A similar approach is used in the Hong Kong Energy Benchmarking Tools (EMSD 2006).

With this information, a building owner can then advertise the performance of their building in a manner which is largely independent of their tenants. Indeed, simulation studies have shown that in the Sydney climate at least, a range of tenancy energy consumption of a factor of more than four has only a 0.6 star effect (approximately 10% of scale) on the base building rating.

In Australia, the use of ABGR has been accepted widely and its role in transforming the market is widely accepted. The central impact has been around the brokering of the landlord-tenant relationship, with government tenants requesting 3.5 star and higher base buildings and developers endeavouring to achieve 4 stars and higher in new construction.

The key power of this approach is that efficiency becomes linked to a far stronger factor – in this case, lettability – with a significant leveraging effect on the market's level of interest and activity in relation to efficiency.

In the US, with increasing awareness of the Energy Star rating system, along with a growing sense of urgency toward energy savings in some parts of the country, the transformation of the market toward benchmarking is making great progress. As noted earlier, following the results of voluntary efforts, the State of California has recently mandated that all public and commercial buildings in the State will be benchmarked within a few years. As this initiative continues into implementation, other states in the US are likely to develop similar requirements.

Technical Information

The role of empirical benchmarking in providing technical information is equally critical but more complicated.

At a basic level, empirical benchmarks provide only limited resolution of differentiation between buildings – effectively "good", "bad" or "average" – and thus provide a crude indication of the technical status of a building.

Furthermore, as noted earlier in this paper, the available empirical benchmarking systems do not correct for levels of service or differing amenities. Thus a building that provides only limited space temperature control, or perhaps provides fewer other services than the general comparison data set will perform better than would otherwise be expected given the technology, operation and maintenance of the building.

However, given that there is demand for empirical benchmarks even in sectors where there is no market mechanism in operation (e.g. hospitals, schools), it is clear that an empirical performance assessment can provide useful information. Underlying this is the reality that the range of actual building performance driven by manageable efficiency related issues is generally far greater than can be ascribed to all but the most obvious (and therefore easily identified) differences in service.

Experience with the Australian Building Greenhouse Rating scheme has identified a wide range of technical applications to the various ratings. From a technical perspective it has been repeatably shown that poor ratings indicate the existence of genuine efficiency issues, even where energy audits have previously failed to detect these.

However, the success of this type approach is strongly affected by the relevance and accuracy of normalization factors, and of course the quality of the underlying data. A poorly formulated benchmark, with poor normalizations or dubious underlying data, has a high risk of providing misleading or incorrect information. This of course has implications for both the market and technical uses of the rating.

What arises from this from a technical perspective is that there is a strong need for knowledge surrounding the "meaning" of different positions relative to a benchmark or a rating to be recorded and made public. It is only in this manner that a fully qualified understanding of the technical meaning of the rating can be developed.

This has been the partial experience under ABGR, where there is a reasonable amount of knowledge built up on the rating and the "meaning" of the various ratings, and it has been shown that the rating is a good indicator of actual efficiency. However, the degree of knowledge at this level in the broader market place is limited and it has been left very much up to individuals to determine this knowledge for themselves.

New Buildings

The role of empirical benchmarking in new buildings is more complex again, as the obviously the building is not yet operating.

Irrespective of this, it is very likely that, given a successful benchmarking system for existing buildings, building project clients will start demanding that these benchmarks are met for new buildings – after all, a new building is, upon handover, just an existing building.

This creates a significant challenge for the design and construction industry, as there are no well defined processes for the assessment of actual performance during the design process. The most obvious – computer simulation – is not generally geared towards absolute energy use prediction and there are significant issues in the reconciliation of this against actual performance.

Furthermore, in a situation where the "cutting edge" may be at levels of performance that have not yet been achieved in any building, the challenge of how to meet such a target is clearly problematic. This situation is made worse when tenancy organizations seek high performance levels but then also specify energy-wasting requirements within the balance of the brief that are directly incompatible with the achievement of the goal.

These problems notwithstanding, it is reasonable for the market to expect delivery of buildings that actually work to a defined performance level as long as the parameters of performance are reasonably within the control of the design and construction team. Thus for example a "landlord services" style benchmark is reasonable as this can largely be controlled by the design/construct team, while a tenancy or whole building benchmark is not, as the tenants may significantly affect this. Compliance with a tenancy or whole building benchmark performance places significant requirements upon the tenant as well, as tenancy energy consumption is as much about internal office system and operation as it is about lighting design.

To manage the various issues, a number of market information issues need to be addressed:

1. Provision of advice to tenancy organizations on what level of performance to reasonably expect for new buildings.
2. Provision of advice to tenancy organizations on how to specify target performance levels and what other brief items may be incompatible with this.
3. Provision of advice to designers and construction organizations on what the ratings mean, and any existing precedents for their achievement

4. Development of processes and information to assist all participants in the delivery of performance targeted projects, drawing on the best knowledge available, and updated as experience increases.

These items have the potential to make a significant difference to the market response – and the possible levels of inter-party conflict – to the use of performance based requirements for new buildings.

Future Directions

Activity in the empirical benchmarking field lacks any form of international cooperation and is characterized by an inefficient process of learning and repeating each other's lessons and mistakes rather than learning from these. There is a need to elevate activity in this field to achieve the following key outcomes:

- Greater data and lesson sharing internationally;
- An improved understanding of the benefits, challenges and limitations of the available processes;
- An improved understanding of the meaning of benchmark results in different climates, countries and subsectors;
- Collaboration with and feedback to design assessment systems;
- Improved industry acceptance and use

This paper has been prepared with the intention of promoting interest in the creation of activities to meet these needs. It is suggested that the major international professional organizations (e.g ASHRAE and/or CIBSE) would be ideal forums for such activity.

Conclusions

Empirical benchmarking provides a strong basis for the assessment of actual building performance and is essential if actual energy use and greenhouse emissions are to be reduced internationally.
The creation of good quality benchmarks requires good quality data plus the use of normalization factors to separate operational issues from efficiency issues. Benchmarks may take the form of an individual "pass/fail" or a banded system ranging from poor practice to best practice. In either case, it is important that knowledge is built up and disseminated as to what performance at a given benchmark level actually means, so that industry can act upon this information.
Benchmarks have the potential to be used in market transformation, by linking performance to market expectations when leasing, as a technical tool, and in the prescription of new buildings.
It has been proposed that there needs to be greater coordination and promotion of empirical benchmarking activities internationally to ensure that lessons and information are shared to the benefit of all.

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Table 1. Summary of benchmarking schemes.

Scheme	Sector	Description
Australian Building Greenhouse Rating Scheme	Office buildings – land lord services (air-conditioning, common area services, tenant car parks) Office buildings – tenancies (tenant light and power) Office buildings – whole buildings Retail shopping centres (under development) Hospitals (under development)	Five band star rating scheme with 2.5 stars set to population median. Assesses greenhouse gas emissions related to energy use. Scheme established in New South Wales in 1999 and extended nationally across Australia in 2000. Benchmarks adjusted in each state to allow for different local population characteristics. Typical data sample per state approximately 60-200 buildings. References: www.abgr.com.au, Bannister et al 2004.
National Australian Built Environment Rating System	Office buildings – water Homes – greenhouse emissions Homes – water	Five band star rating scheme with 2.5 stars set to population median. Assesses greenhouse gas emissions associated with energy use and water consumption in kL per m^2 for offices and kL per occupant for homes.
Hong Kong Energy Benchmarking Tool	Office buildings – whole building Office building – tenancies Office buildings – landlord services Retail (several types) Hotels Boarding houses Universities Post-secondary colleges Schools with air-conditioning Schools without air-conditioning	Statistically based system that reports position in the market place in terms of percentiles. Assesses energy use. Scheme has been operating for several years during which time it has expanded to cover a wide range of building types. References: EMSD 2006
US Energy Star for Buildings	Office Buildings – whole buildings Hotels K-12 Schools Medical offices Supermarkets Warehouses Hospitals Dorms	Rates buildings on a 1-100 scale, based on weather normalized primary energy consumption per year per square foot of floor area. Voluntary scheme developed by the US Environmental Protection Agency (EPA), began for office buildings in 1999 and additional building types have been added since. Candidate buildings are compared to similar buildings from a large dataset, the US Commercial Buildings Energy Consumption Survey (CBECS), the most comprehensive

		measured building energy performance database in the world. Over 18,000 buildings have been benchmarked, representing approximately 300 million square meters, or about 5% of the total US commercial building stock. References: Hicks et all 2004.
Cal-Arch	All commercial buildings (non-residential, non-industrial)	Cal-Arch is a distributional benchmarking tool developed by Lawrence Berkeley National Laboratory, a research laboratory affiliated with the US Department of Energy. The Cal-Arch system utilizes a California specific dataset of energy use, and allows users to determine the percent of similar buildings that use more or less energy than their building. A user can compare their building EUI (energy use intensity) to that of similar buildings in the same climate zone. References: CEC Energy Benchmarking White Paper 2005

building
performance
congress

EPA-NR, tools for the assessment of the Energy Performance of Non Residential Buildings in the European countries

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Abstract

The Energy Performance Buildings Directive (EPBD) obliges EU Member States (MS) to:

- set energy performance requirements for new buildings and major renovations;
- implement the issuing of Energy Performance Certificates for new and existing buildings;
- control the quality of heating and air-conditioning equipment.

In parallel CEN has planned to work on over 30 standards related to the EPBD. MS are striving to incorporate these standards or draft standards into methodologies that they are planning.

The European project EPA-NR is executed within the framework of the 'Intelligent Energy – Europe' Programme (EIE) of the European Commission. EPA-NR will produce a European assessment method including software for the existing non-residential building stock, taking into account the context of the non-residential building stock and its actors.
Practitioners and policy makers are the major target groups.

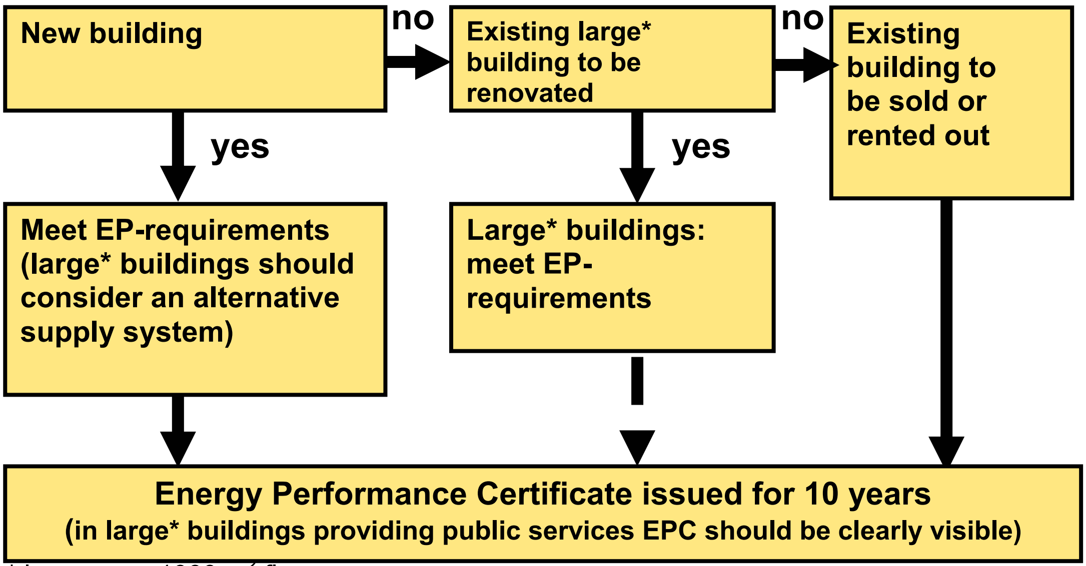
- Practitioners will be offered a complete assessment method and accompanying tools (a calculation model and process supporting tools like inspection protocols, checklists, building component libraries, etc.) Pilot projects will test the method and tools. The results will be available as high quality prototypes that can be easily adapted to the local context.
- Policy makers are provided with recommendations regarding the implementation issues related to the EPA-NR method.

The EPA-NR method will provide practisioners and policy makers with an EP assessment method that enables them to take into account the local contexts such as legal aspects, technical aspects, design and building management processes and acceptance by the actors in the market.

The EPBD as a starting point

The European Directive on the energy performance of buildings (EPBD) requires that an energy performance certificate is made available by the owner to the prospective buyer or tenant when buildings are constructed, sold or rented out. The certificate has to express the Energy Performance (EP) of the building as a numeric indicator that allows benchmarking. The certificate has to be accompanied by recommendations for the cost-effective improvement of the energy performance. In larger buildings occupied by public authorities or institutions providing public services the certificate should be publically displayed. For new buildings and major renovations energy performance requirements should be set. Figure 1 gives an overview of these aspects.

In order to facilitate the EU Member States in setting up a general framework for the calculation the European Committee for Standardisation (CEN) is working on the final elaboration of over 30 new standards to satisfy the requirements of the EPBD. Most of the standards are already available as a draft and the final CEN standards will provide the basis for standardisation on national or regional level.
The overall objective of the directive is to improve the energy performance of buildings. Issuing EP-certificates for the existing building stock requires a major effort and it is a challenge to design the certificate and the assessment process in such a way that there is optimal impact in terms of implementing energy saving measures.



* large: over 1000 m^2 floor area

Figure 1: EPBD flowchart EP-certificates

Energy Performance and CREM

Corporate Real Estate Management (CREM) addresses the performance of buildings related to cost. In essence a building in the non-residential sector is a means of production. The building has to be functional, safe, comfortable and of an adequate appearance. The performance levels on these fields are related to cost categories like operational cost, property value and investments. The energy performance of a building is becoming an increasingly important issue due to the need for the reduction of greenhouse gasses and the strategic dependence of the fossil fuel. Requirements are set for new buildings and renovation of existing buildings. CO_2-reduction and energy saving targets are expressed on national policy levels and will be translated to operational (building) level in the near future.
CREM is therefore more and more confronted with the need to incorporate the energy performance in their considerations. The obligation to express the energy performance in a certificate and an energy label will raise awareness in the market and it is expected that the authorities will require further steps in order to improve the energy performance of the existing building stock.

CREM has to deal with the energy issue more intensely in the near future, embedding this issue in the usual decision making and execution processes. The introduction of the EPBD is the logical starting point.

Energy saving is mostly defined in terms of investment and reduction of energy cost. Executing energy saving measures is considered to be an additional process that is experienced as a burden. This is a far too limited approach. In many cases energy saving has important non-energy benefits. Taking these into account substantially reduces the pay-back time of the measures. For instance: the necessity of improving comfort can often be achieved by applying energy saving measures. A very profitable approach is to combine energy saving with maintenance and retrofitting activities. In this way eneryg saving fits into the ordinary CREM processes. Apart from these very efficient ways of incorporating energy saving in the execution of maintenance activities, energy labelling is also advantageous on a strategic level. Managers of building stock portfolios can use aggregated labels in order to define their policy on the energy issue. Even on municipality level policy can be formulated based on labelling schemes (see figure 2). In that case energy is not an added issue but incorporated in the day-to-day processes.

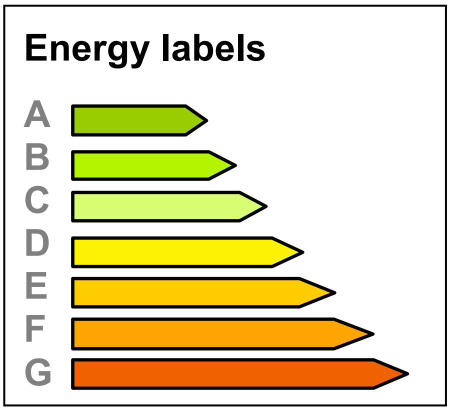


Figure 2: Example of energy labelling

All these applications are locally defined and stimulate improvement of the energy performance. The consequence is that form and functionalities of the assessment method and its output should be flexible in order to meet the needs of the different actors. For instance, establishing the energy performance of a building stock is not a multiplication of the assessment process for a single building, but a completely different process. The instruments have to allow and facilitate these different approaches. This aspect is dealt with in the development of the EPA-NR method.

The EPA- NR project

The EIE project "Energy Performance Assessment for existing Non-Residential buildings" (EPA-NR) is supported by the European Commission and participating European member states. The objective of the project is to achieve an adequate and efficient assessment method and provide tools (including software) that can easily be adapted to local circumstances and project specific conditions. Practitioners and policy makers are the major target groups.

- Practitioners will be offered a complete assessment method and accompanying tools (a calculation model and process supporting tools like inspection protocols, checklists, building component libraries, etc.) Pilot projects will test the method and tools. The results will be available as high quality prototypes that can be easily adapted to the local context.
- Policy makers are provided with recommendations regarding the implementation issues related to the EPA-NR method.

An overview of all deliverables is shown in Figure 3.

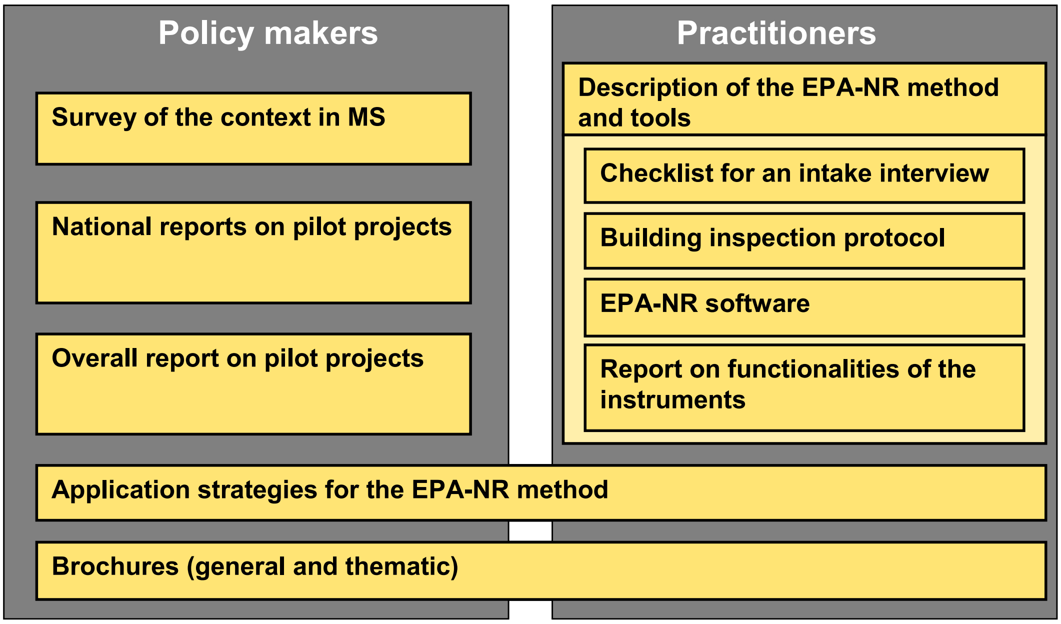


Figure 3: EPA-NR deliverables

The deliverables specified:

- The **survey of the context** was the first deliverable. The report presents the context regarding the non-residential building sector in all European Member States together with the policy approach towards energy saving and the implementation of the EPBD. This report[1] is already available through the website.
- The **description of the method and tools** is giving an outline of the EPA-NR assessment method and positions the available tools.
- The **tools** are:
    - A **checklist for an intake interview** supporting the consultant in order to structure the start of the assessment process
    - The **building inspection protocol** is giving guidance and examples on how to structure the inspection of the building and how to assure the quality of inspection
    - The **EPA-NR software** is flexible and easy to adjust software to calculate the energy performance according to the EPBD and relevant CEN-standards. The software is accompanied by a manual
    - A **report on functionalities of the instruments** is providing background information and justification of the approach
- **Pilot studies** will be executed in order to test and evaluate the method and the tools. They also provide examples how to apply the EPA-NR method. This activity results in **national reports** and an **overall report**.
- **Application strategies for the EPA-NR method** are being outlined in terms of opportunities in the market for applying EPA-NR and for additional consultancy. The added value of energy saving for the client is addressed as well.
- One **general** and several **thematic brochures** will be produced in order to provide concise information towards practitioners and policy makers on the EPA-NR method and its application.

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[1] Survey: national context and need for instruments, WP1-Final Report, May 2005, C.A. Balaras Ph.D. (ed.), www.epa-nr.org

The EPA-NR method will take the local contexts into account i.e. legal aspects, technical aspects, design and building management processes and acceptance by the actors in the market.
In order to accomplish this, the key issues during the development of this method are:

- The accuracy of the assessment process as a whole
- The reproducibility of the outcome of the process
- The effort and cost for issuing the certificate.

The first two issues relate to effectiveness and the last one to the efficiency of the approach.
The main considerations on how to balance these key issues in the development of an assessment method are addressed below.

Accuracy and reproducibility of the assessment process

The assessment of the energy performance of a building consists of several stages. The organisation of the assessment process is not standard but depends on the specific circumstances and the type of buildings. In general a number of stages can be distinguished that are relevant in the majority of assessment processes (Figure 4). Each stage has its specific characteristics.
The process typically starts with an intake interview with the client in order to discuss and define starting points and conditions to take into account during the assessment. Also the availability and quality of building data is discussed. This stage is a starting point for efficient data acquisition in order to perform energy analyses. An important issue is to what extend default values can be used to generate input for the calculations. Based on these results, the energy performance can be established together with the cost-effective energy saving measures to be recommended. During this stage the EPA-NR software will be used. Finally the results have to be expressed into an Energy Performance Certificate and presented to the client. The impact of the certificate in terms of taking measures depends on the combination of the quality of the assessment and the acceptance of the advice by the actors in the market. A good quality assessment with a poor acceptance is ineffective.

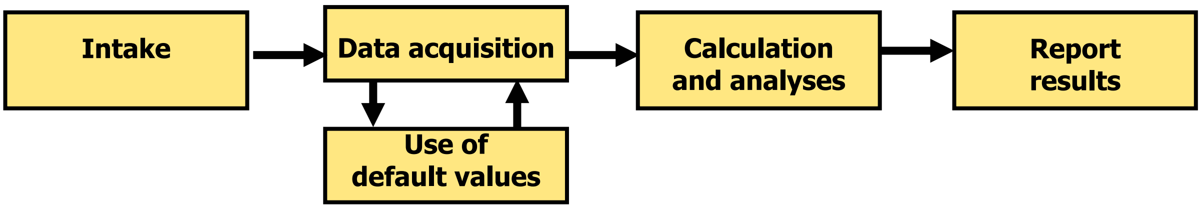

Figure 4: Stages in the assessment process

With regard to the accuracy of the entire assessment process three aspects are important:
1. The quality of the default values in component lists or libraries linked to the calculation model;
2. The quality of data acquisition especially inspection of the building;
3. The quality of the calculation model itself.

The other stages in the process, “intake” and “reporting results” have a minor influence on the overall accuracy, assuming they are performed in a professional way. The inaccuracies of the relevant aspects are depicted in figure 5.

The accumulating accuracy is also shown in the figure5. The total inaccuracy sums up to a total of 45%. Of course this range is a worse case scenario. In practice, deviations will compensate each other and normally the error will be less, as illustrated by the distribution curve on the right. Nevertheless, an inaccuracy of about 15% to 20% is quite usual.

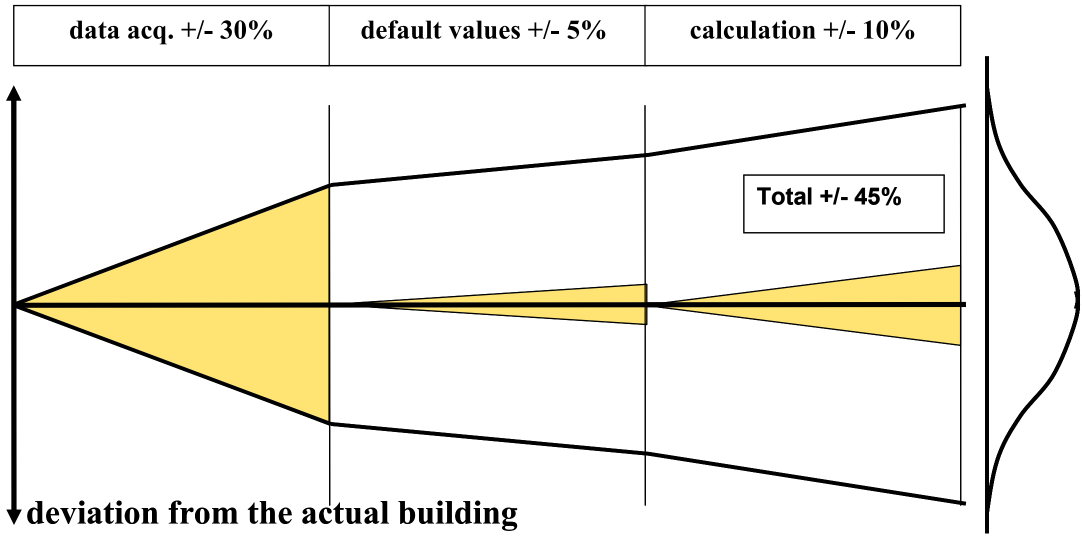

Figure 5: Inaccuracies of the assessment process

Reproducibility
The credibility of a certification scheme reduces dramatically if the reproducibility is poor; that is to say; if various consultants using the same method end up with different results.
Especially the stage of data acquisition is very sensitive for variation in interpretation by the consultant. Describing a data acquisition procedure in an extremely explicit way is hardly possible for the diverse existing building stock. Such an approach is very complex in daily practice and a source of inaccuracy in itself. The most effective approach is to simplify the data acquisition process, for instance by using default values for parameters that are susceptible to misinterpretation. Another advantage is that the effort for data acquisition reduces and consequently there will be a reduction of assessment cost. The obvious disadvantage is that the use of low quality default values will lead to a poor accuracy for the building concerned. This implies that the availability of good quality default values allows simplification of the data acquisition through building inspection. Instead of defining accuracy on the level of the building it can also be defined on the level of a building stock. By establishing the default values in such a way that they are representative on stock level, accuracy on this higher level is still served, while on the building level physical accuracy is (partly) compensated by a better accuracy during data acquisition and a far better reproducibility.

Balancing the accuracy and reproducibility
It is important to understand that there is interaction between the accuracy of the default values, the calculation model and data acquisition. A very advanced model with a high accuracy that requires detailed and complex input using little default values may lead to very inaccurate data acquisition. Of course the overall accuracy of the assessment process is what counts. Therefore, more simple input using default values that are not the ultimate fit for the building concerned may result in higher quality results and significantly less effort. This even is the case if a more simplified calculation model with slightly less accurate output is used.

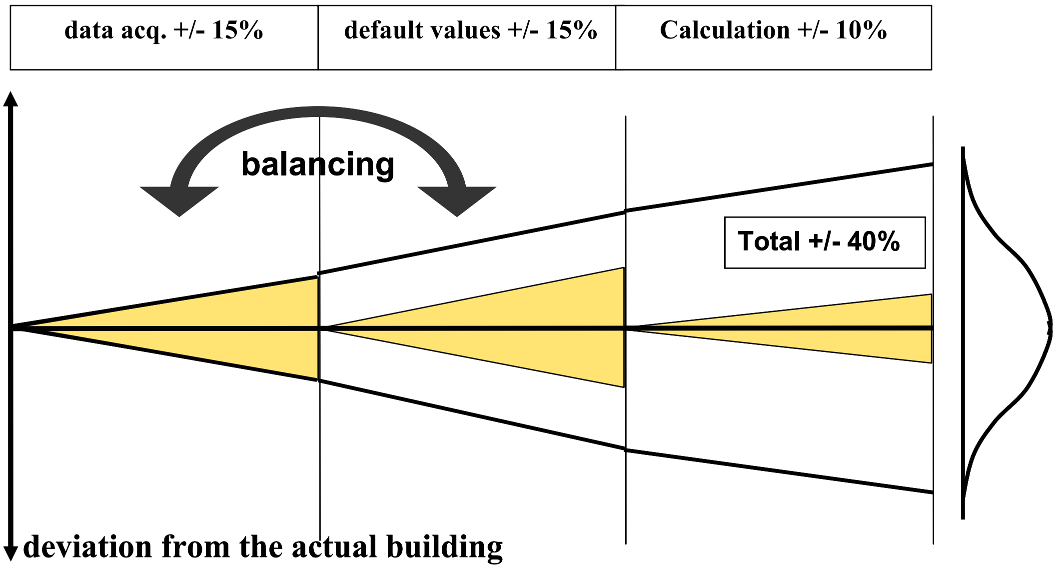

Figure 6: Balancing inaccuracies related to reproducibility

This is shown in figure 6 were the total accuracy is reduced from 45% to 40% and taking into account the fact that deviations are partly compensated, an error margin can be expected of about 10% to 15%. At the same time there is a much better reproducibility of the assessment process.

EPA-NR: Flexible and effective

The EPA-NR method takes into account these considerations. The method is in line with the available (draft) CEN-standards and will be easily adjustable to the national context and the diversity in the market and even on project level. Further development and maintenance of the method and especially of the software can be realised against low cost if a number of countries or parties are joining efforts. The flexibility of the method guarantees simple transfer to all EU Member States. The instruments will be developed in such a way that adjustment to new or modified CEN-standards will be relatively easy.

A good example to illustrate this approach of flexibility is the EPA-NR software. It has a flexible structure (Figure 7). The software consists of a standard calculation core which can be used all over Europe and abroad (independent of local context), and will fully comply with EPBD and CEN-standards. The calculation core is equipped with a technically defined input and output facility. Around this structure, future users will be able to build their own country or region specific interface. The calculation core makes use of local weather files, construction libraries, nationally adaptable method constants, etc. Specific project data are provided through the input interface. The input and output interfaces can be easily adapted to local requirements for different languages or other user needs.

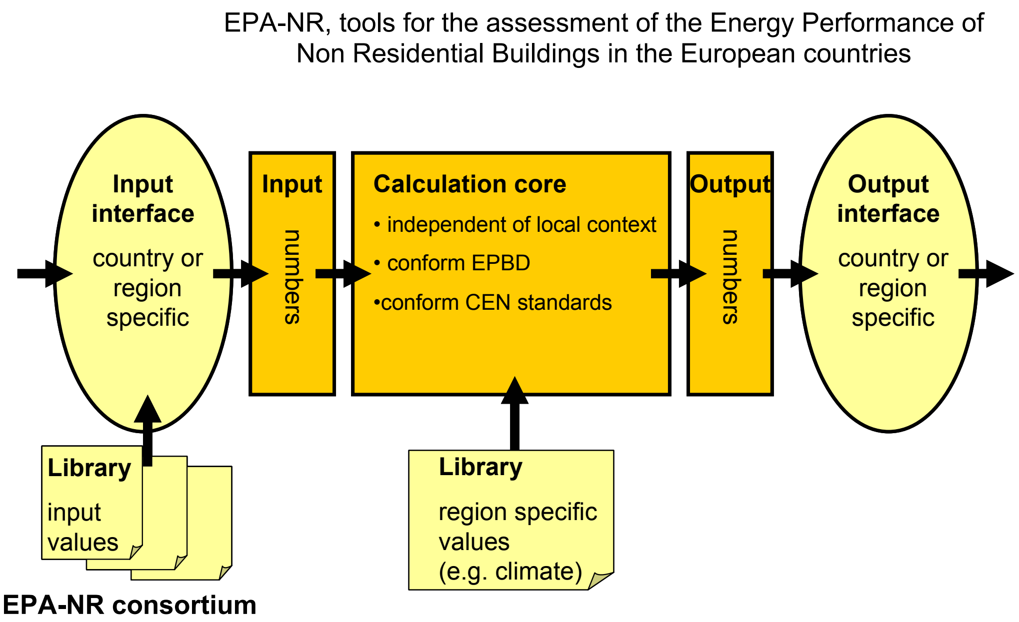

Figure 7: Structure of the EPA-NR software

The EPA-NR project is executed by a leading consortium consisting of parties that are closely involved with the further elaboration of the EPBD in their country, harmonisation by CEN.
The EPA-NR project closely co-operates with other European projects addressing the implementation of the EPBD. Participating in the consortium are: EBM-consult and TNO (The Netherlands), Danish Building Research Institute SBi (Denmark), Fraunhofer IBP (Germany), Österreichisches Ökologie Institut and Arsenal Research (Austria), CSTB (France), ENEA (Italy) and Institute for Environmental Research & Sustainable Development, NOA (Greece). On a national level National Feedback Committees will be established in which policy makers and market actors will have a role in providing feedback.
Representatives from other EU Member States will also be invited to participate in the project as an observer country in order to account, as much as possible, for the national EPBD activities throughout the EU-25. EPA-NR creates a strong relation between important partners from seven Member States, which together with the observer countries operate in a broader European network.

EPA-ED a twin project for residential buildings

A similar project "The Energy Performance Assessment for Existing Dwellings" (EPA-ED) is the preceding project that was recently completed in the Altener research program of the EC. The EPA-ED project also provides an assessment method and is accompanied by a set of tools, including software, which enables the consultants to audit and assess a dwelling or an entire residential building in a uniform way. The consultant is also supported to provide owners with specific advice for measures that can improve the energy performance of the dwelling or building. The software was used for a number of pilots performed in four European countries.

All final deliverables from the EPA-ED project are available from www.epa-ed.org.

For more information about EPA-NR please visit www.epa-nr.org or contact the co-ordinator, EBM-consult in the Netherlands, directly (Bart Poel and Gerelle van Cruchten, tel. +31 26 353 7272 or e-mail bpoel@ebm-consult.nl gvancruchten@ebmconsult.nl).

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Risk Assessment in Efficiency Evaluation

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Abstract

Energy efficiency projects can be modelled as investment decisions under uncertainty. Efficiency projects occur in the physical world, but are justified through financial determinants. In the simplest sense, an efficiency project is no different from any other investment. The primary difference is the difficulty in quantifying the value and risk resulting from the investment.
A range of financial metrics are applied, such as benefit/cost ratios and simple paybacks. The energy efficiency industry is just beginning to add risk and uncertainty metrics for financial returns. Uncertainty can and should be included in the valuation of projects in a manner that is efficient both in terms of quantification of energy savings (physical settlement) and financial appropriation of the resulting value (financial settlement). Tools for establishing a baseline and measuring the resulting energy savings, such as the International Performance Measurement and Verification Protocol (IPMVP), provide a framework for defining options, but stop short of providing a financial decision framework that includes the costs and benefits of M&V for a particular project. Hence, critical decisions regarding the amount of metering for a particular program or project are typically made using expert judgement, not quantitative analysis. Whereas efficiency investments are becoming an ever more important part of global efforts to optimize productivity and reduce sources of climate change, all participants in efficiency projects will require enhanced guidance on risk reduction through the appropriate use of M&V.
This paper discusses a framework for performing efficiency investment valuation and making decisions based on the combined physical and financial uncertainty, and the value of information resulting from the M&V plan. The authors hope that wider discussion on this topic will lead to a growing body of expertise on efficiency valuation techniques and thereby enhance investment in efficiency.
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Context - Efficiency Investments – Assets, Behaviour and Externalities

Global energy use is on the rise. Global electric power capacity is forecast to add 3,000 GW of capacity over the next 25 years (EIA, 2004). Much of this capacity will be generated with fossil fuels. All of this energy growth will occur in the context of increasing concern about the impacts energy systems have on the global environment and the security of energy supplies. A reliable supply of electric power is considered a necessity for development in an increasingly competitive economic world.(Barnett, 2004). The question facing policy makers, regulatory bodies, private corporations and average citizens around the planet is how much to invest to mitigate the impact of our growing thirst for reliable energy.

The most obvious way to mitigate energy impacts is to assure that the energy productivity is maximized. Whether by reducing negligent waste of energy, optimizing existing physical systems, or retrofitting with newly available technology, energy efficiency is a common sense part of the long-term solution. And given that efficiency can eliminate the need for some of the expected investment on the energy supply side, it can make good economic sense at every level. Deciding to be efficiency is not difficult, deciding how much to invest in efficiency, whether at the level of nations, regions or households, can be very difficult. Furthermore, having made investments in efficiency programs and projects, it is often very difficult to evaluate the financial benefit of those investments.

Energy supply and demand issues did not begin recently. In most countries the energy sector has been regulated and decisions regarding the optimal mix of supply and demand investments took place within a legislative and regulatory environment. In the past 20 years natural gas and electricity markets worldwide have been converting to more market-based approaches. “Deregulation” has added a number of new opportunities for valuing energy efficiency. For the most part however, the energy efficiency market is still experimenting with mechanisms to internalize energy externalities in retail energy prices. Market-based instruments (MBIs) hold the promise of efficiently apportioning the risk and value of energy efficiency investments, but they are still in their infancy (Bertoldi, 2005). Recently a number of European countries (UK, Italy, France, the Netherlands, the Flemish region of Belgium) have introduced or are planning to introduce market-based instruments to foster energy efficiency improvements. Some of these schemes are based on quantified savings targets for energy distributors or suppliers, coupled with a certification of the energy savings (via white certificates), and a possibility to trade certificates. This policy instrument often targets parts of the sectors (e.g. power generation) that are subject to carbon reduction targets (mainly under cap-and-trade schemes). In fact, regulatory uncertainty resulting from some deregulation experiments has increased the overall uncertainty of the value of energy efficiency.

In response to this need for better tools to predict and measure the results of energy efficiency projects, the US Department of Energy, in 1994, initiated a program to assist the efficiency industry to account for efficiency projects. The result was the International Performance Measurement and Verification Protocol (IPMVP, 1997). The IPMVP has been revised twice and is undergoing its third revision in 2006. The IPMVP is currently the only international standard for assessing efficiency impacts (often mislabelled “savings”). However, there are still large gaps to be filled to establish globally-accepted norms for valuing efficiency. As noted by Jim Waltz, the IPMVP does not provide guidance on how to attribute financial value to physical impacts (Waltz, 2004). The IPMVP has just begun to provide practical guidance on developing program and project M&V plans based on uncertainty and risk. The lack of risk metrics to go along with expected results greatly reduces the attractiveness of energy efficiency investments (Mills et al. 2004)

Recognizing that the current IPMVP was of limited use in assessing the financial viability of energy efficiency investments, the IPMVP organization has adopted a new mission and a new name – the Efficiency Valuation Organization (EVO). The new mission is “to develop and promote the use of standardized protocols, methods and tools (EVO Protocols) to quantify and manage the performance risks and benefits associated with end-use energy efficiency, renewable energy, and water efficiency business transactions.” The goal is to create a globally recognized centre of excellence on quantifying the physical and financial benefits of efficiency projects. Regions and nations may vary in the policies they choose to address energy impacts, but the underlying economic principals of energy efficiency projects are shared around the globe. Regulators, policy makers and practitioners will benefit from a common terminology and framework for assessing and assigning efficiency value.

EVO will provide guidance on identifying and quantifying all of the value that result from energy efficiency investments. In the simplest case, the only term in the value equation will be the quantity of energy saved times a flat rate for that amount. In more complicated cases the value equation will incorporate risk analysis and advanced economic valuations such as hedge value.

Contracting Efficiency

Efficiency is delivered in many ways, but most of us are familiar with two predominant mechanisms – public programs and private contracts (including internal company decisions). In both of these cases the relevant decision makers seek to calculate the cost and benefit of the efficiency investment. Investment decisions under uncertainty are a common problem that is well addressed in the economic and financial literature (Decisioneering). On the energy supply side, there are a number of tools available that collectively comprise the energy risk management industry. Despite some setbacks to the industry in the U.S., the use of financial risk management tools such as forward contracts, long-term contracts, options and swaps is growing worldwide and is an accepted form of risk sharing. Tools for managing risk on the supply side help to dampen, but not eliminate volatility of demand side estimate for the value of "negawatts". The simple fact is that when one makes an energy efficiency investment, there is often very little chance of knowing what the actual value of savings will be more than a year or two hence. Ignoring this uncertainty, as most energy efficiency planners do now, does not make it disappear. In fact, when energy efficiency is allowed to compete directly with other sources of supply in terms of value *and* risk, it can often provide a more attractive investment. (Mathew *et al.* 2004)

Public programs have had to adapt to meet the changing regulatory structures of energy markets. In the past, regulators would allow or dis-allow certain expenditure of the regulated entity. As efficiency became a higher priority in the 1970's, regulators adopted new methods to unbundle supply and demand investments and incentives, allowing utilities to earn money from it. More recently, deregulation (an partial re-regulation) of energy markets has advanced at different speeds around the planet creating a wide range of regulatory environments. Efficiency valuation in each case is a function of market structure and incentives. In California, while the governor, legislature and regulatory officials have made efficiency investments a priority in resource planning, there is no clear picture on how tariffs and incentives will be designed to implement this policy. It is perhaps ironic that the greatest risk facing many efficiency investments is the lack of a stable regulatory process. While California has allowed uncertainty in tariffs to impede the progress of the efficiency marketplace, it has taken the lead in applying uncertainty analysis to its portfolio of energy efficiency programs. The evaluation of California efficiency programs for 2006-2008 will be based in part on the results of a portfolio-wide risk analysis. The risk analysis provides a framework for assigning evaluation resources, including M&V. (Hall, Jacobs, Kromer, forthcoming). The current risk analysis utilizes databases of historical results (DEER) and promises to become a long-term approach to managing risk and uncertainty in this very large public program.

The Italian white certificate scheme uses three physical valuation: (a) a deemed savings approach with default factors for free riding, delivery mechanism and persistence; (b) an engineering approach, and (c) a third approach based on monitoring plans whereby energy savings are inferred through the measurement of energy use; in the latter case all monitoring plans must be submitted for pre-approval to the regulatory authority AEEG and must conform with pre-determined criteria (e.g. sample size, criteria to choose the measurement technology, etc.. In practice, most of the projects submitted to date have been of the deemed saving variety. There is ex-post verification and certification of actual energy savings achieved on a yearly basis[1]. In principle the metering approach is a more accurate guarantee of energy saved than the standard factors approach (the latter cannot verify details such as location and operating hours of installed CFLs), but in practice it can be difficult to identify the actual saving (e.g. in households there is only one meter for all electricity usage which increases each year due to growth in appliances and can fluctuate with changing household numbers, lifestyle, weather etc.). It may be reasonable for large installations or projects, but may result in high monitoring costs for projects of smaller size (Rezessy, forthcoming).

In Great Britain the Energy Efficiency Commitment (EEC) the savings of a project undertaken under the EEC scheme framework are calculated and set when a project is submitted based on a standardized estimate taking into consideration the technology used, weighted for fuel type and discounted over the lifetime of the measure. There is limited ex-post verification of the energy savings carried out by the Government although this work would not affect the way energy savings are accredited in the current scheme; the monitoring work affects the energy savings accredited in future schemes.

Recently the European Union adopted a new Directive introducing a mandatory annual saving target for Member States of 1% of the total energy consumption (averaged over the past 5 years) for a period of 9 years. This target has to be met with energy efficiency policy measures. The annual saving target has to be measured with an new European Harmonised methodology to evaluate energy savings. The new harmonised methodology will include a combination of bottom-up and top down measurement method (Bowie 2005).

[1] E.g. in the case of CHP the plant operator has to prove that the plant has run a certain number of hours, etc.

A bottom-up measurement system implies that savings (or emission reductions), obtained through the implementation of energy efficiency measures, are expressed in relevant quantities and common units and then aggregated with results from other implemented or planned measures. The aggregation of results can be done at company, local, regional and national level, a task handled very well with standardised templates, websites, databases etc., using standardised lists of measures and assumptions on their average lifetimes, estimates of the average energy saving impact and calculations of the total expected or deemed (technical calculation, often ex ante) energy savings.

In a bottom-up system, the impact of measures can usually be estimated before (ex-ante) actual implementation or metering, using deemed savings: metering is required only to calibrate the real effect of such measures and, when necessary, to verify and this can often be done using representative samples. This is an important characteristic of bottom-up measurements because it means the results can be known without waiting several years to receive statistics on energy consumption. Bottom-up could also be implemented ex-post by using engineering models. An additional advantage of using bottom-up measurements is the additional information obtained on exactly which policies and measures deliver the savings.

While bottom-up measurements could have a high degree of precision for many types of measures, they are difficult to apply to certain types of measures, especially those taken in the past ("early action") and lacking data, and for certain types of more cross-cutting measures such as taxes. Unless the total market for specific energy measures is also monitored, bottom-up calculations can fail to capture multiplier effects or market transformation, "*autonomous*" market development and miss "*rebound effects*", "*free-riders*" and "*free-drivers*". In the case of general, untargeted information campaigns, it becomes difficult to calculate the energy savings that result from the behaviour changes induced by the information made available. Bottom up evaluation could sometime result in overestimating the savings, as there may be overlaps between the effect of two different policy measures. A top-down system is thus a necessary part of any system for measuring energy efficiency improvements, not only during the time a harmonised bottom-up system is being developed, but even afterwards.

A top-down measurement system is one in which the amount of energy saved is calculated using more aggregated sectoral levels of energy consumption and savings as the starting point. Adjustments of the annual data are then made for a number of extraneous factors such as degree days, structural changes, product mix, purchasing power parity, etc. to derive a measure that gives a fair indication of e.g. total energy used per unit of GDP, energy used per square meter of housing space or energy per person-kilometre.

Top-down calculations often lack the possibility to measure *ex ante.* The long time required for collecting statistics from the Member States adds to the problem of using top-down methods to obtain rapid feed-back for making policy decisions. Top-down calculations are also often less accurate than bottom-up systems because aggregations of sometimes heterogeneous sector statistics are used in such calculations.

In private contracts for energy services, the parties must allocate the responsibility for energy asset purchase, maintenance and long term energy use. A common form of energy service contracting involves a host facility and an Energy Services Company (ESCO) under an agreement called an Energy Savings Performance Contract (ESPC). The ESPC contract outlines the responsibilities of the host and the ESCO. The goal is to optimize the productivity of the host facility. These site-specific contracts allow the parties to allocate all of the risks associated with the project. However, finding the optimal mix of efficiency investments for any plant requires a knowledge of future tariffs and other variables indicated below. As energy efficiency investments can have terms of well over 10 years, the valuation uncertainty can be significant. Enron Energy Services produced risk-based curves to address this uncertainty in private contracts. (Mathew, et al).

Due to the guarantee provided by the ESCO, ESPC is a risk management activity (Hansen). Risk assessment and management governs all aspects of the ESCO operation from customer pre-qualifications and investment grade audits to project management throughout the life of the contract.

The inability to identify risks and manage them effectively can be fatal to an ESCO. Successful ESCOs must be able to:

- Identify the risks
- Evaluate them accurately
- Develop effective mitigating strategies
- Put the right price tag on the risks they accept; and
- Determine when to avoid carrying out the contract.

Once risks are identified, ESCOs must be able to evaluate those risks and determine the relative impact on the savings stream and possible mitigating strategies (Hansen). Then, drawing on its experiences, the ESCO must determine the most cost-effective mitigation and incorporate all risk management factors into the project procedures and costs. In some cases, this evaluation will reveal that the risks, or the costs of mitigation, for a give measure (or for an entire project) are too great and the work is rejected. Has Hansen has been teaching all around the world "*The ability to manage risks effectively is the single most important competitive advantage an ESCO can have."* In particular the investment grade audit is a key step in any ESCO projects and is an essential component of risk management. The investment grade audit is an intensive engineering analysis of potential energy saving measures.

The investment grade very often includes a dynamic model of energy use characteristics of both the existing facility and all energy saving measures identified. The model needs to be calibrated against actual utility data to provide a realistic baseline against which to compute operating savings for proposed measures. Attention shall be paid to understanding not only the operating characteristics of all energy consuming systems, but also to all and all the project volatilities described below, that cause load profile variations on both an annual and daily basis.

- Project Intrinsic Volatilities—those energy consumption elements directly affected by changes within the facility, and are thus measurable, verifiable, and controllable. This includes the energy volume risk, asset performance risk, and energy baseline uncertainty risk.

- Project Extrinsic Volatilities—those energy consumption risks which are outside the facility, and hedge-able. These include energy price risk, labour cost risk, interest rate risk, and currency risk.

In order to allow risk metrics to be incorporated into efficiency investments, the authors advocated for public and private efforts to identify and compile data on both the aforementioned intrinsic and extrinsic volatilities and on energy audits, measurement, and verification.

In the case where the public interest in an absolute reduction in energy consumption (or associated emissions) the efficiency valuation procedures are simpler, but less forgiving (needs work)

Risk Terms – Time, Cost and Value

Earlier we mentioned that the IPMVP has become the international standard for quantifying the physical results of energy projects. There remains the challenge of translating the physical impact into financial rewards. As discussed in the previous section, energy markets worldwide have attempted to deregulate with varying degrees of success. Even within fully regulated energy markets, the number and complexity of rate structures precludes a simple solution to this problem of translating physical results to financial value. It is perhaps ironic that the classic 1961 text on rate structure design, "Principals of Public Utility Rates," identified the need for price certainty to allow energy consumers to make informed purchasing decisions. (Bonbright,1961) http://www.terry.uga.edu/bonbright/about/center/).

Nothing of substance has changed. The uncertainty to potential investments in energy efficiency is first and foremost in the hands of the regulators who set the tariff and other incentives. The following are the most important terms in the efficiency valuation equation:

- Tariff: Regulated utilities perform a host of calculations to come up with equitable tariff structures. The impact of tariff design on efficiency incentives is obvious. Recently, there has been an increased interest, and increasing debate, on the role of retail tariffs that include time of use (TOU), real-time pricing (RTP) and demand-response programs (DR). Each of these tools is forced to make a compromise between complexity of implementation and equity among
- Externalities – emissions credits, NOx, SOx, CO2, Security: While still in its infancy, there is a growing interest for instruments that efficiently allocate the external costs of energy use. Indications from early trading of CO2 credits has not yet risen to the level that will significantly impact project valuations, but with increased use there is a growing chance that these policy instruments will benefit energy efficiency investments (Bertoldi, 2005)
- Hedge value: Energy consuming assets represent a "short" position in the energy markets. A "short" position is risk terminology that implies a relationship between future energy prices and price risk. Modern energy supply markets allow energy producers and end-users to protect against volatility by using financial instruments known as hedges. Hedges are effectively insurance instruments where a market participant can pay a relatively small amount to reduce the uncertainty in future prices. Energy efficiency projects provide exactly the same risk reduction function, and hence represent an equivalent value to the implementer.
- Productivity – easy to qualify, difficult to measure. The purpose of any energy-using device is to create some value for the end-user. In the case of commercial and industrial end-users, the economic productivity of energy assets can be measured precisely. Technological innovation in energy efficiency often includes innovations that improve the productivity of the system as a whole. One example is the improved lighting quality provided with electronic ballasts. Energy calculations alone may not capture the increased value from improved technology.
- Associated maintenance cost reductions Owning and operating an energy asset entails costs beyond just the raw fuel. Efficiency valuation must include all of the life-cycle costs of asset ownership.

The Response – Putting a Value on Uncertainty

Assuming that we can assign expected values and uncertainties to the previously mentioned terms in the efficiency valuation equation, what is the role of verification and how much should be spent on it? The IPMVP was designed to help parties to develop an M&V plan for their specific project, but it does not address how the parties should agree on the amount to invest in the M&V. Because the universe of possible projects/investments is effectively infinite, the IPMVP recommends that the parties involved in the contract take three steps.

First, identify all of the values and risks resulting from the energy project. Second, assign responsibility for each of the risks and values. Third, create a cost-effective M&V plan that takes into account the specific risks for that project.

As mentioned above, it is critical to match the physical results to the potential financial value. And it is equally critical that M&V costs be kept reasonable. The goal is to design the optimal "Negawatt meter". The design parameters are the expected uncertainty in the measured system and the measurement uncertainty of the instrumentation. The optimizing equation requires the designer to place a value on the marginal reduction in uncertainty from the last increment spent on the M&V system.

We now get to the final problem of efficiency valuation. We have outlined above how energy efficiency projects are similar to other investments in that there is a unique risk and reward relationship for each project. Some of the project risk results from regulatory and market uncertainty that affect the underlying value of the savings. Other terms in the value equation add uncertainty to project value as a result of related market values such as Carbon mitigation, volatility of energy markets and productivity of the plant. Investment capital will flow to energy efficiency projects and be priced to the degree that these risks and rewards are "better" or "worse" than other investments. It is in this context that the authors see the opportunity for a new approach to energy efficiency investments that focuses equally on risk and reward. The mantra of the this new approach is “Identify, Quantify, Manage…. Risk”. The expected return from most energy efficiency investments is often well above other investments with equal risk profiles. The leap required to clear the investment hurdle is an effective risk evaluation to accompany the expected value of the investment.

This provides a context to answer the question “how much should I spend on M&V”? Where a value can be placed on identifying and potentially reducing the uncertainty in the investment, the proper expenditure on M&V occurs when the last increment (marginal cost of M&V) equals the marginal value from risk reduction. While easier said than done, this approach informed the M&V planning of a large ($300M) DSM program that sought to optimize M&V expenditures (Mathew, *et al.* 2004).
The goal of the M&V activity was to mitigate, not eliminate, the uncertainty in a large portfolio of energy efficiency investments. The approach to cost-effective valuation included the creation of a data-base of results of energy projects. The database was designed as an actuarial tool. It included reported results from a range of programs and projects. Where possible, uncertainties were included with expected value of project results.

The initial steps that the CPUC Energy Division has taken toward measuring uncertainty and risk in the 2006-2008 energy efficiency portfolio show great promise toward identifying the optimal allocation of limited evaluation resources and improving the reliability of efficiency investment forecasting.
In the European contest efficiency valuation is a key component of White Certificates schemes, which imposing saving targets on energy distributor or suppliers. Evaluation need to be accurate enough to assist transferable property rights on the energy savings and at the same time not increase the overall system cost. In addition the new energy saving targets for Member States will demand the creation of an harmonised methodology for assessment of national saving targets, accurate enough to attribute saving to individual policy measures, and at the same time to have a reasonable cost (no more than a few percent of the overall public budget used to achieve the savings).

Conclusion

Energy efficiency is a reliable mechanism for managing our energy future. Whether as a common sense decision or a smart financial investment, or imposed through legislation, energy efficiency implementation will benefit from better tools for calculating the value and uncertainty of planned efficiency activities. Efficiency Valuation goes beyond the quantification of physical results by addressing the financial uncertainties associated with the avoided costs. Efficiency Valuation acknowledges risks and seeks to quantify and manage them – not ignore them. The goal of EV is to identify the optimal mix of planning, modelling, measurement and analysis to accompany energy efficiency investment programs and projects. Enhanced efficiency valuation will lead to increased investment in energy efficiency projects. The Efficiency Valuation Organization will build on the international success of the IPMVP to advance the application of cost-effective M&V around the globe.

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building
performance
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Contracting in German State Properties

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1. Energy-Contracting

Energy-Contracting means a contractually agreed upon service between a building owner (customer) and a specialized energy services enterprise (contractor). The contractor plans, finances and implements measures targeted to optimize the energy supply or to reduce the energy consumption. With Contracting one achieves economically viable energy savings in public real estates without causing additional budget burdens to the public authorities. Through Contracting the building owner is released both of the organizational implementation of the energy saving measures as well as of the needed investments. Here, it is of crucial importance that the energy costs or a certain reduction of the energy costs are guaranteed for a longer contractual period of time. Thereby the investment and running cost risks are completely transferred out to the Contractor and operational incentives for higher energy efficiency are created.

2. Pilot project "Energy Efficiency-Contracting in German State Properties"

2.1 Political objectives

In 2002 the federal government as part of its national sustainability strategy decided in favour of the pilot project "Energy Efficiency-Contracting in German State Properties". The objectives of the project are to optimize energetically as many federal real estates as possible and to reduce with it the environmentally damaging CO_2 emissions through Energy-Contracting. The German Energy Agency was assigned with the implementation and management of the pilot project.
The relevance of the project was emphasized again by the new Federal government in the coalition agreement of November 11th, 2005. It is planned to further strengthen the implementation of Contracting in federal real estates.

2.2 Duties of dena

Dena has created the general framework for Contracting in federal buildings by developing standardized tender instruments and the clarification of budget statutes regarding handling of Contracting. Using the available tender instruments it is guaranteed a highly professional quality of the management of tenders. This contributes significantly to the successful implementation of Contracting projects.
At the same time the buildings administrations are unburdened since the time and effort needed for the preparation and implementation of the tender procedure is reduced due to the use of standardized instruments. Dena professionally supports the buildings administrations throughout all the phases of the bidding; from the creation of the tender documents through the evaluation of the offers to the coordination of the contracts.

2.3 Development of the projects

In order to choose the appropriated federal real estates, a database through which the real estates are archived and evaluated was created.
Following are the criteria gathered to be used in the choice of the real estates:

- Ownership and application rate,
- Structural safety,
- Height of energy costs, development of the use and costs,
- Performed and planned overhaul and respectively energy saving measures,
- Reconditioning and modernization needs of the building's equipment,
- Possibility of bundling, meaning putting together different real estates into one project.

Dena checks in informative discussions with users of potentially suitable real estates and the responsible buildings administrations possibilities of participation at the projects and advantages of the different Contracting models.

There are fundamental barriers opposite Contracting, which have to be negotiated in the discussion with the users of the real estate properties.

The most frequent barriers are:
- Understanding the business model Contracting,
- Long contract periods (7 to 12 years),
- Fear of authority loss of the technical personnel,
- Fear of the reduced flexibility in the use of the real estate properties,
- Expectation that energy conservation can be likewise realized with own money,
- Expenditure for the execution of the tender process,
- Expenditure for the controlling of the contract.

In order to overcome the barriers, dena works on different levels to develop more understanding for Contracting. The successfully realized projects are documented and published in the form of best practice examples. The projects are published in articles of technical periodicals and presented on conferences admits. So it is expected, that imitators are to be found who would like to use Contracting for energy conservation.

The expenditure of the tender process is reduced by the supply of standardized tender instruments. The tender instruments include:
- General explanations on how to start and execute a Contracting tender,
- Introduction in the legal framework of Contracting,
- Forms for the EU wide proclamation of award to contract (contract notice),
- Forms for analysis of the technical equipment and conditions of the building,
- Contracts for energy saving Contracting and energy delivering Contracting,
- Computer programs to calculate the reference energy consumption,
- Computer programs to compare biddings.

Dena supports the building administrations by checking the quality of the tender documents and by including specialized engineering consultants to support the administrations. Dena joins negotiations with bidding Contracting companies and gives proposal for the selection of the best tenderer. During the construction measures in the real estate properties dena is available for technical questions.

2.4 Current projects

Through the successful implementation of the current Contracting bids initiated by dena at 40 federal real estates the to-date energy costs are expected to be reduced by an estimated total of 3.7 million Euros per year. This corresponds to an average cost saving of 25 %. The immediate budget relief of the Federation sums up to a total of approximately 730,000 Euros per year. In order to achieve these objectives the Contractors are investing a total of approximately 17 million Euros in energy saving technical building equipment. Through the energy saving measures the energy caused CO_2 emissions can be reduced by approximately 22,000 tons per year (-25 %). This corresponds to the CO_2 emission of 1,700 one family houses.

The following table shows the energy performance Contracting projects, in which a contract was already concluded. An average reduction of the energy costs is guaranteed around 32% related to the costs of the reference year. The CO_2-reduction amounts to an average value of 30%.

Contracting in German State Properties

Project	Federal state	Reference energy costs	Contractual guaranteed results						
			Guaranteed investments	Guaranteed reduction of energy costs		Immediate budget relief	CO_2-reduction	
Federal police headquarters center, Fuldatal	HE	260,000 €/a	272,000 €	77,000 €/a	30%	15,000 €/a	475 t/a	20%
Customs Office, Cologne	NW	409,000 €/a	336,000 €	128,000 €/a	31%	36,000 €/a	680 t/a	22%
Federal research institute for nutrition and food, Kiel	SH	548,000 €/a	720,000 €	228,000 €/a	42%	77,000 €/a	1,095 t/a	38%
Federal Institution for hydraulic engineering, Karlsruhe	BW	338,000 €/a	320,000 €	77,000 €/a	23%	2,000 €/a	350 t/a	20%
Pool Hamburg	HH	692,000 €/a	1,282,000 €	256,000 €/a	37%	64,000 €/a	668 t/a	18%
Federal Employment Office, Frankfurt	HE	235,000 €/a	174,000 €	35,000 €/a	15%	0 €/a	175 t/a	16%
German library, Frankfurt	HE	481,000 €/a	662,000 €	120,000 €/a	25%	19,000 €/a	958 t/a	27%
Pool German Federal Armed Forces, Hamburg	HH	1,044,000 €/a	2,300,000 €	408,000 €/a	39%	102,000 €/a	1,235 t/a	25%
Kulturforum, Berlin	BE	2,467,000 €/a	4,470,000 €	751,000 €/a	30%	120,000 €/a	6,005 t/a	39%
Summe		**6,474,000 €/a**	**10,537,000 €**	**2,081,000 €/a**	**32%**	**436,000 €/a**	**11,640 t/a**	**30%**

However, the potential of Contracting at federal real estates is by far not yet exhausted with the so far started projects. Thus in the coming months further federal real estates should be bindingly gained for a participation at the project. Through the assimilation of Contracting into the building guidelines of the Federation the use of Contacting as purchase alternative becomes self evident.

3. Contracting campaign for public real estates

Dena also uses the experience from the Federal Pilot project for other public real estates. In October 2004 dena has accordingly started the “Contracting campaign for public real estates” that addresses communal decision taker from politics and administration.

The objective of the information campaign is to promote the integration of Contracting into the communal planning process. Besides it also increases the acceptance of Contracting and the acceleration of the development of the market. The annual energy costs accumulating at communal real estates exceed 2 billion Euros. Through energy Contracting the overhauling and modernization of technical equipment can be made possible and the energy costs can be reduced by up to 30 %. dena assists communities through the “Contracting campaign for public real estates” to make this potential accessible. The information campaign informs on the subject of Contracting with publications, regional and countrywide events and an internet platform: www.contractingoffensive.de.

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Internal Performance Commitments Enabling a Continuous Flow of Energy-Efficiency Measures

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Abstract
Building owners and users are, more often than not, faced with the same scenario: although significant opportunities to save energy costs exist, these profitable potentials are not realised, due to various reasons. It is often the case that despite all efforts to kick-start a process, the systematic and continuous identification, preparation and implementation of energy efficiency measures is still missing.

Internal Performance Commitments cover a spectrum of organisational concepts, enabling a continuous management and financing of energy efficiency measures in buildings. They consist of the following three elements:
- A specific commitment or target describing the level of future energy efficiency investments and energy savings.
- A way of funding the continuous implementation of energy efficiency measures. For example, a revolving fund, kick-started with the provision of seed money for energy efficiency investments in the first years, and continuously fed by the energy cost savings that follow.
- An energy management unit capable of implementing the scheme and co-ordinating projects on energy efficiency.

In contrast to external Energy Performance Contracting, Internal Performance Commitments make use of existing internal capacities and know-how. Profits resulting from energy efficiency investments remain entirely with the public administration and easily pay off the energy management costs.

The paper presents the final results of the European „PICOLight“ project, testing and disseminating Internal Performance Commitment schemes in seven public administrations in six European countries, with a technical focus on energy-efficient lighting. The PICOLight project provides a strategy, criteria, tools and examples from practice of how to overcome the barriers and obstacles, which hinder the broad and continuous implementation of energy efficiency measures in public buildings. Furthermore, it gives recommendations to policy makers on how to support the implementation of Public Internal Performance Commitments (PICO).

The paper further discusses, in how far these Internal Performance Commitment schemes originally designed for public administrations could be applied to commerce and industry, too. It can be concluded that – particularly in small and medium enterprises - many of the existing barriers and obstacles are the same as in public administrations and that commercial and industrial building owners and users could benefit from Internal Performance Commitments (IPC), too. In larger firms with profit centre structures, even an Internal Performance Contracting scheme with a revolving fund could be installed enabling energy efficiency investment by internal agreements between different profit centres.

The PICO idea and the PICOLight project

Building owners and users are, more often than not, faced with the same scenario: although significant opportunities to save energy costs exist, these profitable potentials are not realised, due to various reasons. It is often the case that despite all efforts to kick-start a process, the systematic and continuous identification, preparation and implementation of energy efficiency measures is still missing.

Energy efficiency services often provide a solution to this situation, and particularly to the typical barriers and obstacles of split incentives, lack of finance and lack of know-how and personnel capacities. During the last decade, the related market for third party financing schemes such as **Energy Performance Contracting** or contract energy management has grown. Furthermore, there are more and more public administrations completely outsourcing their building assets or the facility management including maintenance. However, there are several reasons why such an involvement of third parties is not always successful or appropriate:

- outsourcing will not always lead to cost-efficient solutions, if only the possible cost reductions in the short run are focussed on;
- some public administrations try to avoid the transaction costs of concluding energy performance or contract energy management contracts or have no capacities and competences to issue a respective tender or contract;
- energy performance contracts often do not cover all the profitable energy efficiency measures which could have been implemented;
- some of the barriers and obstacles mentioned are also barriers towards Energy Performance Contracting;
- some energy service companies (ESCOs) have made bad experiences with public administrations in the past due to bureaucracy, complex decision processes, insufficient knowledge of administrative officers issuing the tenders and high effort needed to formulate a bid compared to the limited chance to receive a contract; therefore, as the Wuppertal Institute was told by some ESCOs in Germany, those ESCOs which are more successful in the market are often reluctant to conclude contracts with public administrations and hardly take part in public tenders;
- some public administrations have made bad experiences with ESCOs due to 'cherry-picking' by ESCOs or bad quality of energy performance contracts and their implementation; for example, a project measuring room temperature in 30 Bavarian schools showed that in most of these schools actual temperature deviated substantially from set temperature and only minor energy savings could be achieved by running energy performance contracts (energie-AG 2005); and,
- some buildings or single refurbishments are too small for a contract with a third party.

Therefore, there still remains a large potential for effective and efficient **in-house solutions** in public administrations.

The SAVE project "Testing and Dissemination of Public Internal Performance Contracting Schemes with Pilot Projects for Energy-Efficient Lighting in Public Buildings (**PICOLight**)" (Feb 2003 – Jul 2005) has developed, adapted and tried to implement one specific kind of in-house solution. This is what in the end of the project was called a **Public Internal Performance Commitment (PICO)** scheme. Such schemes cover a spectrum of organisational concepts, enabling a continuous management and financing of energy efficiency measures in public buildings. They consist of the following three elements:

- A **specific commitment or target** describing the level of future energy efficiency investments and energy savings that a public administration wants to achieve.
- A way of **funding** the continuous implementation of energy efficiency measures. One example would be a **budget act,** which introduces a specific energy efficiency budget line into the organisation's overall budget. An even more reliable source would be a **revolving fund**, kick-started with the provision of seed money for energy efficiency investments in the first years, and continuously fed by the energy cost savings that follow as a consequence of the investments. .
- An **energy management unit** capable of implementing the scheme and co-ordinating projects on energy efficiency.

Public Internal Performance *Contracting* schemes, which were originally aimed at by the PICOLight project, are the most comprehensive form of a Public Internal Performance *Commitment* (PICO). Very similar to external contracting, **Public Internal Performance Contracting** represents a way to enable energy efficiency investments by internal energy performance contracts (PICO agreements) between different units of the same administration. One unit of the public authority, the 'PICO unit', delivers the financial and technical energy efficiency service to another unit. The energy savings reduce the annual energy bill of the 'customer' unit, which enables it to pay the internal contracting fee (PICO fee) to the PICO unit. In turn, the PICO unit uses the return to finance future energy efficiency investments; a kind of revolving funds is installed, which allows a more continuous implementation of energy efficiency measures.

A PICO scheme in practice – The example of the City of Freiburg im Breisgau / Germany

The City of Freiburg im Breisgau in Germany has a good record of energy saving projects in its public administrations. Between 1990 and 1999, annual CO_2 emissions were reduced by about 17 %.

Savings have partly been achieved by internal performance agreements between the building surveyor's office and the user departments, and partly by energy performance contracting schemes with third parties. In addition, an energy performance contract for a school with the main part of the investment financed by the citizens of Freiburg was also concluded.

The City uses the following as a rule of thumb when making decisions on the way energy efficiency measures should be managed and financed :

- A building with energy costs of up to 50,000 Euros/year: the City itself invests via a Public Internal Performance Contracting scheme. In doing so, it follows the example of the City of Stuttgart, which implemented one of the first successful initiatives of this kind in Germany. During the first year of the 2004 scheme, Freiburg invested 180,000 Euros and cut energy costs by 40,000 Euros/year.
- A building with energy costs above 75,000 Euros/year: an energy performance contract is put out to tender for investment and management by external energy service companies.
- A building with energy costs between 50,000 and 75,000 Euros/year: the City considers creating a pool of several buildings, for which a call for tender is issued.

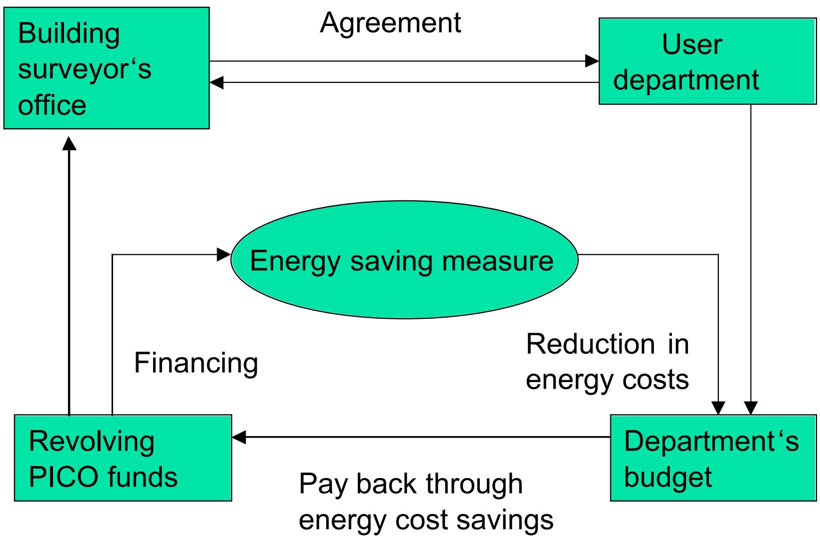


Figure 1: Public Internal Performance Contracting in the City of Freiburg/Germany

Other PICO schemes may only include the three elements mentioned above without concluding a specific contract between departments of the same administration or even without the installation of a revolving funds.

Nevertheless, all PICO schemes **make use of existing internal capacities and know-how**. **Profits** resulting from energy efficiency investments **remain entirely with the public administration**. The **costs of energy management are easily payed off**. And all the PICO schemes finally aim at initiating, enabling and securing a **continuous management and financing of energy efficiency measures** in public buildings.

Results from the PICOLight case studies

In the course of the PICOLight project, Public Internal Performance Commitment (PICO) schemes were adapted to seven participating public administrations in six countries and partly already implemented, thereby trying to overcome the barriers and obstacles, which hinder the broad and continuous implementation of energy efficiency measures in these public administrations. The following public administrations participated in the PICOLight project:

- City of Salzburg, Austria;
- University of Bordeaux, France;
- BLB NRW, Germany;
- Niguarda Hospital, Italy;
- Province of Bologna, Italy;
- City of Jordanów, Poland;
- City of Malmö, Sweden.

The pilot projects in seven public administrations in six European countries have shown, that **Public Internal Performance Commitment (PICO)** schemes offer the opportunity to **at least partly overcome the barriers and obstacles** identified in the current procurement and building investment processes for energy efficiency measures like the installation of energy-efficient lighting technologies. After having started a PICO scheme, it will be easier to finance future energy efficiency measures within the public administrations' routine ordinary maintenance and retrofit activities. A running PICO scheme like a Public Internal Performance Contracting giving the possibility to finance energy efficiency measures from energy cost savings makes it easier for energy managers to justify their work. A PICO scheme with a system of budgeted energy can set further incentives for the implementation of energy-efficient solutions, if the financing mechanism is clear and if it results in a surplus for all participating actors within the public administration.

However, PICO **will not solve all the problems**, barriers and obstacles mentioned in the introduction to this report. Moreover, solving part of the problems even is a precondition for an effective initiation and implementation of PICO. For example, some seed funding, political will and skilled personnel is needed to start with a PICO scheme and the implementation process in a public administration. Furthermore, the implementation of PICO might contradict the general tendency of outsourcing different services in many public administrations.

A PICO scheme must be **adapted** to the specific conditions and circumstances the respective public administration faces. In particular,

- **Legal framework** conditions might not allow the formal implementation of revolving funds on the local level, as it has been the case in the Polish PICOLight example. In this case, other ways of securing that cost savings will be invested into further energy efficiency measures have to be found, like it has been done in the City of Jordanów by a budgetary act.
- If there is no **energy accounting** of the different departments of a public administration, like it is the case in the University of Bordeaux, an internal third-party financing (PICO) system will not be possible. However, a revolving fund at the disposition of the energy or building managers could make continious retrofits easier.
- On the other hand, if the property management has both energy operating and investment budgets in its hands, and can thus in theory optimise energy investments according to lowest life-cycle costs, the PICO methodology in its most comprehensive form as a Public Internal Performance Contracting might be considered too complicated. In such a case the implementation of another kind of PICO scheme (e.g., combining the existing management capabilities with an energy efficiency target and an energy efficiency budget) might lead to an **optimisation** of the existing building investment and procurement routines.

The specific situation in a public administration may also limit the size and scope of PICO schemes that can be installed:

- Lack of **political will** might only allow installing a "light" PICO scheme, with more general energy efficiency targets and different options how to pursuit them.
- Lack of **seed money** might only lead to a small PICO fund, even if the PICO scheme is implemented more or less in its most comprehensive form of a Public Internal Performance Contracting.
- Disputes about demarcation of tasks and lack of **communication** between different departments of a public administration (e.g., the environmental department, the buildings department and the

department of finance) might not only delay implementation, but might lead only to a small PICO fund, since opportunities and responsibilities for feeding the fund with seed money are not clear enough.

Table 1: Overview on PICO elements implemented in the PICOLight pilot projects (September 2005)

Case study	Internal energy performance contract	Special account	Revolving funds	Specific commitment regarding future investment	(simple) monitoring / evaluation of savings / reporting	Energy management unit / officers
PICO elements in the PICOLight pilot projects						
Salzburg		maybe in 2006			X	X
Bordeaux				X (technical commitment)	measuring campaign	X
BLB NRW	planned for 2006			X (agreement with ministries)	X	X
Niguarda		X	X		X	X
Bologna		X	X		X	X
Jordanow		X	X (simulated by budget act)	X (budget act)	X	X
Malmö				increase in resources and improved guidelines considered	X	X
Public Internal Performance Contracting as the most comprehensive form of a PICO scheme						
e. g., Stuttgart / Freiburg	X	X	X	X	X	X

Source: Irrek/Thomas/et al. 2005

There are several kinds of PICO schemes possible. What is important is that PICO leads to a more continuous managing and financing of energy efficiency measures in public administrations. Table 1 gives an overview on **elements of PICO schemes implemented in the seven case studies of the PICOLight project** compared to a Public Internal Performance Contracting scheme like it has been implemented, e. g., in the German cities of Stuttgart and Freiburg. It shows that in none of the seven case studies it has been possible to implement a full Public Internal Performance Contracting scheme.

However, a special commitment regarding future investments (e.g. a specific level of investment planned, specific technical commitment with regard to the energy efficiency standard of future refurbishments) and a specific financing scheme (allowing to continuously finance energy efficiency measures) has been implemented in some, but not in all public administrations participating in the PICOLight project:

- In both Italian cases, a specific budget item for energy efficiency measures was added to the annual investment plan as a kind of revolving fund. A small amount of seed money was provided for this part of the budget to finance first energy efficiency measures. Annual cost savings from these measures will be added to the revolving fund for subsequent use in further energy efficiency measures.
- In contrast to the Italian cases, a revolving funds was not possible in Poland by law. Therefore, in Poland, a budget act was formulated stipulating that returns from energy and water efficiency measures (saved energy and water costs) will be used for future investments in energy efficiency. In this way, the budget act tries to replace and simulate a revolving fund.
- For the BLB NRW, only a framework agreement with the ministries of the state of North Rhine-Westphalia could be reached as a basis for future more concrete schemes.
- The University of Bordeaux did not see the implementation of a specific financial scheme appropriate, but committed itself to a higher energy efficiency standard in future refurbishments.

- In Malmö, it has been considered to increase resources dedicated to energy efficiency and to create more stringent planning and design guidelines.
- In Salzburg, there is still the hope, that it might be possible to start with something which is close to Public Internal Performance Contracting in the year 2006. Furthermore, a specific kind of Energy Performance Contracting scheme called “partner contracting” involves the employees of the city much more into the implementation of measures than it is usually the case.

Conclusions and recommendations for public administrations and policies and measures supporting them

PICO solutions are a flexible way to a more continuous management and financing of energy efficiency measures in public administrations. In times of tight public budgets, PICO offers the opportunity to continuous implementation of energy efficiency measures through the temporary provision of seed money. For example, through a re-organisation of budgets, loans, etc during the initialising phase of PICO, it is possible to stimulate a continuous flow of investments so that the resulting pay-back cash flows in turn provide new funds for follow-up projects. This can be organised in the form of a clearly separated revolving funds, but as the examples of the pilot projects have shown, also other forms to organise the continuous flow might be possible.

However, the analysis has shown that the implementation of PICO schemes on a larger scale in public administrations in Europe will be only possible, if the following **basic conditions** were fulfilled broadly and sufficiently:

- A functioning energy management unit with sufficient technical expertise (for small public administrations, this unit could be installed in co-operation with other public administrations). Such an energy management unit easily pays off its costs, which should be documented well for justification.
- Political will to provide seed money for PICO funds.
- Cost accounting of energy savings based on individual metering and simple measurement and verification procedures.
- Compatibility with national regulations.

Therefore, follow-up initiatives should aim at supporting projects, programmes and legislative and organisational processes towards these directions. A larger **package of policy and management instruments** should be used which would increase the general capabilities and capacities of public administrations to strengthen energy efficiency (cf. Irrek/Thomas/et al. 2005 and Borg & Co./et al. 2003 for detailed recommendations in this direction). Supporting the basic conditions mentioned above is needed for or facilitates increasing energy efficiency. The implementation can be either realised by installing PICO schemes, or external Energy Performance Contracting, or other measures.

With regard to the kind of energy efficiency measures PICO is best suited to, **PICO might particularly be appropriate for small to medium-sized projects** that can be handled inside the administration and are too small to attract external ESCOs. In this way, PICO can be seen as a complementary rather than as a substituting instrument to Performance Contracting (cf. Table 2 and the box with the example of the City of Freiburg which uses both and has implemented a rule of thumb differentiating between Public Internal Performance Contracting and external ESCO contracts depending on the size of energy costs of a building). Both concepts draw on a similar concept and incorporate comparable procedures and project management tasks, so that competence from one field can be used for undertaking projects in the other, i.e. the different strengths and focal points of both approaches can be joined in the sense of a tool box. Both might even act as a door opener for each other. For example, net cost savings from energy performance contracts could be used as a seed funding for a PICO scheme. On the other hand, administrations, which have established a sufficient infrastructure and know-how to carry out PICO projects, are much better equipped to be a capable customer on the market for external, more demanding Performance Contracting projects.

As the results from the pilot projects show, it is possible but takes a considerable effort to implement the principle PICO idea into practice in the different public administrations in the different European countries. The way from the first ideas to the implementation of a scheme often is a long one. Due to the specific conditions and circumstances the respective public administration faces, adaptations and changes to the concept have to be made, **the principal idea of the PICO scheme must be adapted to the conditions and circumstances the respective public administration faces**. While energy efficiency is not on the top of the agenda, and in the absence of external funding for the start of a PICO scheme in most of the European municipalities, it often needs creativity and committed persons who really want to implement such a scheme to get started. Without a broad and sufficient implementation of the basic conditions mentioned, it will hardly be possible to introduce PICO on a larger scale in European administrations.

Table 2: PICO and Performance Contracting through ESCOs in comparison

Instrument	PICO	Performance Contracting through ESCOs
Offers Advantages in Cases when ...	the size of the energy saving measure is too small to cover the transaction costs of performance contracts* the acquisition of external know-how is not required an internal knowledge base can and should be used own capacities allow the project to be handled internally so that risk and profit margins can be saved, improving the project profitability there is the risk of "cream-skimming" which does not meet the complete needs of the public authority	looking for new financial sources and/or overcoming liquidity bottlenecks specialised external know-how is needed risks shall be shared or even transferred to the external ESCO, especially when a fixed saving is guaranteed own staff shall get access to external know-how and qualification only limited personnel resources are available scarce resources – not just personnel capacities – shall be concentrated on core activities

* Transaction costs for PICO are lower than for energy performance contracts with third parties; for example, measurement and verification procedures can be much simpler. However, a ratio for the transaction cost reductions of PICO compared to energy performance contracting through ESCOs cannot be given here.

Potentials and net benefits of energy efficiency investments in public administrations via PICO in Europe

Energy consumption and energy (cost) saving potentials

Improvements in current procedures of public procurement and building management in public administrations can achieve significant economic rewards from the implementation of energy-efficient and at the same time cost-effective solutions in public buildings. Improved consideration of energy efficiency in these procedures is a strategy to make the most of scarce public funds while addressing today’s energy and climate challenges.

And indeed the returns have the potential to be huge. The European study on Public Procurement of Energy Saving Technologies (PROST) indicated that compared to a ‘business as usual’ scenario, public administrations in the EU-15 Member States can save up to 20% of their energy use (heat and electricity) by 2020, if a stronger emphasis is placed on energy efficiency aspects in procurement, investment, and energy management routines.

These results were recently confirmed by a study by the Wuppertal Institute on how to reduce CO_2 emissions in the EU-25 by more than 30% until 2020 compared to 1990 (Lechtenböhmer et al. 2005). The energy efficiency scenario for the tertiary and commercial sector demonstrated the potential to reduce electricity consumption by 18.5% and heat consumption by 27.1% until 2020 compared to a business as usual scenario. It can be assumed that potentials of this size could be realised in the public sector as an important part of the tertiary and commercial sector, too.

However, since there is no systematic and aggregated energy bookkeeping, it is **not possible to exactly calculate** the absolute overall amount of energy consumed and of potential savings in the public sector in Europe. Based on the results of the RELIEF and the PROST studies (Pierrard 2004; Borg & Co, et al. 2003), **total final energy demand in the public sector in the EU-25 can be estimated at between 182 and 239 TWh_{el} and at between 371 and 488 TWh_{th} per year**. This is between **6% and 8%** of the total final energy demand (not including the energy demand of the transport sector) in the EU-25, and about **one third** of the final energy demand of the tertiary and commercial sector. Assuming an average energy price for the public sector of 9.5 Eurocent/kWh_{el} and 3.0 Eurocent/kWh_{th} (assumptions based on recent EUROSTAT data for commerce and industry and on experiences from the PICOLight case studies), today's **energy costs of the public sector sum up to between 26 and 35 billion Euro per year** in total.

Applying the reduction potentials identified by Lechtenböhmer et al. (2005) for the tertiary and commercially sector to the public sector, **potential final energy savings in the public sector add up to between 47 and 61 TWh_{el} and between 108 and 141 TWh_{th} per year by the year 2020** in the EU-25. The corresponding potential energy cost savings add up to **between 7.7 and 10.0 billion Euro per year in total by the year 2020**, compared to a BAU scenario.

Table 2: Final energy demand and energy saving potentials of public administrations in the EU-25 and contribution of PICO schemes to the realisation of saving potentials [TWh/year]

Final energy	Estimate	2005	2010	2015	2020
BAU					
Electricity	High estimate	238.72	270.16	299.75	331.24
	Low estimate	181.74	205.68	228.21	252.18
Heat	High estimate	487.67	500.79	508.55	521.27
	Low estimate	371.28	381.26	387.18	396.86
Total	High estimate	726.39	770.95	808.30	852.51
	Low estimate	553.03	586.95	615.38	649.04
Energy efficiency scenario					
Electricity	High estimate	238.72	263.11	277.78	270.11
	Low estimate	181.74	200.31	211.48	205.64
Heat	High estimate	487.67	471.16	448.21	379.87
	Low estimate	371.28	358.71	341.24	289.21
Total	High estimate	726.39	734.27	725.99	649.98
	Low estimate	553.02	559.03	552.72	494.85
Savings compared to BAU					
Electricity	High estimate	0.00	-7.06	-21.97	-61.13
	Low estimate	0.00	-5.37	-16.73	-46.54
Heat	High estimate	0.00	-29.62	-60.34	-141.40
	Low estimate	0.00	-22.55	-45.94	-107.65
Total	High estimate	0.00	-36.68	-82.31	-202.52
	Low estimate	0.00	-27.92	-62.66	-154.19
… of which are PICO potentials (top-down calculation; 30% realised via PICO)					
Electricity	High estimate	0.00	-2.12	-6.59	-18.34
	Low estimate	0.00	-1.61	-5.02	-13.96
Heat	High estimate	0.00	-8.89	-18.10	-42.42
	Low estimate	0.00	-6.77	-13.78	-32.29
Total	High estimate	0.00	-11.00	-24.69	-60.76
	Low estimate	0.00	-8.38	-18.80	-46.26
… of which are PICO potentials (bottom-up calculation)					
Electricity	Bottom-up	0.00	-1.37	-2.80	-2,85
Heat	Bottom-up	0.00	-4.01	-8.17	-8.31
Total	Bottom-up	0.00	-5.39	-10.97	-11.16

Source: Wuppertal Institute, based on Lechtenböhmer et al. 2005, Thomas/Irrek 2005, Pierrard 2004, Borg & Co et al. 2003.

PICO potentials

How much of these energy saving potentials could be realised via a PICO scheme? A top-down and a bottom-up approach were carried out to get a **rough estimate of the potential impact of PICO schemes on energy consumption and energy costs** in public administrations in the EU-25. The **top-down approach** just assumes, that a specific percentage (e.g., 20% or 30%) of the energy saving potentials identified for the public sector could be realised internally via PICO schemes, but that the main part will probably be realised with the help of external actors (e.g., by an energy performance contract) or from normal public budgets. According to this approach, energy savings of up to **18 TWh_{el}/year and 42 TWh_{th}/year** and energy cost savings of **up to 3 billion Euro per year** could be achieved by 2020, when implementing PICO schemes in public administrations in the EU-25.

The **bottom-up approach** is based on a proposal for an energy efficiency programme supporting public administrations in setting up a (PICO) scheme, which helps them to more continuously manage and finance energy efficiency measures (Thomas/Irrek 2005). Assuming that over 10 years all public administrations in the EU-25 allocate once about 5% of the annual energy bill, which is for local authorities roughly equivalent to **5 Euro per inhabitant,** to an internal energy efficiency revolving fund functioning as "seed money" for energy efficiency investments in public buildings, this would sum up to **3 billion Euro "seed money"** being invested into energy efficiency measures, with energy cost savings achieved being used by the fund for further measures. The total investments would lead to energy savings of about **2.9 TWh_{el}/year and 8.3 TWh_{th}/year,** with energy cost savings summing up to **520 million Euro/year** in the EU-25,15 years after having started these activities. The basic assumptions behind these calculations were derived from pilot projects in schools, where on average an investment of 1,28 Mio. Euro resulted in an energy reduction of 1,020 MWh_{el}/year and 2,980 MWh_{th}/year.

Applicability of the PICO concept to commercial and industrial buildings

Motivations and incentives – procurement and building investment approaches in the commercial and industry sector

Many of the **barriers and obstacles**, which hinder the implementation of energy efficiency measures in public buildings, are also known in the commercial and industry sector, particularly in small and medium enterprises (cf. also Blok et al. 2004, Brüggemann 2005, Mills et al. 2006):

- Lack of financial and personnel resources;
- Lack of technical information and know-how;
- Energy efficiency is not the core of the business of these firms; investment in the core business has a higher priority;
- Split incentives in case the building is only rented or in case there are separate processes and contradicting incentives for the different procurement and building investment decisions;
- Procurement and building management routines with a strong reliance on the company's own accumulated experience and existing networks to suppliers when making decisions;
- Limited possibilities for exploiting economies of scale and scope; installations vary in type and age and are often procured on a one-by-one basis;
- Uncertainties associated with energy saving technologies: development of prices and qualities of these technologies, development of prices for energy carriers, development of interest rates, equipment lifetime, technical feasibility of potential savings.

In addition, in comparison to the normal situation in public administrations, for investments in the commercial and industry sector **shorter payback periods** are usually required, which can make it more difficult to implement energy saving measures even if they are economical, i. e. if they lead to a high rate of return.

On the other hand, two developments might at least partly facilitate the implementation of energy efficiency measures in commercial type of buildings. First, there is a trend from the so-called 'scrap and build' approach looking only at the first investment costs of a building to an internal or external **building asset management approach** aiming at enhancing the value of a property or facility over their life cycle, thereby achieving more cost-effective operation and maintenance and economic efficiency. In this context, companies have to ask themselves:

- What is the value of the property or facility?
- How can the property or facility be planned and designed, operated and maintained to reduce the total lifecycle cost of the property or facility? How to incorporate such a long-term perspective into the planning, design, operation and maintenance of properties and facilities, instead of employing a suboptimal, ad-hoc approach? What are plans for retrofits to maximise economic efficiency of the property or facility?
- How can the property be planned and designed, operated and maintained so that it best contributes to the value of the business and is able to adapt flexibly to changes in the business environment?

While the concentration on maximising the value of a property or facility over the total lifecycle would help to implement more energy saving measures, the need to provide for possible changes in business might hinder some of them.

Second, in the course of the Kyoto and post-Kyoto discussion and facing natural disasters like the hurricanes in summer 2005, there are international (often US) companies committing themselves to energy saving or **CO_2 reduction targets** without possessing a feasible strategy how to reach them. These companies need an internal strategy and often also external help in making use of the energy cost saving potentials in their buildings, which can be realised at no or even negative CO_2 reduction 'costs'.

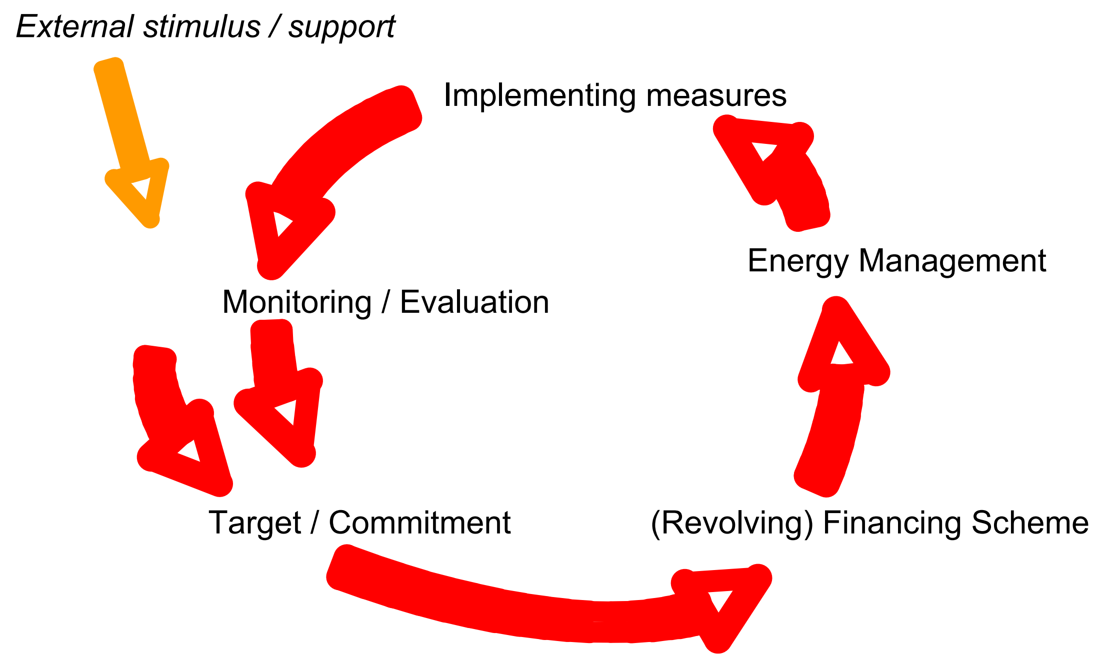
How the PICO concept could be applied
Energy efficiency services often provide a solution not only to the situation of public administrations, but also to the situation of commercial and industry building owners as it has been described above. However, particularly for small and medium enterprises – similar to the situation of many public administrations - an involvement of third parties is not always appropriate. In particular:

- Outsourcing will not always lead to cost-efficient solutions,
- Outsourcing means to take extra transaction costs into account
- Some buildings or single refurbishments are too small for a contract with a third party.

In a survey by the German banking group KfW, for only 3% of the companies answering the survey and for only about 10% of the companies answering the survey and having already implemented energy efficiency measures in the past energy performance contracting plays a role in financing their energy efficiency activities, in contrast to cheap credits and own means of finance, which are the main financial sources (Brüggemann 2005).

Furthermore, even if the energy management, the complete facility or property management or parts of it are outsourced to third parties, there is a need for an **internal counterpart** or trustee with at least some knowledge on the energy issues and being responsible for the deal with the external company.

Figure 2: The Internal Performance Commitment Loop of a More Continuous Implementation of Energy Efficiency Measures



In this context, an explicit **Internal Performance Commitment (IPC)** might have the following advantages:

- A specific commitment or target describing the future energy (cost) savings or energy efficiency investment the company wants to implement could be part of the overall strategy of the firm (part of a general management by objectives) and makes it commitments with regard to CO_2 reductions, cost management and innovation more concrete. It helps to sensitise the top-level management for the importance and net benefits (cost savings) of energy efficiency activities.
- Reserving part of the firm's operation and maintenance budget for energy (water and resource) efficiency measures makes it easier to achieve net cost reductions and to increase the value of the firm's building asset. In larger firms with profit center structures, even an Internal Performance

Contracting scheme with a revolving fund could be installed enabling energy efficiency investments by internal agreements between different profit centres, i. e. between different units of the same company.

- The commitment might allow to install an energy management system as part of the overall management system and to build up respective energy management know-how helping to reduce energy costs, with a person or unit of the firm being responsible for implementing the targets set and co-ordinating projects on energy efficiency. Such a person or unit could also make it easier to apply for available public support. A survey among firms in Germany by the KfW banking group confirms results by older studies, which show, that companies with own personnel posessing know-how in energy issues estimate a higher energy efficiency potential for their firms and have implemented more energy efficiency measures than companies without such persons or units (Brüggemann 2005).

However, the implementation of such IPC’s will not evolve automatically. Therefore, there is a role for well-designed policy instruments in the commercial and industry sector, particularly giving support by independent information and advice, and by providing part of the seed money needed to start cost saving loops.

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Comparison of Different Finance Options for Energy Services

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Summary

Financing of energy services (ES) has become increasingly burdensome for ESCOs as well as their customers: Market partners reach their credit lines, credit liabilities burden balance sheets and Basel II and international accounting guidelines cast their shadows.

As a result, innovative finance options like operate or finance lease agreements for ES have to be considered and compared to classical finance instruments like loans. In order to keep the energy efficiency market financially liquid, also the question of who is best capable of providing financing – customer, ESCo or a finance institution as a third partner has to be answered.

The paper starts from the perspective of the financing customers, which can be either ESCOs or their customers (companies, building owners, public institutions, …) by proposing a structured customer demand profile to describe their financing requirements (demand side).

On the financial supply side we summarize properties and implications of credit, finance and operate lease financing in a comprehensive matrix. The following categories are being considered:

1. Direct financing cost
2. Legal aspects
3. Securities required
4. Tax implications
5. Balance sheet & accounting implications
6. Business management efforts

To conclude, we compare the above financing options to the customer requirements and discuss their advantages and disadvantages. Evaluation is done with a rating matrix considering factors such as financing cost and fees, tax aspects, balance sheet effects, credit lines, Maastricht criteria, applicability of subsidies as well as suitable project sizes.

We promote a comprehensive look at the sum of all business implications of any financing option. The best suited financing solution shows at the bottom line of the profit and loss account. The sole look at direct financing cost as expressed in interest rates or fees will not deliver an optimal financing solution. The proposed rating matrix allows to account for the individual situation of the debtor and to consider all financing implications in order to help finding the best suited financing option. Further results are listed in the comparisons and conclusions chapter.

Introduction

The goal of any finance planning is to minimize overall capital cost, secure liquidity and to reduce transaction cost. But also legal aspects, tax implications and balance sheet issues have to be considered.

What are the implications, advantages and disadvantage of different financing options for energy services? In this paper, we will compare credit financing to operate and finance lease options and also take a look at forfaiting (selling of future contracting rates). Also the question of who is best capable of providing financing – customer, ESCo or a finance institution as a third partner will be discussed.

Customer Requirements for Financing Energy Service Projects

A Systematic Approach
In this chapter we describe financing requirements from the perspective of professionals, who wish to borrow money in order to implement energy efficiency projects. Relevant actors will in most cases be either real estate owners or ESCOs, both of which can provide the necessary project financing. Energy Agencies (EA's) typically have the role of project developers and mediators in the process.

Off course, financing needs depend on the individual circumstances of the borrower. And they depend on the individual project. Nevertheless we aim at developing a flexible methodology of describing general characteristics of financing needs for EE projects. Here we are talking about properties such as financing terms, legal implications, business management aspects like interest rates and fees as well as tax and balance sheet effects. **Only a comprehensive look at the sum of all financing implications will allow to decide for the best financing option.**

These financing characteristics will be put into a **demand profile**, which can be used to get a structured overview of the different implications of EE project financing issues. In succession, this profile can be applied to different financing options offered on the market in order to find the best suited fit, taking all implications into account.

In order to structure financing implications, relevant categories under which issues can be organized are:

1. **Direct financing cost** (financing conditions, interest rates, fees, …)
2. **Legal aspects** (Rights and duties, ownership, contract cancellation, end of term regulations, …)
3. **Securities required** by financing institution
4. **Taxation implictations** (purchase tax/VAT, corporate income tax, acquisition of land tax, …)
5. **Balance sheet & accounting implications** (who activates the investment (=> on or off balance?), balance sheet effects like credit lines, Maastricht criteria, …)
6. **Business management efforts** (transaction cost, comprehensive consultancy, …)

These six categories will be used throughout the paper to structure the different implications of financing issues. The result will be a profile of requirements for financing products from the perspective of the borrower, which is either ESCOs or their customers (company or building owners, public institutions).

Customer Demand Profile
The customer demand profile lists typical customer requirements. For an easier overview, the different criteria are grouped and presented in a chart:

Criteria	Customer expectations
Direct financing cost	**Costs as low as possible:**
	✓ Low interest rates, fees and other cost
	✓ Extent of financing: as high as possible (100 % external finance)
	✓ Subsidies: Integrability, compatibility, eligibility
Legal aspects	**Legal implications:**
	✓ Financing term: affordable, adjustable terms during contract period
	✓ What can be financed? Financing of complete energy service investments
	✓ Cancellation of contract: flexibility and conditions
	✓ Legal and economic property aspects
	✓ Transfer of ownership at end of term
Securities	**Reduce securities requested and own risks:**
	✓ Preferably project based finance: => repayment from future incomes/savings
	✓ Financial securities (equity capital, bonds, insurances, guarantees …) as low as possible
	✓ Physical (entry in land register, mortgage, …)
	✓ Personal (e.g. personal liability)

Criteria	Customer expectations
Taxation	**Reduce taxable income and use tax exemptions:**
	✓ Increase of tax deductible expenses:
	✓ Point in time of deductible expenses (e.g. depreciation, interest, …)
	✓ Value Added Tax (VAT)
	✓ Benefits from tax exemptions
Balance sheet & accounting aspects	**Optimize balance sheet ratios:**
	✓ Legal and economic property aspects => who capitalizes investment?
	✓ Balance performance ratios (e.g. debt-equity ratio, credit lines, Maastricht criteria, …)
Management effort / Transaction cost	**As small as possible:**
	✓ One face to the customer/one stop shop
	✓ Knowledgeable financing partner with regard to energy services and subsidies
	✓ Consultancy comprehending tax, accounting, legal optimisation and subsidies => custom tailored financing solutions
	✓ Reduce paperwork (investment documentation, …)
	✓ Reduce time to receive financing promise + reliable time frame for provision of money
	✓ Customer approval process: complexity and reduction of approval necessities

Of course all descriptions are of a general nature and may vary with individual project and and actors involved.

The classification of some criteria is not always unambiguous and depends on the readers individual experience. To the authors it was more important to have all relevant aspects considered and to facilitate an overview by grouping the different aspects in categories. Amendments are welcomed.

Finance Options

From the customer's perspective, an energy service project can be financed in one of three fundamental ways: (1) through self-financing, (2) debt financing or (3) third party financing. We concentrate our comparison of financing options on credits/loans, operate and finance leasing and forfeiting:

- ✓ A **credit** is also known as committed assets or loan capital. A one-time payment to the borrower is made at the start. Payback is over a defined and fixed period of time with a number of fixed installments plus interest rates. The debt is on the balance sheet of the borrower and thus reduces the borrower's credit line. The interest paid and depreciation is deductible from the company's profits for tax purposes.
- ✓ **Operate Leasing** is an agreement between a lessor and a lessee, which distinguishes between the ownership and the right to use the asset. The lessor pays for and owns the asset and gets all the tax deductions for depreciation and interest. The lessee uses the asset in exchange for a pre-determined fee. The asset does not appear on the lessee's balance sheet.
- ✓ The **finance leasing** model is a mixture of credit and operate leasing. The user of the asset (lessee) has the economic ownership of the asset and the obligation to capitalize it within his balance. The financier (lessor) on the other side has the legal ownership of the asset as security (e.g. stronger than a lien on moveable goods or a reservation of property rights).
- ✓ From an EPC-contract, the ESCO has receivables in form of contracting rates. **Forfeiting** means that the ESCO cedes these future contracting rates to a financial institution and gets in return a discounted present value of the total to finance the energy conservation investment.

The comprehensive matrix in the annex gives a detailed view on the customer needs compared with the characteristics of the different finance options.

"Real World" Leasing-Financing Examples

Refurbishment of Street Lighting in the City of Laa, Austria

Object data, initial situation and objectives

The city of "Laa an der Thaya" is located in Lower Austria and has approximately 5.000 inhabitants. As in many cities, public street lighting installation were up to 40 years of age. Wiring, lamp poles, lighting heads and lamp technology did not comply with current norms and safety regulations. Not to talk about state of the art in lighting technology and energy efficiency.

When refurbishing public street lighting, you take a decision for the next three to four decades. Special attention has to be put on safety and reliability issues, lighting standards (e.g. pedestrian crossings) aswell as longterm operation and maintenance cost (life cycle cost). But also creative and artistic aspects come into play: lighting provides quality of life, security and brightens up the public space and highlights places of interest in the community.

Important requirements for the project implementation included a close cooperation with the cities building department, meeting a very tight time frame and finding an innovative finance solution to credit the municipal budget.

Figure 1: Modernized street lighting including advertisement boards

The refurbishment measures included:

- ✓ some 167 light points in the main streets of Laa including masts, civil engineering below ground level, wiring and switching units,
- ✓ auxiliary services like removing of old installations, assembling of new street lights, protective earthing,
- ✓ some 57 lamp posts are equipped with illuminated advertisement boards (size A0) to generate an income to the city.

The total investment sums up to 450,000 € (excl. VAT).

Innovative Financing Model and Contract Relations

Financer (FIN) and customer (CLIENT) have concluded a **financing lease agreement**. An operate leasing model would not have been feasible, because the majority of the investment (e.g. underground engineering, wiring, …) does not qualify for operate leasing according to Austrian leasing regulations (VAT-law).

The main contract relationships are displayed in the following diagram:

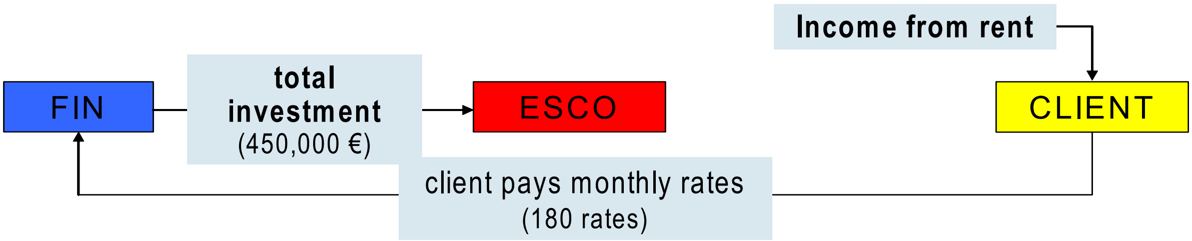
The new street lighting is planned and built by an ESCO by order of FIN with a purchase contract. There is no direct contract relationship between ESCO and CLIENT.

All operation & maintenance (o&m) tasks remain within the responsibility of the community (as before the modernization). This results in additional savings for the community due to longer o&m intervals.

To keep the model simple, there is no energy savings guarantee included, because the achieved savings are partly compensated by an increase in illumination levels at flash points (e.g. pedestrian crossings, crossovers, ...) and the additional illumination of the advertisement boards. The remaining savings were considered too small to bother with a measurement and verification procedure.

Guarantees were given by the ESCO for the total investment cap and the time frame (Christmas lighting had to be in place on time).

The main cash flows are displayed in the following diagram:



The total investment was capped to 450,000 € (excl. VAT). The city provides no equity capital or building cost subsidy. The investment is paid with 100% external capital by FIN. The debt is being repaid by the CLIENT in 180 monthly rates over a contract period of 15 years.

By renting out the advertising boards on the lamp posts, the city generates an additional income of approximately 30.000 €/a. A part of the total investment costs is made input VAT deductible by a contractual differentiation between sovereign community tasks (lighting) and income from rent and lease. For the latter the community is entitled to deduct input tax, resulting in a 20 % cost saving.

Evenly, all investments apart from the sovereign community tasks (advertisement boards) qualify for input tax deduction, resulting in a 20 % investment saving of approximately 20.000 € for the community.

For all investments concerning the street lighting itself (sovereign community tasks), the city has to pay VAT. The 20%-VAT payments are included in the finance lease payments.

Energy Performance Contracting for the Production Facility of a Pharmaceutical Plant

Object data, initial situation and objectives

The customer facility is a production site of an international pharmaceutical enterprise with a usable floor space of 48,000 m^2, erected in 1981/82.

Cost for heat and electricity amounted to 1.5 Million € per year. Heating and process steam were provided by natural gas fired thermo-oil Boilers.

The decision to have a third party involved in the energetic rehabilitation measures was mainly driven by the fact, that companies investment funds were reserved for research and production investments. The ESCOs know how and savings guarantee were an additional incentive to the customer.

Project goals were to maintain and improve energy supply and distribution facilities, to ensure a reliable operation and to raise availability, to increase maintenance intervals and the useful life of the equipment. And off course to tap cost saving potentials Short pay back time of investments were mandatory to have a short contract term.

Measures taken:

The feasibility study – prepared jointly by client and contractor - explored all possible measures in the fields of heating, cooling, ventilation, air conditioning (HVAC) and electrical engineering. Demand side building measures (e.g. refurbishment of building envelope) were not considered.

Implemented measures include:

Figure 2: View over the contracted pharmaceutical production facility

- ✓ Recirculation units for the ventilation system (reduction of outside air flow intake)
- ✓ Installation of three new ventilation units with a total air flow of 120,000 m^3/h
- ✓ Exhaust gas heat recovery system for natural gas fired thermo-oil boilers
- ✓ Rehabilitation of hot water system
- ✓ Adaption of complete building control system
- ✓ Implementation of a continuous energy control system, monitored by both contract parties
- ✓ Electricity savings from improved ventilation and cooling systems (not accounted for => extra benefit to customer)

The total investment sums up to 1,150,000 € (excl. VAT).

User motivation measures to encourage energy efficient behaviour were not deemed to be necessary, because of an already existing high level of awareness with all energy concerned company members.

All measures were implemented during continuous operation of the production process.

Contract Relations and Financing Model

In this financing model, the ESCO formally takes over responsibility for the complete energy service project including a savings guarantee over the contract term of 6 years. ESCO and CLIENT have entered into an **energy service contract** including financing. This contract also contains a **cession agreement** of ESCOs claims to FIN. Other than that, FIN has no direct contract relationship with the CLIENT.

At the same time ESCO and FIN have concluded an **operate lease agreement.** This avoids entering the investment on the ESCOs balance sheet. FIN also accepts the risk of an economic downfall of the CLIENT, which is recorded in a **project framework contract** between FIN and ESCO. To assure completion and technical and economical performance of the measures, ESCO has to provide a **bank guarantee** to FIN to secure the amount of the total savings.

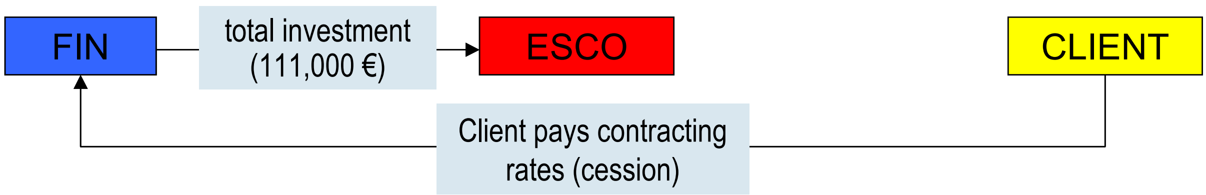
The contracts concluded are displayed in the following diagram:

All operation & maintenance (o&m) tasks remain within the responsibility of CLIENT as before the modernization. This results in additional savings for the CLIENT due to extended o&m intervals.

The CLIENT provides no equity capital or building cost subsidy, so the investment is paid with 100% external capital, provided by FIN. ESCO invoices the total investment of 1,150,000 € (excl. VAT) to FIN and is being payed according to a payment plan.

The CLIENT pays the ceded contracting rates directly to FIN. The CLIENTs payments are being covered by the guaranteed energy and maintenance savings.

The cash flows are displayed in the following diagram:



Electricity savings are additional benefits to the CLIENT which are not accounted for. Any savings above the guaranteed level goes to the CLIENT as well.

Innovative aspects of the model include:

- ✓ The CLIENT has only one contact for all energy matters. Financing is in the back ground.
- ✓ Assets were activated by FIN and do not appear in the books of ESCO nor the CLIENTs.
- ✓ FIN (rather than the ESCO) accepts the economic risks of the (industrial) CLIENT

Comparison and Conclusions

Comparison and Evaluation of Financing Options with Customer Needs

Comparisons are drawn mainly between **credit, operate and finance lease financing** options (Forfaiting characteristics still require some more clarification). Not all implications will be mentioned though. Only major distinctions between financing options are listed. Of course all comparisons are of a general nature and may vary with individual financing institutions (**FI** or **LFI** for Leasing Finance Institute) and products. Equally, all properties and implications need to be checked with respect to concrete the project and borrower.

The comprehensive **matrix** of customer financing demands compared to credit, operate and finance lease and forfaiting financing options compiles individual properties with regard to financing costs and fees, integration of subsidies, legal aspects, securities required, tax implications, balance sheet effects, management and transaction costs suitable for comparison. Individual properties of the different financing options can be drawn from the table, attached.

Direct financing costs have to be compared on an individual bases, taking all factors into account. Interest rates and fees tend to be somewhat higher for leasing, because of additional services offered by the LFI and the assumption of higher risks on the lessors part. LFI's extent of financing typically is higher allowing for up to 100 % external financing.

Subsidies can be integrated into all financing options. LFIs often will include subsidy acquisition and handling in their port folio, thus providing a more comprehensive service to the client.

Not all energy supply and conservation investments can be **operate lease** financed though. The technical term is called **fungibility** or **interchangeability** required (by tax laws) of an asset to qualify for operate leasing: After the basic lease term the asset has to be re-utilizable without suffering substantial damage when being removed from its place of installation. In praxis this leaves room for interpretation and is still under discussion.

A Lessor will generally require a **comprehensive insurance package** as well as **operation and maintenance guarantees** for his equipment which may result in additional external cost for the borrower.

Direct financing costs can be compared by way of a **cost comparison calculation**: All financing expenses (including equity capital and opportunity cost) over the contract period of the different financing options should be recorded and discounted to a net present value to calculate the lowest direct financing costs.

Some Leasing Finance Institutes (and hopefully other FIs as well) have **specialized and knowledgeable staff**, who have a good understanding of the nature of energy service projects. Based on their analyses of the project, these LFIs are able to base the refinancing mainly on the project cash flow rather then the creditworthiness of the borrower. These LFI's may also accept higher risks and require fewer or only project based securities like a cession of project revenues (e.g. feed in tariffs from renewable electricity production on site).

Main distinctions with regard to securities, taxation and accounting between credit and leasing financing derive from the differentiation between **legal and economic ownership** of the asset. **Economic ownership** implicates recording the asset in the owners books. In other words: Off balance financing with all its implications (e.g. balance sheet performance ratios like credit lines, balance sheet contraction, …) requires, that a third party is willing and able to account for the asset. This is possible with operate lease financing only[1].

Maintaining **legal ownership** of the investments – apart from implying legal responsibilities – allows LFIs to require fewer securities from the lessee compared to credit financing. This is true for both finance and operate leases.

Finance lease can be seen as a mixture between a conventional credit and an operate lease. Many properties are closer to the credit, except the more project oriented approach for refinancing and securities required.

LFIs generally offer a more **comprehensive consultancy** comprehending taxation, balance sheet matters and legal aspects of the energy service project, which suits well with the proposed comprehensive look at all financing implications. Leasing typically includes consultancy on contract design and management, insurances, commissioning of contractors, accounting, controlling and payout of invoices, VAT-clearing, to list the most important services. This may result in reduced overall transaction cost. Of course consultancy for taxation, accounting and legal issues can also be sought for separately, as long as all implications are considered.

For suitable **project sizes**, no concrete figures can be given. To justify transaction cost of setting up an external financing a minimum financing volume is required. Concrete minimum figures vary between € 50.000 and € 500.000 depending on the individual FI.

The more a project can be standardized, the smaller the financing volume may be. A well prepared project prognoses and documentation (see below) provided by the project developer also reduces transaction cost. LFIs tend to have a somewhat higher involvement resulting in larger financing volumes required.

To our knowledge what is being labeled as **Forfaiting** is in fact in most cases a cession of contracting rates only. The ceded receivables serve as (additional) security for a credit or leasing finance contract. In return the creditor or lessor should take over financial performance risks of the client. Nevertheless a "pure forfaiting" financing based on selling the future project cash flow would be a very desirable financing option from the customer perspective.

Conclusions and Recommendations

We keep the customer perspective and describe the conclusions and recommendations mainly from the point of the party who seeks financing.

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[1] For the public sector special regulations apply to avoid capitalization of finance leases.

Generally, all financing options described are suitable for financing energy supply and conservation investments. It is not possible to recommend any particular financing option or product as best suited for energy service financing. Each option has its advantages and disadvantages as shown in the broad range of implications in the customer demand profile.

Finding the best available financing requires a **comprehensive look at all implications of any financing option** including securities required, transaction cost, taxation and balance sheet effects. The best financing option can not be recognized by a simple look at the lowest interest rate or annuities offered. It depends on the borrowers background as well as the individual project. This requires the integration of bookkeeping and tax consultancy into the financing decision.

A prognosis of the **profit and loss accounts will best reveal the total effect of all quantifiable cost** for each financing option. In addition the indirect cost like management effort or a decline in balance sheet performance ratios need to be taken into consideration to find the best finance option.

From a customer perspective, it is desirable to **base debt service on the project cash flow** as opposed to basing it on the customers creditworthiness alone. Debt should be repayable from future project income like energy cost savings (performance contracting) or delivered energy (delivery contracting)[2]. This concept requires a better understanding of the nature of energy service projects respectively of the ESCOs business models on the side of the financing institutions.

Generally speaking, the loan commitment for a **credit financing** is mostly based on the debtors creditworthiness and not on the cash flow of the project invested in. Banks tend to view themselves as pure money lenders, not being concerned with the project, the funds were borrowed for. In contrary LFI's own the assets and make money by leasing it out. They are much closer to the actual usage of the investment and generally have a better knowledge and judgement of the market of the investment and the expected return on it.

Leasing financing legally requires that no automatic **transfer of ownership** (without reimbursement) is settled in the energy performance contract. Otherwise it is considered as a supply contract. In other words: if a performance contract includes a definite transfer of ownership to the client at the end of the contract term, a leasing financing is not possible.

Existing EPC model contracts often include a fixed transfer of ownership free of charge after contract termination. These have to be revised if you want to allow for a leasing finance option.

Not accounted for leasing finance agreements can have a **substantial influence on the balance sheet performance ratios** and confine their explanatory power. The reader of the financial statement, who does not posses additional information, will receive a distorted image of the assets and financial position of the enterprise, e.g.

- ✓ Creditworthiness performance ratios like debt ratio or equity-to-fixed-assets ratio will be positively distorted.
- ✓ Cash flow and derived ratios like debt-redemption-duration are misleading.
- ✓ Profitability ratios like total-capital-profitability are not heavily influenced by not accounted for lease agreements.

Further Recommendations include:

1. The customer demand profile from the previous chapter can be used as a **checklist** to control if all important implications of the project financing have been considered.
2. Financing is a service which can be tendered to receive the best offer and conditions. Make financing services a **competition between different financing options**.

[2] Progress of the "Energy Efficiency Financing Protocoll"-initiative will hopefully help in supporting this case.

3. It is possible to **combine operate und finance lease** in one project, to make use of the tax or balance sheet accounting advantages, for the leasable portion of the investment. Due to higher transaction costs for the LFI, this requires a higher project volume.
4. To allow FIs (and yourself) a solid basis for decision, it is Important to compile a meaningful and comprehensive **prognoses and descriptions of the project planned**, including a cash flow and profit and loss prognosis over the complete term of the project. This also requires a sensitivity analyses for the most critical parameters of the project.
5. For large projects, a comparison of the broad range of implications from the five categories could be accomplished by way of a **cost-benefit-analyses**, allowing to integrate monetary and other criteria into one evaluation system.
6. **Sale-and-lease-back** contracts are mainly used to finance overall building projects, not just EPC-measures. In many cases the purpose is to realize “hidden reserves” e.g. in public buildings. If a Sale-and-lease-back financing is used for a building project, it is strongly recommended to write minimum performance standards and guarantees e.g. for thermal refurbishment or maximum energy consumption into the terms of reference.
7. **Differentiate between financing and technical+economic services.** ESCOs are experts in technical, economic, and organisational matters of energy services, which is what they should be commissioned for. Financing is not necessarily their core business. In many cases including a financing institution (FI) as a third party to take over financing matters and risks makes good sense.

This list does not claim to be complete. The broad range of implications of each financing option requires an individual check to find the best suited fit. For the project and for the debiting party. Remarks and supplements are welcome (Bleyl@grazer-ea.at).

Comparison of Different Finance Options for Energy Services

Criteria	Customer expectations	Credits/loans	Finance Leasing	Operate Leasing
Direct financing cost	**Costs as low as possible:**			
	✓ Interest rates, fees, …	✓ Repayment + interest (degressive) ✓ Single payments[i]: - Credit fee (0,8% of volume) - Handling charge (negotiable) - Notary fee	✓ Lease payments (annuity) ✓ Single payments2: - Handling charge (negotiable)	✓ Lease payments (annuity) ✓ Single payments: - Contract fee (1% of total lease payments) - Handling charge (negotiable)
	✓ Extent of financing	✓ Part financing only (typically 70 - 80%)	✓ Financing of total investment incl. soft cost (90 - 100% financing)	✓ Financing of total investment incl. soft cost (90 - 100% financing)
	✓ Subsidies: Integrability, compatibility, eligibility	✓ Yes, reduces loan or interest rate[ii] ✓ Application by debtor (owner of investment). Typically no support from bank	✓ Yes, reduces lease rate ✓ Application by lessee economic (owner of investment) or lessor on behalf of lessee. ✓ special know how required – typically leasing banks have subsidy specialists	✓ Yes, reduces lease rate ✓ Application by lessor (owner of investment) ✓ special know how required – typically leasing banks have subsidy specialists
Legal aspects	**Legal implications**			
	✓ Financing term	✓ Flexible: according to customer demand. Usually below useful life time	✓ Flexible: according to customer demand (no legal regulation). Below useful life time of asset	✓ Object oriented: Basic lease term: 40 – 90% (mobile), < 90% (immobile) of useful life
	✓ What can be financed?	✓ Complete energy service hardware	✓ Complete energy service investment incl. soft cost (e.g. project development)	✓ Only leasable energy service investment incl. soft cost (e.g. project development)
	✓ Cancellation of contract	✓ Depends on contract type, usually fixed terms. ✓ Short rate penalties apply for premature cancellation	✓ Depends on contract type, usually fixed terms. ✓ Short rate penalties apply for premature cancellation	✓ Generally no cancellation during basic lease term possible
	✓ Legal and economic property aspects	✓ Debtor is legal and economic owner (bank may put retention of title or lien)	✓ Lessor is legal owner ✓ Lessee is economic owner (lessor may hold retention of title)	✓ Lessor is legal and economic owner
	✓ Transfer of ownership at end of term	✓ Debtor remains owner ✓ EPC contract may include transfer of ownership	✓	✓ Lessor remains owner ✓ EPC contract must not include automatic transfer of ownership to client
	✓ Responsibility for operation and maintenance	✓ Debtor is responsible for o & m at his own risk	✓ Lessee has to perform o & m and to insure the investment according to lessors requirements	✓ Lessee has to perform o & m and to insure the investment according to lessors requirements

Comparison of Different Finance Options for Energy Services

Criteria	Customer expectations	Credits/loans	Finance Leasing	Operate Leasing
Securities	**Reduce securities requested and own risks:**	**Bank wishes to safeguard loan. Generally securities are based on debtor, not on project. Securities ~ 100 %**	**Lessor wishes to safeguard lease object. Generally securities are based on project with some additional debtor liabilities**	**Lessor wishes to safeguard lease object. Generally securities are based on project with some additional debtor liabilities**
	✓ Project based finance	✓ No project finance but client finance. Repayment based on company cash flow and economic key figures, not project cash flow	✓ Project cash flow accepted as main security (requires detailed project check and know how) ✓ Cession of revenues e.g. from feed in tariffs and insurances.	✓ Project cash flow accepted as main security, (requires detailed project check and know how) ✓ Cession of revenues e.g. from feed in tariffs and insurances.
	✓ Financial securities	✓ Typically equity capital required (> 20 %) ✓ Additional securities like bonds (Hermes, ÖKB) and guarantees from parent companies depend on individual project	✓ Equity capital required (0-30 %) (some client commitment required) ✓ Insurances for project equipment (elementary-, break down- and interruption of service insurance) ✓ Additional securities like bonds (Hermes, ÖKB) and guarantees from parent companies depend on individual project ✓ Public entities: non-appropriation-risk for lessor	✓ Equity capital required (0-20 %) (some client commitment required) ✓ Insurances for project equipment, (elementary-, break down- and interruption of service insurance) ✓ Additional securities like bonds (Hermes, ÖKB) and guarantees from parent companies depend on individual project ✓ Public entities: non-appropriation-risk for lessor
	✓ Physical securities	✓ Desired/required, ✓ Entry in land register, lien on movable objects, reservation of property rights	✓ No, because lessor holds property title until payment of last rate![iii]	✓ No, because lessor holds property and economic title
	✓ Personal securities	✓ Applicable for small projects only	✓ Applicable for small projects only	✓ Applicable for small projects only
Taxation	**Reduce taxable income:**		**Lessor can support customer to save taxes in order to offer the cheapest overall finance solution**	**Lessor can support customer to save taxes in order to offer the cheapest overall finance solution**
	✓ Tax deductible expenses	✓ Interest and depreciation (linear AfA-tables) are tax deductible. Redemption payments are not tax deductible	✓ Interest and depreciation (linear, AfA-tables) are tax deductible. Redemption payments are not tax deductible	✓ Complete leasing rate is tax deductible.
	✓ Point in time of deductible expenses	✓ Depreciation is linear (sometimes degressive) ✓ Interest payments decline over time, degressive	✓ Depreciation is linear (sometimes degressive) ✓ Interest payments decline over time	✓ Depreciation can be accelerated through “Leasing effect” (shorter depreciation periods for lessors) ✓ Constant rates (annuities) over contract period

Comparison of Different Finance Options for Energy Services

Criteria	Customer expectations	Credits/loans	Finance Leasing	Operate Leasing
	✓ Value Added Tax (VAT)	✓ VAT due on total investment at the beginning of project ✓ Public entities can not deduct input tax (additional initial cost)	✓ VAT due on sum of rates at the beginning of project => VAT also on bank margin[iv] ✓ Public entities can not deduct input tax (additional initial cost) ✓ "Similar-to-business-activities" can be made input VAT deductible, (e.g. renting out of advertisement boards)	✓ VAT due per rate (pro rata temporis) => VAT is dispersed over project duration
	✓ Benefits from tax exemptions	✓ Not known	✓ Not known	✓ Not known
Balance sheet & accounting aspects	**Optimize balance sheet ratios:**			
	✓ Capitalization of investment	✓ Debtor is legal and economic owner => Debtor has to capitalize investment	✓ Lessor is legal owner ✓ Lessee is economic owner => has to capitalize investment	✓ Lessor is legal and economic owner => has to capitalize investment on his balance sheet => shortening of balance sheet for lessee
	✓ Balance performance ratios	✓ Loan and assets have to be capitalized in the balance sheet account => negative effects on balance sheet performance figures ✓ Public sector: Treated as additional debt => Maastricht criteria apply	✓ Lease and assets have to be capitalized in the balance sheet account => negative effects on balance sheet performance figures ✓ Public sector: special regulations apply to avoid capitalization of lease	✓ Assets and lease payment obligations are not capitalized in the balance sheet account => distortion of ratios, e.g. improvement of debt-equity ratio ✓ Public sector: Maastricht neutral
Management effort / Transaction cost	**As small as possible:**	**FI wants to reduce transaction cost, (standardized products, increase finance volume => larger projects)**	**FI wants to reduce transaction cost, (standardized products, increase finance volume => larger projects)**	**FI wants to reduce transaction cost, (standardized products, increase finance volume => larger projects)**
	✓ One face to the customer	✓ Generally no (ESCO + FI)	✓ Yes, depends on LFI	✓ Yes, depends on LFI
	✓ Knowledgeable financing partner	✓ Depends on bank and requires special know how: energy services is not a typical core competence of banks	✓ Depends on bank and requires special know how: some LFI have specialized project finance departments for ES	✓ Depends on bank and requires special know how: some LFI have specialized project finance departments for ES
	✓ Consultancy for tax, accounting, legal optimisation and subsidies	✓ Service is limited to financing. Additional tax, legal service typically not included ✓ => higher effort for coordination on customer side ✓ Accounting of investment is done by debtor	✓ Service typically comprehends tax and legal advice => less effort for coordination on customer side ✓ Accounting of investment is done by lessee	✓ Service typically comprehends tax and legal advice => less effort for coordination on customer side ✓ Accounting of investment is done by lessor

Comparison of Different Finance Options for Energy Services

Criteria	Customer expectations	Credits/loans	Finance Leasing	Operate Leasing
	✓ Reduce paperwork	✓ Company documentation: last three annual accounts ✓ Some project documentation required: investment plan ✓ Credibility inquiry	✓ Documentation depends on project finance (=>operate lease) or company finance (=> credit) ✓ Credibility inquiry	✓ Detailed project documentation (investment plan, project cash flow, profit and loss account) ✓ Credibility inquiry
	✓ Time to receive financing promise	✓ Typically 1 month after documentation is complete (documentation required depends on security concept)	✓ Typically 1 month after documentation is complete (documentation required depends on security concept)	✓ Typically 1 month after documentation is complete (documentation required depends on security concept)
	✓ Customer approval process	✓ Approval is easier if funds are drawn from operative (not investive) budgets ✓ Public entities: credit finance is subject to debt ceilings and may require approval legislative or supervising authority => possibly time consuming ✓ Some local authorities have adopted general approval for savings-cash-flow financed EPC-projects (third party financing)	✓ Approval is easier if funds are drawn from operative (not investive) budgets ✓ Public entities: finance lease is legally not considered indebtedness which may make approval process easier. ✓ Some local authorities have adopted general approval for savings-cash-flow financed EPC-projects	✓ Public entities: operate lease is legally not considered indebtedness which may make approval process easier. Approval is easier if funds are drawn from operative (not investive) budgets ✓ Some local authorities have adopted general approval for savings-cash-flow financed EPC-projects

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[i] Values applicable in Austria

[ii] Some subsidy programmes support interest rates rather then direct investment subsidies

[iii] Assets firmly connected to an object become part of it (ABGB § 417). This risk has to be mitigated

[iv] no VAT on interest (UStG § 6 (2) 1994)

Promoting Energy Efficiencies: Energy Services Sector Development in Singapore

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Abstract
The Singapore Government is putting in place several energy efficiency initiatives, estimated to reduce up to 190,000 tonnes of carbon dioxide emissions by 2012 and help achieve the target of 25% improvement in carbon intensity between 1990 and 2012.

The development of energy service sector has become a major consideration of the government. Meanwhile, it is seen as a strategic and emerging sector with significant growth potential in Singapore and the region. The development of the energy service sector is expected to serve and expand the general service sector, underpin economic development through enhancing cost competitiveness and at the same time strengthen Singapore's energy security.

This paper is focusing on the initiatives taken by the government to promote the energy efficiencies in Singapore. For example, the establishment of an Energy Services Company (ESCO) Accreditation Scheme for auditing services, the development of a local Measurement and Verification (M&V) Protocol and the engagement of a Certified Energy Manager (CEM) Scheme. These, in turn, will enhance confidence in the energy services sector and help promote the growth of the industry as well as achieve the above target in the reduction on the use of energy.

Introduction
In Singapore, with the economy slowdown especially in the construction and property industries in the past few years, energy cost is becoming an important concern for building owners and developers. The potential energy and cost savings in existing buildings are very large since there is a vast stock of existing buildings and many of them have been in use for ten or more years. Therefore, it is the right time for Singapore to establish a standard, efficient and reliable system for Energy Services Sector, which is based on the local best practices.

There are a lot of opportunities for achieving energy and cost savings in existing buildings. For instance, recent local studies have pointed out that oversized equipment is one of the key factors for poor energy performance of commercial buildings in Singapore. If an investigation through the building and its equipments can be conducted systematically by using Energy Performance Contract (EPC) techniques, significant savings can be achieved.

The EPC has not been widely practiced in the country due to lack of public awareness, as well as the financial, educational and legal framework. Nevertheless, the industrial, commercial, public and financial sectors are becoming more aware on the benefits from energy efficiency activities and ESCOs business.

To assess the development potential of energy services market, it is crucial to consider better political support on regional development trends. In recent years, the Singapore Government through its agencies such as Energy Market Authority (EMA), National Environment Agency (NEA) and Economic Development Board (EDB) is putting a greater concentration on energy efficiencies and environmental impacts. A number of policies and programs have been launched and conducted.

This paper will address some of these energy efficiency initiatives:

- Energy Audit Scheme for Large Consumers of Energy
- Singapore Green Mark
- ESCO Accreditation Program
- Energy Efficiency Improvement Assistance Scheme (EASe)
- Energy Labelling Energy Smart Building Label
- M&V Protocol
- Certified Energy Manager (CEM)

By conducting all these initiatives, Singapore is expecting to reduce up to 190,000 tonnes of carbon dioxide emissions by 2012 and help achieve the target of 25% improvement in carbon intensity between 1990 and 2012.

Energy Audit Scheme for Large Consumers of Energy

The Energy Audit Scheme is also implemented by National Environment Agency (NEA) in partnership with major industrial consumers under the initiative of the National Energy Efficiency Committee (NEEC) [1].

The Scheme is voluntary, designed to provide an impetus for industries to improve the energy efficiency of their operations. Its objective is to encourage industries that use large amount of oil and gas to put in place a formal system for the management of energy use, to improve their energy efficiency. This is mainly for facilities that consume in excess of 10TJ of energy per annum.

Under the Scheme, companies can either use in-house staff or engage external energy audit specialists in carrying out their energy audits. Such audits, which are carried out every 3-5 years, would help industries to systematically identify opportunities for improving energy efficiency regularly. The companies could then take measures to improve the energy efficiency of their facilities.

To date, 3 oil refineries, namely, Singapore Refining Co. Pte Ltd, Shell Eastern Petroleum Pte Ltd, and ExxonMobil Asia Pacific Pte Ltd, and 2 petrochemical companies, Seraya Chemicals Pte Ltd and ExxonMobil Chemical Operations Pte Ltd, have opted into the scheme, demonstrating commitment towards improving energy efficiency and mitigating the environmental impact of their operations.

Singapore Green Mark

The Green Mark [2] for Buildings program was developed by the Building and Construction Authority of Singapore and also supported by the National Environment Agency to demonstrate the building and construction industry's commitment towards sustainable development.

(http://www.bca.gov.sg/GreenMark/green_mark_buildings.ht ml).

Environmental awareness among the real estate and construction sector in Singapore is still in its early stage. An assessment system to rate the environmental impact and performance of buildings will encourage the industry to pay greater attention to its impact on environment. In developed countries such as the US, UK and Australia, similar green building rating systems are already in place to accelerate the implementation of green building practices.

Hence, the Green Mark for Buildings was developed to promote sustainable development for the construction industry and raise environmental awareness among developers, designers and contractors when they start project conceptualisation and design, as well as during construction. The Scheme will also apply for existing buildings under operations.

The Green Mark for Buildings will assess the environmental impact of both new and existing buildings. The scheme's objectives are to:

- Recognize developers and building owners who build and maintain buildings that are environment-friendly,
- Promote best practices in the development, design and maintenance of buildings that minimize adverse environmental impact, and
- Provide a benchmark for buildings in Singapore

The Green Mark will assess five key areas of concern globally - energy efficiency, water efficiency, project development & management for new buildings (building management and operations for existing buildings), indoor environmental quality and environmental innovations.

The measurement scale used in Green Mark is based on a points scoring approach. The total number of points obtained provides a benchmark of the building's environmental performance and allows comparison between buildings.

The overall rating scale for both type of buildings are as follows:

Green Mark Points	Green Mark Rating
85 and above	Green Mark Platinum
70 to <85	Green Mark Gold
55 to <70	Green Mark Award

ESCO Accreditation Program

The overall objective of accreditation is to enhance the professionalism and quality of services offered by ESCOs. This, in turn, will enhance confidence in the energy services sector and help promote the growth of the industry. It is an important market development measure for Singapore. The accreditation scheme can lead to the following benefits:

Development of professional and qualified ESCOs and energy engineers;
Enhance the standing of ESCOs, and in particular energy auditing services;
Support services procurement and selection procedures;
Support public sector incentive schemes in the promotion of energy efficiency; and
Reduce wastage and false claims amongst industry players.

The accreditation is open to any company established in Singapore who wishes to be accredited in the provision of energy auditing services for Building and Industrial facilities.

This scheme provides accreditation of energy auditing services at the following levels:

a. ESCOs accredited for Level II Energy Audit Services
b. ESCOs accredited for Level III Energy Audit Services

Within each level, accreditation is also differentiated according to facility types at general and system level.

In order to qualify for accreditation, the ESCO or company must satisfy the following requirements:
a) Existing ESCO (In operation for 3 or more years)

- Have under its full-time employment a minimum of one (1) Key Qualified Person (KQP) to carryout and/or oversee energy audit work;
- Have undertaken a minimum of NINE (9) energy audits works at Levels II and / or III within the immediate past THREE (3) years; and

- Have in place a number of relevant calibrated equipment/ instruments to carry out energy audit works.

b) Newly Formed ESCO (In operation for less than 3 years)
Newly formed ESCO may be given provisional accreditation on a 12 monthly basis, up to a maximum period of Three (3) years, whereupon full accreditation shall be sought. Requirements:

- The ESCO has under its full-time employment a minimum of one (1) Key Qualified Person (KQP) to carryout and/or oversee energy audit work;
- Have available a number of relevant calibrated equipment/ instruments to carry out energy audit works.

Since it launched in April 2005, 21 applications have been received from locally based ESCOs of which 12 have been accredited. The accredited ESCOs are listed in the ESU website at http://www.esu.com.sg/esco/index.html

Energy Efficiency Improvement Assistance Scheme (EASe)

The Energy Efficiency Improvement Assistance Scheme (EASe) [3] is a co-funding scheme administered by Singapore's National Environment Agency to give incentives to companies in the manufacturing and building sectors to carry out detailed studies on their energy consumption and to identify potential areas for energy efficiency improvement.

Funding would be provided for up to 50% of the qualifying cost of engaging an Accredited ESCO to conduct investment grade energy appraisals and recommend specific measures that can be implemented to improve energy efficiency. Nevertheless, over a 5-year period, the maximum amount of funding to any single facility or building is capped at $200,000

The qualifying costs include the energy appraisal fees comprising:

i) Salaries
ii) Use of instrumentation and evaluation tools
iii) Expendables
iv) Overheads

As for the cost of implementing the recommendations of the energy appraisal , it would not be supported under the EASe.

The eligibly criteria to apply for the funding is that the owner or operator of the manufacturing facility or building must be registered and located in Singapore.

Energy Labelling Energy Smart Building Label

A new energy-efficiency labelling scheme aimed at bringing Singapore closer to its vision of a truly green city with environmentally sustainable development was launched on 16 December 2005.

It was jointly developed by the National Environment Agency (NEA) and the Energy Sustainability Unit (ESU) of the National University of Singapore. The Energy Smart Building Scheme [4] accords recognition to buildings in the top 25 per cent of their class for achieving exemplary energy efficiency without compromising the indoor environmental quality.

It also serves to encourage property owners and professionals in the real estate industry to give due consideration for energy efficiency in the design, development and management of buildings by providing them with quantitative and objective indicators to track the energy efficiency performance of their buildings.

Indicators that will be used include air-conditioning plant, lighting and mechanical ventilation system performance, as well as the building energy efficiency index. Buildings that currently do not perform within the reference values to qualify for the Energy Smart Office award can use the measures to ascertain their current performance level, predict energy savings potential and set management targets. This will pave the way for them towards achieving the label.

Labelling Method
The label will be granted on a scientific and objective basis. Buildings whose energy performance are among the nation top 25% (≤ 178 kWh/m^2/yr) and maintain a healthy and productive indoor environment can qualify to attain the label. However, the labelling scheme also serves to work as a benchmark and checking scheme for buildings which may not completely fulfil the criteria.

The Energy Smart Office is the first category of buildings launched in this program. Other categories of buildings will be launched in near future.

The Energy Smart Building Labelling Scheme complements the Green Mark for Buildings program, which was launched earlier by the Building and Construction Authority to raise environmental awareness and promote sustainable development in the construction industry. For existing office buildings, the prerequisite for achieving the Green Mark Platinum Award is attainment of the Energy Smart Building Label.

M&V Protocol

In order to promote its energy service market, Singapore needs to establish a standard energy saving performance contract (EPC) framework, which provides Standard EPC form, financial options and relative documentations.

There are several widely recognized measurement & verification protocols, like IPMVP, ASHRAE Guideline 14P and etc., which are available for the industry use. However to encourage the local property owners, Energy Services Companies (ESCOs) and the Third Party financers to fund energy saving projects, Singapore is developing its own Performance Measurement & Verification Protocol for the Tropical region.

According to IPMVP, there are four (4) options which are universally recognized. Singapore M&V Protocol will basically adopt the methodologies stated in IPMVP. However the structure of the local M&V Protocol will be simplified to encourage the industry for usage. The typical case study for how to choose the option, as well as the application of each option will be given.

In the local M&V Protocol, it will provide detailed guideline on establishing baseline model using either Statistical regression, Neural Network or Support Vector Machine which is developed especially for Option C.

In the local M&V Protocol, there are steps which user shall refer when contemplating to carryout any retrofitting works at pre and post-retrofitting period.

Pre-Retrofit Period:
Conduct Level III Energy Audit;
Gather base year energy consumption data;
Design the retrofits and their M&V;
Document M&V Plan with baseyear data (energy and operations);
Install measurement equipment; and
Commissioning of measurement equipment.

Post-Retrofit Period:
Gather post-retrofit data (energy and operations) as defined in the M&V Plan
Maintain measurement equipment
Make any non-routine Baseline Adjustments required
Compute and report savings as defined in M&V Plan
Typical M&V activities:

Define the M&V requirement for inclusion in the project contract;
Prepare a site-specific M&V Plan;
Define the pre-installation conditions that influence the baseline energy consumption;
Define the post-installation conditions that influence post-installation energy consumption; and
Conduct M&V activities to verify operation and achieved energy savings.

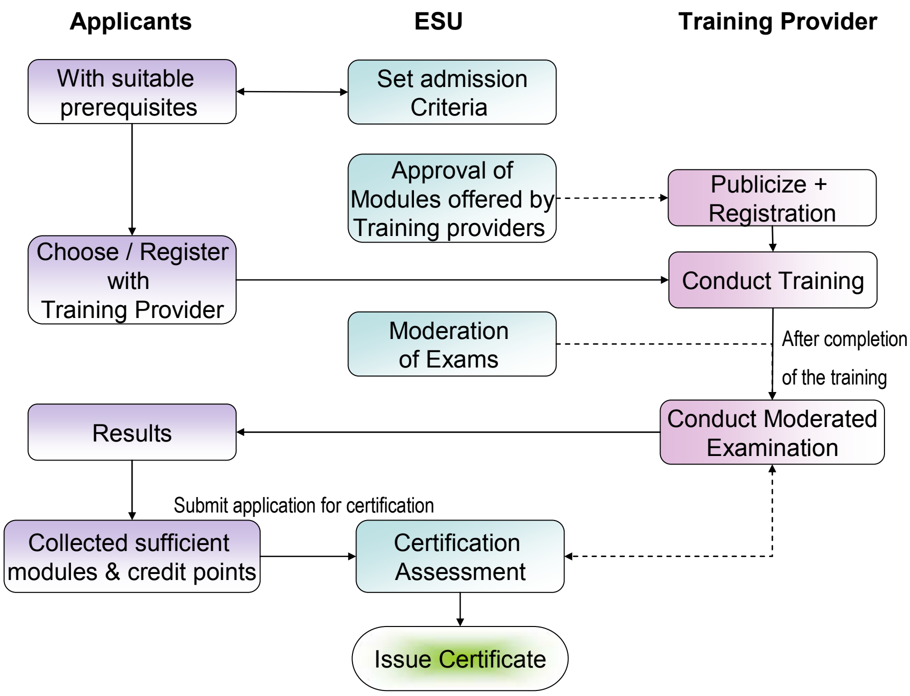
Certified Energy Manager (CEM)

The certified training is designed to meet the following objectives:

1. To build competent technical capacity in support of the energy services sector.
2. To establish a formal training and certification system for Energy Managers.
3. To motivate the provision of training services in relevant areas of energy management.

The program envisions a CEM as a competent energy professional equipped to perform technical and managerial functions as a qualified person.
The CEM program is designed as a voluntary professional career upgrading scheme. It supports the national effort to enhance energy efficiency services for businesses.

The flowchart below shows the organization for the CEM program.



Flowchart of certification and training procedure.
Notes: Indicates the flow of processes for the applicants;
Indicates the flow of Processes between ESU and Training providers.

The CEM program is designed with the following features to encourage participation of industry players:

1. Flexibility: candidates may take different modules and develop their own plan of study.
2. Specialization: encourages training provider to focus on their niche areas of expertise for training modules development.
3. Cost efficiency: avoids duplication of services provision and low rate of participation through specialization.

There are three (3) targeted training levels for CEMs, namely Associate Level, Professional Level and Executive Level. All these three levels are defined for the industry and building sectors.

Associate Level
Associate level CEM training focuses on skill training and practical development in energy auditing works, installation, measurement and instrumentation. The training aims to develop competency in energy auditing, energy efficiency technologies and energy economy.

Professional Level
Professional level CEM training focuses on the theory and practice of energy management, energy efficiency and analysis, procurement, finance and economics. The training aims to develop competency in energy auditing (at Level III) , energy performance contracting and project management, energy efficiency analysis, Energy Management and Economics and financial assessment. He/She is also expected to carry out data analysis, identify saving potentials and make sound recommendations and proposals.

Executive Level
For company executives the suitable strategy should be the generation of awareness in relation to the impacts of energy policies and economics on business management and development. This may be achieved through focused executive programs targeted at different sectors of the economy.

Training Course Contents
The training curriculum is set at a level according to educational background of the Applicant. The curriculum shall be flexible and designed to meet the needs of the various professional disciplines, including the building and industry sectors.

The curriculum shall cover both core (compulsory) and elective modules. The modules may be subjected to modifications from time to time based on the feedback received and future new developments. Modifications maybe incorporated in the syllabus through consultation with the Training Steering Committee (TSC), feedback from participants and training providers from time to time.

The training modules are designed to be four (4) Compulsory Modules: Energy Audit and Measurement; Energy Management and Economics; Energy and Environment; Energy Efficiency, and some Elective Modules. One assignment is designed as a case study of an actual situation for candidates who wish to be certified at the CEM professional level.

Future Concerns

Besides these developments, the Building and Construction Authority (BCA) has recently developed performance-based building regulations which also include a provision for a performance-based standard for efficient buildings. This can provide a significant impact on energy efficiency improvement in Singapore.

The future is based on capacity building now. A number of new initiatives – collectively involving all stakeholders – to build a base for future environmentally-sound development are already in place.

With this increasing awareness and growing concern for energy efficiency and climate change, this might open up a huge market and create many business opportunities for the Energy Service industry. This result will be very important for ensuring sustainable energy development, not just in Singapore, but also the region.

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building performance congress

Private Investments Move Ecopower (PRIME) – A Participatory Approach To Financing Energy Efficiency Measures

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Abstract
Municipalities across Europe often face a similar dilemma: the opportunities for energy savings in public buildings clearly exist and could save substantial amounts of money, but the funding for the necessary initial investment cannot be found in the coffers of the public administration. In these same communities, however, we can find citizens who are concerned about environmental hazards caused by energy production and would be able and keen to provide funds as a form of investment that will foster local development and the dissemination of environmentally sound technology. The PRIME project aims to bring these two sides together by making possible the retrofitting of pubic buildings to implement the rational use of energy (RUE) and introduce the utilization of renewable energy sources (RES). The initial investment is financed by private investors and the financial gains from the energy savings measures are distributed in a previously agreed-upon way across the actors.
The basis for this Europe-wide endeavour is the success of the German Solar & Save projects that have been implemented in four schools across North-Rhine Westphalia. The state-sponsored initiative by the Wuppertal Institute has retrofitted the schools with energy efficiency and renewable energy measures by raising the necessary funds through the financial participation of local citizens. The financing model includes the foundation of an energy service company (ESCO) specific for the project of which private investors can buy ownership and thus become 'sleeping partners'. They are not liable beyond their investment amount.
The EU-sponsored initiative PRIME is intended to pass on the knowledge and experience gained from the German example to other municipalities across Europe. Partners from eight countries – Austria, Belgium, Bulgaria, Germany, Greece, Ireland, Italy and Slovenia – are investigating energy savings potentials in their communities and planning diverse ways to include public participation both in the implementation and the financing of the projects.
The paper will elaborate on the concept of the participatory approach, introduce the Solar & Save idea and developments and describe how it serves as a model for the PRIME project. Furthermore, the PRIME process with its successes and challenges will be discussed and recommendations are outlined for policy makers and stakeholders. Finally, parallels will be drawn to the commercial buildings sector which may chose to apply such a participatory approach. Companies can also benefit from the PRIME experience when they apply RUE and RES measures across European cultures and nations.

1. Introduction
Municipalities across Europe often face a similar dilemma: the opportunities for energy savings in public buildings clearly exist and could save substantial amounts of money, but the funding for the necessary initial investment cannot be found in the coffers of the public administration. In these same communities, however, we can find citizens who are concerned about environmental hazards caused by energy production and would be able and keen to provide funds as a form of investment that will foster local development and the dissemination of environmentally sound technology. The PRIME project aims to bring these two sides together by making possible the retrofitting of pubic buildings to implement the rational use of energy (RUE) and introduce the utilization of renewable energy sources

(RES). Private investors finance the initial investment and the financial gains from the energy savings measures are distributed in a previously agreed-upon way across the actors.

Our experiences show that there is great need for a European approach as well as substantial potential for the introduction of "PRIME projects" in Europe. The idea of the participatory approach as an instrument to achieve energy savings in public buildings in a cost-effective way offers great potential to municipalities. In many European countries, such schemes are unknown, whereas in others, profound experience is available. In some countries, moreover, a lack of confidence in the public sector impedes the creation of collaboration and collective financing schemes. PRIME aims to be the catalyst as well as a pre-eminent vehicle to work toward European energy and climate change policy objectives.

The PRIME project has been built around the experiences gained in Germany using the participatory approach to financing energy savings projects in public schools. The Solar&Save initiative will be explained in quite some detail to provide insight into the model energy savings projects that PRIME is based on. PRIME is taking the idea of participatory financing that has proven successful in Germany to the European level.

On the other hand, commercial buildings are a key area for the improvement of energy efficiency and thus have a direct effect on greenhouse gas emission reduction and on the security of energy supply. This highlights the importance of the building sector, especially in achieving the overall European energy saving target. Consequently, the authors finally analyze if the experiences made with the participatory approach in public buildings are applicable to the commercial building sector. What parallels could be drawn to the commercial building sector? What benefits could commercial buildings/ companies achieve by applying the rationale use of energy and introducing measures of renewable energies – involving private investors?

2. The Participatory Approach to Financing Sustainable Energy Projects

The PRIME project is an exercise in broadening the application of bottom-up decision-making and direct democratic involvement of citizens to include the choice of energy options in a community building. It is a learning experience in democracy and shared decision-making for all participants. Through the consideration of needs of a variety of stakeholders, the PRIME process not only teaches participation and negotiation, but also provides for the establishment of a more robust project that has a greater chance of success simply because it has broader support in the community.

Experience has demonstrated that building users are much more careful with energy resources when they are directly involved in both the decision-making processes and the financing of the measures. This has lead to greater energy savings than initially estimated. Furthermore, the involvement of a broad range of citizens has lead to a snowball effect in learning about energy efficiency and renewable energy measures. Not only can the municipality use their newly-acquired knowledge about energy savings measures on other buildings, but building users and participants in the financing scheme have also been part of the natural dissemination of energy savings ideas and practices.

Overall, the participatory approach to financing energy savings measures has proven to be cost-effective and helped to secure the success of the project through a stable foundation of trust and support amongst the various stakeholders. For these reasons, a similar approach to financing energy savings can be embraced by the commercial sector. In addition, financing a sound energy savings project through citizen involvement can raise capital for measures that may not be easily acquired through conventional capital markets. Although transaction costs for involving citizens in the financing of such projects may be high, the company can also regard such efforts as part of their marketing strategy and public relations activities.

3. The Solar & Save Initiative in Germany

With the start of the "100,000 Watts Solar Initiative for Schools in North Rhine-Westphalia (NRW) – Energy School 2000+", a new approach in energy performance contracting was introduced: climate protection in public buildings as a profitable capital investment by private citizens. The project combines the construction of solar power plants (up to an output of 50 kW) with measures to modernise lighting and introduce other possibilities to save energy (the "Solar & Save" concept). In specially chosen schools, about 50 watts of solar energy per student are installed. Another 50 watts per student are saved by other energy efficiency measures (e.g. energy efficient lighting, heating and ventilation systems). Thus, 100,000 watts are being saved in an average school with 1,000 students. The objective was to build combined solar and negawatt power plants at schools in NRW. Simultaneously, a new approach was introduced for the financing of the projects: To show that these kinds of projects can be profitable, financing was conducted through energy performance contracting. The necessary capital was collected from private citizens, a majority of which are directly or indirectly related to the schools where the investment was done.

3.1. Four Solar & Save Projects

Between November 2000 and March 2002, the first project was successfully accomplished at the Aggertal High School in Engelskirchen. A four hundred square meter solar power plant was installed on the roof of the Aggertal High School, and the lighting system was refurbished. This solar power plant is the largest in the region to be put into operation yet.

In the meantime, four projects have been implemented. For example, at the Willibrord High School in Emmerich/Rhine, in co-operation with the city-government, the energy supplying-company Stadtwerke Emmerich and the school, the following investments were initiated: establishment of the largest solar power plant with private citizens' involvement (50 kWp) in the region Niederrhein, modernization of the lighting system, refurbishment of the heating and ventilation systems, and the installation of a small natural gas-fired co-generation plant. The other two projects are being implemented at the Gesamtschule Berger Feld in Gelsenkirchen and at the Europaschule (Europe School) in Cologne where the investment is mostly done.

3.2. Design of financial investment

What makes all these projects so different is the fact that they were realized through private citizens' involvement. For each project, a special Solar&Save Contract GmbH & Co.KG was founded, and the investors could join these companies as 'sleeping partners'. The company then invested the money in solar energy and energy saving measures. In return, the company received the proceeds from the energy, which the solar power plant provides to the local energy supplier. The company also receives the energy costs saved by the municipality. After considering the running costs of servicing loans and business operation expenses, the surplus will be paid to all participants over a period of 20 years. Table 1 gives an overview on the investment and results of the four projects.

Table 1: Solar- and Save Schools in North Rhine-Westfalia within the "100,000 Watt-Solar-Initiative for Schools in NRW – EnergySchool 2000+"

	Investment in Euro	**Electricity Consumption in kWh/year before installation**	**Electricity-Saving in kWh/year (and percent)**	**Heat Consumption in kWh/year before installation**	**Heat-Saving in kWh/year (and percent)**	**Solar Energy production in kWh/year**	**CO_2-reduction in t/year**
Aggertal-Gymnasium Engelskirchen	419,000	122,000	68,000 (56%)	1,585,000	222,000 (14%)	30,400	200
Willibrord-Gymnasium Emmerich a. Rhein	617,000	434,000	254,000 (59%)	1,912,000	600,000 (31%)	38,000	472

Gesamtschule Berger Feld Gelsenkirchen	935,000	887,000	465,000 (52%)	4,442,000	875,000 (20%)	22,500	750
Europaschule Cologne	1,230,000	1,580,000	800,000 (51%)	3,604,000	608,000 (17%)	15,600	1,500
Total	3,201,000	3,023,000	1,587,000 (52%)	11,543,000	2,305,000 (20%)	106,500	2,922

The total investment for the four projects is about 3,2 Mio. Euro. This investment will save about 3,000 tCO_2 per year and will reduce the cost for the energy supply of the four buildings for about 6 million Euro over a timeframe of 20 years. An exact average per year is difficult to assess because of differing project timing and contractual circumstances in the four participating schools.

On average, the CO_2-reduction is higher than 50 % in relation to the baseline. The projects show that effective emission reduction can be done with profitable measures. The most important condition for high efficiency of the project is that the planning of the refurbishment is done with accuracy and high efficient technologies are used. The measures that are usually done for such projects are shown in figure 1.

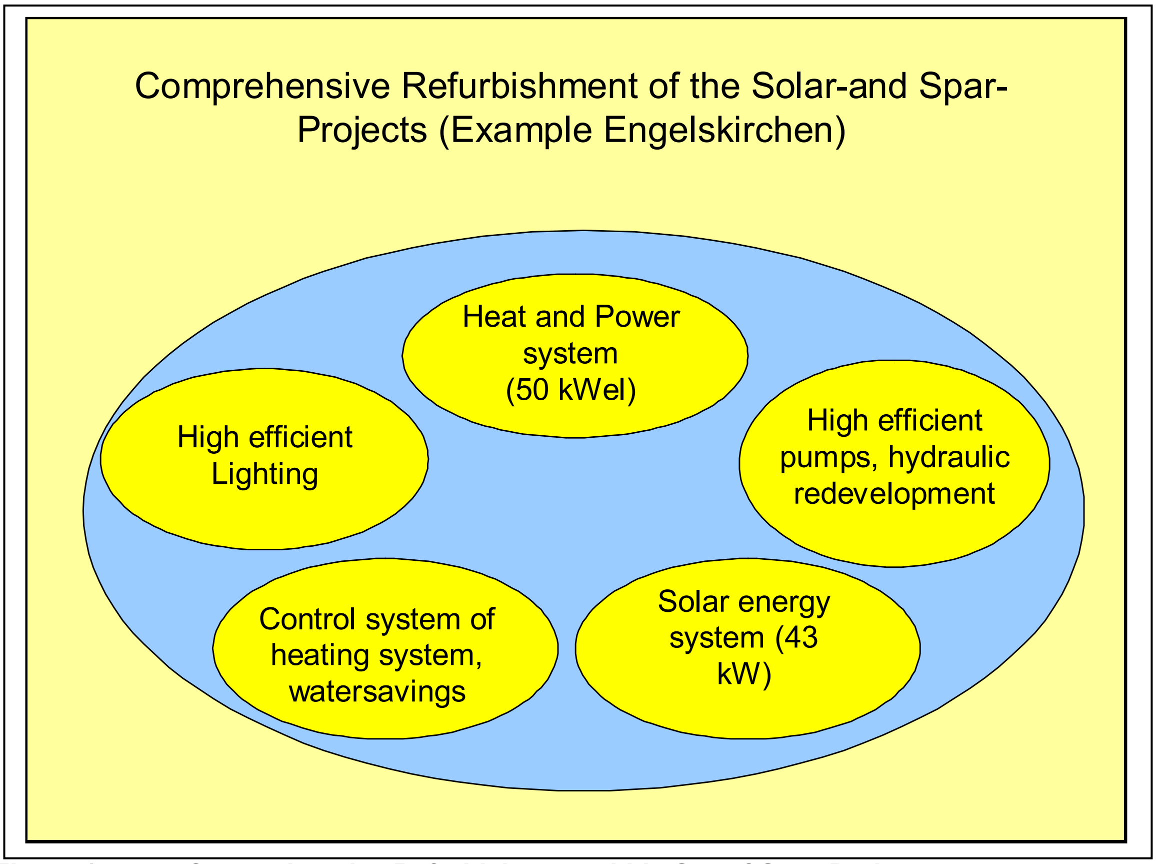

Figure 1: Comprehensive Refurbishment within Solar&Save Projects

The following figure shows the planed and realized results for the project in Engelskirchen.

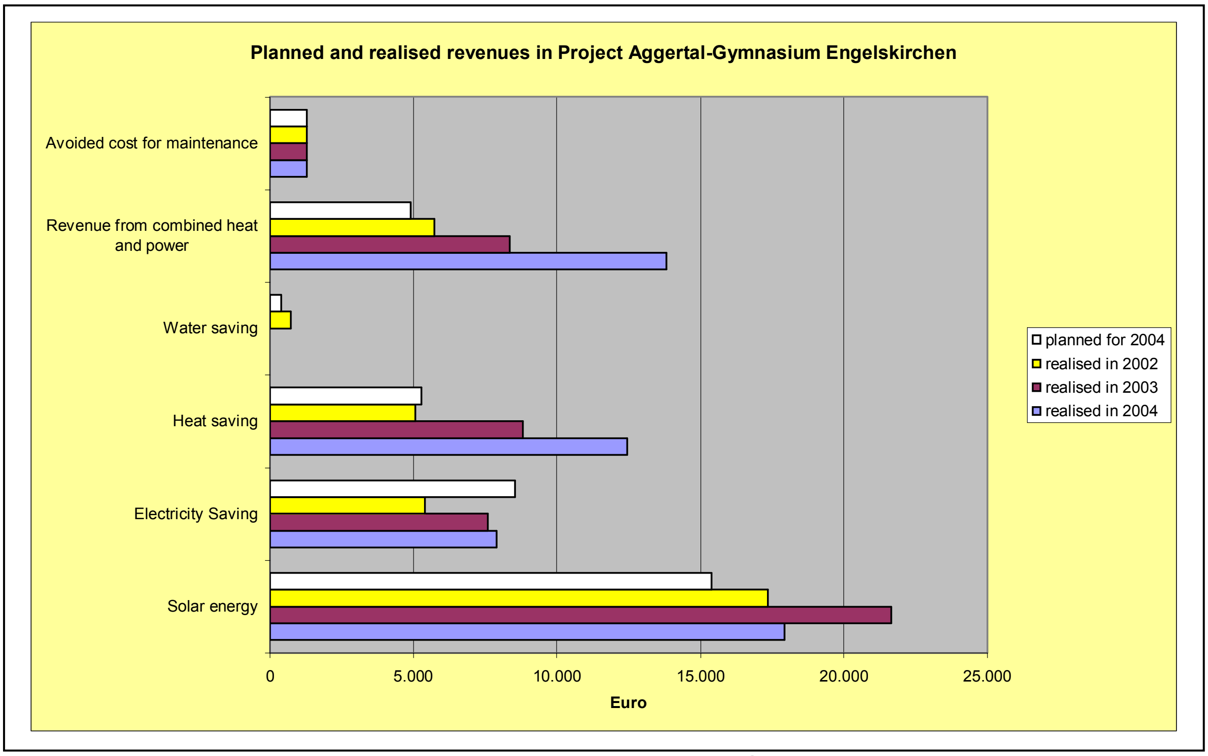

Figure 2: Planned and realized revenues at Aggertal-Gymnasium, Engelskirchen

3.3. Energy Savings

As it is easy to see, the realized revenues are obvious higher than originally planned. Thus, investors with the project would get a higher return on their capital. In addition, the school also takes profit from the good results. One third of the revenue, which is higher than the planned revenue, will go to the school for a purpose of their own choice. In 2004, Euro 2,560 have been paid to the Aggertal-Gynmasium in Engelskirchen.

The main advantages of this participatory solar & save approach therefore are:

- Investors receive a reasonable payment of interest (about 5 percent)
- Schools and communities save on renovation and running costs
- Teachers and students experience practical climate protection
- Less maintenance work for the caretaker
- Local tradesmen receive work orders
- Thousands of tons of carbon dioxide emissions per year are prevented.

3.4. Public relations and feedback

To attract the capital from private investors different ways have been used:

- The Solar&Save Contract GmbH produced a leaflet for each project. Within the leaflet a description of the financing system, a description of the energy saving measures and a preview of the success of the project was given.
- Teachers and parents of pupils of the schools were invited to presentations of the projects.
- The project was communicated through newspapers and journals (see figure 3).

Figure 3: **Articles in Newspapers to advertise for the projects**

4. PRIME – Private Investments Move Ecopower

4.1. Design of the PRIME project

The EU-sponsored initiative PRIME – Private Investments Move Ecopower – is intended to pass on the knowledge and experience gained from the German example of the successful Solar&Save Project to other municipalities across Europe. Partners from eight countries – Austria, Belgium, Bulgaria, Germany, Greece, Ireland, Italy and Slovenia – are investigating energy savings potentials in their communities and planning diverse ways to include public participation, both in the implementation and the financing of the projects. The description of PRIME below is based on the grant agreement issued by the European Commission under its Intelligent Energy Europe programme (European Commission: 2004).

Thus, PRIME aims at fostering a participatory approach for private investments from citizens and local stakeholders in sustainable energy measures by Energy Performance Contracting (EPC). Such a participatory approach has already been used, e.g. for wind power, photovoltaic and biomass plants in Germany, Austria, Denmark or Belgium or as Solar & Save in some German schools. Consequently PRIME projects will be local RUE and/or RES projects for which private capital from citizens and local stakeholders will be mobilized for the investments via such a participatory approach. The focus will be on integrated RUE&RES investments in public buildings. Within 2.5 years the project will prepare the ground, and promote and facilitate the application of “PRIME projects” including the involvement of the users of buildings into the efforts to protect the climate.

Below the main characteristics of a PRIME project are summarized:

Private Investments Move Ecopower (PRIME) – A Participatory Approach To Financing Energy Efficiency Measures

What is a PRIME project?

- Participatory approach
- Private capital from citizens and local stakeholders
- Local project
- RUE and/or RES (energy efficiency, CHP, renewables)
- Implementation of measures by kind of energy performance contracting (EPC)

The ideal PRIME Project:

- At least 50% private capital from many citizens and local stakeholders
- Investments in public buildings
- Integrated RUE and RES investments (energy efficiency, CHP, renewables)
- Substantial size of project
- Implementation of measures by kind of energy performance contracting (EPC)
- More than financial participation: participatory approach includes further measures

The choosing of a potential PRIME project provokes the question of an upper/ lower limit to project size. In general, there is no particular indicator for the minimum size of a building. However, calculations and experiences from other projects so far show (e.g. the Solar&Save project) that a minimum of annual *saving* in energy costs should be approximately 15,000 Euro. This corresponds to a minimum of annual energy *costs* of about 30,000 Euro. Experiences also show that an upper limit for contracting using citizens' capital can be estimated at 2 million Euro.

4.2. Target group

The project targets local authorities and energy agencies as well as the private sector including households. As demonstrated by a growing number of Local Agenda 21 processes, local governments do play a major role in local climate protection policies. Local authorities are the owners of public buildings and many private actors are interested in financing renewable energy measures as well as RUE and have sufficient capital to do so. In addition, community members often have a common interest in improving the physical environment (lighting, heating, etc.) of public buildings that they use (for example schools) (see Duscha and Hertle: 1999, Forum für Zukunftsenergien e. V. : 1998).

The target groups and key actors have also been involved in the preparation of the project proposal in a participatory way: by becoming either a partner of the project or by signing a letter of intent. Further key actors are being involved during the course of the project via mailing lists and discussion forums on the Internet. They receive draft versions of the main elements of the action package and are asked to give feedback and further input. Key actors and target groups are as follows:

- European local authorities as owners of public buildings
- Energy agencies and ESCOs as professionals for carrying and organizing PRIME projects and looking for new markets
- Private households and other potential local and regional investors, looking for financially and ecologically sensible investments
- Environmentally oriented NGOs as promoters for climate protection
- Research Institutes

4.3. Expected results

PRIME will develop practical models for CO_2 reduction measures that can be implemented by other European municipalities and thus will avoid the costs for developing strategies on their own. Such tools will contribute to lowering the transaction costs for implementing a PRIME project. This project will result in the development of an easy to implement action package, including best practice examples and tools.

In addition, PRIME will create an effective European network for stakeholders in the field of participatory sustainable energy projects, in which experiences, initiatives and ideas can be exchanged and strategies discussed on the Internet. This will contribute to a broader base of knowledge and application of such approaches and will include best practice projects, tool-kit, calendar with relevant events, interactive tools for a pre-feasibility check, databases with contacts, etc.

Not only sound technical and cost-benefit analysis, and reliable financing models are needed, but also confidence needs to be built up between the partners. Therefore - beyond the practical actions and investments in the participating cities - raising awareness is directly linked to offering practical options to tap into sustainable energy potentials. All partners will work on a promotion campaign for local authorities on the instrument of energy performance contracting as well as on a promotion campaign to raise and mobilize social capital and trust.

Next to designing tools for the project partners, PRIME aims to initiate concrete processes in participating cities. All partners will work on the local level and will evaluate public buildings according to a list of criteria and decision tree for a pre-selection of public buildings, define a set of buildings with relevant energy saving potentials, will analyze the feasibility of a “PRIME project” via preliminary analysis of energy cost saving potentials and benefit-cost ratios. Thereby, the project will lead to practical tools ready for a broad application in Europe and offers ESCOs excellent opportunities with extremely low preparation costs for investments.

Furthermore, all partners will involve users and carriers of buildings to inform them about the relevance of energy efficiency and renewable energies and to start campaigns to address behaviour-related energy savings (in particular, benefit-sharing projects). This will lead to raised awareness, increased confidence between private and public sector and will prepare the ground for realizing “PRIME projects”. Moreover, economically viable energy performance contracting projects rely on suitable user behaviour. Experiences from more than 1000 projects in Germany show that by addressing user behaviour energy savings of 10% can be reached.

Participating cities will work on the implementation of “PRIME projects”. This will go hand in hand with the testing and application of the PRIME tools. Thus, connected to the joint learning process, the project will lead to concrete investments in cities.

It is intended to focus particularly on projects combining renewable sources of energy and energy efficiency in public buildings. The cities will explore the opportunities and threats for integrating citizen financed funds as one source of financing the investment. The partners following the approach of PRIME projects will implement the model projects or the Solar&Save approach.
The successful implementation of the projects across Europe will lead to:

- Energy savings. Based on experiences in Germany, it is possible to estimate that retrofitting of public building leads to energy savings of 25-30%.
- Strengthening institutional capacity in local authorities for climate protection, increase energy efficiency in the local authorities’ own buildings and operations, and mitigate the urban impact on climate change. By this, help local authorities increase community sustainability and community livability.
- Improved physical environment (lighting, heating, etc.) of public buildings
- Participatory involvement of many stakeholders in climate protection, motivating them to disseminate successful models in their own surroundings.

4.4. Obstacles towards investments in public buildings using the PRIME approach

Despite the success of the Solar&Save Project, various obstacles to implement such participatory approaches EU-wide or in another sector exist (see also Bemmann: 2002, Graz Energy Agency). Major barriers towards RUE and RES investments in public buildings are a lack of know-how, and a lack of capital on the side of the public sector. The experience of the Solar&Save Project as well as from the PRIME projects so far shows: The major challenge is to mobilize the large potential of private and/ or public capital.

More concretely, activities within the PRIME project face a variety of obstacles towards investments in public buildings, depending on particular national circumstances:

- Varying national legal foundations
- Public environmental awareness
- Public awareness on green/ethical investments
- Awareness within the municipalities to progress in energy savings in public buildings
- Cultural differences
- Changing energy prices
- Little knowledge on ESCOs
- Little knowledge on contracting
- Technical knowledge and expertise on energy efficiency
- Integration of experts

The question of public procurement often appears in terms on how those projects comply with the public procurement rules. Experience so far has only been made with pilot projects; therefore general standards on how to comply with public procurement rules have not been generated and applied.

Transaction costs are an important cost factor in the development and realization of PRIME type projects. Whereas practical experience undertaking such projects needs to be taken into account in terms of lowering transaction costs, well-defined transaction costs can be identified and calculated roughly.

Experiences as well as literature distribute the following transaction costs for such projects as follows:

- Planning costs: Planning costs must be differentiated between rough and detailed planning (implementation of planning) as well as project processing and site supervision. For those parts a total amount of about 20% of the investment can be seen as realistic.
- Project development, contract negotiations und communication: This part of the transaction costs is rather independent from the total size of account. The amount rather may vary significantly from project to project as it is depending on the contracting partner and its individual situation (about 15,000 to 30,000 Euro).
- Transaction costs during implementation and realization: (checking accounts and bills, allocating, purchase tax, consultation with client, controlling): about 2-3% of the total investment.
- Costs for support of technical equipment during the contract period: depending on the outline of the individual contract and what problems regarding the technical equipment might occur during the contract period. Varying from minimal support (projects running smoothly) and one month per year (in case of persisting support needs).
- Transaction costs during the contract within well-rehearsed and running projects: (accounting of cost savings, administrative efforts, transaction of taxes, etc.): about 5.000 Euro per project.
- Support of the shareholder (annual information, updating contacts, occasional requests): about 3,000 to 5,000 Euro per project and year.

The given amounts and rates of transaction cost are without any guarantees as they are very difficult to assess, highly varying and based on experiences gained from realized projects so far. Nevertheless, they can help provide a tendency for project developers and partners as on what costs as well as duties are influencing the realization and investment of such a complex project outline.

5. Development and application of tools

5.1. Development of tools

Especially in Germany, a whole series of energy performance contracting projects have already been implemented in the field of energy performance contracting. Based on the success of the Solar&Save Project as well as gathered experiences, in particular the analysis of existing approaches to RES and RUE measures and their preconditions, the experiences made have been translated into practical and easy-to-use tools for the PRIME project partners: schemes, spreadsheets, model contracts and guidelines have been developed that are to provide partners with tools to implement "PRIME projects". The tools being developed are:

- A criteria list and decision tree have been developed to allow for the pre-selection of public buildings suited for "PRIME projects", including a "quick and dirty" economic tool for a preliminary analysis of energy cost saving potentials and cost-benefit ratios. (Tool1)
- In order to provide a sound economic analysis of potential projects, simple spreadsheets have been developed to perform a first cost assessment and cost-benefit analysis. This method will be applied by all projects within PRIME to ensure the comparability of the results. (Tool2)
- Furthermore, model concepts and contracts for "PRIME projects" involving a contractor (ESCO – energy service company), the municipality and citizens holding shares in the investment project, mainly based on the existing German examples. This scheme can be adapted to national conditions (property and responsibilities, legal background, scope of existing actors, etc.). (Tool3)
- Finally, several tools have been developed, suited to inform, motivate, and involve target groups addressing potential ESCOs, the affected departments and offices of the local authority, the users of public buildings, and local stakeholders who are potential private investors. In order to raise awareness and build up trust between all these partners who are involved in, or affected by, the measures, communication tools have been developed. Moreover, practical options have been offered to tap energy conservation potentials due to behavioural changes. This includes incentive schemes for building users, in particular benefit sharing between owners and users. (Tool 4)

5.2. Short presentation of the tools

In order to present a brief overview of the tools designed for the development of a PRIME project, the "Decision Tree" will be presented in more detail. The decision tree explains the flow of analyses, decisions and planning from the start of the considerations to initiate a PRIME project to its implementation. The decision tree further shows in which phase of the project which PRIME tool could be used. The main PRIME project phases are:

1. Selection process: selection of building to be retrofitted and/or of open space/area suitable for renewable energy measures
2. PRIME project development
3. Implementation.

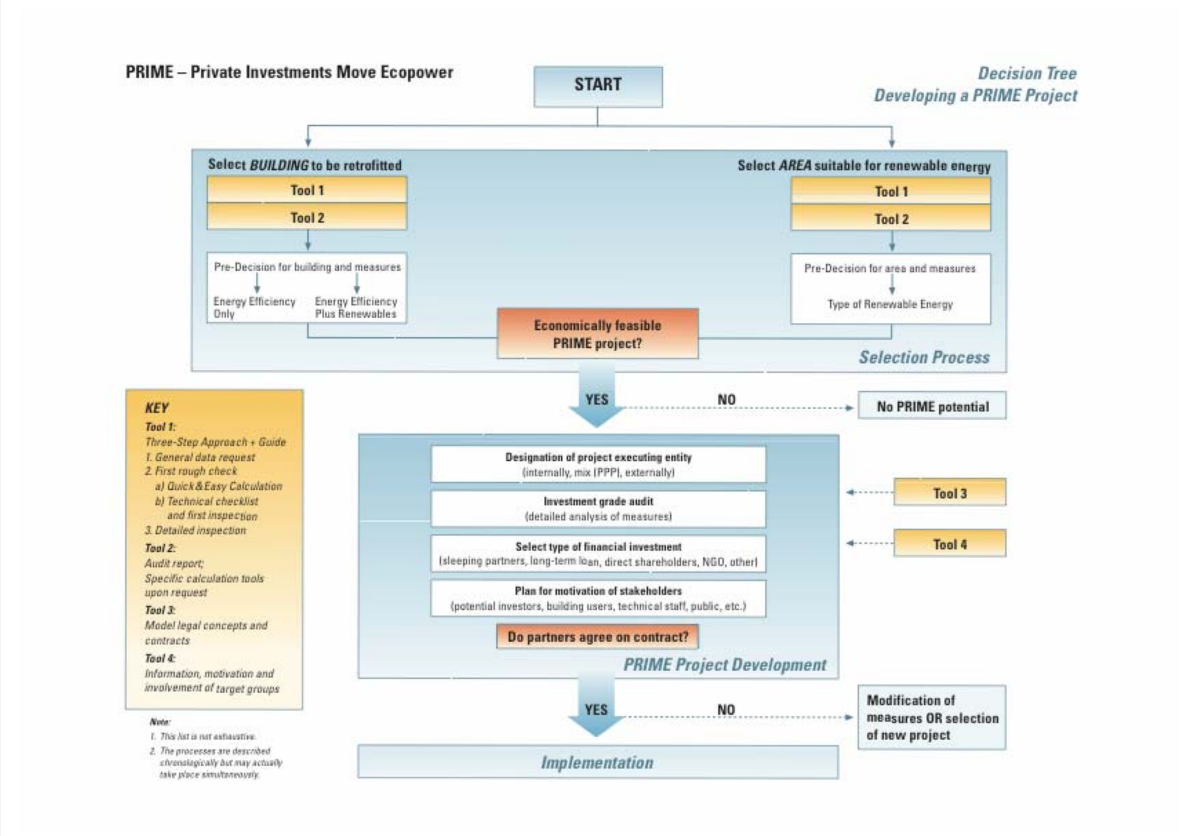

Figure 3: Decision Tree – Developing a PRIME Project

The Decision Tree briefly presents three phases for the development of a potential PRIME project. The first phase includes the selection process towards either a building to be retrofitted or an area suitable for renewable energy measures. Within this first phase two tools should be applied (Tool 1 and Tool 2) for a pre-decision, esp. for a building, including the measures of energy efficiency as well as on renewable energy.

For this first phase, a set of questions developed for Tool1 helps scan public buildings and open spaces (public areas) to identify potential PRIME projects, including three steps:

- The first step is made up of the “General Data Request”. It will help decide whether a building or area is suitable at all for a PRIME project. This information is also helpful to the PRIME coordinator in order to compile a list of PRIME projects for the final report.
- The second step, the “First Rough Check”, helps narrow down the choice of potential PRIME projects in two ways: a) The “Quick & Easy Calculation” will give a very rough estimate of the net benefits of an average of best practice energy efficiency measures in a typical public building in a specific country. b) A “First Inspection” of technical installations in the building can be conducted following a list of criteria to be checked. The criteria list thus acts as a first selection mechanism to separate a small number of buildings. In most cases, it will be sufficient to carry out this first inspection together with a person knowing the building very well, e.g. a caretaker. The involvement of a specific technical expert is not needed at this stage of analysis.
- In the third step, the “Detailed Inspection”, the data will be further examined by a detailed analysis, i.e. an expert assessment of the public building or area. A technical expert is required to conduct this inspection.

Intended as a basis for background information, in addition a developed “Guide” provides a general overview of the aspects that are of particular importance for potential PRIME projects, with focus on the technical-economic aspects of projects (e.g. indoor lightening, heating, ventilation and air conditioning, energy and water costs, etc.). The guide should be used as an information tool to cross-check the answers while working along the three steps.

Tool 2 provides an overview on various tools for cost assessment and cost-benefit analysis of building measures available for PRIME projects in order to provide a sound economic analysis of potential projects. Once the building has been selected, the PRIME partner has to calculate exactly which measure will allow for which financial gain. In order to estimate the costs of the investment and calculate the returns, a very detailed analysis of the measures has to be conducted. The PRIME partner will be able to provide the expertise in making such calculations or contract an expert to conduct the study. Tool 2 therefore lists more or less detailed spreadsheets that have been developed for similar projects.

Having compiled all requested information with the help of the developed Tool 1 and Tool 2, the decision for a building to be retrofitted or an area can be made. If, however, the selected building/ area shows no potential for an economic feasible project, a new building or area has to be selected – again with the help of Tool 1 and Tool 2.

After the selection process of a potential PRME project the second phase of the Decision Tree shows the main steps in order to support the further development of the project. Therefore, Tool 3 and Tool 4 have been developed to assist in the

- Designation of a project executing entity (internally, mix (PPP), externally)
- Investment grade audit (in combination with a detailed inspection)
- Selection of type of financial investment (sleeping partners, long-term loan, direct shareholders, NGO, other)
- Motivation of stakeholders (potential investors, building users, technical staff, public, etc.)

Whereas Tool 3 provides information on legal concepts and model contracts for integrated RUE & RES investments in public buildings via a participatory approach, Tool 4 focuses on ways of informing, motivating and involving target groups (see also description in 5.1.). Having received feedback from all project partners regarding the testing of the developed tools, finally, the third phase of implementing the project will then be undertaken in the course of the project.

5.3. Implementation of tools and potential PRIME projects so far

The project-timeline for the PRIME partners foresees the testing of the tools by all project partners at the end of 2005 / beginning of 2006. In this regard, the project partners across Europe are currently testing the application of the tools within their municipalities. An adjustment of the tools will be made once the feedback of the partners has been received in an individual designed feedback-form. During the 3rd PRIME Workshop, to be held in spring 2006, the partners are given the opportunity to report back and share experiences on their work so far: on testing of the tools, identifying buildings, initializing ESCOs, communicating with municipalities and other important stakeholders, etc. In this line, the implementation of identified and evaluated buildings becoming PRIME projects is scheduled to start as of summer 2006.

However, the course of the PRIME project so far shows that the simple application of the successful Solar&Save Project, and more generally a participatory approach, within different municipalities across Europe proves to be more challenging than expected. Next to the identified obstacles towards investments in public buildings, there are two major underlying factors influencing the course and success of the project.

First, the construction of a PRIME project itself is very complex. Second, the participatory approach of PRIME projects in general is rather innovative in many European countries. So far, the endeavour shows the need to raise awareness and basic knowledge on the idea of PRIME projects among the projects partners as well as among the various participating municipalities across Europe before applying the complex and detailed project-approach and structure in these countries.

Nevertheless, the experience so far also shows a clear opportunity: The concept proves to be a good and applicable model concept and model contract for public participation energy contracting projects. Even if the process might not be developed promptly and easily in light of the PRIME course, in sum the concept and contract can serve for potential contracting projects, even without public participation.

6. Further Considerations

Energy performance contracting (EPC) opens up opportunities for the owners of public and commercial buildings to install improved energy-efficient equipment and systems without tying up their own capital, leading to energy savings in the magnitude of 20 to 40%. Greater use of these mechanisms could substantially contribute to reducing energy consumption and lowering emissions of greenhouse gases.

Thus the participation of private investors proves to be a future-oriented approach to energy efficiency. Nevertheless, obstacles exist to translate the positive experiences of this participatory approach EU-wide as well as to the commercial sector.

6.1 Obstacles to translate the experience EU-wide

One way of avoiding to take action in the field of ecological conversion is to insist on the non-transferability of a solution applied with success elsewhere. In its elegant form this usually goes along with a compliment to the authors of the practice and the national culture of the place. The extensive use of bicycles in a given country or city, the many solar collectors on the roofs, the high shares of separate waste collection are, in this view, to be explained as a result of the elevated ecological consciousness of the citizens in Denmark (Germany, Netherlands...). Which is a simplistic way of looking at ecological innovation that ascribes to a mysterious national character, if not outright to some ethnic disposition certain kinds of behaviour. A reductionist’s view at best that frees the speaker from the need to take a closer look at the particular conditions and obstacles for transferring good practices from one reality to another.

PRIME certainly is a case in point. To involve the beneficiaries and their relatives financially and in the decisions of retrofitting a building and the use of renewable energy seems a patently simple idea. To promote this innovative model in Italy, for example, will be the demanding task of the Province of Bologna and the national coordination of Climate Alliance. A first step, of course, is to have all the instruments available in the national language and in conformity with the national and state laws and regulations. A demanding task, but solving all the technical, financial and legal questions within the national framework, as important as it is, unfortunately is not enough. The following step is to experiment the various phases of a PRIME project under the most favourable conditions that can be created in order to analyze then attentively the obstacles that present themselves and the points of friction. This approach is based on the idea that the various actors – the public authority, the school administration, the energy company, the investors – all follow, sometimes consciously but often unconsciously their own specific rationale which only becomes evident to the attentive observer in the moment when there are some disturbances in the process and things do not take their usual course. To activate, for example, in Denmark, the Netherlands or great Britain the participation of a group of parents in a PRIME project will take a different form than, e.g. in Italy. While in Northern Europe one can rely on a tradition of self-help and autonomous civic activity of citizens as individuals or as families e.g. in Italy citizens’ initiatives and participation are nearly entirely mediated by parishes, associations, unions and other organizations. To awaken interest in a given project, fabulous as it may be, addressing single persons or households will produce a very limited response. A much more promising approach is to secure first the support of the parish council, the local chapter of a union or an environmental association.

National circumstances are therefore to be observed carefully and integrated into the planning of a PRIME-type project without simply attributing any difficulties to more or less obscure cultural or ethnic characteristics. It is important that PRIME projects are conducted in a way sensitive to social, legal and institutional structures which may not always prove to facilitate the progress of the project. Creative solutions may need to be sought.

6.2 Benefits for the commercial sector?

The Solar & Save Project has demonstrated the success of the participatory approach. This financing of energy-related measures in public buildings by citizens has not only led to energy savings and emissions reductions but also to a considerable return on investment for the individual investors. At the same time the commercial buildings sector is one of the fastest growing energy consuming sectors. Are these experiences transferable to the commercial sector? What benefits could owners or operators of commercial buildings obtain from a participatory approach when implementing energy efficiency, cogeneration and/or renewable energy measures in their buildings?
In fact, companies could also benefit from the application of the participatory approach as part of their investment scheme. Whereas the financial benefits were not the only motivation to involve private investors in retrofitting measures in several municipalities, responsible decision makers stated that the processes of motivation, communication and identification had an enormous positive impact when applying the participatory approach.

Derived from these processes, companies could gain positive feedback due to various factors applying the participatory approach. By involving customers and/or employees directly in the financing of energy measures, companies can strengthen customer and/or employees' loyalty. They can position themselves as an innovative firm using a unique marketing instrument and demonstrating the sustainability focus of the company. Of course, they can obtain net energy cost savings and access to capital outside of the traditional capital markets. Despite the concern that transaction costs for obtaining capital from private citizens are quite high due to marketing expenditure to attract the investment, to conclude contracts, to monitor the impacts of the energy-related measures and to repay the investors, it can be argued that the above-mentioned benefits exceed these costs and also include positive public relations measures. The benefits to the company are therefore twofold.

Experiences show that energy savings combined with renewable energy and/or cogeneration measures are a secure investment. The prospect to gain financial benefits and at the same time integrate customers, employees and/or further partners (e. g., suppliers) should provide an incentive for the commercial sector to apply the participatory approach through involving several individual private investors.

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GreenBuilding: Enhancing the Energy Efficiency of Non-residential Buildings

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Abstract

In 2004, the European Commission's Joint Research Centre initiated the GreenBuilding Programme, which aims at improving the energy efficiency of non-residential buildings in Europe on a voluntary basis. Since January 2005, thirteen organisations from ten European countries are implementing a two-year pilot phase in the context of a project, which is being supported by the European Commission's EIE programme. Co-ordinated by the German Energy Agency (dena), the project partners set up so called National Contact Points (NCPs) in the ten participating countries. Owners of non-residential buildings can receive from the NCPs support in the implementation of energy efficiency measures at their buildings. They can apply to become official GreenBuilding Partner on a voluntary basis by performing an energy audit at their premises, laying out an action plan and reporting on the results of the measures. The NCP will assist the potential Partner in this process by providing practical help and technical know-how through guidelines and technical modules, through a website in national language with an inventory of best practices, as well as by providing public recognition by the use of the signet and publicity work.

Since the public promotion of GreenBuilding started in September 2005, many owners of non-residential buildings have contacted the GreenBuilding contact points in order to participate in the programme. The feedback in Europe so far encompasses many different types of building owners and building types: public authorities with schools, hospitals or swimming halls; companies from the services and industry sectors with office buildings; and even churches.

GreenBuilding is complementary to the Building Energy Performance Directive as it stimulates additional savings in the non-residential building sector. In Germany, where GreenBuilding is part of dena's "EnergieEffizienz Initiative" and the dena campaign "zukunft haus", synergies with the process of building certification are being used for a combined promotion of the certificate and the participation in GreenBuilding. In Austria, the national project activities are combined with the national programme for climate protection "klima:aktiv".

The most important reasons for participation are the lack of information, the need for technical assistance, support for the internal decision making processes, staff motivation and the public recognition for becoming a GreenBuilding Partner.

Background

Relevance of the building sector for the improvement of energy efficiency in Europe
Representing almost 40% of the final energy demand in the EU-25, the building sector (residential and commercial) holds the largest potentials for energy savings in Europe today. In the face of the accelerating energy demand in many regions, rising energy prices worldwide, the significant dependency on energy imports in the EU and the need for more effective measures for the reduction of CO_2 emissions, the European Commission has adopted the Directive on the Energy Performance of Buildings (EPBD[1]) in 2002. This directive, which is the latest of several EU initiatives for improving the energy efficiency in the building sector, lays down the requirements for the member states to

adopt legislation by 2006 concerning the introduction of energy performance certificates for new and existing buildings.

The implementation of the EPBD on the level of the Member States will bring about a significant impetus to the establishment of energy efficiency markets throughout the EU and will constitute a major milestone on the way to a more energy efficient building sector. In the case of Germany, thousands of architects and planners have already registered to become official issuer of the new building certificate (Gebäudeenergiepass), which has been developed and widely tested by dena.

Complementary voluntary measures
In order to achieve a real transformation towards higher energy efficiency in the building sector, the introduction of new regulations will need complementary measures as well. The ambitious European goals and obligations in the context of energy efficiency[2], security of energy supply[3] and climate protection (Kyoto Protocol) can only be reached, if the relevant actors in the building sector can be motivated and informed, that the improvement of the energy efficiency is an opportunity for significant cost reductions as well as a means to maintain and improve the long-term value of their building stock.

The European Commission's GreenBuilding Programme
Initiated by the European Commission's Joint Research Centre in 2004, the GreenBuilding Programme has been developed to enhance the energy efficiency and the use of renewable energies in non-residential buildings in Europe on a voluntary basis. The programme's main focus lies on the modernisation of existing buildings, but new buildings can participate in GreenBuilding as well.

GreenBuilding's message to building owners is that many energy efficiency measures are highly economical with short payback times of the investments and that most of the measures can be realised with proven technology. In short: Energy efficiency pays off!

To achieve significant progress concerning the energy standard of non-residential buildings, the lack of information and thus motivation for building owners and planners, which currently prevents the necessary acceleration of the modernisation cycle in the European building stock, have to be addressed. The lack of information consists especially in non-sufficient technical know-how and public recognition. The GreenBuilding Programme aims to reduce these deficits in Europe with a network of organisations providing support to building owners throughout Europe.

Figure 1: Logo of the GreenBuilding Programme, by EU JRC

Structure of GreenBuilding
The European Commission's Joint Research Centre (DG JRC) in Ispra is the central contact point for the European GreenBuilding Programme. The JRC was a driving force for the establishment of this kind of marketing for energy efficiency in the non-residential building sector. The DG JRC and is also the body granting "Partner" and "Endorser" status to participating organisations or companies.

In the programme's pilot phase in the years 2005-2006, a network of GreenBuilding National Contact Points (NCP) has been set up in ten European countries. The NCPs' main task is to aid organisations, who consider participation in GreenBuilding. This pilot phase of the GreenBuilding programme is supported by the European Commission's Intelligent Energy Europe Programme. The German Energy Agency (dena) is the co-ordinator of this Europe-wide action.

Goals of GreenBuilding
The main objectives of GreenBuilding can be summarised as follows:

1. GreenBuilding wants to trigger investments in energy efficiency and renewable energy technologies in non-residential buildings with focus on existing premises on a voluntary basis.
2. GreenBuilding is designed to help to open up markets – in particular by increased awareness, know-how and technical capabilities, the access to finance and energy service offerings – to achieve investments with high benefits and short payback times.
3. GreenBuilding wants to initiate energy efficiency investments in non-residential buildings which are clearly profitable and are based only on proven technologies.
4. GreenBuilding complements and goes beyond the standards imposed by the European building directive and national building codes in force.
5. By encouraging energy efficiency and renewables energy measures which are economically viable, GreenBuilding does not stop at the implementation of state-of-the-art energy standards but actively contributes to the advancement of the present state-of-the-art in energy saving techniques in the non-residential building sector.
6. GreenBuilding intends to provide information and support as well as public recognition to companies, which are ready to make commitments to improve the energy efficiency of non-residential buildings well beyond the legal requirements with measures that are proven and profitable.

Participation in GreenBuilding

GreenBuilding Partner
Organisations or companies, which are ready to show actual commitment to adopt ambitious energy efficient measures in non-residential buildings, can receive the official status of a "GreenBuilding Partner". In order to become Partner, the respective organisation submits an action plan defining the scope and nature of the company's commitment. Based on an initial energy audit, the action plan defines the buildings in which energy efficiency actions will be undertaken as well as the energy services and the specific measures, to which the commitment applies. If the action plan is accepted by GreenBuilding, the organisation is granted Partner status, which includes the right to use the GreenBuilding signet for public relations activities. Three years after the completion of the last GreenBuilding project, the Partner status will expire.

To qualify for GreenBuilding Partner status, the respective organisation commits itself to energy efficiency improvements in one or more buildings. The following cases are eligible:

1. Refurbishment of one or more existing non-residential buildings, which will result in the reduction of the total primary energy consumption of at least 25% (if economically viable), total or related to the end-use or subsystem, which is being modernised.
2. New non-residential buildings, which consume 25% less total primary energy (if economically viable) of the building standard in force at the time or below the consumption levels of "conventional" buildings presently constructed.
3. Buildings already renovated or refurbished (after 01.01.2000), if the total primary energy consumption was reduced by at least 25% or the buildings consume 25% less energy than required by the building standard in force at that time.

To aid the potential partners in fulfilling their commitments, GreenBuilding provides documents (so called Technical Modules) defining the technical nature of an appropriate commitment for each energy service covered in the programme. There are Technical Modules on issues like "Building Envelope", "Heating", "Combined Heat and Power", "Air Conditioning", "Lighting", to name just a few. The modules are complemented by guidelines on horizontal issues, such as "Financing", "Energy Audit" and "Energy Management".

GreenBuilding Endorser
The GreenBuilding Endorser Programme has been established to help promoting GreenBuilding to potential participants. The Endorser Programme also supports already registered GreenBuilding participants in their efforts to reduce the energy consumption in their non-residential buildings. To become a GreenBuilding Endorser, an organisation must have assisted at least one building owner in becoming a GreenBuilding Partner. Furthermore, it is expected that a GreenBuilding Endorser will undertake specific actions to support GreenBuilding. In return, the Endorser will get public acknowledgement for their efforts. Applications are especially welcome from:

- Equipment manufacturers,
- Building contractors,
- Energy management and system design companies,
- Electric utilities and energy service companies,
- Energy equipment importers, distributors and vendors,
- National professional and trade associations.

Present State of GreenBuilding

Infrastructure
In 2005, the National Contact Points together with the European Commission set up the necessary infrastructure for the implementation of the GreenBuilding Programme. In a first step, the GreenBuilding documents have been developed. They consist of guidelines laying out the procedures for participation, and technical modules illustrating energy efficiency potentials in various technical disciplines relevant for non-residential buildings.

In a second step, GreenBuilding internet sites have been established on the international and national level. The websites introduce the GreenBuilding Programme, explain the options to participate and provide the Guidelines and Technical Modules for download. Furthermore, the GreenBuilding Partners and Endorsers are listed on the websites and examples of successful implementation are presented in a Best Practice Inventory.

On the central project website www.eu-greenbuilding.org, the latest information on GreenBuilding and all the links to the relevant websites of the European Commission and the National Contact Points can be found.

Promotion events and publications
Since summer 2005, the GreenBuilding National Contact Points in the ten participating countries are organising workshops to introduce GreenBuilding to the target groups of the building sector, commerce, industry, local and regional authorities as well as service providers for energy efficiency technologies.

Additionally, brochures or leaflets have been produced on the national level to increase the publicity of GreenBuilding.

GreenBuilding implementation on the national level

National Contact Points for GreenBuilding have been established in ten European countries. In each country, one or more organisations are responsible for the promotion of the programme and for aiding participants in acquiring partner or endorser status:

Table 1: National Contact Points GreenBuilding; contact information and links to the institutions and organisation can be found at www.eu-greenbuilding.org.

Country / region	**Responsible organisation / National Contact Point**
Austria	Austrian Energy Agency
Germany	German Energy Agency (Deutsche Energie-Agentur, dena), in collaboration with Berliner Energieagentur and Fraunhofer Gesellschaft ISI
Finland	Motiva Oy
Greece	Centre for Renewable Energy Sources (CRES)
Spain	CREVER, Universitat Rovira i Virgili National
Sweden	Fastighetsägarna Sverige (Swedish Property Foundation)
France	ADEME - Agence de l'Environnement et de la Maîtrise de l'Energie, in collaboration with Ecole des Mines de Paris
Portugal	ADENE -Agência para a Energia
Slovenia	Jozef Stefan Institute
Italy	End-use Efficiency Research Group (eERG) – Building Engineering Faculty - Politecnico di Milano
Europe	European Commission, DG JRC

GreenBuilding activities in Austria

In Austria, GreenBuilding is co-ordinated by the Austrian Energy Agency (AEA). The activities in Austria are combined with the national initiative "KLIMA:AKTIV", in the context of which the programme "ecofacility" focuses on buildings in the private services sector. In a GreenBuilding workshop that took place in September 2005 in Vienna, the programme was introduced to the target group of property managers in the services sector.

In January 2006, the Magistrate of the City of Vienna became the first official GreenBuilding Partner of the European GreenBuilding programme with the modernisation of a swimming hall in the district Florisdorf. The indoor swimming hall was renovated by means of performance contracting. The retrofitting included the installation of a solar power system, heat pumps for the outlet air of the swimming hall and a heat recovery system for the outlet air of the sauna. The regulation system of the ventilation was exchanged and a control technology was installed for the whole building. The bathwater filters were retrofitted and the filter flushing was optimised. Measuring technique and chemical dosage were refurbished. The heating energy consumption was reduced by about 64%, the water consumption by about 40%. The pay back time of this investment is less than 9 years.

Figure 2: Swimming Hall Florisdorf, Vienna

Following are further examples of projects in Austria which are currently applying for partner status:

- The protestant church in the community Stadl Paura was refurbished. By improving the building's insulation, renewing the lighting system using energy saving lamps and installing 60 m^2 of solar collectors and a 3.000 litre heat reservoir, the costs for electricity were reduced by 40%, the heating bill by even 60%.

- The civil-engineering and transport company Felbermayr in Salzburg realised a new office building, making extensive use of geothermal and solar energy for the heating and cooling of the building, using underground thermal reservoirs, thus saving up to 75% of energy.

The interest in GreenBuilding is also strong in the tourism sector (hotels) and the public sector (schools, hospitals), where several potential partners are currently preparing an application for partner status in GreenBuilding. In the case of hospitals, complete refurbishments of a building rarely occur. Since GreenBuilding also allows partner status in the case, that the 25% energy savings target is achieved for a special subsystem, the General Hospital Linz, which renewed its air conditioning system, thus reducing the related energy consumption by 30-35%, is currently also considering to apply for GreenBuilding partner status.

GreenBuilding activities in Germany

The German Energy Agency (Deutsche Energie-Agentur, dena) is the National Contact Point for GreenBuilding in Germany. The activities are part of dena's nationwide campaign "Initiative EnergieEffizienz" for energy efficiency with electricity and the initiative "zukunft haus" for energy efficiency in the building sector.

Figure 3: Logos of dena's "Initiative EnergieEffizienz" and the campaign "zukunft haus"

Since September 2005, dena is active in addressing owners of non-residential buildings as well as energy planners or energy service providers to participate in GreenBuilding. The German website www.green-building.de went online in 2005, furthermore a German GreenBuilding leaflet was published. In January 2006, a GreenBuilding workshop was organised at the headquarters of the German Bank for Reconstruction (KfW), which administers a very successful funding schemes for energy efficiency measures in the building sector.

Following the workshop in Frankfurt, many organisations and companies expressed their concrete interest in becoming GreenBuilding partner or endorser, among them public authorities, companies from the services sector or industry, ESCOs, energy planners and architects.

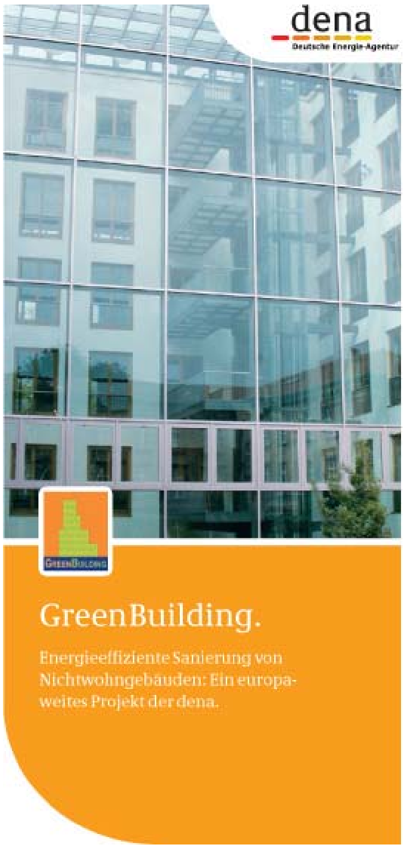

Figure 4: German GreenBuilding leaflet, published by dena

The first GreenBuilding partner in Germany is the City of Nuremberg. The city's department for communal energy management submitted to the GreenBuilding programme the project "Kindertagesstaette Philipp-Koerber-Weg 2". After the complete refurbishment in 2004, this former cantina building of the former Nuremberg abattoir is now the new home of a public Kindergarten. Through improvements in the building envelope and the installation of a new condensing boiler, the primary energy demand for heating was decreased by more than 80% and is now even 32% below the requirements of the German energy savings ordinance (EnEV). Furthermore, the inefficient lighting equipment was substituted with fluorescent lamps with electronic ballasts.

Figure 5: Kindertagesstaette Philipp-Koerber-Weg 2, Nuremberg (foto: City of Nuremberg)

Among the other organisations which have contacted dena in order to become GreenBuilding Partner, there are likewise public authorities, institutions from the services sector and from industry. Examples are:

- The KfW banking group will refurbish parts of their headquarters in Frankfurt and aims to become GreenBuilding Partner. The refurbishment will encompass a higher insulation standard, improved daylight utilisation, summer time heat protection, reduced cooling energy demand through night time cooling, modernisation of the ventilation system, heat and electricity generation with co-generation using natural gas.
- Alpha Management, a Logistics Provider from Duisburg, is interested to become GreenBuilding Partner with one of their office buildings, which makes extensive use of renewable energy sources.
- Hansa-Invest AG, subsidiary of the insurance company Signal Iduna, presently plans the complete refurbishment of their Hamburg offices and intends participation in GreenBuilding.
- Rehau AG, manufacturer of high-quality technical products from polymer materials, plans the modernisation of their premises in Rehau, Germany, switching the heating system to make use of geothermal energy sources.

Parallel to the promotion of GreenBuilding, dena performs a field study with 50 non-residential buildings of various types, locations and construction periods. In the context of the study, the building certificate as developed by dena for residential buildings will be customised for non-residential buildings.

Since dena's building certificate refers to energy demand and not consumption, recommendations for measures to enhance the building's energy efficiency can be made as part of the certificate. These recommendations may lead directly to the implementation of measures as proposed by the GreenBuilding programme. dena will therefore link both activities in the context of the public relations work and will encourage projects from the field study to take the next step and become GreenBuilding Partner.

Experiences with GreenBuilding

After several months of work with institutions and companies interested in becoming GreenBuilding Partner or Endorser, the following observations concerning the motivations to become involved in GreenBuilding can be made.[4]

GreenBuilding is encouragement

There are building owners, who already considered the implementation of measures to enhance the energy efficiency of their non-residential buildings, but lacked know-how and support to get active. GreenBuilding clearly serves as an impetus for them to now get into implementation. The GreenBuilding procedures and technical modules provide orientation for assessing the relevant issues, for defining the necessary steps and for identifying external support, where necessary. Through the support of the National Contact Points, the threshold for organisations with little experience in energy efficiency issues is lowered.

GreenBuilding is public relations

Some of the interested building owners have been sensitised for energy efficiency matters before they contacted a GreenBuilding National Contact Point or the European Commission. In some cases, the realisation of energy efficiency or renewable energy measures was already in the planning phase or is being implemented.

In the context of external communications of the respective organisations, GreenBuilding offers a unique chance to enhance the quality of the public relations activities by using the GreenBuilding logo. A special significance can be attributed to the fact that the GreenBuilding status is being awarded through the European Commission, thus providing a high level of credibility through an institution of international reputation.

GreenBuilding supports marketing

Especially for companies renting office space to third parties, the GreenBuilding partner status, awarded for a certain building, can be actively used in the marketing among potential tenants, thus realising higher rents. Among a certain target group of institutions or companies – for instance from the environmental sector – for whom it is very important to demonstrate energy efficiency also in the offices they work in, GreenBuilding can be very relevant.

GreenBuilding as an instrument of staff motivation
Another motivation to become GreenBuilding Partner can be internal communications. Companies cultivating a philosophy of responsibility for society and environment are often interested to underline this philosophy to their employees. For some of the potential partners, the greatest benefit in the awarding of the GreenBuilding Partner status is therefore seen in its importance for the motivation of the personnel and the enhanced identification with the employing company.

GreenBuilding as an argument in decision making processes
Energy planners – be it internal or external experts – are often confronted with the difficulty of explaining and justifying higher initial costs for a more efficient technology or renewable energy applications with reference to the life cycle costs of the system. In this context, GreenBuilding can be used on several levels to help convincing the persons in charge to decide for investments in energy efficiency or renewable energies. Firstly, referring to recommendations given in the context of an EU programme provides additional credibility to the arguments for a certain technology. Secondly, the chance to qualify for a publicly recognised GreenBuilding Partner status adds a further dimension to the decision, which may open up wide-ranging opportunities in the presentation of the organisation to the public.

Multipliers for GreenBuilding
Energy planners or energy service providers are very important multipliers for the success of GreenBuilding. Being in the position to support building owners in the refurbishment of their premises, they can easily make reference to the added value the building owners can receive through participation in the GreenBuilding programme. They themselves can qualify for the GreenBuilding Endorser status in this process, which provides an additional incentive to promote GreenBuilding. In order to motivate a large number of organisations to become GreenBuilding partner, the multiplying potential of GreenBuilding Endorsers will be significant.

Conclusions

At the present stage, with the GreenBuilding promotion activities on the national level begun, it can be stated, that there is a broad demand for information and assistance in matters of energy efficiency in the non-residential building sector. Facing rising energy prices and a higher standard of legal requirements, many building owners are now ready to take a closer look at the energy consumption of their premises.

A variety of measures is needed to achieve ambitious energy saving targets of 30% or more, which are regarded possible in the building sector. In the case of Germany, dena’s various services for enhancing the energy efficiency in non-residential buildings – as offered in the context of the dena “Initiative EnergieEffizienz” and dena’s campaign “zukunft haus” – are well-complemented through the activities and incentives offered to the building owners in the context of GreenBuilding.

As the experiences show so far, GreenBuilding can serve as a leverage to raise awareness, provide information, ease decisions, support the realisation and – last not least – spread the knowledge of the successful implementation of energy efficiency measures in non-residential buildings.

There is a German proverb, which fits well in this context: “Do the right thing and talk about it”.

dena’s claim for promoting energy efficiency is: “Efficiency decides”.

References

[1] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings.
[2] COM (2005) 265 final of 22 June 2005: Doing more with less: Green Paper on Energy Efficiency.
[3] COM (2000) 769 final of 29 November 2000: Green Paper: Towards a European Strategy fort the Security of Energy Supply

[4] The observations of this section are based on the experiences with GreenBuilding in Austria, Germany and Sweden.

The Austrian programme for private service buildings: ecofacility

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Abstract

In the last few years, many of Austria's public building owners discovered the advantages of a modernisation focused on energy efficiency. Main reasons are tight budgets, rising costs and their function as role models.

In comparison with the public sector, in the private service building sector modernisations which focus on energy efficiency are still the exception rather than the rule. In most cases this arises from a lack of foresight and a low awareness of the benefits (economic and non economic) that such modernisations can create.

As part of the Austrian climate protection programme klima:aktiv, the ecofacility programme targets the energy efficient optimisation of private service buildings.
It aims to:

1. Increase the quantity and quality of modernisations with focus on energy efficiency within the private service building sector
2. Increase the awareness of advantages of modernisation with focus on energy efficiency
3. Implement & develop existing and new modernisation models for different framework conditions
4. Develop standardised project procedures to reduce transaction costs for the client to make projects repeatable
5. Gain know-how and spread it all over Austria and Europe.

The activities are split into several tasks:

1. Task 1: Setting Quality Securing Standards
2. Task 2: Adapting or creating EPC-models for specific needs
3. Task 3: Training EPC and modernisation consultants
4. Task 4: Establishing a national wide EPC- and modernisation-consultant network
5. Task 5: Marketing and dissemination
6. Task 6: Co-operating with regional players
7. Task 7: Co-operating with EU-Programmes
8. Task 8: Implementing high quality projects.

The programme has been successful so far and the concept works. ecofacility co-operates with several EU-projects (EUROCONTRACT, greenbuilding, green light, keepcool) to gain and disseminate know-how from and with other countries in the fields of modernisation models, cooling & lighting and dissemination. The network of consultants has delivered several large projects in the sectors: retail buildings>, office buildings, student homes, tourism, garages and more.

Background

… starting a building modernisation programme for private service building owners

In 2001 a comprehensive Energy Performance Contracting (EPC)[1] campaign[2] for federal buildings was initiated by the Council of Ministers. The campaign is running successfully. About 220 buildings

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[1] and in Guaranteed energy cost savings by an external energy service company (ESCO) through planning and designing, realisation and construction, operation and maintenance, optimisation, user motivation some cases

have secured EPC contracts. An average energy saving of 19,83% was guaranteed by the Energy Service Companies (ESCOs) for the next ten years' contract duration.

The energy saving potential of private service buildings is approximately the same than in public service buildings (and potentially even higher due to more technical equipment). However, in spite of this potential and the positive example of the public sector, high-quality building refurbishments with a focus on energy efficiency are still the exception not the rule in this sector.

Further, in 1997 in Kyoto the European Union and its member countries committed themselves to reducing greenhouse gases by 8 % in comparison to their emissions in 1990. The EU reduction target has been split between the member countries in different shares (the so called 'Burden Sharing Agreement'). The reduction target for Austria was thereby set to 13 % (by 2008/2012 in comparison to 1990 or 1995 for HFCs, PFCs and SF6)[3].

The Austrian Federal Government therefore developed a national climate strategy, together with the Federal Provinces. The strategy is based on five methodologies:

1. regulatory measures,
2. subsidies,
3. environmentally-friendly taxes,
4. flexible mechanisms (like Joint Implementation programmes) and
5. target-orientated information & qualification campaigns together with implementation of pilot projects.

Within the fifth methodology, a national climate protection initiative – called klima:aktiv[4] – was started by the Ministry of Life. The Austrian Energy Agency is responsible for the operational implementation of klima:aktiv.

klima:aktiv is an initiative with about twenty programmes for different target groups (municipalities, federal government, enterprises, end users, etc.) and different technologies (energy efficient buildings, mobility, renewable energy, energy efficient appliances, etc.). It focuses on qualification & education of consultants for the target groups or the target group itself. The success will be disseminated broadly. The main aim is to increase quality and quantity of innovative projects. In the future, renewable energy and energy efficiency will hopefully become standard in all areas of life.

klima:aktiv provided the framework for starting ecofacility, a programme to exploit the large energy saving potential in private service buildings.

… of the private service (tertiary) building sector[5]

Private service sector buildings are very diverse. Office and administration buildings, hotels, homes, leisure and shopping centres, private hospitals and schools, parking garages and many more kinds of buildings belong to this sector. What connects them is the fact that they are owned by private individuals or institutions - often a fusion of several owners.

About 25% of the energy consumption of all Austrian buildings occurs in this sector[6]. Due to the often higher density of technical equipment in the sector, the potential for both energy consumption and energy saving are higher than in residential buildings. Energy related costs may constitute up to 50%[7]

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prefinancing. EPC is not limited to buildings: other typical EPC projects include street lighting, indoor swimming pools, parking garages, etc.

2 Decision of Council of Ministers 51/22 (2001): Energy Performance Contracting or Delivery Contracting in the all suitable federal buildings (about 500 buildings).

3 Austrian Climate Strategy: http://www.ji-cdm-austria.at/en/klima/nationale_klimapolitik.php

4 klima:aktiv (2005): www.klimaaktiv.at

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7 Leutgöb Klemens, Benke Georg (2000): Energie und Umwelt im Lebenszyklusspiegel von Gebäuden, http://www.eva.ac.at/(de)/projekte/lzyk.htm

of the operating costs (costs for fuel and electricity, maintaining, controlling, optimisation and repair of energy related systems, administration of supply security, etc.) in the building. However, only 2 to 4.5 %[8] of the overall business volume are energy related costs, including costs for electricity and heat, as well for other services (operating, maintaining, reconditioning). The Austrian experience with public buildings shows that energy savings of more than 20% can be achieved in an economical manner (payback periods of less than 10 years)[9]. Some projects in the private sector show similar figures.

… of the reasons for energy efficient optimisation of buildings[10]
Beyond energy consumption, energy costs and the fulfillment of the Kyoto Protocol, there are many other reasons that make energy efficient modernisation of buildings desirable for the building owner.

<u>Need for new technical equipment, refurbishment and modernisation:</u> The needs of the users may change over time. In addition, the natural service life of materials and equipment is limited, resulting in a strong demand for new construction and building services equipment. Rich building owners are especially keen to invest in state-of-the-art technologies.

<u>Lack of comfort:</u> If a building is not kept up-to-date or is badly maintained and operated, its level of comfort will eventually decline and the occupants will be dissatisfied.

<u>Rising energy prices:</u> Energy prices are likely to increase over the next few years. Poorly funded owner-occupiers are the most vulnerable to any energy price increases.

<u>Energy saving potential:</u> The consumption of energy in buildings is increasing significantly, due to the demand for greater comfort and the associated technologies. The lack of life cycle cost calculations in the planning phase and/or poor installation and commissioning of building services technologies (heating, ventilation, air-conditioning, etc.) increases the potential for energy saving. More than 40 % can sometimes be saved by adjusting and regulating the existing energy systems. Examples show, that in old and very inefficient buildings, up to 95 % energy savings can be realised with a comprehensive modernisation package[11].

<u>European Building directive (Directive on the energy performance of buildings):</u> All building owners will need to provide an energy performance certificate to their buyers or tenants in the near future[12]. For buildings with a total useful floor area of over 1,000 m², and occupied by public authorities or by institutions providing public services to a large number of people, the energy certificate has to be placed in a prominent position; clearly visible to the public. This will increase general awareness of the building's energy performance.

<u>Operating safety:</u> Building owners have to provide specific building services to their users. It is a priority for the owners to ensure that these services are in good working order.

… of the barriers to energy efficient optimisation of buildings[13]
This chapter explains why many buildings are not renovated or optimised, despite the clear benefits that such measures would provide.

<u>Investor-User-Dilemma:</u> Building owners who rent out their buildings have little interest in the budgeting of the annual energy costs, and therefore are unaffected by the increasing energy prices.

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[8] Hämmerle Kurt (1998): Tourismus und Energie; SAVE-Project EE-Net (2002): Assessment in Hospitals http://www.eva.ac.at/projekte/eenet.htm
[9] Within the federal EPC campaign in Austria, more than 400 buildings have been modernised with an average of 19,83% guaranteed energy cost savings.
[10] Grim Margot (2005): Energy Performance Contracting: An opportunity for the private service building sector or a tool for public buildings only?
[11] ecofacility (2004): Best Practise Projects "Fashion Wholesale Centre", "Joanneum Research", "Nordpool"
[12] Definite date depending on the transition phase in each European country.
[13] Grim Margot (2005): Energy Performance Contracting: An opportunity for the private service building sector or a tool for public buildings only?

These buildings are often constructed or renovated at minimal expense. The tenant is not in charge of refurbishment investments, but has to pay for any increases in energy prices. Economical energy saving measures are usually not implemented.

Lack of awareness: Awareness of energy saving measures depends on the individual. The less a building owner has available to spend on running a building, the higher is their awareness of any increases in running costs.

When the building owner rents out the building (this also includes owners of hotels), top priority is given to the rate of occupancy. In general, the building owners invest in areas that bring the building closer to full occupancy. Owners are often unaware that "invisible" measures (e.g. improved heating is not registered by the user the same way than newly painted rooms) can also improve occupancy rates by retaining tenants. Indeed, they have an incorrect impression that energy saving implies reduced comfort (e.g. cold rooms).

Further, as energy related costs are just about 2 to 4.5%[14] of the overall cost of occupancy, building owners and occupiers do not care much about energy savings. There is a lack of awareness that energy costs can be up to 50 %[15] of the costs of looking after the building, and that energy savings of 20%[16] or more are often possible.

Core competence different from property management: Property management is rarely the core competence of building owners who occupy their own buildings. In such cases, the building is a means to the end of supplying customers with the owner's real core competence. Such owners are only marginally interested in the building itself, and sometimes they do not even know about its optimisation potential.

Lack of financial resources – need of investment: Building owners with limited funds have problems financing energy saving measures. In order to grant loans, banks request certain collateral. Thus, poorly funded building owners have difficulties securing loans for investments. In a similar way, financial problems can occur for the biggest national building owner "BIG" too In many buildings, which in 1992 were outsourced to BIG, no investment or maintenance was undertaken for several years. Old systems still remain in the buildings and need replacement soon. The volume of the investment required is so high that even BIG cannot fund all measures at same time.

Lack of personnel: Whether the building has enough technicians of high quality depends strongly on the building owner or building user (whoever is in charge of servicing and maintenance) and the building type. Due to lack of money (high personnel costs) and lack of awareness (underestimation of economic advantages through regular servicing/maintenance), many buildings also lack enough technicians of sufficient quantity for maintenance and monitoring. Full-time in-house technicians have to fulfil more and more tasks: they are no longer responsible only for the technical facilities of the building, but are also required to perform the tasks of building managers, caretakers, etc. This inevitably leads to an excessive workload, which makes the issue of "energy savings" a low priority.

In large, complex buildings, external service providers (maintenance companies, FM providers, etc.) are often entrusted with these tasks. Sufficient high quality human resources are available, but since these companies have only to guarantee the reliability of the systems and not a full performance including guaranteed energy savings, energy efficiency is not the priority in many buildings. Furthermore, external service providers are usually hired for individual systems (heating, cooling, lighting, etc.) and not for the whole building. As a result, insufficient networking among complex systems often does not allow external service providers to achieve maximum efficiency.

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[14] Hämmerle Kurt (1998): Tourismus und Energie; SAVE-Project EE-Net (2002): Assessment in Hospitals http://www.eva.ac.at/projekte/eenet.htm

[15] Leutgöb Klemens, Benke Georg (2000):, Energie und Umwelt im Lebenszyklusspiegel von Gebäuden, http://www.eva.ac.at/(de)/projekte/lzyk.htm

[16] Within the federal EPC campaign in Austria, more than 400 buildings have been modernised with an average of 19,83% guaranteed energy cost savings.

Table 1. Summary: Problems that prevent building owners from optimising their buildings

	BIG (owner of federal buildings)	Large estate companies (rented out buildings)	Large companies with owner occupied buildings	Building owners with small budgets such as small and medium hotels
Investor-user-dilemma	Applicable		Not applicable	
Lack of awareness	Low awareness due to the investor-user-conflict.		Low awareness as energy related costs are just 2 – 4.5% of overall costs. Measures have to refinance within 2-3 years.	The lower the budget, the higher the awareness of rising costs. Measures must be visible for the guest.
Core competence	Building management is core competence.		The actual core competence is more important than property management.	
Lack of financial resources	The high volume of necessary repair tasks makes financing a problem.	Sufficient funds for investments or bank loan on good terms.		Often lack of money. Lower loan cap at banks.
Lack of personnel	Quantity of personnel resources varies from building to building. Mainly in-house technicians, not bound on guaranteed operating costs and mostly not up-to-date.	In-house or external service providers (assigned either by owner or user), not bound on guaranteed operating costs.	In-house or external service providers, not bound on guaranteed operating costs.	Quantity of personnel resources varies from building to building. Mainly in-house technicians, not bound on guaranteed operating costs and mostly not up-to-date.

Basics of different modernisation models

The barriers described above make it difficult for building owners to decide on undertaking energy-efficient refurbishments. Legal, financial, organisational, economic and financial framework conditions interact together.

Further, every building is different. The differences are not only in the construction, the materials and implemented technologies. Differences also lie in the usage. Those, who use the building (such as building owners, caretakers, building users, etc.) influence it according to their needs.

Different and flexible approaches are therefore needed to achieve a successful building modernisation. If the building owners are interested in reducing their energy costs, the following modernisation models are used in Austria to reach this goal.

Do it Yourself modernisation

This is the most common method of renovating a building and integrating energy saving measures. Planning of the modernisation is overseen by a professional like e.g. architect or engineer, etc.. A model such as this would require the building owners to rely on their own budgets. In addition, the building owners are only guaranteed a two years warranty for the work undertaken. Energy cost savings are not guaranteed.

EPC classic model
In the classic EPC-model, an external energy service company (ESCO) takes charge of planning, financing (generally with a partner bank (loan financing)), and implementation of the required constructional and technical measures. Furthermore, the operation and maintenance of the technical equipment is guaranteed by the ESCO for a certain contract period. For this duration, the investment in energy efficiency measures is refinanced by the cost savings that result from these measures. Upon expiration of the contract, the client obtains the full benefit of the savings. The key aspect of this model is that energy savings are guaranteed by the ESCO.

Operation and maintenance contracting (O&M contracting)
Handing over control of an existing power supply installation to an ESCO is called operation and maintenance contracting. This option is advantageous if the building is equipped with a basically intact energy supply system that does not require any large investments in remodelling, but has areas for potential efficiency improvement. The ESCO ensures efficient operation of the installation and performs optimisation measures on the building (usually at low cost). The ESCO guarantees the performance target in terms of proper operation and energy consumption. If the ESCO fails to achieve these performance levels, its compensation can be reduced.

Guarantee models
One extension of purely performance-based thinking is to integrate construction measures into the contracting guarantee and to provide single-source modernisation services. Under the guarantee model, the contracting parties agree to a performance target for the complete building modernisation under a contracting agreement, and the ESCO guarantees compliance with the agreed-upon performance level for the duration of the agreement. In its capacity as general contractor, the ESCO carries out the construction measures and guarantees a maximum limit of energy consumption (performance level). It also takes care of the service, maintenance and operation of the power supply installations. The contractor's fees are paid annually, and will be reduced if it falls short of the guaranteed performance level.

Investments in measures to improve the technical facilities of a building usually need to be recouped from energy savings within 10 years. At current energy prices, constructional modernisations (e.g. complete thermal insulation) may not meet this criterion. So the building owner may have to contribute to the funding by granting a construction cost allowance (also from subsidies) and/or residual value payments to the ESCO.

The difference between a guarantee model to conventional self-managed modernisation lies in the long-term guarantee of the quality of the implemented measures, which goes far beyond statutory warranties. If difficulties arise after completion of the modernisation project (unexpectedly high energy consumption, mildew, etc.), it is the contractor's responsibility to put them right under the guarantee model. For self-managed modernisation, building owners will usually have to bear the responsibilities.

ecofacility – the Austrian programme to increase energy efficiency in private service buildings

ecofacility started in 2004, as part of the national climate initiative klima:aktiv. The main purpose is a visible increase of the quantity and quality of modernisations focused on energy efficiency and renewable energy. The target group is building owners of private service buildings. A comprehensive bundle of activities are helping to achieve this goal:

Task 1: Setting Quality Securing Standards
Long term experiences of Austrian project managers[17] shows that the quality of a project can be secured by a defined project procedure, with ready-made tools that only need to be adapted to the conditions of the specific project. A standardised project procedure was therefore developed which could secure the quality of the project whilst simplifying process and shortening the various steps; so helping to reduce transaction costs. The project procedure is as follows:

[17] Austrian Energy Agency, Grazer Energy Agency

Rough energy check
Benchmark the building against similar buildings in the databank and values from literature

Decision base for building owner
This step delivers a “management and decision making paper”, which gives the decision-maker for the building a structured overview of all framework conditions. It shows the advantages and disadvantages of each possible modernisation model for the specific case.

Relevant framework conditions in the building are:
1. Technical framework conditions: Actual state of the building shell and existing technology, e.g. Which technology is implemented? Does it function or is there a need of replacement? How much energy saving potential can be attained (rough assumption)?
2. Financial framework conditions: e.g. What budget for the modernisation is available? What are the terms of the loan?
3. Economic framework conditions: Possible pay back period of investments through energy cost savings.
4. Legal framework conditions: e.g. Who owns the building? Financial Flows: Who pays for energy, maintenance and operating? Are there any maintenance contracts running? Is it possible to cancel them?
5. Organisational framework conditions: e.g. Is there an internal division of technicians and/or planners? Who is in charge of which decisions? Who has to be integrated in the project? Who is in charge of project co-ordination?

The building owner is often not aware that all five fields above influence the modernisation and its consequent success. For example, a building owner with a large number of technicians, a good credit rating and no interest in long term contracts would require a completely different modernisation model from an owner with poor access to finance and interested in outsourcing its maintenance. In both cases, a high quality modernisation is possible.

Decision of building owner
After developing the “management and decision making paper”, the building owner has to choose which modernisation model to use.

Decision 1: Do it Yourself modernisation
After the “management and decision making paper” the building owner decides to renovate the building or implement energy saving measures together with a planner. The building owner has to provide all investments – subsidies can be applied. The investment risk for a correct installation and performance is the responsibility of the building owner.

Decision 2: Modernisation within a contracting-model
The ESCO’s creativity is one of the most important parts of a successful contracting-project. A tender (or at least gathering different offers) is therefore highly recommended. To receive high quality and comparable offers from ESCOs, well-prepared tender documents are necessary. It is suggested to delegate the preparation to a contracting-experienced consultant as most contracting-projects go together with long term contracts. It is necessary to consider all framework conditions and eventualities beforehand.

The core element of the tender is the contract, in which the risk sharing and responsibilities of the different parties (building owner, building user, care taker, in house technicians and ESCO) have to be clearly defined. Further, comfort parameters and the priorities of the building owner for the modernisation have to be determined. As the ESCO has to give a guarantee of performance and energy cost savings that go along with the measures, reference energy costs[18] (baseline) are needed to prove that the ESCO reached its guarantee.

[18] In most cases the energy costs of the previous year, if data of the whole year are available.

The tender is based on functionality for the building owner. It does not need to specify the exact measures unless they are deemed essential. The best offer is a combination of the most suitable measures, the best quality, the greatest investment and the highest energy saving guarantee. The best offer will be defined by a cost-benefit-analysis. In two to three rounds of negotiation, the detailed measures will be defined. The contract can then be signed and the ESCO can start implementing the measures.

Monitoring and checking
After implementing the measures it is highly recommended to start a monitoring system. Within a contracting-project this will be needed to prove the ESCO's performance and to calculate the fee. A do-it-yourself-modernisation does not require such strict monitoring. However, if a system is in place, mistakes can be found easily; and future energy saving projects can be based on good quality data.

Task 2: Adapting or creating new EPC-models for specific needs
Modernisation models which have been successful in the past may not meet the requirements of all private building owners. Changes may be needed to guarantee complete satisfaction. Two new models are therefore being developed and tested; one for lease-financed buildings; and the other for buildings maintained by Facility Management (FM) enterprises. These models also incorporate the standardised project procedure.

Combined EPC-Leasing models
Leasing is becoming a more and more common form of investment for building owners. Borrowers can add the leasing payments to their expenditures, so simplifying procedures and saving tax. Since the investor (bank) is the registered proprietor of the investments, this in turn raises the balance of the borrower so that they can get better terms for further investments and loans. Existing EPC-contracts do not take leasing into account, so either the building owner or the ESCO is the registered proprietor of the investment and has to take out a loan. As part of ecofacility and the co-operating EU EUROCONTRACT project, EPC-models will be adapted to leasing criteria and tested in pilot projects.

Combined EPC-FM Models
Owners of large buildings often outsource technical operation and maintenance to external service providers such as Facility Managers. However, as FM-providers are not bound to energy saving guarantees, they will not necessarily undertake energy saving measures. Combining FM with EPC contracts will often be advantageous, especially since FM-providers already have good contacts with building owners. In this new scheme, FM providers would also take responsibility for certain elements of EPC, such as guarantees for performance, quality and energy cost savings. On the other hand, it is also possible for an ESCO to take over the full range of FM services. This would increase the quality and competitiveness of these enterprises.

Task 3: Training of EPC and modernisation consultants
The experience from the market introduction of EPC in the public building sector[19] in Austria shows that, in implementing any innovative modernisation model, one of the most important success factors is the availability of competent advice to building owners and investment decision makers. Owing to the complexity of the implementation of a building modernisation, building owners and administrators need professional support in:

1. defining the framework of the modernisation project (technical, economical, organisational, legal);
2. choosing the right modernisation model for the specific case;
3. discussing the risks and benefits related to the implementation of an EPC project; and
4. if a contracting model is chosen:
    - defining the goals and the framework conditions of an EPC project;
    - preparing EPC contracts and tender materials;
    - accompanying the selection (tendering) process of EPC providers;
    - monitoring the success of the EPC project implementation

[19] Bundescontracting-Offensive (2003): federal EPC campaign in Austria, www.bundescontracting.at

Training courses for (potential) market developers are therefore being implemented. These prepare market developers to provide concrete advice on the implementation of any modernisation model as described above (quality securing standards). The training seminars will focus on standardised project development, implementation procedures and a marketing approach towards building owners. Potential partners for market development may be energy agencies, independent energy consultants, civil engineers etc.

Task 4: Establishment of a national wide EPC- and modernisation-consultant network
The training of modernisation consultants forms the basis for establishing a network of modernisation advisors. The trained market developers are expected to market their service actively – i.e. choose specific market segments, target building owners and administrators, and provide advice.

The market developers will get support through a network that provides:
1. information and know-how-exchange (intranet with updated standard documents for project implementation, internet-based benchmark tool, e-mail platform, periodic workshops and network meetings);
2. coaching during a start-up project;
3. quality assurance through cross-checks of the standard of advice to building owners
4. marketing and dissemination activities in specific building segments (e.g. tourism, office buildings, commerce etc., see task 5).

Task 5: Marketing and dissemination
All tasks in ecofacility start and end with marketing and dissemination activities. The main aim of this work package is to use material from the other work packages to encourage building owners to increase the energy efficiency of their buildings and for ecofacility to become an established quality label for profitable and high quality modernisations in private service buildings.

Dissemination activities include permanent press and media activities in daily newspapers and journals; events, awards, conferences, flyers, folders and workshops for different target groups; and one central website (www.ecofacility.at) which carries the main information.

The following material will be distributed:
1. Best Practice Projects
2. Services of ecofacility
3. Subsidies for ecofacility-consultation
4. Different modernisation models
5. Diverse topics that are relevant to target group and the implementation of energy saving measures (e.g. Building Directive, Life Cycle Costs, efficient technologies, etc.)

One of the most promising marketing instruments is the network of consultants, because they market their services themselves. However, two years into the programme, we have realised that consultants find acquiring small and medium projects highly risky, being time consuming and with a relatively low chance of success. In 2006, students of related studies (energy efficient buildings & technologies) will therefore be trained to support the consultants in this phase. The training focuses on instrumentation, data collection, benchmarking and data evaluation. The students will be supervised by a consultant. Five Austrian Universities for applied sciences have showed interest in co-operating with ecofacility.

Task 6: Co-operation with regional players
One obstacle to the appointment of consultants is the high cost of their services. Although consulting usually accounts for well below 10% of the investment costs and pays off after four to twelve months (through the guaranteed savings in energy costs), building owners often do not want to pay for professional assistance. In Austria, state-funded regional programmes grant subsidies for a part of the consulting costs. These subsidies are intended to serve as an incentive for building owners to call upon the services of consultants when embarking on a modernisation project. ecofacility therefore co-operates with these programmes to exploit the funding. The regional partners also take charge of co-ordinating the regional consultants, project and marketing activities.

Task 7: Co-operation with EU-programmes and projects
At the EU level, the EUROCONTRACT[20], keepcool[21] and greenbuilding[22] projects were launched in early 2005. All these projects are devoted to improve the quantity and quality of service building modernisation and modernisation. They will deliver some of the training material for the consultants (checklists for different technologies, market diffusion of innovative cooling mechanisms, development of modernisation models, etc.) and undertake some of the marketing activities.

Task 8: Implementing of high quality projects
All the activities described above will eventually lead to many high quality modernisation projects in the private service building sector. Implementing projects is the overall aim of the programme. The first projects of the ecofacility-modernisation-consultants will be coached by the programme management. Realised projects will provide further input for marketing to target groups.

Results of ecofacility after 2 years programme duration
After running the programme for two years, results are becoming available. 250 “rough checks” have been done and 180 “decision making papers” have been delivered by the trained consultants. Three EPC tenders have carried out and several energy saving measures have been realised through “Do it Yourself modernisations”. Most consultations are in the retail building sector. The tourism and office building sectors seems to be the most hard to penetrate.

So far, about 45 EPC and modernisation consultants have been trained and are active all over Austria. The acquiring phase is still risky and not very successful. To lessen these risks in 2006, trained ecofacility students will be supporting the consultants within this phase.

Co-operation with four regional programmes was running successfully at the beginning of 2006, and two more are likely to be added during the year. Most consultants are co-ordinated by these programmes.

The co-operating EU-projects EUROCONTRACT, keepcool, greenbuilding and greenlight have supplied many training materials, good practice projects and much more.

Conclusion
The ecofacility programme appears to be successful. However, the start-up phase took longer than expected and not many projects were realised within the first 18 months. The addressed target group did not show much interest in the services of ecofacility. The programme managers had to experience yet again that energy efficiency services are not easily sold to the target group. Within the sector, each business line (tourism, offices, commercial or any other) has to be addressed differently; and different door openers had to be developed.

Nevertheless, in the middle of 2005 the programme had its breakthrough. It is now becoming more popular within the target group; the order books of the ecofacility-consultants are getting better; and several promising projects are on their way.

However, the programme is still in the set-up phase. Most building owners still underestimate the advantages (e.g. lower energy costs, greater comfort and safer operation) of an energy efficient building optimisation. Much work has been done so far, even more lies ahead.

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Beyond Energy Efficiency: How the USGBC® and LEED® are Driving Market Transformation

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U.S. Green Building Council

Abstract

The U.S. Green Building Council (USGBC) is transforming the building industry in the United States with a voluntary, consensus-based process that goes beyond energy efficiency. With six different LEED (Leadership in Energy and Environmental Design) Green Building Rating Systems, dozens of local chapters, hundreds of educational workshops and thousands of members, the USGBC is having a ripple effect on the entire market. This paper will focus on how the USGBC has been able to impact the building industry in only twelve short years since its founding, and with new initiatives and building performance data demonstrating the financial benefits of green building, the USGBC is positioned to transform an exponentially larger size of the U.S. construction market.

LEED is a catalyst for driving market transformation and one of the most important tools of the USGBC. By creating a benchmark for the design, construction, and operations of buildings, LEED has created new best practices for the entire building industry. From product manufacturers and service companies who are developing and marketing sustainable products to state and local governments that are adopting LEED, the impact of the USGBC is tangible and growing.

Large corporations, investment analysts, and the corporate real estate community are taking notice. Recent analysis of publicly held companies affiliated with the USGBC show an aggregate total return that outperforms the Dow Jones Industrial Average by over 18% from 2000 to 2004. This may indicate well-managed, progressive companies are looking to build and operate green as an opportunity to differentiate themselves as leaders in the marketplace

To further the momentum of green building, the USGBC is creating an initiative to recognize performance on a portfolio-wide basis. Rather than recognizing single building success stories, organizations will now have the ability to showcase their broader achievements through portfolio commitments to a well established, credible green building rating system – LEED. This initiative will take corporate social responsibility and green building practices to a new level – increasing awareness, adoption, and acceptance of green buildings and furthering the mission of the USGBC to create healthy, productive places to live and work that are less costly to operate and maintain and reduce environmental footprints.

About the USGBC: Creating a Community

The U.S. Green Building Council (USGBC) was founded in 1993 to establish a national consensus and provide the building industry with the tools necessary to design, build and operate buildings that deliver high performance inside and out. The USGBC is committed to:

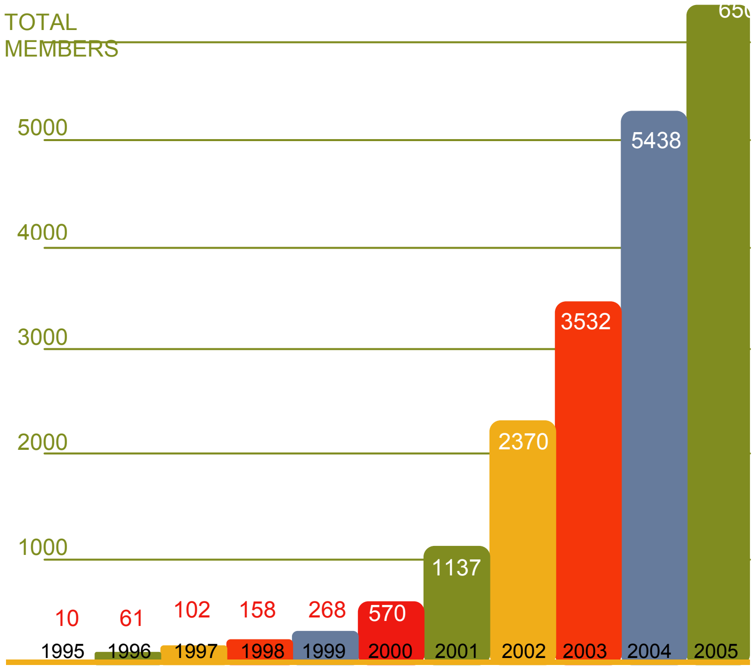
- The environment as fundamental to human health, prosperity and well being
- Innovative, catalytic, visionary leadership both individually and collectively that leads the transformation of the built environment
- Market based transformation
- Performance based solutions grounded in technical rigor and science.
- Collaborative and non-partisan processes that build consensus among diverse industry stakeholders.
- Understanding and addressing the shared and unique need of all members of our community
- The “triple bottom line:” social, economic, and environmental performance

Membership
The Council is member-driven and consensus based and has attracted the foremost coalition of leaders from across the building industry. Council membership has grown to over 6,500 organizations. Membership is comprised of visionary leaders representing the following categories:

- Building Product Manufacturers
- Building Owners, Managers, Users and Brokers
- Financial and Insurance Firms
- Press
- Professional Societies & Trade Associations
- Design, Architectural, Engineering and Professional Firms
- Contractors and Builders
- Nonprofit Organizations
- Utilities
- Universities, K-12 School Systems and Research Institutes
- State, Local and Federal Governments
- Building Control Service Contractors and Manufacturers

The strength and diversity of USGBC members significantly enhances the resources available and the effectiveness of efforts to improve the quality of buildings both in the U.S. and internationally.
The growth of USGBC membership reflects the growing interest in green building. The figure below shows how quickly the USGBC has grown in little over a decade. But most notably, how it dramatically increased in 2000 with the launch of LEED and in subsequent years as new products continued to be developed and released in the marketplace.

USGBC Membership Growth



All USGBC programs are developed with member input and are committee-based. Council members work together to develop LEED products and resources, the Greenbuild annual International Conference and Expo, policy guidance, and educational and marketing tools that support the adoption of sustainable building. Members also forge strategic alliances with key industry and research organizations and federal, state and local government agencies to transform the built environment.

Members propel the mission of the USGBC at a local level by participating in any of the over 60 regional USGBC Chapters, Affiliates and Organizing Groups throughout the U.S. and Canada. These organizations provide local green building resources, education, networking and leadership opportunities to spread knowledge and awareness about green building.

Outreach and Education

Knowledge of green building practices is quickly becoming a necessity to remain competitive. To help professionals develop their skills and personal career paths, the USGBC provides educational offerings for all levels of knowledge and experience on green design, construction, and operations. More than 30,000 designers, builders, suppliers and managers have attended USGBC educational programs. The USGBC offers dozens of full-day LEED Workshops and half-day Modules for professionals to learn the details of the LEED Rating Systems, gain practical knowledge, explore new business opportunities, and learn how to create healthier, more productive, and more efficient places to live and work.

To further distinguish individuals with detailed knowledge of LEED project certification requirements and processes, the USGBC offers LEED Professional Accreditation. LEED accreditation is awarded to building industry practitioners who successfully demonstrate their knowledge and proficiencies on a comprehensive exam. A web-based learning course, the "Essentials of LEED Professional Accreditation," supports individuals in their exam preparation.

To further the green building educational opportunities, every year the USGBC hosts the Greenbuild International Conference & Expo. This event is the U.S.'s largest conference on high-performance building practices where attendees can learn about new products, innovative projects, and the latest building research. Thousands of building industry professionals attend over 100 educational sessions, visit over 500 exhibitors, and take tours of local certified buildings.

LEED Green Building Rating Systems

Following the formation of the U.S. Green Building Council (USGBC) in 1993, the membership quickly realized that a priority for the sustainable building industry was to have a system to define and measure "green buildings." The USGBC began to research existing green building metrics and rating systems. Less than a year after formation, the membership followed up on the initial findings with the establishment of a committee to focus solely on this topic. The diverse initial composition of the committee included architects, realtors, building owners, a lawyer, an environmentalist and industry representatives. This cross section of people and professions added a richness and depth both to the process and to the ultimate product.

The first LEED Pilot Project Program was launched in August 1998. After extensive modifications, the LEED Green Building Rating System Version 2.0 was released in March 2000. This rating system is now called the LEED Green Building Rating System for New Commercial Construction and Major Renovations, or LEED-NC. As LEED has evolved and matured, the program has undertaken new initiatives. In addition to a rating system specifically devoted to building operational and maintenance issues, LEED addresses the different project development/delivery processes that exist in the U.S. building design and construction market. Currently, the LEED product portfolio is being expanded to the areas shown below in the LEED Rating System Product Portfolio figure.

LEED Rating System Product Portfolio

*under development as of March 2006

Features of LEED
LEED provides a complete framework for assessing building performance and meeting sustainability goals. Based on well-founded scientific standards, LEED goes beyond energy efficiency and emphasizes best practices across several environmental areas impacted by buildings.

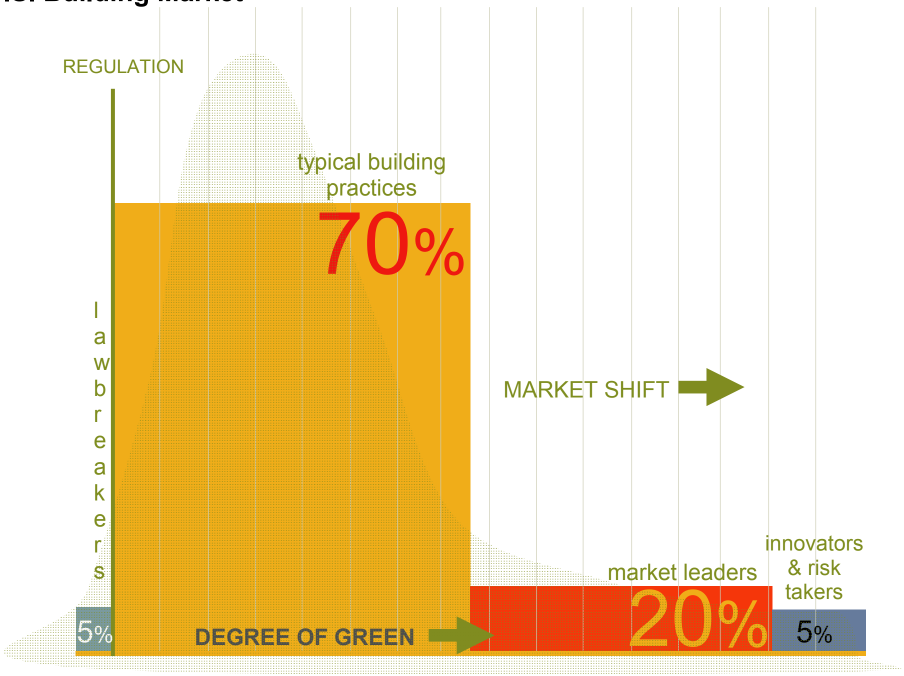
Sustainable site development minimizes the impact of buildings on surrounding ecosystems and reduces or eliminates the need for employees to individually drive to work each day, thereby significantly decreasing the number of cars on the road and the need for increased infrastructure. The rating systems include water reduction strategies, which is becoming increasingly important as population growth and climate change strain access to fresh water for billions world-wide. Energy and atmosphere credits in LEED focus on reducing energy use and the harmful pollutants released in the atmosphere by buildings. The materials and resources section focuses on reusing materials and purchasing products with recycled or rapidly renewable content. Finally, indoor environmental quality credits highlight the importance of daylighting, increased ventilation and thermal comfort. All of which have significant implications on improvements in productivity and reduction in absenteeism.

Transforming the Market
LEED has set the benchmark for best practices in the entire building industry and was created to:

- define "green building" by establishing a common standard of measurement to prevent ‘greenwashing,’ or the misrepresentation of environmental benefits or actions that do not meet any specific standards
- promote integrated, whole-building design practices across disciplines
- recognize environmental leadership in the building industry
- stimulate green competition with four levels of certification awarded on the total credits earned
- raise consumer awareness of green building benefits
- transform the building market

As more organizations learn and understand the value of LEED certification and green building, market transformation will begin to accelerate. The figure below represents the U.S. building market that the USGBC through the LEED rating systems is working to transform. Market shift will occur as the innovative, green building practices of today become standard practice of tomorrow.

The U.S. Building Market



A tangible shift in the marketplace is already occurring. Hundreds of new products and even industries have emerged to serve the needs to project teams seeking LEED certification. These products are the next generation of environmental performance, meeting not only stringent environmental criteria but also performing at or above the level of traditional products.

One of the largest drivers for pushing market transformation has been cities, regions and states across the country. These state and local governments have led the way in incorporating green building into executive orders, resolutions, ordinances, policies, and incentives. There are currently 41 cities and 13 states across the United States and Canada in addition to the U.S. Federal government that incorporates LEED initiatives.

Building the Business Case

Green building and operations is a sound business decision for any organization – whether they are a tenant, owner-occupier, property manager, building investor, or other stakeholder in the building industry. LEED buildings and spaces are better for employees, less costly to operate, and less taxing on natural resources – making green building benefits go straight to the bottom line. Actually to the triple bottom line of people, planet, profits.

Making Productivity Pay
When focusing on people –employees, tenants, hospital patients, students, etc – an investment in green building is an easy decision. In an office setting, for example, productivity increases alone often offset any initial additional upfront costs for green features. The Harvard Business Review reported "because workers [were] more comfortable, better able to see, and less fatigued by noise, their productivity and the quality of their output would rise. Eight recent case studies of people working in well-designed, energy-efficient buildings measured labor productivity gains of 6% to 16%."

Productivity can have several components, all of which are impacted by green, healthy buildings. Productivity benefits can be seen not only in more work completed, but also in reductions in absenteeism and turnover, improved worker morale, and employee recruitment.

The Boulder Associates office, a LEED-CI Gold project, has received rave reviews from staff who feel valued by their employer and appreciate the careful attention paid to reduce indoor pollutants and incorporate natural daylighting. The space has even helped attract new employees. Several recent hires have joined Boulder Associates since the move, in part motivated by the message the new office space conveys; commitment to the organizational mission of health, sustainability and employee satisfaction. The office has left an impression on previous employees as well, two of whom have even returned to Boulder Associates, excited about the improved vitality of the firm and the office space. One employee remarked, "There's no comparing the two offices. The design, location, use of day lighting, operable windows, shower on site, material selection make this an office I'll be honored to be a part of for the rest of my career. The space beckons you to want to work more, it just feels good!"

Operational Savings: a focus on the California Environmental Protection Agency
The California Environmental Protection Agency (Cal/EPA) understands the value of LEED certification. Managed by Thomas Properties Group, LLC, the Cal/EPA building incorporates the latest green design and engineering principles to be sustainable, yet economically competitive.

Thomas Properties initially invested nearly $500,000 to make efficiency upgrades to equipment, operations and employee practices. These improvements paid for themselves in less than one year, generating $610,000 in annual savings.

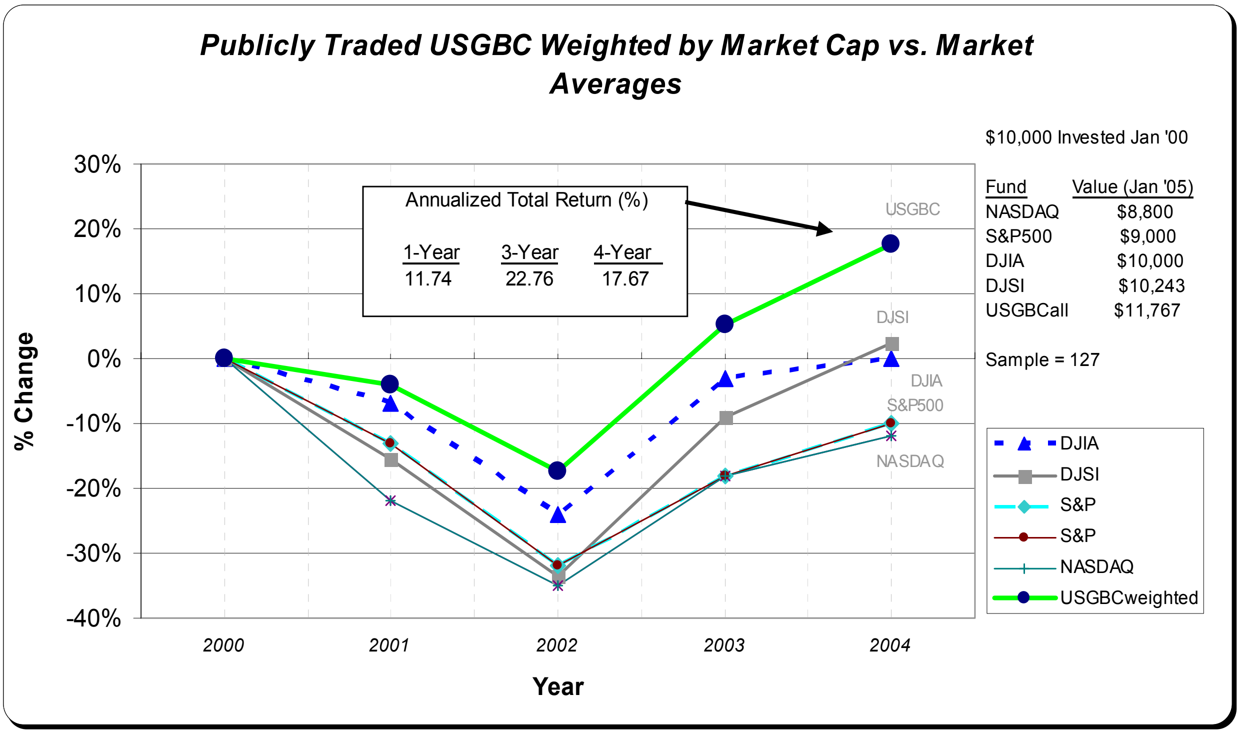
In addition to standard energy and water efficiency savings, operational savings are coming from some unconventional sources. Craig Sheehy, Director of Property Management for Thomas Properties, initiated a vermicomposting program which diverts over 10 tons of waste from landfills and saves $10,000 annually.

The improved operational performance, indoor systems, and management practices have helped to attract and retain tenants and increase the asset value of the Cal/EPA building. Cal/EPA calculates annual operational savings of $1.00 per square foot compared to the downtown Sacramento average for Class A office buildings. Using an 8 percent capitalization rate, the annual cost savings have increased the asset value of the building by nearly $12 million.

On the positive outcome of their LEED-EB Platinum Certification, Sheehy notes "Through significant reductions in operating expenses, I have determined that green building operation is not only good for the environment, it is good for the bottom line”

Verified Performance
Many operations savings for energy efficiency are estimates relative to code requirements instead of actual performance. To more fully understand how green buildings are performing, the U.S. Environmental Protection Agency working with the USGBC is analyzing actual performance of several buildings that previously received LEED-NC Version 2.0 or 2.1 certification. Initial findings indicate performance persists year to year. More information will be provided at a later date as this study progresses.

Organizational Leadership
More consumers are voting with their dollars and valuing corporations that have social responsibility initiatives. Many leading corporations are looking to green building as not only a way to foster good employee relations, but also with the wider community. Recent analysis of publicly held companies affiliated with the USGBC through membership and/or LEED registration or certification show an aggregate total return that outperforms the Dow Jones Industrial Average by over 18% from 2000 to 2004. This may indicate well-managed, progressive companies are looking to build and operate green as an opportunity to differentiate themselves as leaders in the marketplace.



Source: U.S. Green Building Council analysis

Based on the above analysis, environmental leadership is clearly recognized and rewarded by shareholders and stakeholders. Sustainability reports are very common in the corporate world, but many corporations are looking for demonstrable, meaningful improvements in environmental performance and ways to address environmental opportunities across entire building portfolios. Rather than recognizing single building success stories, the USGBC is developing an offering that will offer guidance, criteria, and recognition for organization-wide environmental excellence.

This offering might, for example, recognize organizational changes in water usage, shifts in corporate purchasing toward green cleaning products, or portfolio-wide training in building operations and associated efficiency improvements. Likely it will include adoption of LEED in new and existing buildings.

The USGBC is working to shape this future offering with partners such as: Syracuse University, Emory University, California Department of General Services, U.S. State Department, USAA Realty, Toyota Motor Corporation, HSBC, Bank of America, CitiGroup, and Thomas Properties Group. These organizations are helping to find creative ways to move into the world of portfolio performance. It is anticipated that the size and influence of the participating members will result in changes in the marketplace for environmental services and products. For the first time, USGBC member actions can result in measurable impacts on the availability, pricing, and quality of "green" options in the marketplace.

This initiative will take corporate social responsibility and green building practices to a new level – increasing awareness, adoption, and acceptance of green buildings. This new offering will give organizations a way to demonstrate real environmental leadership for their entire building portfolio. Their achievements and the associated recognition will result in improved financial results, improved community and stakeholder relations, and an improved risk profile.

Conclusion

Western economies are using resources at an alarming rate, and with the emerging economies of China and India, the world cannot sustain its inhabitants at the current rates of consumption. Green building has the potential to have a dramatic impact on curbing resource consumption and limiting green house gas emissions. Not only do buildings use resources through building materials and heating and cooling loads, but building development also determines land use and can eliminate or propel sprawl. Location of workplaces, schools and homes dictate the need for individual transportation in cars, thereby compounding the potential for buildings to help significantly reduce climate changing greenhouse gases.

The U.S. Green Building Council is going beyond mere energy efficiency improvements to foster a new community of green building that looks at materials, site selection, regional variations, productivity, occupant health, and water efficiency. From college students to Wall Street investors, the green building movement is not just for environmentalists. Its impact is tremendous, and only growing, and the USGBC is leading the charge to create a new way of thinking about how buildings are designed, financed, built, operated, and lived in.

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Saving for Success: The European Energy Trophy

Theresa Glasmacher

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Abstract

A number of pilot studies have shown that cost-free measures such as changes in user behaviour and optimised regulation of equipment and appliances can result in 10-15% energy savings in office buildings. This theory has been proved in practice through an easy, fun and very effective instrument: an EU-wide competition („**European Energy Trophy**“) in which the participants aim to save as much as energy in one office building in one year using cost-free measures only. Whoever saves the most compared to the previously determined base line (average consumption of past 3 years), wins.

The first round of the **European Energy Trophy** competition took place from 1. October 2004 to 30. September 2005. A total of 44 participants from six countries entered the competition and implemented a wide variety of cost-free measures in their respective office buildings. During the course of the competition, six participants resigned due to internal reasons such as lack of staff capacity etc. As a result, 38 participants completed the competition on 30. September 2005.

The results of the Energy Trophy competition are phenomenal. For example, Dresdner Bank in its headquarters in Berlin has reduced its electricity and heat consumption by about 19 % and will thus save about € 100,000 per year. This was achieved by simple measures such as adjusting warm water boilers in the toilets, optimising the air conditioning regulation and asking staff to turn off all office equipment at the end of the day. Other competition participants showed similar results, some even reductions of 28-30% (the average for all 38 participants was 6.9 % reduction). Through this, the first Energy Trophy competition achieved a reduction of 3,700 MWh, 1,885 tonnes CO_2 and cost savings of 205 000 EUR.

What makes the **European Energy Trophy** unique and so successful is that it is an easily communicable – and fun – idea and therefore wholly accepted and actively supported by the staff working in the buildings, the local energy managers as well as the management of the respective company or organisation. Most of the participants of the first round of the competition have said that they intend to transfer the experiences made in the competition to other buildings under their management. Also, many staff members intend to now be more diligent with stand-by losses in their own homes.

From 2007 onwards, the **European Energy Trophy** will take place every year with an ever increasing number of countries and participants. The winners of last year’s competition were celebrated at a prize gala in Brussels in November 2005.

The **European Energy Trophy** was realised through an international project funded by the European Commission (SAVE Programme), which is co-ordinated by B.&S.U. mbH and involves six further partners from France, Germany, Great Britain, Hungary, Italy and Poland. Further information is available under www.energytrophy.org

Saving for Success: The European Energy Trophy

Background

A number of pilot studies have shown that cost-free measures such as changes in user behaviour and optimised regulation of equipment and appliances can result in 10-15% energy savings in office buildings.

For those interested in realising these potentials, ample information exists on the internet or in leaflets, guides etc. on which individual measures can be taken in offices. One example is the website www.energyoffice.org which provides hands-on information and instructions in the form of posters, checklists, equipment labels, teaching units etc. The website was developed through an EU funded project in 2000/2001 and is available in five EU languages: English, German, French, Polish and Spanish.

Examples of such cost free measures are:

- heating only the rooms that are being used
- turning off computers, printers etc. at the end of the work day
- switching off the lights where it is not needed
- keeping the openings closed and using air-conditioning appliances with moderation
- motivating all employees for energy saving measures

Despite this abundance of information on cost-free energy savings in offices the practice shows, however, that the large majority of persons working in offices are either unaware of these measures or not motivated to change their routines accordingly. Also, experience has shown that even energy managers tend to underestimate the energy saving potential of such cost-free measures and therefore do not pursue them actively.

In order to bridge this gap between knowing and doing, a consortium of seven partners from six countries together developed a competition for energy saving in offices, the “European Energy Trophy”. With this, the theory that 10-15 % energy savings are possible has been proved in practise through an easy, fun and very effective instrument. In the Energy Trophy competition, the participants aim to save as much as energy in one office building in one year using cost-free measures only. Whoever saves the most compared to the previously determined base line (average consumption of past 3 years), wins.

Developing the rules of the game

In the development of the competition rules and methodology, the project partners placed the emphasis on keeping it simple – both in terms of the amount of baseline data that the competition participants had to provide and in the complexity of the rules including exceptions to the rule etc. Honesty and fair play were the underlying principles of the competition, i.e. the participants were not required to certify the energy consumption provided to the competition bureau, but instead were only asked to provide copies of invoices in cases where the consumption was deemed unfeasible. As a result, the participants had to provide information on:

<u>Section A. Information to be provided before the start of the competition</u>

1. General information on the participant (e.g. name, name of contact person, sector)
2. Environmental Profile (e.g. environmental management system, company environmental policy)

3. Information on the building (e.g. year it was built, last renovation, office space in m2, number of work places, hours of daily use)
4. Information on the building's energy consumption (heating consumption for the years 2001 – 2003, electricity consumption for the years 2001-2003)

Section B. Information to be provided after the end of the competition

1. Heating and electricity consumption from October 1st, 2004 to September 30, 2005
2. Substantial changes in use of building (e.g. more than 10% change in number of work places)
3. Are there substantial changes in the technical equipment of the building (e.g. installation of energy efficient lighting throughout, introduction of thermal windows)
4. Feedback on the Energy Trophy competition

After spending the spring and summer of 2004 recruiting the participants for the competition, the first round of the Energy Trophy took place from October 1st, 2004 to September 30th, 2005. Overall, 44 organisations registered for the Energy Trophy competition, of which six withdrew during the implementation of the competition. The active participants were:

From Germany (15)
- City of Bielefeld
- Deutsche Bank Bauspar AG
- Digital Images GmbH
- Dresdner Bank
- E-Plus Mobilfunk GmbH & Co. KG
- Flughafen München GmbH
- Goldbeck Bau, Bielefeld
- City of Hanover
- Lufthansa Technik AG
- MAN Nutzfahrzeuge
- City of Schwabach
- T-Com
- TechniData AG
- University of Lüneburg
- City of Viersen

From Italy (5)
- COOP estense
- Ducati Motor spa
- Gruppo Cremonini
- Comune di Modena
- Provincia di Bologna

From United Kingdom (5)
- Centrica Business Services
- Lafarge Cement UK
- LandSecurities
- Sheffield Council
- University of Edinburgh

From France (4)
- EDF Electricité de France
- Association RESPIRE
- Chambre de Commerce et d'Industrie de Saint-Etienne/Montbrison
- EUROVIA (Groupe VINCI)

From Hungary (4)
- ALCOA-KÖFÉM Kft.
- British American Tobacco Hungary
- Maszer Rt.
- Valeo Auto-Electric Magyarország

From Poland (5)
- 3M Poland Sp. z o.o.
- Administacja Domów Wspólnot Mieszkaniowych "Włochy"
- ALSTAR Sp. z o.o.
- Biblioteka Bielsko-Biala
- Z.U.R. “HEMMAR”

All of the participants received a small “Starter Kit”. It was intended to help get started and to lend support during the contest. Besides generally information on the contest the starter-kit includes technical information as well as suggestions on how the companies can motivate management and employees (Examples are nomination of an Energy Trophy spokesman, endorsement by company’s senior management or set up of reward schemes such as a 50:50 model whereby the employees will receive 50% of the costs saved at the end of the year).

These companies and public administration competed for awards in three categories:

1. **best in-house publicity campaign / employee motivation campaign:**
   € 5 000, sponsored by Sharp Electronics Europe.
2. **highest percentage of energy saved nationally**
   € 5 000 per country, sponsored by Wintermayr energiekonzepte GmbH (Germany), AESS (Italy), KAPE (Poland), BCSD-UK (United Kingdom), CIRIDD (France), ECO-Invest Kft, Hewlett-Packard, Denkstatt Hungary Kft and Tisztább Termelés Magyarországi Központja (Hungary).
3. **highest percentage of energy saved EU wide**
   Gold: € 10 000, Silver: € 5 000, Bronze: € 2 500, sponsored by the main sponsor of the competition: meteocontrol GmbH.

Competition results

The results of the competition are phenomenal: As a result of the many in-house measures introduced by the participants, real and effective energy savings of up to 30 % were achieved, with the average being 6.9 %. Through this, the project achieved a reduction of 3,700 MWh, 1,885 tonnes CO_2 and **cost savings of 205 000 EUR**.

The winners of the Energy Trophy competition were approved by the Jury on November 7th, 2005.

They are:

1. best in-house publicity campaign: **Province of Bologna**.
2. highest percentage of energy (electricity and heat) saved nationally:

– Germany: **Dresdner Bank AG in Berlin**, 19.36 % reduction
– France: **EDF**, 7.01 % reduction
– Hungary: **Biopetrol**, 13.43 %
– Italy: **Ducati**, 15.62 %
– Great Britain: **Centrica Business Services / British Gas Business**, 31.28 % reduction
– Poland: **Library Książnica Beskidzka**, 11,89 % reduction

3. highest percentage of energy saved EU wide:

– Gold: **Centrica Business Services / British Gas Business**, 31.28 % reduction
– Silver: **Land Securities** (UK), 29,18%
– Bronze: **Dresdner Bank AG in Berlin**, 19.36 % reduction

The average savings for all participants was 6.9 %. The savings for the entire group of participants (including those that increased their consumption during the competition year) are -998,234 kWh for heat and -2,733,028 kWh for electricity, equivalent to -1,885 tonnes CO_2 emissions p.a.

Selected Case Studies

In the following, short summaries of the main activities carried out by the winners of the Energy Trophy are provided:

Company name: **Biopetrol Kft**
Company location: Szeged, Hungary
No. of employees: 28
Sector: Environmental protection

Biopetrol Kft competed with two buildings of 220m² in their companies seat. Both buildings were in good order with very good working conditions. Bight working areas allow the using of natural light, every room has its own air-conditioning system and radiators can be controlled separately.

Biopetrol used some industrial equipment in their store room during the competition, so their electricity consuption could not be assessed. However, the results for heating consumption were excellent. Besides good and well communicated plans, regular meetings were held and responsible leaders for energy saving on each floor were announced, Biopetrol put the goals of Energy Trophy into their ISO 14001 programme and the employee with highest energy saving engagement has been awarded by an intern award.

Biopetrol decreased the CO_2 emission by 4 tonnes and saved 275.14 euros. Altogether the company achieved energy savings of - 13%.

Company name: **Centrica Business Services / British Gas Business**
Company location: Oxford Business Park, England
No. of employees: 300
Sector: Utility

British Gas Business (formerly: Centrica Business Services) competed with two buildings of totally 1800m². An assessment of energy use on site served to provide a breakdown of the key areas of consumption. HVAC was confirmed as the area of greatest usage, and prompted a reappraisal of all settings and set points, including comms room conditions. Out of hours usage was also assessed, resulting in improved management of office equipment and better control of lighting.

For example, reminder stickers were placed in all intermittently-used areas, such as meeting rooms and toilets, to remind users to switch lights off as they leave.

Total energy consumption (gas and electricity) over the study period was down 30% over the corresponding period the previous year.

6. Results

6.1 Environmental results (decrease of CO_2-emission)

	Consumption/kWh			
	Oct 03 - Sep 04	Oct 04 - Sep 05	Reduction/kWh	Reduction %
Gas	159,551	149,542	10,009	6%
Elec	817,127	536,944	280,183	34%
Total	**976,678**	**686,486**	**290,192**	**30%**

6.2 Economic results (savings)

	Reduction/kWh	Rate / p/kWh	Saving/p	Saving £
Gas	10,009	1.118	11190	£112
Elec	280,183	5.703	1597884	£15,979
Total	**290,192**	-	**1609074**	**£16,091**

Company name: **Dresdner Bank AG**
Company location: Berlin, Germany
No. of employees: approx. 760 in Berlin
Sector: Bank

Dresdner Bank competed with its Berlin office of approx. 19.000m². A joint environmental team was created with the manager in charge of building management and employees with specific areas of specialisation (occupational safety) and decision making competence. In order to involve all employees, emails, circular letters, flyers, Intranet, and presentation boards at frequented sites provided tips and suggestions for saving energy. Information about the Energy Trophy was published and the ongoing successes were updated monthly.

Besides financial savings of more than 100.000 euros, Dresdner Bank acclaimed an annual reduction of approximately 680 tons of CO_2. Total energy savings were 19%.

Company name: **Ducati Motor Spa**
Company location: Bologna, Italy
No. of employees: 91
Sector: Motorcycles producer

Ducati Motor Spa competed with one office building of 1.320 m². Measures were mainly implemented in the production process, and during the last year, also in the office area. The Energy Trophy participation represented for Ducati the opportunity to modify and improve the employee's behaviours at the working place, and also at home. Organisational measures primarily consisted in cooling system regulation that has strictly been regulated on working time and turned of on Saturday. Average temperature has been decreased by 1-2°C.

A communication campaign focused on the economic benefits deriving from energy saving. Leaflets explained the objectives of the competition among the employees and stickers were positioned on electronic devices, instruments and computers, specially produced for the Energy Trophy campaign. An information desk was established where employees could obtain advises, receive the "E-Ducati" leaflets and stickers on energy saving. A person was identified to collect internal suggestions from the employees on saving opportunities and measures. Ducati achieved about 4.600 euros savings, -32 tonnes less CO_2 emission, and reduced energy consumption by 15.6 %.

Company name: **Książnica Beskidzka (Library of Bielsko-Biala)**
Company location: Bielsko-Biała, Poland
No. of employees: 73
Sector: Public services

Książnica Beskidzka competed with its office building of 394 m². During the competition period the continuous monitoring of energy parameters was conducted. Energy supply was adapted to actual needs (regulation of the heat distribution centre to reach optimal thermal conditions on low costs), switching off not used lighting and office equipment (i.e. computer displays).

Activities leading to energy saving awareness included a drawing competition for children “You also can save energy” and initial presentations and lectures for all employees. The goal of these events was to encourage participants save energy and develop ecological attitudes. Książnica Beskidzka total energy consumption was reduced by 12%.

Company name: **EDF**
Company location: Nice, France
No. of employees: 383
Sector: Electricity supplier

EDF competed with its office of approx. 11.000 m² in Nice. EDF mobilized its employees around a lucid and well planned campaign, involving them constantly. A demonstration room showed the use of energy measurement devices (Energy Monitors) using standard office equipment and posters & messages on PC monitors informed on concrete measures. Lighting was switched off and computers turned off in the evening, during the lunch and appointments. Heating/air-conditioning was lowered in the evening and special labels on the campaign were created. EDV decreased their CO_2 emission by 91 tonnes annually and achieved energy savings of 7%.

Factors of success, outlook

What makes the European Energy Trophy unique and so successful is that it is an easily communicable and fun idea and therefore wholly accepted and actively supported by the staff working in the buildings, the local energy managers as well as the management of the respective company or organisation. The scale of the energy savings reached through the competition surprised every one: the organizers, the participants as well as the project's supporters.

Most of the participants of the Energy Trophy competition have confirmed that they will continue to implement the selected energy saving measures in their office buildings in the years to come. In addition, many participants plan to transfer the identified measures to other buildings under their management. Many staff members now also intend to be more diligent in avoiding stand-by losses in their own homes.

From 2007 onwards, the European Energy Trophy will take place every year with an ever increasing number of countries and participants. In a follow-on project that was submitted in the 2005 call for the programme "Intelligent Energy Europe", the project partners intend to **professionalize, extend and continue** the competition:

- ***Professionalization**: evaluating the existing competition rules and procedures based on the experiences of the pilot round, adapting them where necessary and using a web-based energy data system to collect the current energy consumption from the participants*
- ***Extension:** transferring the Energy Trophy to the following new countries: Austria, Belgium, Bulgaria, Denmark, Estonia, Latvia, Lithuania, Netherlands, Romania, Slovenia, Spain and Sweden.*
- ***Continuation:** holding the second round of Energy Trophy competition with an increased participant base of 350-450 companies and institutions from the 18 countries*
- ***Long term institutionalisation:** establishing the financial basis for holding the Energy Trophy competition every year covering all 18 countries.*

Continuing the EU-wide competition shall introduce the European Energy Trophy as a regular event in the European Union that effects energy savings, cost savings and a reduction in CO_2 emissions by a fun and easy way. Through this, the Energy Trophy competition could potentially lead to 37 GWh energy savings and over 2 million € cost savings per year.

Project partners, duration, budget

The European Energy Trophy project was implemented by a consortium of seven partners:

- **B.&S.U. Beratungs- und Service-Gesellschaft Umwelt mbH**
  (B.&S.U., EU-wide co-ordinator)
- **B.A.U.M Consult GmbH**
  (BAUM, National co-ordinator Germany)
- **Centre International de Ressources et d'Innovation pour le Développement Durable**
  (CIRIDD, National co-ordinator France)
- **Business Council for Sustainable Development - United Kingdom**
  (BCSD – UK, National co-ordinator UK)
- **Agenzia per l'Energia e lo Sviluppo Sostenibile**
  (AESS, National co-ordinator Italy)
- **Krajowa Agencja Poszanowania Energii S.A.**
  (KAPE, National co-ordinator Poland)
- **Hungarian Association for Environmentally Aware Management**
  (KÖVET-INEM Hungária, National co-ordinator Hungary)

The project duration was January 1st, 2004 to December 31st, 2005.

The total budget was 399.786 Euro. The project was funded by the European Commission (SAVE II) and the Ministry of Economic Affairs and Energy of North Rhine-Westphalia. The competition is carried out under the official patronage of Germany's Federal Environmental Agency (Umweltbundesamt, UBA).

Further information is available under www.energytrophy.org

Energy-Efficency Regulations and Better Design Practices in New Commercial Buildings in Mexico

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Abstract
Mexico has had several processes coinciding to make energy efficiency regulations and better design practices a necessity. One has been the economic growth in regions with hot (and both dry and humid) climate. A second one has been the growth of the services sector, thus increasing the need for new offices and other types of commercial buildings. The third one has been the increasing cost of electricity. As a result, the Mexican Government established mandatory energy-efficiency standards for commercial buildings and many practitioners have became more aware of the importance of better designs to reduce solar and outdoor-air conduction gains. This paper shows the evidence of the above-mentioned processes, describes the basis and the process for the implementation of the energy-efficiency standards, and gives an example of compliance with the standard as a result of the design practices of a well-known architect.

Context
Mexico is a country with a population of more than 105 million people with 66% of its territory in regions with hot (dry and humid) climate. For decades before the end of the last century, most of its development took place in the central, moderate-climate, regions. But economic development created new areas of urban growth in regions with hot climate. Coincidentally, the services sector has been growing in importance, which is reflected in the form of many new offices, stores, schools, hospitals and other buildings used by this sector. This combination has resulted in the growing importance of energy consumption in commercial buildings, and the need to find ways to reduce their energy intensity.

1.1 Changes in the economic geography
During the last twenty years some regions of Mexico have been growing faster than the rest of the country. The establishment of the maquiladora industry [1] in the border with the United States and the growth of the tourism industry have been the drivers for this process. As a result, the center of gravity of the nation's power consumption has moved north, where, during the summer months, the climate is hot and dry. This has occurred after several decades dominated by the central region (where Mexico City is located) where climate is moderate. This is reflected in the fact that, just in a twenty year period (1982 to 2001), the electricity consumption of the six northern states[2] as a percentage of Mexico's´ total power consumption has increased by 6%, from 28 to 34% (Fig.1). Also developing fast have been the coastal regions, particularly in the Gulf of México, and the Yucatan and Baja California Peninsulas. These regions have hot (dry and humid) climates, and most of the new buildings have been dedicated to tourism, an activity that demands high levels of comfort. As a final result, the energy requirements for space conditioning have been greater for many of the new buildings in the country.

[1] The "Maquiladora" program promoted the creation of twin plants in neighboring cities along the México-U.S. border with the labor intensive part of the production on the Mexican side. These Mexican plants were (and are) allowed to assemble imported products, tax-free, for immediate, duty-free (except on the value added in México) re-export.
[2] Baja California, Chihuahua, Coahuila, Nuevo León, Sonora, and Tamaulipas.

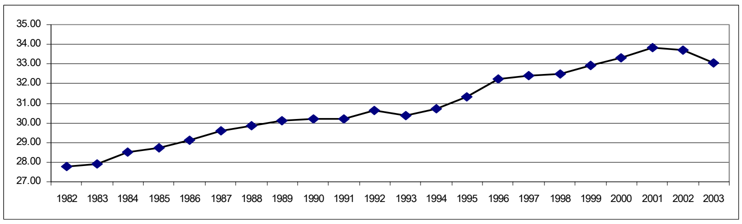

Figure 1 Percentage of national electricity use consumed in Mexico's northern states.

1.2 Climate

Mexico is clearly dominated by hot climate and recent works by the *Asociación de Empresas para el Ahorro de Energía en la Edificación* (AEAEE) demonstrates it. AEAEE has preformed a study to establish R values based on US building codes for residential and commercial buildings in Mexico. As part of the work, degree days for Mexico had to be estimated. Results show that most of the territory has a need for cooling and only a few locations have needs to insulate for cold weather (Fig. 2).

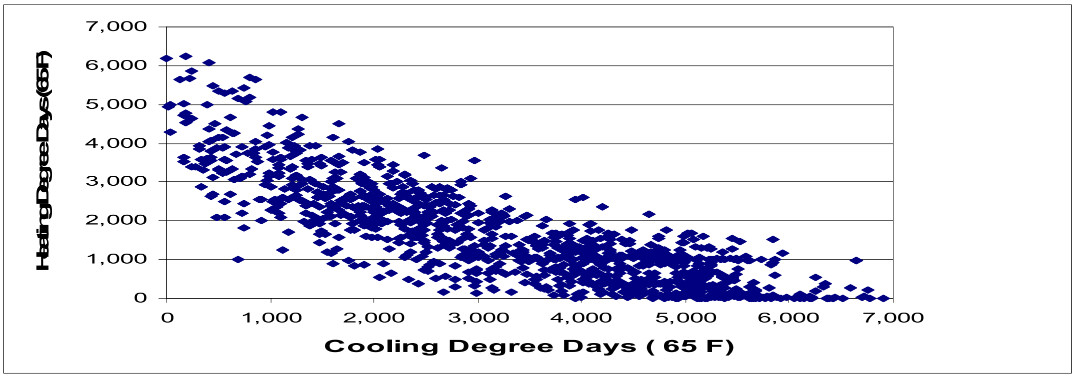

Figure 2. Degree days for México

1.3 Energy demand

The growing demand for energy to be used to keep buildings comfortable has been reflected in the daily load profiles of the national power utility (CFE), where air conditioning has become the end-use that determines peak power—and the need for new power generation capacity. A comparison of the hourly demand profiles for the same type of day (Wednesday in July) in CFE´s Northern Division[3] in 1987 and 1997 shows how in a ten year period the peak demand of the day has shifted from the night to the afternoon, a phenomena that reflects the dominance of the air conditioning demand over that driven by illuminating devices (Fig. 3).

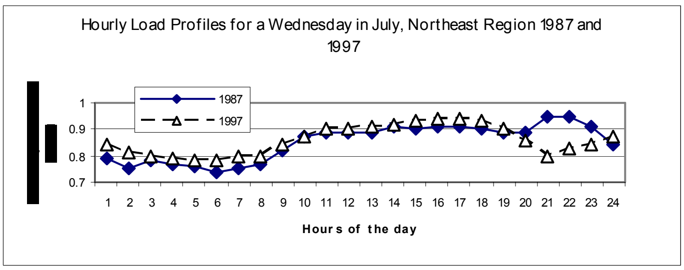

Figure 3. Typical hourly profile in a summer day, 1987 and 1997

In México, given its large dependence on fossil fuels, greater power consumption is reflected directly in increased air pollution. In 2004, power plants based on fossil-fuel provided 82% of the electricity generated in México (Fig. 4). This represents a serious environmental challenge for Mexico, a country that has signed the Kyoto Protocol and that holds sustainable development as a national goal. Also, given the fact that most of the new capacity uses natural gas as fuel, the high and volatile price of this fuel has impacted the cost of electricity. As electricity tariffs for medium and large customers pass through the costs of generating fuels, the cost of electricity for medium and large users increased by

[3] Parts of Chihuahua, Coahuila and Nuevo León

more than 25% in the last year, to average costs that can reach US$ 0.10 per kWh. This has many facility managers worried, and the long-term effect of these energy prices in building operating costs is making developers and designers consider a change in design practices.

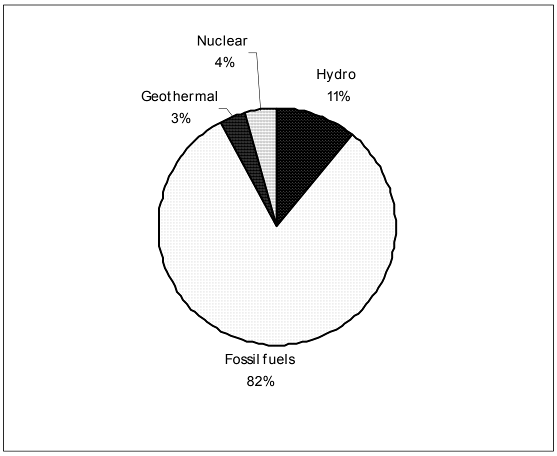

Figure 4. Primary energy sources for power generation, México 2004

2. Early practices on bioclimatic design and construction

Even though Mexico has many examples of good practices in building design that originated with its early inhabitants and from Spain, these practices were lost as Mexico became industrialized in the Twentieth Century. Its great pace of development in the second half of that century was partly driven by a wealth of energy resources and subsidies, and its architects and designers replicated the practices of their peers abroad, which had little concern for the energy intensity of the new buildings. It was not until the last part of the century that concerns about these practices drove researchers, practitioners and policy makers to change this path.

2.1 Research and training on better practices

The first reference in recent history in Mexico of designers´ concerns about the energy and environmental impacts of buildings is from the late sixties when Jauregui works on bioclimatic guidelines for buildings of the National Social Security Institute of México (IMMS) (Morillón, 2004). Through the next ten years some efforts are made to include better design practices in some prototypical residential buildings in hot-dry climates.

Beginning in 1980 there has been a growing interest in better design and work is done on better knowledge of the driving variables (Becerril and Rodríguez and Palacio), documentation and diffusion of better practices (Tudela, Deffis and Reyne Mel), and demonstration projects done by Sámano, such as the auditorium and working areas of the—presently—Center for Energy Studies of the Mexico´s National University (UNAM) in Temixco, Morelos. Also, Héctor Cevallos starts his now world renown work on buildings and eco-tourism (Morillón, 2004).

Interest in the field drives the creation of several university graduate-level programs in solar and bioclimatic architecture and a growing network of researchers and teachers. This is reflected in the growth of papers on the subject presented at the yearly national congress of Mexico´s National Energy Association. By the second half of the nineties half of the papers on this congress dealt with bioclimatic design practices (Morillón, 2004).

2.2 Mexicali

Of great importance in the process for more sustainable construction in México is what was done in Mexicali by the national utility (CFE). Driven by increasing energy costs in one of the most climate-extreme cities in the country (with ambient temperatures going above 45°C in the summer afternoons) in 1987 the utility performed the first quantitative studies on energy-efficiency measures for residential sector buildings. As a result, by 1990 it financed the first demand-side program in the country, with very good results as the energy bills of more than 60,000 households were reduced on an average of 30% by retrofitting through the insulation of their roofs.

3. The commercial building energy-efficiency standard

By the end of the eighties the concerns about Mexico´s energy consumption patterns and its dependence on oil drove policy makers to act. As a first step, the National Commission for Energy Conservation (CONAE) was created in 1989. CONAE immediately took to the task of developing energy efficiency standards, with that for buildings as one of the priorities. However, it took more than five years to start work on an energy efficiency standard to be part of the building codes.

Developing the standard was not an easy task. Lack of detailed climate and building data and of quantitative analysis were the main barriers to overcome. Also, the complexity of the consensus building process among a very large number of stockholders was not something Conae´s officials were ready to deal with. As a result, the process was a complex and long process that went from 1994 to 2001, a period in which Conae worked—besides more than 15 energy-efficiency standards and other projects in a context of institutional uncertainty—to create an acceptable commercial building code, develop consensus on its requirements and implement it according to the law that regulates standards in Mexico (de Buen, 2004).

In this process, Conae had the help of Lawrence Berkeley National Laboratory, whose building analyses experts integrated the required data and did the simulations that helped analyze the alternatives and define the best possible code design.

The official name of the standard is NOM-008-SENER and is mandatory for, basically, commercial buildings. Its purpose is to reduce heat gains through the building’s envelope and reduce the need for air conditioning.

3.1 The requirements of NOM-008-SENER

NOM-008-SENER was designed for easy compliance-demonstration, and this process involves comparing two geometrically identical buildings, one with the required envelope characteristics (reference) and the other with the proposed envelope elements. Using simplified formulas, the heat gain through the both buildings is calculated and compared. If the heat gain through the reference building is equal or greater than that of the proposed design, the building complies with the standard (Conae, 2005).

The general requirements for the reference building are shown in Table 1. More specific requirements—K values—are defined for specific locations.

Table 1. General requirements for reference building under NOM-008-SENER

	REQUIREMENTS	
SURFACE	ROOF	EXPOSED WALLS
Non-translucent (walls)	100%	90%
Translucent (windows)	0%	10%
K for non-translucent	From tables	From tables

The calculations involve the use of location specific heat gain factors for walls and windows. These values are part of the standard.

3.2 The process of enforcement

According to Mexico´s standards law, there has to be what are known as verifying units, which are professionals that are accredited to confirm compliance with a systems´ standard. These verifying units produce a certificate that is then used by the building owners to prove compliance with those authorities that require it. To date, only two units have been accredited (Conae, 2005)

3.3 Present status

Even though the standard has become mandatory and Conae can enforce it, only a small number of new commercial buildings have proved compliance. One of the main reasons for this situation is that

Conae doesn't have the manpower to enforce it, so generalized compliance and enforcement requires the active participation of local authorities through the inclusion of the standard in the local building code. For three years, efforts have been made to convince local authorities in most of Mexico´s largest cities to do so. Success on this endeavor has been partial, as only a few municipal authorities have formally included the requirement in the local code. However, Mexico City—the largest metropolitan area in the country—has modified its code to include text that mandates compliance with all the national mandatory standards, such as NOM-008-SENER.

One development that has kept the standard alive was the creation of an industry association in 2003. The Asociación de Empresa para el Ahorro de Energía en la Edificación (AEAEE) was formed in 2003 by the most important building-materials manufacturers in México has become the leader in the promotion of compliance with the standard (AEAEE, 2005). As a result of the association's efforts, the newest and tallest building in the Mexico (Torre Mayor) recently got—in a well publicized ceremony—its NOM-008-SENER certificate. Other landmark buildings will soon follow suit.

4. An example of current practices: buildings by José Piccotto

Some of the most influential architects in México City have been aware of the existence of the standard but, more generally, they have been very aware of the need for a more pro-active approach to the need of environmental sustainability in the building stock. This has resulted in a number of buildings that comply with the standard and go well beyond its requirements with the inclusion of architectural elements that limit heat gains.

4.1 Parque Insurgentes

José Piccotto is a Mexico City architect who has designed several large office-buildings with a very particular and personal style. A good number of these buildings are located on the Avenida de los Insurgentes, Mexico City's longest avenue and one of Mexico´s most commercial venues. All of his new buildings comply with NOM-008-SENER.

Parque Insurgentes is a twenty story, 28,000 square meter office building located in the south-central part of México City, and comfort is reached by both passive and active systems (Fig. 5). To control solar radiation gains, the building envelope includes a set of aluminum louvers on the east and south façade that shade the standard clear glass on the façade. Master Point glass (safety tempered and safety laminated glass for maximum security) is used for the other outside areas where the louvers on the façade do not provide shade, in the area. Also, extra insulation is obtained with aluminum and precast concrete in the form of double walls with an inside air chamber containing polyethylene.

Prevailing winds are taken advantage of through the north façade on the side of the atrium, transforming it into a large open space of hot air or thermal funnel. The atrium in as element that permits air to be conducted from the offices because each floor opens out to the atrium seeking to push hot air produced in the offices through ventilators ad extractors letting it out in the upper part of the atrium through a suction system of outside wind in respect to the building.

Additional energy conservation measures include automation to monitor and control energy consumption in lighting, air conditioning, and elevators. The system is also used for fire protection under the "intelligent building" concept.

4.2 Corporativo Insurgentes.

Corporativo Insurgentes 553—also located in the south-central part of México City—is used both as a hotel and an office building (Fig. 6). The building has 17 floors and 40,000 square meters. Its envelope was designed based on a climatic analysis of the building's location. Data was collected on monthly and annual average, maximum and minimum, temperatures; relative humidity; cloud cover and rainfall; as well as the direction and speed of the dominant winds. These data were used on a bioclimatica chart to identify requirements for artificial space cooling and or heating. Results identified the need for artificial air conditioning for the spring and the summer.

Figure 5. Parque Insurgentes Building

The building's envelope has both laminated glass and tempered glass with a special screen printing in up to three colors, which allows the surrounding views to be visible and at the same time providing shade patterns to the interior. The use of intelligent glass (Self-cleaning and colored glass are new reduces heat gain by 55%, eliminating up to 73% of the exterior noise. Horizontal sunshade louvers made of thermal membranes with Teflon were used for the south and east facades with the intention of controlling the heat gains without loss of natural lighting.

Air conditioning to the hotel rooms is provided by means of modular heat pumps. An interior atrium is located to organize the interior life of the hotel and to create a way out of the warm air produced by the offices, making the hall a temperature moderator element.

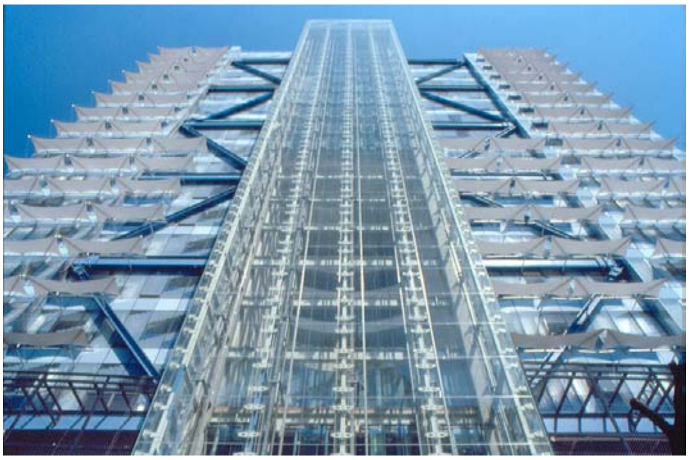

Figure 6. Corpotarivo Insurgentes Building

5. Conclusions

A wealth of energy resources kept Mexico away for more than two decades from world tendencies for greater energy efficiency and sustainability in its energy use. These tendencies and personal exposure by local researchers and practitioners to them helped the development of local research and design capacities, though this has not been enough to transform the market.

Other policy concerns—such as the rapid economic growth in regions with hot climate and Mexico´s great dependency on fossil fuels—drove the federal government to push for mandatory energy-efficiency standards, among them one that reduces heat gains through the envelope in commercial buildings. Via a long and complex process, the standard (NOM-008-SENER) came into place, but its widespread compliance has been limited due to the required involvement of municipal and city authorities, something that has not happened as widely as required.

Nonetheless, the growing involvement of the private sector in the development of markets for products and services related to greater sustainability in buildings has become the driving force of this process. The work of José Piccotto is an example of this process. It is expected that this involvement drives the market all through the development chain, from specific materials to the real state market.

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High Performance Buildings in the US: Beyond Energy Code-Based Models for Supporting Premium Efficiency in Commercial Building

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Abstract
In recent years there has been a proliferation of programs in the United States to encourage and promote development of higher performance buildings, which are characterized by enhanced energy efficiency, reduced building site impact, use of materials that are recycled or low environmental impact, enhanced indoor environmental quality, and better water conservation features. Programs like the US Green Building Council's LEED or the Collaborative for High Performance Schools are examples of such efforts. For all of these programs, energy efficiency is a predominant factor.

Innovative "code-plus" programs are now providing programmatic structures that motivate high performance construction by paying incentives only when codes and standards are outperformed. Most of the new energy codes for the commercial sector are based on ASHRAE Standard 90.1 or the International Energy Conservation Code. At present, many efficiency program managers are undertaking baseline assessments for their programs and initiatives, and results of these efforts frequently state that the new energy codes and trends in current (baseline) practice are becoming more similar. In line with this, numerous programs have been developed that use a code-plus model, where the estimates and achieved savings (and incremental costs) are based on how much better the project does than the applicable (lighting, HVAC, envelope, whole building, etc.) energy code.

This paper will describe key features of high performance buildings programs and the details of current trends in code-plus new construction programs. Recent program endeavors by Efficiency Maine, NSTAR Electric and National Grid will be explored. We will also discuss current efforts to utilize the New Building Institute's Advanced Building Guideline and Benchmark as a model that establishes "prescriptive" objectives for a high performance, code-plus new construction programs. Code-plus initiatives will be compared and recommendations will be established for optimizing these programs' potential impacts.

Introduction
In recent years there has been a proliferation of programs in the United States to encourage and promote development of higher performance buildings, which are characterized by enhanced energy efficiency, reduced building site impact, use of materials that are recycled or low environmental impact, enhanced indoor environmental quality, and better water conservation features. Programs like the US Green Building Council's LEED or the Collaborative for High Performance Schools are examples of such efforts. For all of these programs, energy efficiency is a predominant factor.

Concurrently, there has been a considerable effort to have the various US states adopt more aggressive energy codes. The motivation for these new and more aggressive codes is to elevate baseline new construction practice and to improve the overall quality of new buildings.

Traditionally, new construction energy efficiency programs have not relied on energy codes and standards as the source for baseline assumptions and characteristics to which proposed (energy efficient)

systems could be compared. In fact, it had frequently been possible to receive financial incentives for technologies even when minimum energy conservation code compliance is not met.
Innovative “code-plus” programs are now providing programmatic structures that motivate high performance construction by paying incentives, including federal tax credits, only when codes and standards are outperformed. Most of the new energy codes for the commercial sector are based on ASHRAE Standard 90.1 or the International Energy Conservation Code. At present, many efficiency program managers are undertaking baseline assessments for their programs and initiatives, and results of these efforts frequently state that the new energy codes and trends in current (baseline) practice are becoming more similar. In line with this, numerous programs have been developed that use a code-plus model, where the estimates and achieved savings (and incremental costs) are based on how much better the project does than the applicable (lighting, HVAC, envelope, whole building, etc.) energy code.

Code-plus new construction programs include recent program endeavors by the States of Maine and California, and the New England based utilities, NSTAR Electric, National Grid USA, and Northeast Utilities. In addition, program operators around the country are adopting a program entitled Advanced Building Guideline and Benchmark as a model that establishes “prescriptive” objectives for high performance, code-plus new construction programs. The Advanced Buildings Guidelines and the accompanying standard, Benchmark were developed by non-governmental, non-profit organizations as tools to be used by program administrators and the architectural and engineering communities to advance the performance of newly constructed buildings.

During the fall of 2005, the United States Congress passed a bill that has been signed into law that offers federal tax credits for new construction projects, and some renovation projects, that outperform ASHRAE Standard 90.1 2001. The credit is scheduled to go into effect January 1, 2006. However, final rule-making has not yet taken place, so full programmatic details are not yet available. Plans are now underway for State government and utility operated new construction programs to work with the Federal Tax Credit Program to further advance the energy performance of new commercial buildings.

Energy Codes as the Baseline

Until very recently, almost all new construction energy efficiency programs operating in the United States have been structured on the incremental performance and cost difference between the installation of “standard practice” equipment and the premium efficiency equipment the program promotes. Establishing appropriate baselines is challenging, and utilities, state and federal governments, and other entities that operate programs have experimented with various methodologies for many years.

Typical ways to define the baseline are varied, but usually established as “current practice” for the region or what program operators or regulators believe should be current practice. The key problem is developing the understanding of what current practice really is for a specific geographic region or market. Frequently, considerable effort is undertaken through market surveys and on-site data collection efforts in order to establish the local standard practice level.

Once the baseline concepts to be used for a program are well understood, and once the data and algorithms are developed, day-to-day determination of program savings or cost details can be more readily determined. Energy and cost savings for a given project are simply the incremental difference in energy use or operating costs between the baseline technology or approach and the alternative proposed technology or approach. Project incremental costs are also readily determined as the difference between the costs that would be incurred for implementation of the baseline system versus that incurred for the proposed system. Incentive energy efficiency programs would then pay a set amount for a particular measure (prescriptive), or would pay some percentage of the incremental cost.

ASHRAE 90.1 standards are designed to define standard practice baselines. Beginning with the 2001 version of 90.1, ASHRAE began “maintaining” the standard, updating the requirements in order to keep pace with improving technologies and design/construction techniques. Many upgrades were made to the standard during 2002 and 2003 and issued as addenda to the standard. In January of 2005 ASHRAE introduced a new version of the standard (90.1, 2004).

When states adopt 90.1 as the legal energy efficiency code, they are defining the standard as the "least efficient building that may be built, by law." Under pressure to not be too aggressive, lawmakers typically choose to adopt earlier outdated versions of the standard. Most states, and indeed the International Energy Code are based outdated versions of ASHRAE 90.1. Versions 1989, 1999, and 2001 are commonly used throughout the United States, as bases for energy efficiency codes. For those states using outdated versions of 90.1, it can be assumed that standard practice is actually somewhat more advanced than the "least efficient building that may be built, by law." However, in the total mix of commercial buildings projects, there are always: those that meet codes, those that outperform codes and those that fall short of code compliance.

Recently ASHRAE has felt significant pressure to keep 90.1 more current with advancing technologies and to move the standard toward the promotion of energy efficient design and construction. Concurrently, state governments have felt political pressure to promote energy efficient design and construction that goes beyond the low levels established by outdated versions of the standard.

The recent progression of 90.1 standards and the codes that are based on them, has opened the opportunity for efficiency program administrators to relax their efforts in defining standard practice baselines and instead offer incentives for construction projects that result in buildings that will outperform 90.1 based standards and codes. The methodology for evaluating performance in comparison to 90.1 may be prescriptive and technology based, or may be based on whole building performance. Categories of systems with clear prescriptive requirements include: building envelope; HVAC systems; and electrical/lighting systems. In each of these categories, various programs have established methodologies for documenting performance parameters that improve upon the prescriptive requirements. Additionally, all versions of 90.1 provide for documenting compliance through the modeling of predicted building performance, and comparing it to the predicted performance of a similar building that meets the prescriptive requirements. Most of the efficiency programs based on the 90.1 standard, also allow a total building performance modeling approach to be used to document performance that outperforms the standard.

The balance of this paper describes four new construction programs that are based on promoting enhanced energy efficiency through the documentation of performance that improves upon ASHRAE 90.1 standards and codes based on those standards.

Example One: High Performance School Programs

The construction of new schools continues to grow dramatically throughout most of the United States. The growth of the student age population and a fairly uniform deterioration of schools built during the school building boom of the 1960's, have coincided with the recent robust economy and healthy tax base to promote the school construction boom over the last five to ten years. This continued growth has coincided with the expanding interest in new construction energy efficiency, and therefore many programs have been developed that focus on new school construction and energy efficiency.

In order to encourage beyond code performance, many utility companies in the United States have developed programs that encourage beyond code performance by offering enhanced design and construction grants. Under these programs incentives are offered for projects that outperform energy code mandates. The grant amounts are typically calculated on kW and kWh saved compared with a code compliant design of a similar project. In some cases, integrated design approaches are mandatory, or encouraged, but most of these programs focus on individual (lighting, HVAC, window, etc.) system efficiency levels.

At the same time that the utility companies have been developing these incentive programs, State governments have been establishing programs that promote the construction of high performance schools. These programs have a wide focus and address classroom performance, student and teacher comfort, environmental responsibility, maintainability and community development along with energy efficiency.

CHPS - The Collaborative for High Performance Schools is an organization formed in the State of California to promote the construction high performance schools throughout the state. The mechanisms utilized are a standard that focuses on mandatory and optional criteria that are related to the construction and maintenance of high performance schools. As companion pieces to the standard, the Collaborative published "Best Practice" manuals that serve as guides for designing and building to the standard.

In its approach to energy efficiency, the CHPS documents rely on demonstrated performance that improves upon California's Energy Efficiency Code. The code is referred to as Title 24, but like most U.S. Energy Codes is based on ASHRAE 90.1. In order to comply with the CHPS standard, the applicants may document a prescriptive approach or a "building performance" approach. The prescriptive approach uses the ASHRAE 90.1 blueprint with efficiency levels 10-25% higher than California code. The building performance approach requires full modeling of the design. Credit points are awarded based on an escalating performance scale that compares the modeled performance with a similar building that meets prescriptive requirements.

Recently the original California CHPS model has been adopted by several other states, with some states offering financial incentives in the form of enhanced construction funding from the state education department. Other states have passed regulations mandating that all publicly funded school construction projects adhere to high performance principles, typically using the CHPS standard as the model.

New England Regional High Performance Schools Protocol – All of the New England States have adopted regulations that either mandate high performance new schools or promote their construction through enhanced construction incentives. Recognizing a need to ease the bureaucratic burden on the individual states, a regional High Performance Schools Protocol has been developed and is being adopted by each of the New England States. The Protocol is an initiative of the Northeast Energy Efficiency Partnership and was developed with the help of a grant from the Kendall Foundation. ERS developed the Protocol, basing the energy criteria on the Benchmark model (covered in the next section) and on improved performance compared with ASHRAE 90.1 2001, the model for the energy code for most of the participating states.

In order to comply with the protocol, school administrators must demonstrate performance equal to or better than the performance levels achieved through adhering to Benchmark, or must demonstrate performance at least 20% better than that achieved by adhering to the provisions of ASHRAE 90.1 2001. States are free to adopt only portions of the regional protocol, but all states have decided that adherence to the energy efficiency provisions is to be mandatory.

Example 2 – Advanced Buildings Benchmark™ Program

A program recently developed jointly by the New Buildings Institute in the State of Washington, and the Energy Center of Wisconsin focuses on improving the efficiency of newly constructed commercial buildings ranging in size from 20,000 to 80,000 ft2. Building types addressed by the program include office, educational, retail, grocery, medical clinics, commercial and industrial storage space, etc. Although other factors are addressed, the main focus of the program is energy efficiency and indoor environmental quality.

The program offers a suite of technical resources designed to improve the way buildings are designed and built, emphasizing an integrated approach. The Benchmark itself can be viewed as a standard that outlines specific performance criteria that must be met for the building to be considered in compliance. Its companion piece, the Advanced Building Reference Guide provides information on design and construction methodologies for implementing the Benchmark criteria.

Benchmark was created with the intention that State and Local Governments, along with utility companies, would adopt the criteria as the basis for various new construction energy efficiency programs. Again ASHRAE 90.1 standards were used as the model for the energy efficiency provisions. Lighting, HVAC, and building envelope systems are covered, with the efficiency levels being set at approximately 20-30% higher than 90.1 2001 levels. Total building performance approaches may also be used to demonstrate compliance, with building modeling being required, mirroring ASHRAE 90.1 requirements for modeling protocol.

Starting in New England, a series of training workshops are being held around the country introducing the Benchmark concept to the A&E community, and efficiency program administrators. Some states have begun to adopt the Benchmark as the minimum energy efficiency requirements for governmental buildings, or for all publicly funded building projects (schools, libraries, governmental offices, etc.).

Several utility companies have announced efficiency programs for the year 2006 that rely on the Benchmark as the criteria for program compliance. Upon successful documentation of compliance with Benchmark, incentives are paid per square foot of interior space, or per energy unit conserved.

Example Three: Efficiency Maine Commercial/Industrial Program

The State of Maine offers a statewide government administered energy efficiency program that is funded by the systems benefit charge that is collected by each of the state's electric utility companies. ERS, working with the Maine consulting firm North Atlantic Energy, developed a program for the State that pays incentives for projects and measures that outperform energy code mandates

The State has also adopted the 2001 version of ASHRAE Standard 90.1 as a statewide energy conservation code for new construction. Like the Benchmark program outlined above, this program pays incentives for new construction measures that outperform the levels mandated by code by at least 20%.

Unlike many other programs that focus on energy usage only, the Maine program is enhance with many provisions that promote high performance work and educational environments. Incentives are not paid for measures that represent standard practice, regardless of whether or not energy efficiency goals are met. Designers must go beyond standard practice in order to demonstrate that the projects are promoting advanced technologies and are contributing to the long term maintainability and performance of the new building.

Similar to the High Performance Schools Programs, the Maine program strives to promote such indoor environmental quality issues as lighting quality, thermal comfort, and indoor air quality along with energy efficiency.

Lighting Systems - High performance fluorescent technologies are emphasized, with enhanced incentives for technologies that promote low-glare, high uniformity, and high color rendering. Technologies that are promoted include:

- Super T8 systems with program start ballasts.
- Advanced optics T5 systems.
- High intensity fluorescent low-bay and high-bay fixtures.
- Daylight harvesting systems.
- Premium performance indirect and direct/indirect fixtures.

Only premium efficiency technologies are eligible for incentives, with many "standard practice" measures being excluded from receiving incentives, despite the fact that they are efficient technologies. Examples of excluded technologies include LED exit signs, standard T-8 lamp/ballast combinations, metal halide, etc. Energy Code mandated lighting power density (LPD) levels must be outperformed by at least 20% for each building/space type.

HVAC Systems – The ASHRAE based Maine code contains numerous prescriptive HVAC requirements governing such measures as:

- ❑ System sizing
- ❑ System rated efficiency
- ❑ Free-air cooling (economizing)
- ❑ Heat recovery ventilation; etc.

Designers may choose to follow prescriptive paths, or they may choose to utilize a building performance analysis method to demonstrate that their design will use no more energy than a similar building that meets all of the prescriptive requirements. Similarly, grant applicants under the Maine program may choose the same two paths to demonstrate their qualification for incentives. They may choose equipment that outperforms prescriptive program requirements. These prescriptive requirements, on average, represent performance levels 20% more efficient than those mandated by code. Alternatively they may use building simulation methods to demonstrate that the project they have designed will outperform a standard practice, code compliant, building by at least 20%.

Example 4 – Federal Tax Credit Program EPACT 2005

During the fall of 2005, the United States Congress passed the Energy Policy Act of 2005 (EPACT 2005). The Act deals with numerous aspects of energy development and conservation, with the efficiency of new buildings being only one topic addressed in the law. Most of the conservation and efficiency provisions are based on federal tax incentives (credits) and new construction projects are no exception. The credit is scheduled to go into effect January 1, 2006 and would offer tax credits for new construction projects that outperform ASHRAE Standard 90.1 2001. However, final rule-making has not yet taken place, so full programmatic details are not yet available. Plans are now underway for State government and utility operated new construction programs to work with the Federal Tax Credit Program to further advance the energy performance of new commercial buildings.

Although final rule-making will likely produce some changes, the provisions of the law offer tax credits for newly constructed buildings, or renovations, that outperform the ASHRAE standard by 50%. That is viewed by the construction industry as a very aggressive standard to meet, and in at least some circumstances, limited tax credits will be available on a prorated basis for projects that outperform the Standard by at least 25%.

In addition to the incentives offered for the construction of efficient buildings, projects that include only lighting, HVAC, or envelope measures may also qualify for limited tax incentives. The incentives for whole building approaches are capped at $1.80 per square foot, while the incentives for each of the individual disciplines are capped at $0.60 per square foot.

The legislation specifies that certification for the tax incentives must include development of procedures for inspection and testing by qualified individuals to ensure compliance. These individuals must be accredited by an authorized organization. These procedures and the authorizing organization have not yet been identified, and the Federal Department of Energy is considering several proposals for the certification procedures.

Details of the EPACT Tax Credit Program will be announced within the next two months and will be presented at the conference.

Conclusion

For too long, energy efficiency programs have focused on individual energy using pieces of equipment rather than taking an integrated approach to efficient design and construction. Unfortunately, it is all too easy for efficient equipment to be used inefficiently, and/or be installed in such a fashion that not even mandatory code requirements are met.

Basing efficiency programs on mandating performance levels that are higher than mandated code levels will not cure all of these problems, but it is surely a step in the right direction. In order to participate in these programs, designs are being modified to increase energy efficiency, and designers are incorporating techniques learned through the programs in their subsequent design work. In the case of our work with various school construction programs we have observed that the design ideas incorporated by architects, engineers, and lighting designers, are being transferred to designs for other commercial/industrial building types. In Maine, the market penetration of such technologies as Super T-8 lamp/ballast systems, T-5 High Bay industrial lighting, and premium efficiency HVAC systems has increased dramatically since the introduction of these programs.

Energy efficiency codes provide not only a baseline for designers to use as their lowest allowable performance levels, but provide efficiency program developers widely accepted baselines of acceptable practice on which to formulate program participation and incentive levels. With the current trend of developing efficiency programs in concert with energy efficiency codes, assurance is provided that rate based programs do not pay incentives for projects or measures that fall below code mandated levels, and that code and program administrators work together to advance the state of energy efficient construction.

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Australia's Path to Energy Efficiency in Commercial Buildings – Regulation, Rating Tools and Market Approaches

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Abstract

The role of government as a regulator of the building industry is well understood. Australia's national performance based building code can encourage innovation, but government can do more by promoting best practice to industry and consumers, by being innovative with its own procurement decisions, and informing the market of building energy performance.

Since 1998 the Australian Greenhouse Office (AGO) has been actively engaged in a program to incorporate minimum energy performance standards in the Building Code of Australia. This has involved working with all jurisdictions in Australia through the Australian Building Codes Board. By May 2006 it is expected that all classes of building covered by the BCA will be subject to energy performance standards.

The paper outlines the path to regulatory minimum energy performance requirements for commercial buildings, and the role of the Australian Government in promoting industry best practice in building markets through information dissemination, and use of rating tools.

The Australian Government is a major lessee in the commercial office market. Arising from the Energy White Paper in June 2004, new targets are being developed for government energy consumption, together with a suite of innovative green leases to assist individual agencies improve their energy performance. This is a case of the government as client driving innovation. All Australian Governments are also working cooperatively to explore the impact of mandatory energy performance disclosure for commercial buildings. Australia is seeking to benefit from European experience with the implementation of the directive on energy performance.

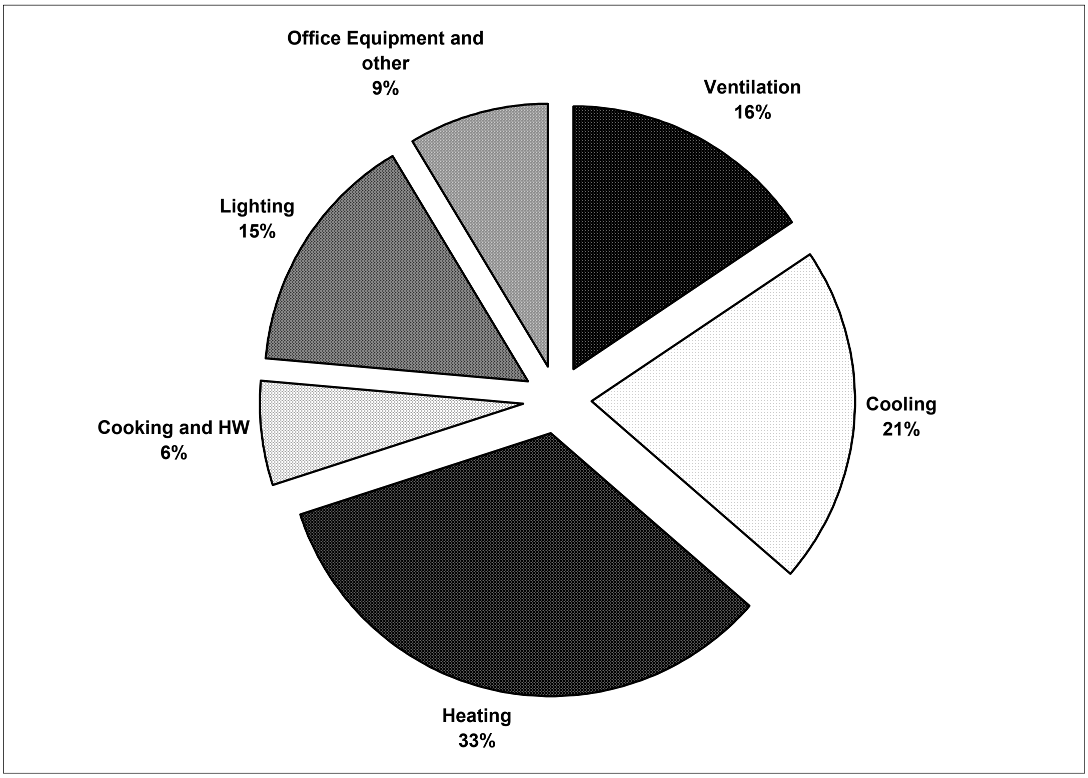
Introduction

The Australian Government has developed a comprehensive strategy to cost effectively address the energy and greenhouse impact of commercial buildings. A programme that incorporates new building standards, legal instruments, market mechanisms, and industry development opportunities to give Australian companies the technical expertise and incentives to fund, design, build and operate better performing buildings.

This paper will describe the energy and greenhouse impact of commercial buildings in Australia, point to some of the main trends in consumption, explore the key parts to the strategy and indicate the expected impact of its programme.

Energy and Greenhouse Impacts

Australian buildings have a significant impact on the natural environment, particularly the production of greenhouse gas emissions. Research conducted for the Australian Government has found that the share of greenhouse gas emissions from the building sector represents some 20 percent of the total Australian emissions and is increasing at a rate faster than almost all other energy related emissions. Findings published by the Australian Greenhouse Office established that emissions from commercial buildings are expected to double from 32 to 63 Mt between 1990 and 2010 (Australian Greenhouse Office, 1999).



Australian Greenhouse Office, 1999

Figure 1 Commercial Building Energy Use 1990

Energy use in commercial buildings varies according to building type but on average most of the energy is used to maintain thermal comfort for the occupants (see Figure 1). When greenhouse impacts are considered, space cooling becomes the highest impact at 28 percent of emissions and a key driver in their growth.

Not only is the growth in annual energy consumption of concern, but the increase in climate sensitive peak energy demand is also growing strongly, and putting a strain on the available electricity generation capacity.

Increasing demand for energy in the form of electricity due to increasing use of air conditioners is a problem identified in many nations with hot dry or hot humid climates. Australia is no exception, as air conditioner prices have fallen and comfort expectations increase, the number of businesses and households with air conditioners has dramatically increased.

Since the early 1990s the sales of air conditioners to the domestic market has tripled from less than 400,000 units in 1993 to around than 1,200,000 units in 2003 (see Figure 2). This trend is expected to continue with sales approaching 1,500,000 units in 2006.

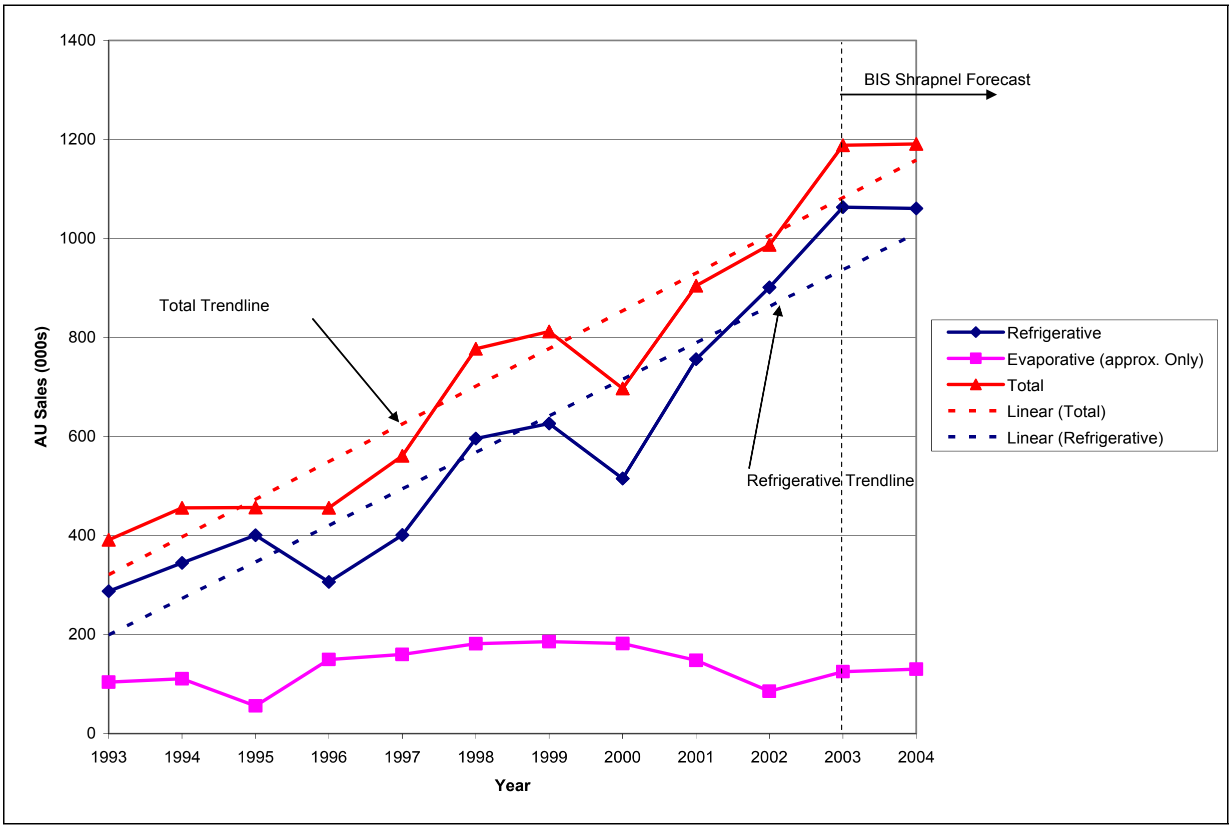


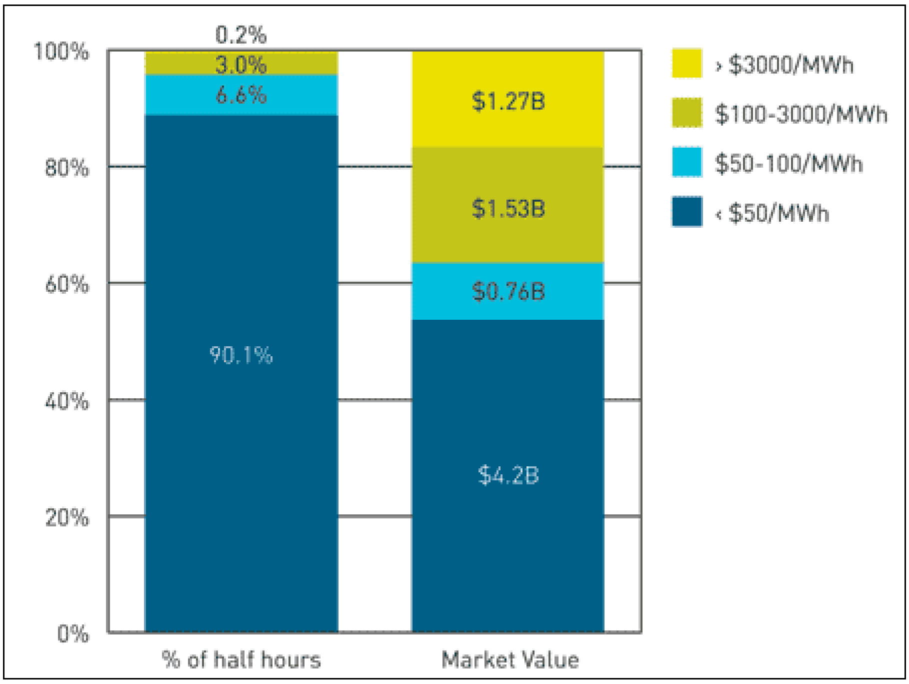
Figure 2 Product Sales, Air Conditioners, Australia

One of the key drivers for this phenomenon in Australia has been the impact of relatively poor thermal performance of buildings, linked in no small way to relatively cheap electricity and a mild climate where no major city suffers from extreme climatic conditions such as annual snow falls. In fact, Australian residential and industrial electricity prices are cheaper than those in the United Kingdom, Spain, France, Ireland, Germany, Italy and most of the European Community (Department of Industry, Tourism and Resources, 2005). As the availability of cooling technologies increased and the price has fallen, developers have become even less likely to construct buildings to naturally maintain thermal comfort during periods of higher temperatures.

In recent years, many parts of Australia have more frequently experienced periods, particularly on hot summer days, when the demand for electricity is close to or exceeds the available supply. In the past two decades electricity demand has more than doubled.

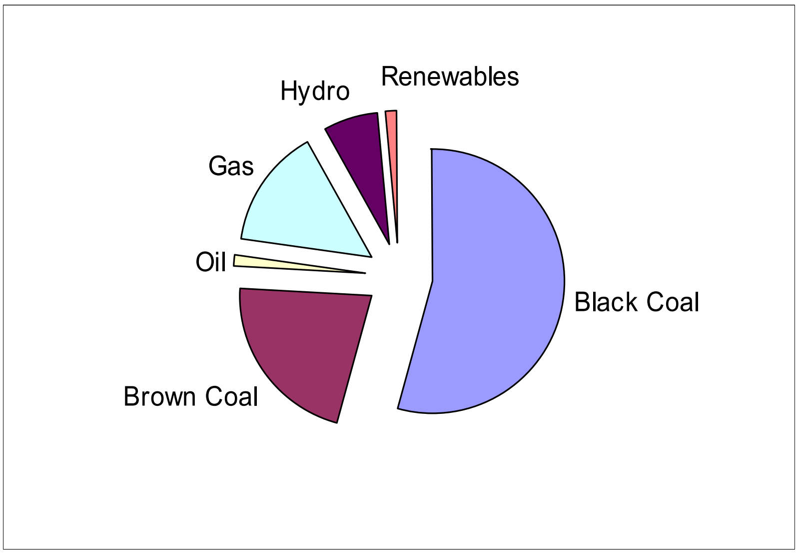
The additional demand for energy on days of summer or winter peaks is directly related to the inherent performance of a building to maintain human thermal comfort. While commercial air conditioning energy consumption and greenhouse emissions is some four times that of the residential sector, the relatively constant business load, though dependent on climate and weather extremes, means it is not as large a contributor to summer peak loads as residential buildings.

Volatile demand patterns can lead to a number of electricity market problems that tend to put upwards pressure on the wholesale cost of supplying electricity, including: (1) high spot market prices for electricity (more than 100 times the average price); (2) inefficient investment in network and generation infrastructure; and (3) network failures and supply disruptions.



Department of the Prime Minister and Cabinet, 2004
Figure 3: Value of spot market - National Electricity Market, 2002

Meeting peak load is very costly, as electricity generation and transmission infrastructure needs to be designed to cope with peaks that happen quite rarely, and the cost of electricity is increased to cover extremely high market prices that occur on those occasions when demand gets close to supply. Figure 3 shows that peaks lasting for only 3.2 per cent of the annual duration of the market accounted for 36 per cent of total spot market costs. Reducing the magnitude and costs of these peaks will reduce overall system costs.



Department of Industry, Tourism and Resources, 2005
Figure 4 Electricity Generation by Fuel 2004-05

The generation of electricity is also the single largest source of greenhouse gas emissions in Australia, with 77% electricity from coal-fired power stations, giving electricity a carbon intensity of 0.8 tonnes CO_2 per MWh (Australian Greenhouse Office, 2005). Australia 's energy needs continue to grow rapidly, with the Australian Bureau of Agricultural and Resource Economics estimating that net electricity demand will rise by around 50 per cent by 2020 (ABARE, 2003).

Growth of commercial building sector CO_2 emissions has been driven overall by economic growth increasing the need for new buildings, but also by electricity consumption growth linked to ever increasing use of air conditioning, increases in retail lighting levels, and rising standby loads.

Australian Government Policy Perspective

The Australian Government recognises climate change as a real and serious global challenge. Australia is already experiencing the impacts of climate change, although it is difficult to discern these precisely in a climate that is subject to extreme variability (Commonwealth of Australia, 2004).

In 1997, the Prime Minister, Mr John Howard in his statement "Safeguarding the Future" committed the Australian Government to a program of action to address global climate issues. An important part of Australia's commitment was the formation of the Australian Greenhouse Office as the lead Commonwealth agency on greenhouse matters.

Energy efficiency is, and will remain a central element of a cost-effective greenhouse abatement strategy, and improving our energy efficiency performance is a priority for the Australian Government (Commonwealth of Australia, 2004). The relationship between energy performance and greenhouse abatement is strong because more than 90 percent of Australia's electricity production relies on the burning of fossil fuels, namely coal, gas and oil.

Following extensive consultation with the building and construction industry, the Australian Government agreed on a dual approach of mandating energy performance requirements through existing building regulatory mechanisms, complemented by voluntary industry driven best practice initiatives, and market instruments.

Building Regulation

Building regulation in Australia, although implemented by regional governments, is collectively developed as the Building Code of Australia. Minimum energy performance standards for all new and refurbished buildings are being progressively introduced into the Building Code of Australia. In 2003 standards were established for detached housing and in 2005 for multi-unit residential buildings. All commercial building classes are scheduled to have minimum operational energy performance requirements within the Building Code of Australia by May 2006.

For commercial buildings, the Building Code of Australia will establish standards for the building fabric, lighting systems and controls, and the heating, cooling and ventilation system. The initial requirements will not be ambitious when compared with standards in some European nations, but, taking Australia's climate and the former absence of any energy requirements, provide a challenging adjustment for the building industry. A system of regular reviews will allow the standards to be upgraded in line with community expectations.

The process for establishing minimum energy performance standards for commercial buildings began in 1997 when the Australian Prime Minister gave the building industry 12 months to respond on the most appropriate route to address the greenhouse impact of buildings. The industry worked cooperatively with government to develop a comprehensive approach to the issue, including the establishment of minimum standards and funding support for complementary industry capacity building programmes.

With broad industry agreement, the Australian Greenhouse Office commissioned a scoping study to examine options for setting appropriate standards, technical options for treating particular building systems, and to recommend a programme of work to establish cost effective minimum standards. The Scoping Study was published in November 1999 and formed the basis for governmental agreement to the project.

With Governmental sign-on, the energy project was incorporated within the normal standard setting process for the Building Code of Australia. Of particular importance has been the active involvement of industry experts and representative organisations on all levels of decision making from technical working groups to the final Australian Building Codes Board decision.

Throughout the process all stakeholders have been driven by the need to demonstrate that the minimum energy performance standards are a net positive to the Australian economy. The

Regulatory Impact Statement requirement provided the final proof that the recommended standard would provide benefits to building users and to the general community.

With the addition of around 2% to the building stock each year, commercial building energy regulation is expected to deliver cumulative greenhouse abatement of about 24 Mt by 2020, and while this is important for improving the performance of new buildings, other mechanisms are needed to address the energy and greenhouse impact of the existing building stock.

Mandatory Disclosure

Markets always work more efficiently with perfect information, and the separation between design intent and eventual tenant means that the market is unlikely to be able to fully consider the value of energy efficiency in commercial building transactions. The 2004 Energy White Paper "Securing Australia's Energy Future" (Department of the Prime Minister and Cabinet, 2004) announced that the Australian Government would work with State and Territory jurisdictions to introduce legislation that required the disclosure of the energy performance of existing buildings on their sale or lease. Later in 2004 the Australian Government and the State and Territory Governments agreed on a National Framework on Energy Efficiency which reinforced the need to address the energy performance of buildings and described their commitment for the mandatory disclosure of building energy performance.

Mandatory energy performance disclosure was established for residential buildings in the Australian Capital Territories in 1999, and research recently undertaken for the Australian Greenhouse Office has found that the market is recognising the value of energy efficiency and is willing to pay a premium for better performance (Australian Greenhouse Office, 2006).

Most interesting is that the local market values the ongoing benefit of energy efficiency at a rate higher than the cost to upgrade buildings to that performance, therefore providing a real incentive for the current owners to improve the efficiency of buildings prior to sale or lease.

Research scoping the potential for mandatory energy performance disclosure has commenced and it is expected that by the second half of 2006 the Governments of Australia will have a roadmap for this initiative.

Green Leases

While mandatory minimum standards for building design provide a platform for energy efficiency, and market recognition allows tenants and owners to select buildings with the potential for lower consumption, measurable energy efficiency outcomes are more likely to be achieved if there is a binding commitment between the building owner and the tenant to monitor, manage and report ongoing operational energy performance.

The Australian Government is investigating the potential to create a green lease schedule for all new leases for Australian Government department and agency office buildings. A green lease schedule is an additional schedule to the tenancy lease document that outlines the agreed energy and environmental performance outcomes between the landlord and the tenant. The green lease schedule holds the landlord and tenant legally accountable for achieving these outcomes over the duration of the lease.

The green lease schedule will also provide scope for the inclusion of other environmentally sustainable initiatives into the lease, such as the use of renewable energy and strategies to minimize waste and water usage.

It is proposed that green lease requirements will vary according to the size and nature of the lease, with more detailed requirements where the Australian Government is a larger and more significant tenant. Existing environmental performance assessment tools such as the Australian Building Greenhouse Rating Scheme (ABGR) allows the performance ratings to be separated into the building's tenancy and base building components. It is proposed that departments and agencies negotiate office tenancies as 'gross' leases, whereby the landlord is responsible for recovering the cost of energy used by the building's central services during normal hours of operation. This gives the landlord a financial incentive to minimise energy use.

The proposed minimum green lease requirement will be that the building be fitted with lighting systems using a maximum of 10 Watts per m² and minimum metering requirements, including separate on-market status metering and sub-metering to the extent that the energy use of individual departments and agencies can be isolated from that used by the building's central services.

For larger leases where an Australian Government department or agency occupies at least 91 per cent of the tenancy, it is proposed that the green lease schedule for all new office building leases also stipulate the ongoing achievement of a minimum ABGR whole building rating of 4.5 stars (out of 6 stars) for every year of the lease; continued failure of the building to achieve this level will result in a breach of lease by the landlord. ABGR 4.5 star design performance is already required by some State governments and can be achieved cost-effectively. A number of recent Commonwealth leases have included this design requirement, with consequent demonstration effects in the wider market.

For larger leases where the Australian government department or agency occupies between 51 and 90 per cent of the tenancy, it is proposed that the green lease schedule for all new office building leases stipulate the achievement of both an ABGR tenancy rating of 4.5 stars by the tenant and an ABGR base building rating of 4.5 stars by the landlord for every year of the lease. Under these arrangements, failure to achieve specified outcomes will be handled through dispute resolution processes in the lease. Where special circumstances impede the achievement of 4.5 stars in relation to Commonwealth owned heritage and special purpose properties, it is expected that the Department of the Environment and Heritage could approve a suitable alternative ABGR rating for the property.

To assist departments and agencies, a suite of green lease schedule templates has been developed by the Department of the Environment and Heritage to accommodate offices of various sizes and percentage of occupation. An accompanying handbook is being developed in cooperation with Australian Government Solicitor and the Department of Finance and Administration to assist departments and agencies to negotiate new leases in relation to the green lease schedule.

The establishment of green lease schedules is designed to complement new Government building energy design targets expected to be introduced in 2006.

Industry Capacity Building

The Australian Government recognises that although some Australian firms are working at the cutting edge of energy efficient and green building design and construction, the majority of participants involved in the financing, design, construction and operation of a commercial building have undertaken very little formal training in addressing the environment impact of buildings, and many firms do not have the resources to research issues in detail for each new project.

To help build the capacity of the Australian industry to improve the environmental performance of commercial buildings the Australian Government has funded, jointly with the building industry, the development of a technical guide, a hub of information on both the financial benefits of building green, and how to design, build and maintain green buildings. Branded *Your Building*, this guide is expected to be the commercial building companion to the very popular "Your Home" guide to environmentally sustainable residential buildings (www.yourhome.gov.au).

The *Your Building* technical guide will provide a link between the "how to" information on designing and building green and environmental assessment using energy, greenhouse or sustainability rating tools, and will be the key reference for numerous professional development training courses.

Energy and Greenhouse Impact

In total, the Australian Government programme is expected to reduce the annual greenhouse impact of commercial buildings by about 7.2 Mt CO_2 against BAU in 2020 (Australian Greenhouse Office, 2005), with cumulative savings of around 53.0 Mt CO_2. Energy savings in 2020 are expected to be around 33.2 PJ, representing a saving of around 8.6 percent for the sector against business as usual estimates.

Conclusion

Energy consumption by the commercial building sector is large and growing faster than the overall economy. The volatile nature of climate influenced demand leads to upward pressure on energy costs and eventually poor electricity generation capacity investment decisions.

The Australian Government's commercial buildings programme has been designed to cost effectively address energy and greenhouse issues whilst encouraging innovation within the industry, building market recognition of performance, and eliminating practices that are wasteful.

The programme is expected to lead to a significant reduction in energy consumption and sectoral greenhouse gas emissions, and establish an industry with the capacity to deliver long-term improvements in building performance, and a market that recognises the value of green buildings.

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building
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Changing values: what makes the value of a building in the 21st century? Different types of values and how to determine them

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Abstract

Rational use of energy (RUE) and renewable energy sources (RES) are promoted by the European Commission and national governments. The building sector accounts for approximately one third of energy consumption in Europe and is therefore a main target to be addressed by European and national policy makers. Recent consumer interviews show, that occupants of residential buildings have little knowledge about the amount and the price of energy they consume. In office buildings, expenditures caused by energy consumption are low compared with other operational costs such as security systems, cleaning, etc. Taking these considerations into account, the question arises: is there a market for energy efficient buildings? Inhabitants of the western hemisphere spend the majority of their lifetime in buildings. In most cases the user is not interested in the technology the building is equipped with, but in high comfort and a healthy environment provided at low costs. Investors' motivation is all about risk management.

The paper outlines recent policy instruments to promote sustainable buildings, presents an overview on conventional and "green" building assessment systems (e.g. Life Cycle Assessment methods and Life Cycle Cost methods), and then focuses on the TQ building assessment system developed and applied in Austria. The paper closes with a suggestion how to merge conventional and "green" assessment methods, in order to explicitly point out the value of energy efficient buildings for investors.

1. Changing values

Inhabitants of middle and northern Europe spend about 90% of their life time in buildings. The building sector is of utmost importance both from the economic as well as from the environmental point of view. Buildings use more than one third of final energy thus also being responsible for a large proportion of carbon dioxide emissions. Further more the building sector causes a large share of material flows with their related impacts.

Europe's high dependency on energy imports as well as the Kyoto obligations to reduce carbon dioxide emissions led to the Directive on the energy performance of buildings, targeting the increase in energy efficiency of buildings regarding space heating, domestic hot water, and electricity, and targeting the utilisation of renewable energy sources under the terms of cost efficiency (Directive 2002/91/EC). However, environmentally oriented policy instruments at the EU level are not limited to energy efficiency and renewable energy sources, but also address other issues such as building materials, closed cycle economy, indoor air quality, and life cycle costs in order to progress from energy efficient buildings to sustainable buildings.

The Thematic Strategy on the Urban Environment is one of the key actions outlined in the Sixth Community Environment Action Program. Among others, it stresses the subject „sustainable construction". This main focus deals with strategies and measures how to communicate the medium and long term benefits of sustainably constructed and renovated buildings in order to make customers and financial institutions aware of the differences between traditionally and sustainably constructed buildings. The Thematic Strategy considers the Directive on the Energy Performance of Buildings to be a step towards the right direction in terms of enlarging the concept of the energy performance certificate and to include other performance aspects such as indoor air quality, barrier free access, noise, comfort, environmental impacts of building materials, and life cycle costs. To achieve this, a common method for the assessment of a building's „sustainability performance" is needed as well as a common method for calculating life cycle costs. Life cycle costs of sustainable buildings are expected to be lower and therefore sustainable buildings are expected to be more attractive for vendors and financial institutions (Thematic Strategy on the Urban Environment 2006).

The „Working Group for Sustainable Construction" was initiated by Enterprise General-Directorate and developed an agenda for sustainable construction together with representatives of the European Commission, the member states and industry (Sustainable Construction Final Report 2001). Also in this group "life cycle costs" was one of the focal points, besides „environmentally friendly building material", „energy efficiency in buildings", and „waste in construction and demolition phase". In November 2005 the Enterprise Directorate-General awarded a contract to develop a method for the standardised calculation of life cycle costs based on existing LCA and LCC methods (Invitation to Tender No ENTR/05/024). Results are expected to be available by end of 2006.

The communication of the real costs of resource use is one main focus of the implementation of the European Sustainable Development Strategy after 2005 (The 2005 Review of the EU Sustainable Development Strategy 2005). The subject „real costs", or rather external costs has been tackled by European projects since 1991. Several EU projects have been working on the investigation of external costs of energy supply to provide the basis for either avoiding those costs or allocate them correctly and call the polluters to account (ExternE project series 1991 - ongoing). External costs will arise if activities of one group cause negative impacts for another group and the polluter does not pay for the damage but the general public does (External Costs 2003). External costs are generated by a lack of regulations, market mechanisms or property rights for impacts caused by defined activities. Several EU projects have developed indicators and best practice guidelines in order to provide the ground for controlling the progress towards sustainable buildings. The example CRISP developed indicators for the global, national, regional and urban level (CRISP 2004). The results of this project were transferred to the ISO working group on „Sustainabiliy Indicators", led by the former task leader „Building" in CRISP. CRISP indicators are available in the crisp database.

All these activities and strategies highlight the importance and last but non least the great societal value of sustainable buildings.

2. Life Cycle Assessment and Life Cycle Cost methods to measure the sustainability of buildings

Life Cycle Assessment (LCA) is a well established technique for assessing the environmental aspects and potential impacts associated with a product. LCA is defined by SETAC (Consoli et al. 1993), CLM (Heijungs et al. 1992), the Nordic Guidelines on Life Cycle Assessment (Lindfors et al. 1995) and ISO 14040 (1997).

The LCA method entails compiling an inventory of relevant inputs and outputs for a clearly defined system which is defined based on the study objectives. Then the potential environmental impacts associated with those inputs and outputs are evaluated. Results are interpreted in the context of the study objectives. This means that results of different LCA studies cannot be compared among each other because system boundaries (scope of the study) and functional units (subject of comparison) might have been defined differently. Although this limitation is sometimes undesirable in practical work it is in full compliance with the ISO standard 14040 regulating only the procedure but not the details of a life cycle assessment study.

LCA studies environmental aspects and potential impacts throughout a product's life – from resource acquisition through production, use and disposal. Figure 1 illustrates schematically the simplified life cycle of a building and the resources consumed. Generally considered are the quantities and qualities of used materials, energy, and land as well as the impacts of the input and output flows on resource use, human health, ecological systems and environmental media (air, water, soil).

LCA methods can be directly applied to the building sector – building products, single buildings and groups of buildings. Annex 31 on Energy-Related Environmental Impact of Buildings analysed the application of LCA to the building sector and came to the conclusion that buildings are exceptional products and have many characteristics that complicate the application of standard LCA methods (Life Cycle Assessment Methods for Buildings 2004).

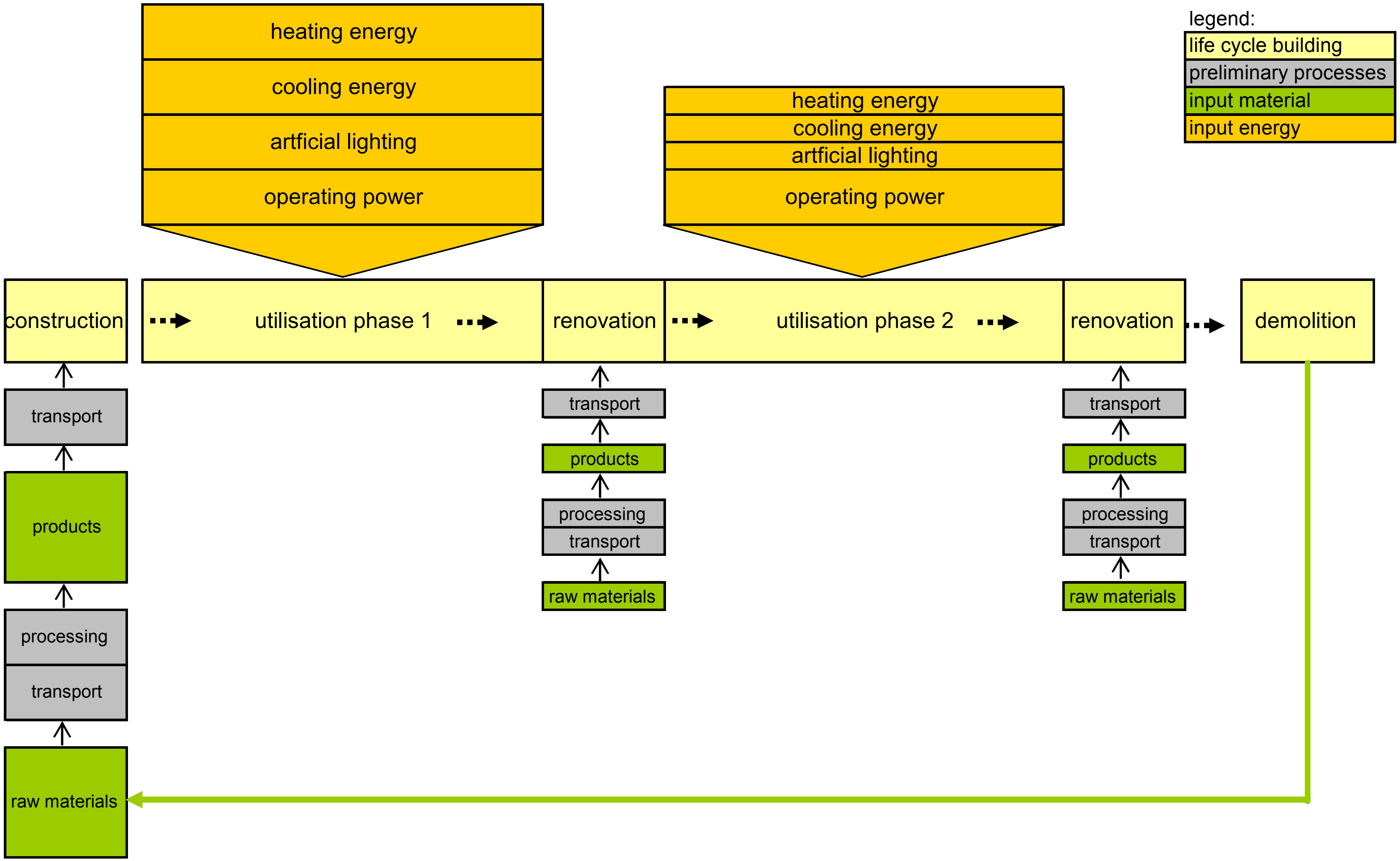
Among others, buildings are difficult to assess because the life expectancy of a building is both long and unknown, buildings are site specific and many of the impacts are local – something not normally considered in LCA, a building is highly multi-functional, which makes it difficult to choose an appropriate functional unit, buildings are closely integrated with other elements in the building environment, particularly urban infrastructure like roads, pipes, wires, green space and treatment facilities. And last but not least, a building can be regarded as an assembling product consisting of many other products (building material, building services engineering components) with their life cycle specific consequences on the environment.

The LCA method is not the only approach to analyse the impact of buildings on their environment, but it is probably the most comprehensive one. However, due to the complexity of buildings, complete life cycle assessments are hardly carried out. More often so called simplified life cycle assessment are applied focusing on specific aspects of the specific building under assessment.

Annex 31 compiled tools from 14 countries and classified them according to their methodology (Directory of Tools 2004). An excerpt is shown in table 1, demonstrating the importance of energy modeling software for data acquisition on the one hand and on the other hand the variety of rating systems, environmental guidelines, checklists, and certification and labelling systems which are used besides or in addition to LCA methods.

It is evident that life cycle assessment of buildings provide valuable data for life cycle cost assessments. Advanced tools provide support for carrying out life cycle assessment as well as life cycle cost assessment, such as legep (the former legoe tool) developed in Germany (Lützkendorf 2002).

Figure 1: Life cycle of a building and associated resource consumption (simplified scheme)



Geissler, S. (2005)

Table 1: Overview on methods for building assessment

Country	Energy Modeling Software	Environmental LCA Tool for Building or Building Product	Product Environmental Assessment Frame-work, Rating System	Environmental Guideline or Checklist for Building Design / Management	Environmental Product Declaration, Catalogue, Reference Information, Certification, Label
Finland	BUS++ [DOE]; RIUSKA [DOE]; SMOG [DOE]	LCA-HOUSE; TAKE-LCA	BSEA 1.0	ECOPROP	Environmental Classification of Properties
France	SIMBAD Building & HVAC Toolbox [DOE]	EQUER [DOE]; TEAM; ESCALE; PAPOOSE; REGENERS	Performance Guidelines for Green Buildings		
Germany	PVCad [DOE]; SolDesigner [DOE]; Sombrero 3.01 [DOE]; SUNDI [DOE]; T Sol [DOE]; THERMOSIM [DOE]	LEGOE; EcoPro 1.5			BAU Building Passport; Blue Eco Angel
Nether-lands	NEN 2916: Energy Performance of office buildings; NPR 2917: Energy Performance of office buildings–calculation program; NEN 5128: Energy Performance of housing buildings; NPR 5129: Energy Performance of housing buildings-calculation program	EcoQuantum; Eco-Instal; MMG	GreenCalc; EcoIndicator	National Packages Sustainable Building; Costing Reference Model	Dutch MRPI
Sweden	1D-HAM [DOE]; CELLAR [DOE]; DEROB-LTH [DOE]; EED [DOE]; HEAT2 [DOE]; HEAT3 [DOE]; IDA Indoor Climate and Energy [DOE]; SLAB [DOE]	EcoEffect; LCAiT	The Natural Step		
Switzer-land	ACOUSALLE [DOE]; LESO-[Tools] [DOE]	OGIP	E2000; Ökobau	Planer Kit for Controlled Ventilation systems □ SIA D0122: Ecology and buildings	Ecological Submission Document SIA 493: Declaration form for building products
United Kingdom	APACHE [DOE]; Building Energy Modeling & Simulation; ESP-r [DOE]; FLOVENT [DOE]; FLUCS [DOE]; INDUS [DOE]; LifeCYcle [DOE]; Microflo [DOE]; Pisces [DOE]; Radiance; Interface [DOE]; ShadowFX [DOE]; Solacalc [DOE] ; Suncast [DOE]; TAPS [DOE]; TAS [DOE]	ENVEST [DOE]	BREEAM; SPeAR	Environmental Management Toolkits	Environmental Profiles of Construction Materials

Directory of Tools: A Survey of LCA Tools, Assessment Frameworks, Rating Systems,Technical Guidelines, Catalogues, Checklists and Certificates. Annex 31, Canada Mortgage and Housing Corporation, 2004

3. TQ – Total Quality Building Assessment in Austria

It is the aim of TQ to provide the information necessary for designing a high performance building and to confirm the result by assessing the building in two steps: (1) prior to construction and (2) prior to handing over (Geissler, Bruck 2001; Geissler, Bruck 2004).

"Total Quality" is defined by a set of indicators that refer to the three dimensions of sustainability: society, ecology, and economy. TQ takes into account ecologically relevant aspects such as energy consumption, CO2-emissions, and water consumption; economically relevant aspects such investment costs, operational costs, life cycle costs and external costs; and socially relevant aspects such as thermal comfort in summer and winter, green spaces, and accessibility for handicapped people. TQ does not primarily aim at assessing the building after design and construction is finished, it is the main target to use the TQ system already in pre-design stage. Clients and their design team will go through the assessment criteria; it will remind them of important aspects to consider. TQ does not assess architectural quality, but technical parameters that have to be taken into account during the process of designing and constructing the building.

The TQ assessment framework follows a life cycle approach in a sense that assessment criteria take into account the impacts caused during construction and operation. In addition TQ utilises results from life cycle analyses of building materials and energy supply systems. Based on these data, total life cycle energy consumption and CO_2-emissions of buildings are assessed (building material and heating energy consumption during operation, including energy consumption for gaining the energy carriers and producing the energy supply system). In fact all the other impact categories of life cycle assessments could be assessed, too, such as ozone layer depletion and acidification, because data are available from life cycle assessments of building materials and energy supply systems. However, there is a lack of experience how to define the assessment scales for the building as a whole. Therefore these impact categories are not yet assessed.

To be widely used in practice, the system has been developed in co-operation with the target audience being construction companies, building owners, architects and engineers according to their demands:

- low effort for data collection,
- transparency,
- easy assessment and time saving assessment,
- utilisation of the assessment result as a marketing instrument.

According to their requirements,

- the assessment is based on data derived from the planning process and quality control measurements necessary during construction;
- the assessment system is a computer program based on data input which remains visible; next to the pure information being assessed, the assessment results appear;
- the assessment system contains many automatic calculation procedures that support the user and save time;
- the assessment procedure is automatically done by the programme, data filled for assessment have to be confirmed by calculations, drawings, etc., in order to allow independent experts to examine the TQ file and issue a TQ certificate.

The TQ Assessment System consists of:

- The TQ guideline pointing out which criteria are used for assessment, which data to deliver for performing the assessment procedure and how to improve design, in order to achieve the best assessment result. The guideline should accompany the design and construction process right from the start, after the decision for construction has been made.
- The TQ tool, a computer based assessment framework with an automatic assessment procedure done by the program, delivering the assessment result after all required data have been entered.

- A procedure for building certification based on the results of the TQ building assessment, in order to utilise the impartially proven building performance for marketing.

Figure 2 describes the concept TQ is based on.

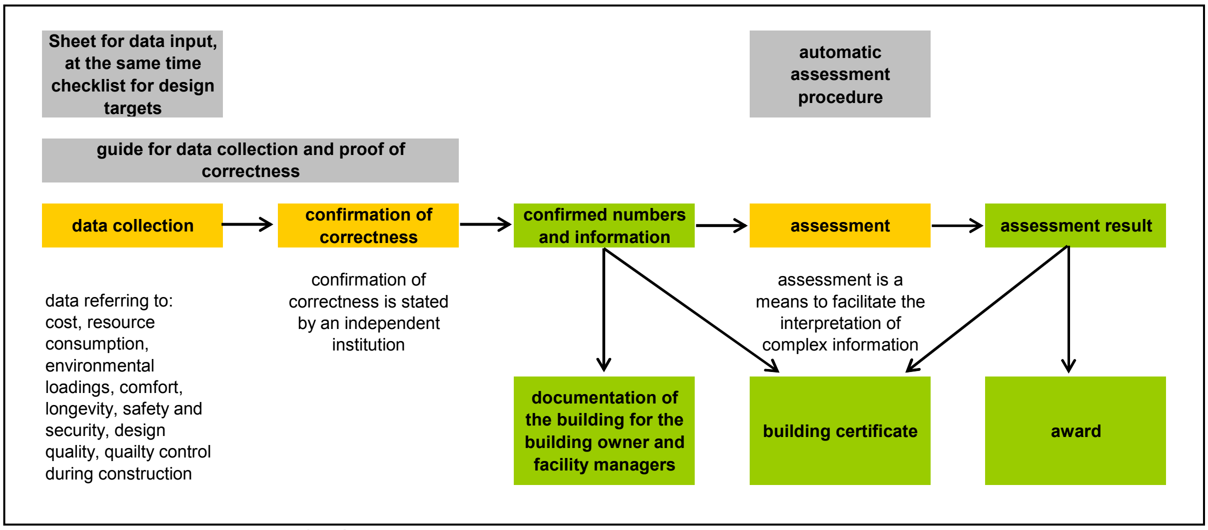


Figure 2: The concept of TQ building design and assessment

The building is assessed two times: (1) after completion of design prior to construction and (2) prior to handing over.
Geissler, S.; Bruck, M. (2004): Total Quality (TQ) design and assessments of buildings

TQ assessment criteria are organised in the following categories (detailed information see www.tq-building.org):
1. Resource Consumption
2 Harmful Impacts on Human Beings and the Environment
3 Comfort
4 Longevity
5 Safety and Security
6. Design (planning) Quality
7. Quality Control during Construction
8. Quality of Amenities and Site
9. Economic Performance

The following table presents the scores and weighted scores for a specific building on the level of criteria and categories. Sub criteria and the corresponding weighting factors (an example for "energy consumption" see table 3) are not presented here. Weighting factors are fixed, in order to allow for comparability. The abbreviation "n.a." stands for "not assessed". During design stage, category 7 is not relevant and therefore it is not assessed. Other defined criteria are optional, either because their relevance depends on local conditions or because the client might decide that the criterion is not relevant for a specific building.

Table 2: TQ categories and criteria; weighting of categories and criteria

Categories and criteria	Scores	Weighting factor	Weighted scores
1. Resource Consumption	2,49	**0,16**	**0,39**
Energy Consumption of the Building	3,25	0,30	0,98
Quality of Soil	1,33	0,20	0,27
Consumption of Potable Water	2,00	0,20	0,40
Use of Building Materials	2,83	0,30	0,85

2. Harmful Impacts on Human beings and the Environment	3,76	**0,16**	**0,59**
Airborne Emissions	5,00	0,29	1,47
Solid Waste	3,00	0,12	0,35
Waste Water	n.a.	0,00	
Individual Car Transport	4,00	0,12	0,47
Human-toxicity and Eco-toxicity of Building Materials	2,00	0,29	0,59
Avoidance of Radon	5,00	0,06	0,29
Electro Biological Installation	n.a.	0,00	
Avoidance of Mould	5,00	0,12	0,59
3. Comfort	3,18	**0,16**	**0,50**
Indoor Air Quality	4,00	0,20	0,80
Thermal Comfort	4,50	0,20	0,90
Daylight	1,00	0,15	0,15
Winter Sun	4,00	0,15	0,60
Sound Protection	3,67	0,20	0,73
Building Automation	0,00	0,10	0,00
4. Longevity	4,00	**0,13**	**0,50**
5. Safety and Security	4,00	**0,13**	**0,50**
6. Design (planning) quality (qualitative)	4,00	**0,13**	**0,50**
7. Quality control during construction	n.a.	0,00	
8. Quality of amenities and site	3,00	**0,16**	**0,47**
9. Economic performance	n.a.	0,00	

Geissler, S.; Bruck, M. (2004): Total Quality (TQ) design and assessments of buildings

Assessment scale and weighting
The TQ assessment system is based on design targets: for each criterion there is an assessment scale, consisting of 8 steps, from –2 to +5, or consisting of 6 steps, from 0 to 5. The best score is 5. Negative scores indicate a very low performance that will not allow the building to pass the assessment. In order to sum up assessment results, weighting factors are used that were derived from experts' discussions. Weighting factors are transparent but fixed, in order to assure the comparability of assessment results (see table 2).
Each step on the scale corresponds to a design target: designers and clients will go through the assessment criteria and define the design targets from the assessment scales. It will remind them of important aspects to consider and they have the chance to influence the assessment result. Whenever it is possible performance oriented targets are used, in order not to limit the design team by given measures and / or technologies but to allow them to develop the best solution under the given circumstances.

The following tables show the criteria under the category "resource consumption" (table 3) and the assessment scale (table 4) of the sub criteria "heating energy consumption" contained in the "energy criterion".

Table 3: Weighting factors of the sub criteria contained in the criterion "Energy Consumption of the Building" under the category of Resource Consumption

Categories and criteria	**Scores**	**Weighting factor**	**Weighted scores**
1. Resource Consumption		0,16	
1.1. Energy Consumption of the Building	3,25	0,30	0,98
1.1.1Primary energy consumption for building materials	5,00	0,25	1,25
1.1.2.Heating energy consumption	5,00	0,25	1,25
1.1.3.Share of renewable energy carriers to cover heating energy consumption	2,00	0,25	0,50

1.1.4 solar energy for domestic hot water	1,00	0,25	0,25

Geissler, S.; Bruck, M. (2004): Total Quality (TQ) design and assessments of buildings

Table 4: Assessment scale for the criterion "heating energy consumption"

Heating energy consumption (HWB)		**Scores (best score is 5)**
< 12,75	$kWh/m^2_{BGF},a$	5
12,75 ≤ HWB < 25,5	$kWh/m^2_{BGF},a$	4
25,5 ≤ HWB < 38,25	$kWh/m^2_{BGF},a$	3
38,25 ≤ HWB < 51	$kWh/m^2_{BGF},a$	2
51 ≤ HWB < 63,75	$kWh/m^2_{BGF},a$	1
63,75 ≤ HWB < 76,5	$kWh/m^2_{BGF},a$	0
76,5 ≤ HWB < 93,5	$kWh/m^2_{BGF},a$	-1
≥ 93,5	$kWh/m^2_{BGF},a$	-2

Area: „Beheizte Bruttogeschossfläche" according to Austrian standard "ÖN B 8110-1"
Geissler, S.; Bruck, M. (2004): Total Quality (TQ) design and assessments of buildings

TQ assessment results in the documentation of the building (about 30-40 pages) and in the building certificate (4 pages) which can be used as a marketing instrument. Figure 3 shows the front page of an exemplary TQ building certificate.

Figure 3: TQ building certificate "Orly Centre"
Bruck, M. (2003): Building Certificate Orly Centre http://www.tq-building.org/gebaeude/index.htm

4. Investors motivation

Experiences from TQ assessments carried out since 2001 indicate that TQ finds great approval as a design and quality assurance tool as well as risk management tool. Several Austrian companies, both developers and producing companies constructing their own buildings, adopted TQ as internal quality assurance tool. It is by far cheaper to invest in avoiding defects or deficiencies during design and construction than to repair after completion of construction. Furthermore TQ contains criteria taking

into account future developments such as presented in the Thematic Strategy on the Urban Environment. A sustainably constructed or renovated building bears less risk of unexpected future costs either due to lack of customers or due to investments needed to upgrade the building according to standards.
As a consequence, TQ design stage certification documents are used as a tool of risk management when it comes to financial negotiations with banks. In this respect Basel II is a driving force for the application of TQ building assessment and thus also a driving force towards sustainable buildings. However, deficits exist with regard to using the TQ certificates as marketing instruments to increase demand for sustainable buildings. Usually customers are not interested in energy and material indicators and vendors are not familiar with the meaning of the indicators. The primary interest of investors is profit and not energy efficiency, renewable energy sources, sustainable materials or other aspects summarized by the term "sustainable building". Therefore, new terms are needed to demonstrate the value of sustainable buildings and to promote sustainability aspects.

To investigate this subject, a series of workshops was initiated in the framework of KinG, the competence network for innovative building services engineering technologies (Geissler et al. 2005). A workshop held with developers and building services engineers on 22nd of January 2005 in Vienna resulted in the following requests:

- Express increase in energy efficiency and utilisation of renewable energy in terms of reduced life cycle costs
- Express increase in well-being in terms of increase in productivity for commercial buildings or added value for residential buildings

Net Present Value Method and Discounted Cashflow Method are the real estate valuation methods usually applied (Falk 2004). Both methods are based on listing the total revenue during the investment period. All gains and all expenditures related with building construction und operation have to be stated. As a consequence, methods are needed to translate "sustainability" into "profit". In fact, this request is not a new one. At the IBO Congress on Healthy Indoor Air Quality 2004 in Vienna a procedure was presented to estimate the cost effectiveness of indoor environment improvements in office work (Seppänen 2004). Figure 4 shows a simplified scheme of the connection between indoor air quality, increase in productivity due to higher user satisfaction, and the market value of the building.

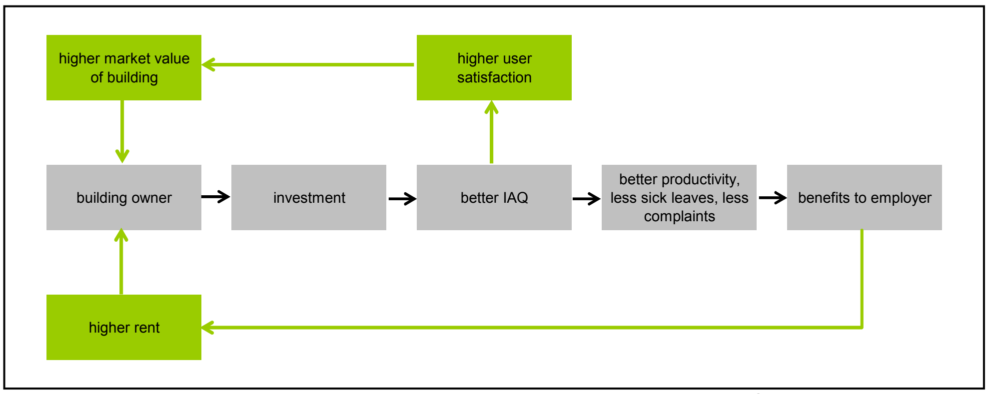


Figure 4: Better indoor air quality and higher market value of building
Seppänen, O. (2004): A Procedure to Estimate the Cost Effectiveness of Indoor Environment Improvements in Office Work

Studies on indoor air quality are very interesting for discussing the value of sustainable buildings. Sustainable buildings provide a healthy indoor environment in a cost efficient way by means of environmentally friendly technologies and materials. A proof for increased productivity (in case of commercial buildings) or wellbeing (in case of residential buildings) due to healthy indoor environment will contribute to promote sustainable buildings.

Seppänen (2004) presents linkages between high temperatures and productivity and linkages between ventilations rates and productivity. A study on indoor air quality in energy efficient buildings compiled results from empirical studies carried out in this field (Hutter et al. 2005). The analysis of studies about health effects of increases in carbon dioxide emissions showed that there is a causal connection with health effects such as headache and fatigue. Tests carried out by Wargocki et al (2000) to investigate the causal connection between carbon dioxide concentration and productivity demonstrated a significant loss with respect to the task “text typing”. With respect to indoor air pollution there are causal connections between health effects and defined chemicals, but it is difficult to describe effects of compositions as they appear in practice.

In fact, this is exactly the problem with all indoor air quality studies and the attempts to link indoor air quality with productivity (in case of commercial buildings) or wellbeing (in case of residential buildings). Independent of the utilisation, wellbeing in a building is influenced by the following aspects:

- humidity and temperature
- ventilation rate and air movements
- indoor air pollution
- natural light
- acoustics, noise
- electromagnetic fields
- visual contact with green spaces outside

Only few interactions are well known and tolerance of individuals affected might be different depending on their personal stress level. To say it with the words of a developer: troubles with colleagues or the boss might affect user satisfaction and thus productivity much more than indoor air quality. Vice versa good human relations might balance the negative effects of unsatisfactory indoor climate.

Depending on the companies’ policy, dialogue partners accept the argument that good indoor air quality reduces the risk of decrease in productivity due to reduced stress levels, a precautionary approach so to speak (see figure 5); others insist on exact numbers which cannot be provided yet.

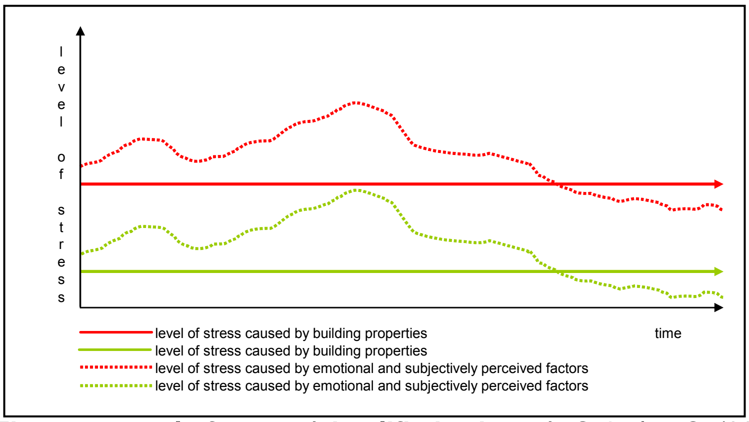


Figure 5: Level of stress (simplified scheme), Geissler, S. (2005)

5. Conclusions

Sustainable buildings provide a healthy indoor environment in a cost efficient way by means of environmentally friendly technologies and materials.

Sustainable buildings are of great value to the European economy and the general public, which is documented by recent policy instruments in this field. However, the market for sustainable buildings is still emerging, just as the methods for the valuation of "sustainability" are still under development. Therefore sustainable buildings need to be supported by regulations such as the extended building certificate described in the Thematic Strategy on the Urban Environment.

Nevertheless, work on valuation methods has to continue. Investors base their decision which objects to finance on the expert opinion of real estate surveyors. Therefore building documents resulting from LCA and LCC methods have to be condensed and made available to real estate surveyors to be taken into account in the valuation procedure.

There are three international standards for the valuation of buildings:

- The „White Book": issued by the International Valuation Standards Committee (IVSC)
- The „Red Book": issued by the Royal Institute of Chartered Surveyors (RICS)
- The „Blue Book", issued by „Europäischer Sachverständigenverband" (TEGoVA)

Standardised methods for analysing and controlling sustainability aspects are available (LCA) or will be available soon (LCC). Complex, unknown interactions with negative effects that might appear in buildings have to be avoided or rather tackled by the precautionary principle in order to reduce future risks. In short, appropriate methods are available to be integrated in property valuation and contribute to the development of sustainability valuation.

2003 TEGoVA created the Property and Market Rating (PaM) method to assess the quality of property. For example, individual modules can be used, such as the valuation of a certain location, or a complete rating for internal loan rating by banks can be carried out. Property and Market Rating is applicable to residential buildings, offices, retail properties and warehousing, distribution, and production properties.

Table 5 lists criteria and subcriteria with the respective weighting factors. Comparison of PaM subcriteria with TQ categories and criteria listed in table 2 show that there is the potential to merge both to create a groundbreaking property valuation tool.

Table 5: Valuation criteria and weighting factors of the Property and Market Rating method (PaM)

	Residential properties Weighting [%]	Offices Weighting [%]
1. Criteria Class 'Market' (national and regional)	***20***	***20***
1.1 national	*30*	
1.1.1 Acts of God	5	5
1.1.2 Socio-demographic development	30	10
1.1.3 Overall economic development and international attractiveness	15	30
1.1.4 Political, legal, taxation and monetary conditions	10	15
1.1.5 Property market	40	40
1.2 regional	*70*	
1.2.1 Acts of God	5	5
1.2.2 Socio-demographic development	35	15
1.2.3 Economic situation and attractiveness	15	35
1.2.4 Property market	45	45
2. Criteria Class 'Location'	***30***	***30***
2.1 Suitability of the micro location for the property type and target occupiers	30	25
2.2 Image of the quarter and the location	20	15
2.3 Quality of transportation infrastructure of the plot and quarter	15	25
2.4 Quality of local supply facilities of the plot and quarter for target occupiers	15	15
2.5 Acts of God	20	20
3. Criteria Class 'Property'	***20***	***20***

3.1 Architecture / type of construction	20	20
3.2 Fitout	10	10
3.3 Structural condition	15	15
3.4 Plot situation	25	25
3.5 Ecological sustainability	10	10
3.6 Profitability of the building concept	20	20
4. Criteria Class 'Quality of the property cash flow'	***30***	***30***
4.1 Tenant / occupier situation	20	20
4.2 Rental growth potential / value growth potential	30	30
4.3 Letting prospects / fungibility	20	20
4.4 Vacancy / letting situation	10	10
4.5 Recoverable and non-recoverable operating expenses	10	10
4.6 Usability by third parties and/or alternative use	10	10

Legend: Criteria (bold italics) and subcriteria (standard) with the respective weighting factors; within "1. Criteria Class 'Market'" there are national and regional subcriteria weighted 30% and 70% respectively
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"Green Buildings" – Investment Benefits

Ashak Nathwani

Norman Disney & Young

Abstract
The paper addresses the fundamental drivers for implementation of Ecologically Sustainable Development (ESD) principles associated with the built environment. It outlines the need to address the social and economic aspects, together with the environmental, by highlighting the long term impact on the occupants resulting from adoption of good engineering and architectural practices and ESD initiatives. The question of thermal comfort, absenteeism and productivity is identified as an important research area where the current compilation of historical and anecdotal evidence needs to be transformed into more tangible and meaningful means of evaluating economic benefits. The analysis needs to take into account the fact that salary and business operation represent 85% of the costs, over the life cycle of a commercial office building.
The key aspect of the paper is presentation of findings of a case study carried out of a specific building in Sydney, which has enabled quantifying items such as cost of complaints, absenteeism and other tenant related costs. These will be presented to demonstrate the economic impact. The paper discusses the economic imperatives and project delivery methods, which have a major bearing on the outcomes. Results will be presented from a unique seminar held recently in Sydney, entitled "Bridging the Gap", where building owner, occupants (tenant) and operator (facility management) perspectives and issues were workshopped.
A key challenge for the property development and building industry is to ensure energy efficiency and ecological sustainability is taken well past the design into the ongoing operation and pro-active facility management that will cater for maintenance of ongoing good indoor comfort levels, for the life of the building.
The paper concludes that community, and in particular office occupant, awareness needs to be increased to generate a commercial imperative, that in turn is supported by government initiative and encouragement in both cash and kind , is the way forward. *A practical approach, comprising an enhanced methodology, is presented as a means of evaluating all aspects of Investment Benefits for Green Initiatives.*

Introduction
Concept of Green Buildings, in the Australian context, has generated various new terms and acronyms. The most popular one is Ecologically Sustainable Development (ESD).

How is ESD defined?

The Australian Government definition is:
"Using, conserving and enhancing natural and developed resources so that ecological processes, on which life depends, are maintained and the total quality of life and life style can be continually improved"

The Property Council of Australia's version is:
"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It calls for a triple bottom line approach to business, balancing environmental, social and economic accountability"

There is little doubt that all levels of communities support the concept and acknowledge that control of greenhouse gas emissions and reduction in consumption of finite resources including energy and water are very desirable objectives. Why then the apparent polarity of views expressed in the debates on limiting greenhouse gas emissions and adoption of appropriate ESD principles? The answer, to a large extent, is economics – from macro to micro levels. There are very few decisions that are made for altruistic reasons. While community conscience can contribute significantly to setting of a particular direction, there is little doubt that the economic imperative is the key driver. However it is encouraging to observe a gradual shift where environmental benefits are gaining recognition.

The Government acknowledges this and has made it clear in various reports that economic policy and environmental policy are intrinsically related and that the proper handling of environmental issues will underline the profitability and sustainability of industries and at the same time improve the quality of life for the present and the future. The Government points out that sustainability deals with risk in the form of externalities and with opportunities in the form of efficiencies. "Companies that effectively manage their environmental and social risks and report them to investors are seen as providing more secure and profitable results for their shareholders" the Report highlights. Hence the investment community is considered a fundamental player in moving Australia towards sustainability (1)

Key Government findings in the Mays Report include:

- Sustainability behaviours add value to commercial endeavour and make for good business sense.
- Sustainability is a useful device for managing intangible assets such as brand and reputation. Benefits would cover human capital and product differentiation.
- Companies need to articulate their value-adding sustainability behaviours. Equally, Australian investors need to develop a discipline for considering sustainability principles.

It is becoming obvious that evaluations made on life cycle costing basis, taking into account economic returns based purely on cost savings due to reduction of energy or water, do not reflect the complete picture. All benefits, including intangible ones, need to be considered.

The long term impact on the occupants resulting from good engineering and architectural practices and implementation of ESD initiatives is an area that requires closer examination. The questions of thermal comfort, absenteeism and productivity are important research topics, where the current compilation of historical and anecdotal evidence needs to be transformed into more concrete and meaningful means of evaluating overall investment benefits.

This paper discusses hypothetical as well as practical aspects of these complex issues.

Background

Essentially there are two broad categories of ESD options, namely:

- Application of sound engineering and architectural practices which result in incorporation of ESD measures, through both active and passive means, within the overall project framework . These generally do not come with high cost impositions.
- Analysis of ESD features which generally have superior environmental and socio-cultural outcomes but invariably encounter economic challenges. These are often referred to as "Stretch Targets".

Both of the above involve varying degrees of ESD inputs and outcomes.

There are also technical dichotomies. For example:

- Increased glass area to provide natural lighting increases heat gains and heat losses with resultant increase in cooling and heating energy consumption.
- Total reliance on natural ventilation for commercial buildings in the warmer climates, such as experienced in Australia, generates conditions that only the most stoic of occupants would be prepared to accept.
- In the retail context, favourably displaying the merchandise by intensive lighting far outweighs any energy conservation consideration.

Introduction of various Rating Schemes in Australia has made ESD input "measurable" by nominating the required Star Rating. There are essentially two types - one which concentrates on energy (Australian Building Greenhouse Rating) and the other one, (Australian Green Building Council – Green Star), which takes into account all the aspects of ESD covering management, ecology, materials, transport, pollution, energy and water minimisation. It is worth noting that the latest Green Star Rating Tool – for Existing Buildings, which has just been released, has a **"Management Efficiency"** supplement which scores the management practices associated with base building energy management. It includes:

- Occupant Feedback
- Ventilation Rates
- Operational Energy
- Cooling Tower Water Consumption

To achieve a higher Star Rating, particularly for the Green Stars, it becomes necessary to incorporate some of the "Stretch Targets", which in most cases cannot be justified purely on energy or water savings basis.

Hence all factors with **Green Solutions** need to considered to assess the **Investment Benefits.**

INDUSTRY STATUS

In line with the OECD report 1998, the building industry has a major impact on energy and material use, as well as on human health.

Following are findings related to the built form:

- The building sector accounts for 25-40% of final energy consumption in OECD countries.

- The construction sector accounts for one third to one half of commodity flow in selected OECD countries. Consequently a great amount of construction and demolition waste is generated, particularly from demolished buildings.

- Indoor air quality (IAQ) can significantly affect human health. Indoor levels of pollutants may be 2.5 times and occasionally of up to 100 times higher than those of outdoor levels. This is significant bearing in mind that people spend as much as 90% of their time indoors.

The built form comprises a myriad of processes and inter-relationships and introduction of "green solutions" is starting to magnify some of the key issues and generating increased discussion.

For example, according to a leading Property Consultant firm in Australia, the big sleeper in the viability of additional ESD features is the establishment of links between green solutions, improved staff comfort levels, higher staff satisfaction levels and increased staff productivity.

Good green solutions start at design stage.

UK based Commission for Architecture & the Built Environment (CABE) in its recent report purports that "the impact of design, can affect workforce performance by up to 11per cent"

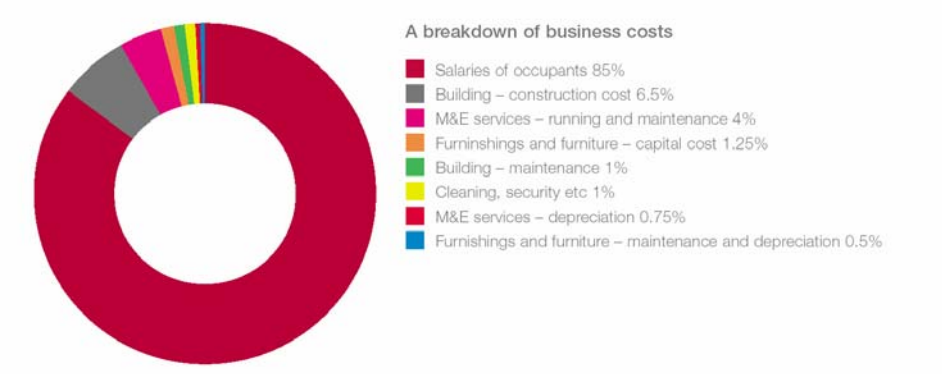
The report points to evidence that office design has an influence on a range of factors critical to business performance, like;

- customer attraction and retention
- staff attraction, motivation, satisfaction and retention
- innovation and creativity plus knowledge and skills of staff

Whilst the report provides a range of evidence showing the links between poor workplace design, lower business performance and higher level of stress experienced by employees, it can be argued that the outcomes depend very much on circumstances, which vary between organisations and buildings. Differences in productivity of 25 per cent reported between comfortable and uncomfortable staff, due to basics, such as, air quality, temperature, overall comfort, noise and lighting appear to be high. So do figures of 15 per cent reduction in absenteeism and increases of between 2.8 per cent and 20 per cent in productivity linked to good lighting design and adequate daylight. A lot more substantiation would be necessary to be able to quote such figures considering the fact that every case needs to be evaluated on its own merits.

Valuable information is contained in the report regarding a break up of various costs associated with a building. Looking at the discounted present value of developing, owning and operating a typical office building over the 25 years of a traditional occupational lease, the report claims that, excluding land, **6.5 per cent of the total goes on the construction cost**; 8.5 per cent goes on furnishing, maintaining and operating the facility; and, dramatically, the balance of **85 per cent goes on the salary costs of the occupiers**.

This is graphically depicted as follows:



It is to be noted that according to this report, these figures are based on the analysis of a real building and will vary depending upon the specification of the building, and its location, occupational density, etc.

THE THREE "O"s

There are three "O"s involved in any building over its life time, namely:

Owner – including Developer & Investor
Occupier – the Tenant, and
Operator.- Facility Manager / Building Engineer

Each group has a different financial objective and indeed responsibility to their respective stakeholders.

To understand the motivation and drivers for each of the "O"s, the author was instrumental in organising special seminars entitled *'Bridging the Gap' (between Owners, Occupiers and Operators)* that were held in Melbourne and Brisbane in April 2005 and in Sydney in May 2004. The seminars were attended by leading industry representatives, with delegates consisting of owners, real estate agents, architects, engineers, facility managers, and representatives from large commercial tenants and developers.

Each seminar posed the question.

Does improved productivity pay for better indoor environmental quality in office buildings?
The key aims of the seminar were to find out what was really happening 'on the ground', what were the opinions of those involved practically in trying to tackle this problem. How were decisions being made?, and where did they believe the answers lie.

Separate workshops were held with each of the groups with facilitators leading the discussions.

The outcomes are summarised below:

Owner Group Feedback
Outcomes fall into following categories:

Capital Investment and Rate of Return for the Investment
Cost was really the bottom line for them and a clear method of costing issues like productivity was essential in order to have an impact. Owners are essentially seeking low cost with maximum investment return

ESD Education
A common concern, which linked the owners with the tenants, was, who is responsible for the education of the intermediaries? In most cases this appears to be the real estate agents, with owners and tenants only communicating through this third party. The importance of initial education of the market, that being tenants and intermediaries such as real estate agents was necessary, as time constraints at the point of choice often prevented wise decisions.

Legislative Change
The group was strong about the need for a regulatory framework and not one that just gives 'lip service'. Clear best practice guidelines and an external driver such as legislation is needed to condense the conflicting information into a workable tool, such as the diminution of ESD features into a single line cost.

Collaboration
Many identified poor integration between base building design and the fit out that tenants occupied, and that there was a need for a stronger collaboration between the groups responsible for both, that perhaps the process needed to be more like a team effort that is employed on residential design. This team process would require a complete rethink of the way a building is developed from the initial acquiring of the land and funding to the occupation by tenants. This approach may also create better windows of opportunity to consider the productivity reality..

Occupant Group Feedback
Awareness and Education
Tenants admit they are often poorly informed and that cost is mostly driving choice. When the tenant is looking for a price the property grade matrix of premium, and A,B,C grades does not account for sensitive ESD issues. The briefs that tenants were basing their initial decisions on were revealed to be frequently inadequate, and often only consisting of basic facts such as cost, space in meters required and the air conditioning system required to meet the space specified. The information in the briefs only drew loosely from individual industry standards with little or no concern for ambient physical conditions.

Better Understanding and Tools
With regard to the issue of productivity related to the environment it appeared that most CEO's felt that this was a 'soft' issue when considering a premises for lease and therefore needed concrete evidence and firm parameters on which to base a decision. Tools that would enable evaluation of options would assist greatly.

Operator Group Feedback
Early Involvement at Design Stage
Facilities managers were concerned with what extent they were in control of the facility, and that they needed to be included into the design process from the start. It was reported that there was a general agreement that a major problem was a lack of integration between building designers and fit-out designers leading to limitations in enhancing desired interaction. It was noted that the technology of

the base building needed to be integrated with the fit out; otherwise systems would work against each other.

Physical as well as psychological Considerations
The discussion of user complaints, absenteeism and staff turnover, supported the contention that psychological control is as important as physical control in the workplace, and how the facility at large could work with individual micro-environments.

Flexibility – lack of
The facility managers voiced concern that range of building users, the hight rate of churn and the fluid nature of business culture, change rapidly in relation to the speed with which change in the facility can be effected. This mismatch requires frequent periodic reviews of the workplace. It was concluded that perhaps the processes of collecting information, the time taken, the costs involved and the measuring of the life cycle of the building over time needed to be merged into an overall holistic approach to the building design, which would need to be formulated at the building conception.

FM Capability and Training
It was acknowledged that Facility Managers will require ongoing training to cope with adoption of newer technologies and advanced operating strategies. The competitive nature of this section of the industry dictates utilisation of FM firms that offer the lowest overall price – often resulting in use of operators with minimum qualifications and experience. The challenge, as expressed by the group, was for the owners and tenants to understand the value of good FM service and offer appropriate remuneration.

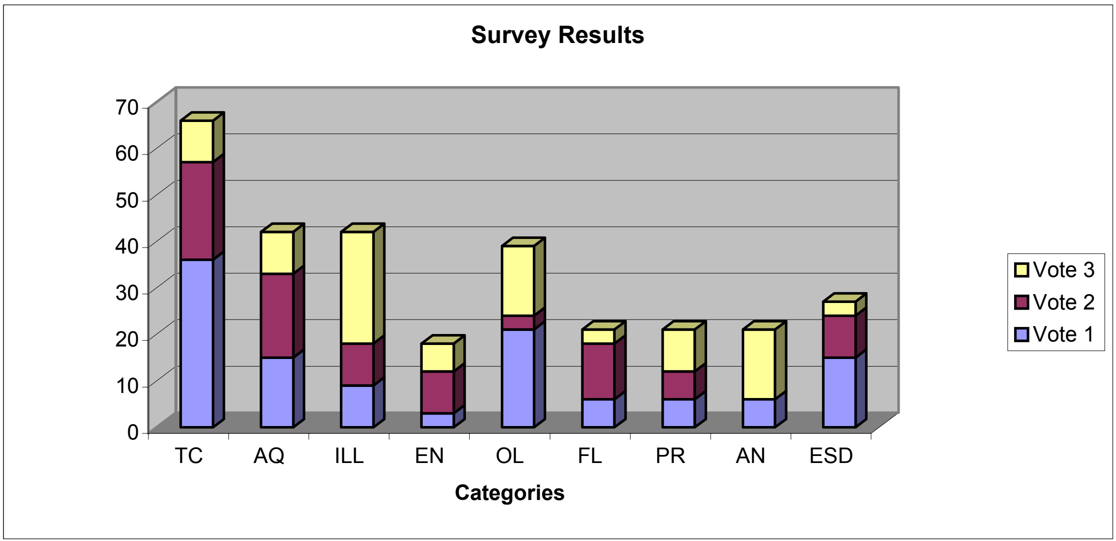
As part of ongoing research, at the end of proceedings, delegates in Sydney were asked to complete a one-page questionnaire. Feedback is presented below:

Survey
Participants were asked to rank, by numbering in descending order, the indoor environmental factors which they considered affect productivity of staff in their offices:-

- TC - thermal comfort
- AQ - indoor air quality
- ILL _ level of illumination
- EN - noise from air or lighting systems or outside the building
- OL - office layout
- FL - layout of furniture
- P - privacy
- AN - noise of conversation, office machines, etc., related to work
- ESD measures (including recyclability of materials; low water use; low energy use; use of natural materials; natural ventilation; natural light; etc)

Survey forms were completed by 117 representing 83% feedback. Votes 1, 2 & 3 were collated to provide the comparison.

Below is a summary of how participants ranked indoor factors affecting staff productivity:



Other questions within the survey form included:

1. Have you relocated your business premises in the last five years?…… yes / no
2. Was poor quality of the indoor environment a driver for the change?… yes / no
3. Do you measure churn rate?…………………………………………. yes / no
4. Do you measure absenteeism?………………………………………….. yes / no
5. Does cost of improving high quality indoor environment return value for money? yes / no

Results: (1) – y = 34%,
(2) - y = 12% of (1)
(3) – y = 42%
(4) – y = 64%
(5) - y = 48%

The feedback from the three main sectors and the survey information provided a good platform to continue analysis of some of the issues related to Owner Vs Occupier and Owner, Occupier Vs Operator

OWNER Vs OCCUPIER

Following example was presented at the above, and subsequent, seminars, as an attempt to "quantify" Owner Vs Occupier short term and long terms financial implications for a hypothetical situation and at the same time generate a debate on these complex topics.

The case presented is based on Sydney costing and takes into account the fact that there is a high correlation between indoor environment (as dictated by type and quality of air conditioning systems) and occupant satisfaction levels as outlined in research carried out in association with the University of Sydney. This has been re-confirmed in more recent tenant surveys – carried out in primarily air conditioned office buildings.

For a new 10,000 sq M building, the cost to incorporate an air conditioning system would range between $4,000,000 based on $400 / sq M, for a higher level "green" solution (eg- chilled beams), $2,500,00 for a higher quality Variable Air Volume system and $1,500,000 for a more basic system at say $150 / sq M. The key differences between systems would be the level of zoning, flexibility, quality of equipment, stability of indoor environment, maintainability and life span.

Air conditioning cost minimisation is, in most instances, a target to lower overall project capital expenditure. To achieve any saving, some compromises in the air conditioning system would be inevitable.

For this exercise if say an air conditioning system at $150 / sq M is selected as opposed to one at $250 / sq M, the **Owner Group** would achieve a significant saving of around **$1,000,000.**

Absenteeism
Bearing in mind that air conditioning is one of the two services that generates most occupant complaints in any building (other one being lifts / elevators) one needs to see what the likely consequences are.

In order to quantify the likely financial impact one needs to work out the cost per day for each occupant. For the 10,000 sq M, at 10 sq M per person, the potential occupancy of the building would be 1000. Tenant cost based on average salary of say $50,000 plus accommodation & operating cost – applying a factor (of 1.2) would be $60,000 per employee. For number of working days, allowing 4 weeks of annual leave, cost to employer per occupant = $60,000 / 240 = $250 per day at work.

It is a known fact that poor air conditioning can have an adverse effect on occupant health. Whilst it is difficult to attribute sick leave purely to inferior air conditioning system, there is evidence that there is a correlation between the two as presented in the Case Study below. It should also be noted that if adequate maintenance provisions are not incorporated, as likely with a less costly a/c system, the adverse impact on indoor environment is likely to increase over time leading to increased potential for absenteeism. Therefore, if say an average of 10% of occupants take say an average of 2 additional sick days per year as a consequence of the inferior a/c system, over the life of the building of 25 years, the cost to **Occupant Group** would amount to as much as **$1,250,000** (= 250 x100 x 2 x 25)

Tenancy Changes
Over the life of a building the occupant tenancy change rates vary considerably depending on the type of organization. With reduced flexibility in the base building air conditioning system, the Occupant Group ends up spending more in the fit-out costs, generally with addition of extra air conditioning equipment. This could be an addition of up to $80 - 120 / sq M every 5 years as discussed in Case Study below. Thus if around 25% of the Occupant Group were organizations that had a high rate of tenancy change and churn rate over the life of the building then the net extra cost to the **Occupant Group** would be an average of around **$1,000,000**

As demonstrated through this simplistic example, any cost saving decisions taken by the Owner Group, at the outset of a building project, could have long term cost implications on the Occupant Group.

OWNER, OCCUPIER Vs OPERATOR
The Operator, particularly for a high rise building with multiple tenants, has a difficult task in terms of meeting the Owner's commercial commitments versus the Occupier's demands for maintaining a safe, functional and comfortable building.

The Operator has to work within an agreed annual budget, which is developed on historical expenditure data plus planned activities involving upgrades and major maintenance works. Generally the funds are limited and hence there are always pressures to minimise the expenditure, where possible. Once again any savings would go to the Owner / Operator Group whilst likely adverse impact could result in indirect long term costs for the Occupier Group.

This equation, involving all three "O"s, gets more complex with the introduction of "Green Solutions". For example the stipulation by most State and Federal Governments in Australia for a minimum energy level as determined by a Star Rating means that the Owner is required to increase spending on regular maintenance and upgrades to achieve this on an ongoing basis. The Operator, too, is required to be more diligent and the Occupier has to do his bit by ensuring that heat generating items such as lighting and computers are turned off, when not required, as they have an impact on increased energy usage via increased base building air conditioning operation.

An important point to note is that with introduction of more "Green" initiatives the level of Operator knowledge and expertise will need to be enhanced. This will mean possible additional cost implication for the Operator Group in terms of securing more qualified Managers and Engineers This ,at this stage is not factored in the analysis of Green Initiatives as a long term cost to the building Industry.

Further amplification and elaboration of these points, with regards to some of the practical aspects, is detailed in the Case Study below

CASE STUDY

Valuable data was recently gathered as a result of a special assignment of the author, for a period of 6 months, that involved handling various engineering tasks including a **tenant facility management role**, for a major Client.

The Client is located in two high rise buildings in the heart of Sydney.

- **Building 1** – 29 levels - 6 years old – client occupancy 16 floors (approximately 1,200 sq M per floor). Air conditioning system comprises a central chilled and hot water system connected to air handling units serving multiple floors with a good modern Building Management and Control System (BMCS) The air distribution is via a variable volume system.
- **Building 2** – 30 levels - 22 years old – client occupancy 18 floors (approximately 1000 sq M per floor) Air conditioning system comprises a central chilled and hot water system connected to on-floor air handling units serving respective floors with recently upgraded Building Management and Control System (BMCS). The air distribution is via a variable volume system.

Each building has gone through various upgrades of the main central plant. The tenancy changes and churn rate was very high in each building during this period.

Regular meetings were held with the respective Owner and Operator representatives for each building to discuss various tenant related issues.

The Client organisation has a help desk arrangement whereby occupant complaints are logged and passed on to the internal engineering department for attention. Generally the advice is in the form of an email or in urgent cases via telephone. Each complaint is also entered into a Facilities Management Database System and is not archived until the task generated is completed.

Once the complaint was received by the engineering department, it was checked out by assessing whether it was as a result of non performance of tenant or owner related systems. The engineering personnel would physically check out the conditions that led to the complaint and would then take actions accordingly.

Some pertinent observations are listed below:

- A majority of complaints were related to air conditioning followed by lifts (elevators), lighting, water and other building related issues. Lifts (elevator) related complaints were advised directly to the Lift Company and hence were logged but not passed on to the Engineering Department
- In the 6 months period. the complaints ratio was in the order of **3 to 1** in favour of Building 2 (older building) compared to newer Building 1.
- The response time for minor complaints was within the hour on average.
- Many complaints **(approximately 32%)** resulted after weekend work associated with tenancy changes and churn activities.
- The level of Operator knowledge and FM "expertise" was relatively better in Building 1.
- The Operator in Building 1 utilised the BMCS to re-adjust the set points as a first measure to address the "too hot – too cold " scenarios.
- **About 28%** of the complaints in Building 1 were as a result of Tenancy modifications where zone temperature sensors had ended up in unsuitable locations.

- Tenancy modification costs, on unit area basis, were lower **by about 23%** in Building 1 as the air conditioning system has a higher degree of flexibility as opposed to Building 2. Average costs for installation of additional fan coil units averaged between $80 – 120 / sq M.

Since Building 2 had more complaints a detailed analysis with respect to levels affected, types, zones, etc was carried out and the **detailed results are included in the Appendix 1**.

Some of the findings are shown below:

Level	Zone	Number of complaints			Sub-total	
		Cold	Hot	Other		Percentage of Total
16	E	3				
	NE	8	1	1		
	S		3			
	SE		2	1		
	SW		3			
	Interior	1	1	1		
Sub-total	16	12	10	3	25	10.59%
17	NE	6	1			
	SE	3	1			
	E	3	2	1		
	NE		1			
	Interior	5				
Sub-total	17	17	5	1	23	9.75%
25	E	12	7	1		
	Interior	4	1			
	NW		1			
	NE	1	1			
Sub-total	25	17	10	1	28	11.86%
Total		138	79	19	236	

An estimation was carried out of time involved from receipt of the complaint to time taken in addressing the item. Taking into account the salaries of the various individuals involved in the process, it was estimated that **<u>Cost of Complaint</u> was $85 per complaint on average excluding rectification costs.** Based on this for the 236 complaints for Building 2 and approximately 80 complaints associated with Building 1, the 6 monthly cost to Occupant was **in the order of $27,000.** It should be noted that there was **loss of productivity,** particularly by occupants who complained, which has not been taken into account

Discussions were held with the HR Department to ascertain relationship between absenteeism in general terms and physical location of where complaints were received from A correlation was apparent between staff time off as sick days and areas from where the complaints were more frequent. Due to privacy policy, there were no individual costs requested nor provided. However a conservative figure of **$25,000** was stated as "best estimate of absenteeism resulting from areas with higher number of complaints". It needs to be pointed out that a majority of complaints were from higher levels in the Building (as shown above) where there were management personnel on relatively higher salaries. If the average salary and on costs were taken as around $90,000 the figure of $25,000 would equate to approximately **10% of those who complained taking an average of over two days of sick leave.** It must be stressed that it was not possible to gauge the cost of absenteeism, in this instance, with any more accuracy.

CONCLUSION

There is no doubt that there are investment benefits associated with green solutions. The key question is how can these be presented to decision makers so that evaluation of options can be carried out on an informed basis.
It is recognised that whilst there is anecdotal and some practical evidence supporting means of "estimating" costs associated with "intangibles" such as absenteeism, productivity gains, etc reality is that these figures will be subject to scepticism. There is reluctance by the industry in acceptance of values that cannot be justified categorically.
An innovative approach, using **Green Evaluation Matrix (GEM)** tool, has been developed, which allocates "points" for economic as well as intangible factors, such as marketing value, community benefits, risk, practicality, etc. Values ranging from 0 to 10, (relating to Low, Medium and High) are entered for each of the options. Once all the points are entered for an option, the tool automatically assigns the option to a priority category. The higher categories would be firmed up and funds would

be allocated on this priority basis. To achieve optimum results, it would be preferable to complete GEM in association with key decision makers, at an ESD workshop
An example of a recent GEM spreadsheet, used to evaluate ESD Options for a Commercial Building, together with the basis for evaluation, is included in Appendix 2.

The Overall Grouping allowed the client to prioritise the options and make informed decisions with regards to incorporation of Green Solutions.
Such initiatives are a demonstration of taking the design well past the energy / water efficiency and ecological sustainability into the ongoing operation and pro-active facility management that will cater for maintenance of ongoing good indoor comfort levels, for the life of the building.
The challenge still remains that community, and in particular office occupant, awareness needs to be increased to generate a commercial imperative, that in turn is supported by government initiative and encouragement in both cash and kind, as the appropriate way forward. We, as professionals in the industry, need to continue to be the driving force to ensure that the momentum is maintained and the overall goal is focused on all three counts namely ecological, social and economical sustainability.

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APPENDIX 1

Detailed results of the Case Study

Building 2 – over a period of 6 months – included Winter (average outdoor temperatures of 7 – 15 Degrees C) & Spring (average outdoor temperatures of 10 - 20 Degrees C)

Level	Zone	Number of complaints			Sub-total	
		Cold	Hot	Other		Percentage of Total
1	NE	7	3			
1				1		
Sub-total	1	7	3	1	11	4.66%
2	Interior	1			1	0.42%
3	Interior	1		1	2	0.85%
4	E	1				
	SW		1	1		
Sub-total	4	1	1	1	3	1.27%
5				2	2	0.85%
6	E	1	1			
	SW		1			
				1		
Sub-total	6	1	2	1	4	1.69%
7	SE	3				
7	Interior	1		1		
Sub-total	7	4		1	5	2.12%
8	Interior	1			1	0.42%
10			2		2	0.85%
11	NE	1	1			
	Interior	1	3			
Sub-total	11	2	4		6	2.54%
12	S	1				
	Interior	1				
Sub-total	12	2			2	0.85%
13	Interior	2	4		6	2.54%
14	E	3				
	NE	2				
	Interior		2			
	SE	1	1	1		
	SW	2				
Sub-total	14	8	3	1	12	5.08%
15	Interior	3			3	1.27%
16	E	3				
	NE	8	1	1		
	S		3			
	SE		2	1		
	SW		3			
	Interior	1	1	1		
Sub-total	16	12	10	3	25	10.59%
17	NE	6	1			
	SE	3	1			
	E	3	2	1		
	NE		1			
	Interior	5				
Sub-total	17	17	5	1	23	9.75%
18	NE	1	2			
	E	2	1			
	Interior	2	1			
	SW	1	1			
	W	1	1			
Sub-total	18	7	6		13	5.51%
19	E		1			
	NW	3	2			
	NE	2	1			
	SW	1	1			
	Interior		2			
Sub-total	19	6	7		13	5.51%
20	NE	2				
	Interior	2	3			
	E	5	3			
	SW	1				
	NW	1	1			
Sub-total	20	11	7		18	7.63%
21	E	2				
	Interior	2	2			
Sub-total	21	4	2		6	2.54%

Level	Zone	Number of complaints			Sub-total	
		Cold	Hot	Other		Percentage of Total
19	E		1			
	NW	3	2			
	NE	2	1			
	SW	1	1			
	Interior		2			
Sub-total	19	6	7		32	13.56%
20	NE	2				
	Interior	2	3			
	E	5	3			
	SW	1				
	NW	1	1			
Sub-total	20	11	7		38	16.10%
21	E	2				
	Interior	2	2			
Sub-total	21	4	2		27	11.44%
22	Recep	6	1			
	Conf Rm 1	1				
	Conf Rm 2	1				
	Meet Rm 1	2				
	Meet Rm 2		1			
	Meet Rm 3		1			
	Meet Rm 4	1				
	Meet Rm 5	1				
	Meet Rm 6	1				
	Meet Rm 7					
	Interior		2			
Sub-total	22	13	5		40	16.95%
23	E	1	2	1		
	N					
	NE	2	1			
Sub-total	23	3	3	1	30	12.71%
24	E	2				
	N	2	2			
Sub-total	24	4	2	0	30	12.71%
25	E	12	7	1		
	Interior	4	1			
	NW		1			
	NE	1	1			
Sub-total	25	17	10	1	53	22.46%
26	Interior	1	1			
27	S	1	1	1		
	Interior	1		1		
Sub-total	27	2		2	31	13.14%
28	NE	5	1	1		
	E	3				
	NW	1				
	Interior		1	1		
Sub-total	28	9	2	2	41	17.37%
29	N		1	1	2	0.85%
TOTAL		138	79	19		

APPENDIX 2

Excerpt from GEM - tool used to evaluate Green Initiatives for an existing building.

Green Initiatives - Building Services		GEM						
Commercial Office Buildings		Copyright - NDY						
Scheme			Financial Return	Risk	Practicality	Marketing Potential	Community Impact	Overall Priority Group
%Weight			40%	25%	10%	15%	10%	100%
BASE BUILDING CATEGORY								
Management								
Man-1	Maintenance	To encourage and recognise improved efficiency and performance of building services through adequate commissioning, monitoring and maintenance.	9	8	8	8	1	B
Man-2	Commissioning - Building Tuning	To encourage and recognise improved energy efficiency and comfort within the building in all seasons due to adequate commissioning of all system modifications.	9	8	8	4	0	B
IEQ								
IEQ-1	Ventilation Rates	To encourage and recognise buildings with provision of increased outside air rates, in order to promote a healthy indoor environment.	4	9	7	5	1	C
IEQ-2	Air Change Effectiveness	To encourage and recognise systems that provide for the effective delivery of clean air through reduced mixing with indoor pollutants in order to promote a healthy indoor environment.	6	9	7	5	3	B
IEQ-3	Carbon Dioxide Monitoring and Control	To encourage and recognise the provision of response monitoring of carbon dioxide (CO2) levels to ensure delivery of minimum outside air requirements.	9	9	7	8	5	A
IEQ-4	Daylight	To encourage and recognise buildings that provide good levels of daylight for building users.	8	9	7	10	6	A
Energy								
Ene-1	Energy Improvement	To encourage and recognise buildings that contain features that help to minimise operational energy consumption and greenhouse emissions of the base building.	10	8	7	8	6	A
Ene-4	Office Lighting Power Density	To encourage and recognise lighting design practices that lessen lighting energy consumption while maintaining appropriate lighting levels.	7	8	7	7	3	B
Ene-5	Office Lighting Zoning	To encourage and recognise base building lighting system provisions that offer greater flexibility for light switching, making it easier to light	1	2	2	2	2	E

Green Initiatives - GEM	
Guide to Scoring	
Category	Description
Score Range - Interpretation	Example
Practicality	
8-10: Relatively easy to implement	There are similar applications - technology is redily available
	Use of high efficiency lighting design to achieve minimum energy use
4-7: Has impact on other elements	Subject to architectural layout and design
	Natural light can be used subject to the availability of lightwells
1-3 : Questionable	Requires further investigations - may have newer Technology / Concept that has an untested / unproven element
	There are new means for energy storage (Phase Change Material), which have not been adequately tested in industry.
0 : Impractical	Not recommended on basis of previous experience
	Use of geothermal heat rejection is impractical where there is not adequate land available
Fianancial Return	
8 -10: Returns less than 15 years	Anticipated that life cycle evaluation would show reasonable financial returns
	High efficiency chillers
4 -7 :Returns within 15 - 25 years	Concept design and further life cycle evaluation would need to be carried out
	Displacement ventilation
1-3 : Returns within 25 - 40 years	Life cycle evaluation would not show reasonable financial returns without some external financial incentives
	Solar lighting
0 : Returns over 40 years	Not recommended on basis of previous experience
	Solar panels / Wind Turbines
Intangible Benefits	
8 -10: Good Marketing Potential	"Recognisible" marketing value - eg makes an environmental statement / potential tenent benefits
	Wind Turbines
4-7 :Average Marketing Potetial	Has flow on impact to general public and/or tenants
	CO2 monitoring
1-3 : Low marketing potential	Has some maketing value - requires "sell" strategy
	Electrical sub-metering
0 : None	No recognisible intangible benefits
Risk	
7- 10: Minimal risk	Tried and tested - acceptable history
	Chilled beams
4-7 :Some risk but manageable	Risks if not managed or implemented improperly
	Cooling Towers
1-3 : High risk	New technology - has potential to mal-function / risk to public
	Shower Towers
0 : Do not touch	Never been done before
	On site power generation using nuclear energy
Community Impact	
8 -10 Demonstrable community value	Has potential for community involvement / benefit
	Renewable energy powered "free" transport to shopping centre / park adjacent a commercial development
4-7 indirect community benefit	Use of systems that will reduce impact on community
	Reduced Night light / Reduced noise levels from external equipment
1-3 Adverse community impact	Adverse impact on general community
	Shadowing / external glare
0 : Nil impact	No impact
	Building Users ESD Guide
Priority Groups	
A	Recommended
B	Can proceed as second priority
C	Can proceed as third priority
D	Reconsider
E	Not recommended

building performance congress

Making Invisible Property Investments Attractive

Rick Wilberforce

EuroACE (the European Alliance of Companies for Energy Efficiency in Buildings)

Abstract

Recent research conducted in the UK has investigated the relationship between the level of energy efficiency of commercial buildings and their property valuation. The research concluded that, whilst there is indeed a range of economic and other benefits resulting from better energy efficiency (that apply differently for owners, occupiers, property investors, facilities managers and valuation professionals), these are still largely financially "invisible" and are unlikely to translate into a bottom-line increase in the nominal value of a building. The first part of the paper starts by presenting the fundamental nature of the problem, and then outlining why there is good reason to hope (as identified by the research). It then goes on to address the major challenges if low energy offices are to become a truly financially attractive investment alternative to standard offices.

The second part of the paper asserts that the arrival of an EU-wide system of energy certification of buildings is the key to making low energy commercial buildings marketable and thereby increasing their asset value. Certificates will make a previously invisible benefit visible. In the next three years throughout the EU, Member States will be incorporating requirements for energy certification into national building codes. Indeed, during the very month that IEECB'06 is taking place, the UK is implementing changes to its Building Regulations to make the energy certification of new commercial buildings mandatory. The presentation looks particularly at this UK development, as a timely example.

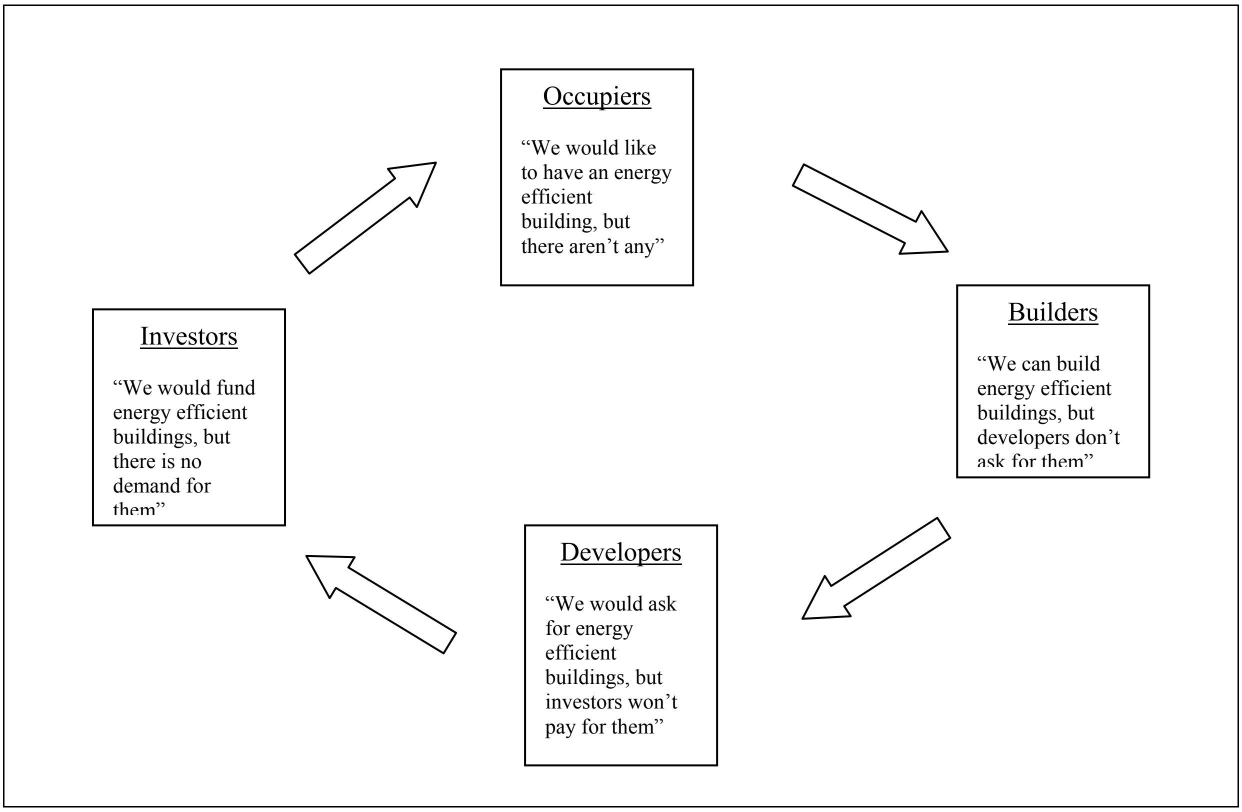
The paper then draws on the on-going monitoring work by EuroACE of activities throughout the Member States to give an audit of the status of energy certification across the EU. Conclusions are drawn about the contribution of technical measures towards improving a building's certificate rating (and hence its valuation). Examples of recently-certificated low energy buildings, and the key design features which resulted in their good performance, are shown.

Breaking the vicious circle

Although we in the "energy-efficiency" industry might regard it as obvious that a low energy office building is more desirable than a conventional building, and indeed that it is worth paying more to build or rent a low energy building, that view is not necessarily held by those whose business is to invest in commercial buildings. It is a fact that the issue of energy is invisible to most people in the commercial building investment business and that low energy buildings are not valued more than standard buildings. These were among the findings of a major investigation[1] of the views of stakeholders in the property business in the UK.

This is hardly surprising, when we consider the typical vicious circle[2] that many of us would recognise:

The vicious circle



It was not surprising therefore that the research was unable to find any publicly available data to show a difference between the valuations of low energy buildings and standard buildings, or that low energy offices provided any rental premium over standard.

However, there were a few positive signs which emerged from the interviews during the research:

1. *An increasing number of leading corporations are taking an interest in low energy buildings.* An assessment of corporate social responsibility reports of 87 of the FTSE 100 companies showed the majority have awareness of, or are actively pursuing, energy best practice in their office buildings.
2. *There is awareness of the Energy Performance of Buildings Directive, and a belief that it will increase energy literacy.* The introduction of Energy Certificates is particularly seen as a tool for demonstrating a company's corporate social responsibility.
3. *Poor energy performance is a risk to rental income.* The research showed that, although good energy performance was not regarded by owners as a means of increasing rental income, a bad building could be a risk as the tenant could use it as a lever to reduce payments. And when projecting ahead to 2020, scenario analysis showed that low energy buildings would represent a less risky investment.
4. *Drivers will come from the public sector.* Increasing government policies for "green procurement" of public sector buildings will inevitably influence specification and practice in commercial buildings.

Energy Certification – the key

It appears that Energy Certificates offer the best prospect of changing the mindset of owners and investors, and research work[3] in the UK has tested that proposition. 28 stakeholders (mainly FTSE100 companies) were surveyed to establish their response to the Certification requirements of the EPBD. Responses were encouraging, including:

1. Currently, energy efficiency is a low priority when acquiring buildings, and for 25% of those surveyed it is never considered. However, once certificates are available under the EPBD, *47% of office users and 40% of retail users are likely to seek to acquire more energy efficient buildings*; a further 32% of office users and 40% of retail users predict a marginal likelihood.

2. Certification will have a greater impact on new buildings than on existing buildings. Making the public display of certificates mandatory would add a five percentage point increase to the demand for energy efficient buildings, compared to "hidden" certificates.
3. Certification would motivate a significant number to improve energy performance. *39% of office users and 60% of retail users predicted that certification would motivate them to seek improved performance;* a further 30% predicted a marginal effect.

There is still no real direct evidence that improved energy efficiency and Energy Certification in themselves will make office buildings more financially attractive or a better investment. The main financial linkage appears to be the prospect of tenants negotiating reduced rentals if they learn that their building is a poor energy performer. Nevertheless, it is clear that Energy Certificates will be a motivator to a significant proportion of companies to improve performance; in general the drivers being reputation with institutional investors, competition between peers, raised internal awareness and any financial incentives (ie grants, loans, tax breaks) triggered by the Certificates.

Nevertheless, it must be true in a market economy that if an item becomes more attractive, it becomes more marketable and therefore it becomes more valuable. This applies even to buildings. Eventually therefore, Energy Certification will result in the energy performance of a building being reflected in its attractiveness as an investment. For energy policy-makers and for environmentalists, in one sense it doesn't matter whether Energy Certificates make energy-efficient buildings a better investment or not, so long as improvements are made. However, if energy-efficient buildings are seen by developers, investors and owners as having greater inherent value than inefficient buildings, it greatly increases the likelihood of existing buildings being improved and of new buildings being constructed to increased standards of energy efficiency. Therefore, all parties have a mutual interest in seeing the link between building performance and building value strengthened. It is my view that Energy Certification is the primary vehicle through which this can be achieved.

The importance of the EPBD

The requirement in the Energy Performance of Buildings Directive for Member States to introduce Certification of all private buildings when constructed, sold or rented, and all public buildings, is therefore extremely welcome. Less welcome is the option for Member States to delay the implementation of Certification for up to three years (ie until January 2009). However, such a delay can only be effected if the appropriate certification infrastructure does not exist, and the Member State must provide appropriate justification to the Commission for the delay, together with a timetable for its implementation. In other words, Member States will have to justify delaying implementation of Certification – it will not be an automatic right.

It is to be hoped that the Commission takes a rigorous line in examining such applications for delay. Certainly many organisations will be monitoring the progress of Member States in implementing Certification. EuroACE is one of these, and my slides show our assessment of the current state of progress at the date of this conference.

In the UK, the Building Regulations covering commercial buildings in England and Wales have just been changed this month (April 2006). To comply with the EPBD (at least partly!) these new Regulations require any new commercial building to achieve a specific whole-building CO_2 emissions rate, known as the Target Emissions Rate (TER). The CO_2 emissions are calculated using standard government software. The owner of the building must be presented with a "Building Log Book" about its efficient operation and maintenance; and the Log Book must also contain data concerning its calculated CO_2 emissions. This is an important initial step towards a system of Energy Certification in commercial buildings in the UK.

Several other Member States have Energy Certificate systems, although not necessarily mandatory. A very interesting opportunity was taken last year to apply these to the following large and complex office building; the exercise assisted in the development and application of some of these national methodologies, and enabled comparisons to be made.

A case study of certification and energy-efficiency technologies

The building assessed was the Berlaymont in Brussels. It was originally built in the 1960's to house the headquarters of the European Commission, and was occupied until 1991 when a major refurbishment started. That is now complete, and the building was reoccupied in November 2004. It comprises 240,000m^2 of floor space, on 16 levels. It is a cross-shaped building, with a central hub and four wings of different sizes radiating out. All the facades are continually curved, so that every conceivable orientation is experienced.

The refurbished Berlaymont Building, Brussels

The building has a double (or "twin skin") façade. The inner skin has floor to ceiling glazing, and the outer skin has moving glass louvres which change their position automatically depending on the position of the sun.

Certification of the Berlaymont was undertaken using methodologies from Austria, France, Germany, Netherlands, Poland and Portugal. Detailed results and comparisons have been published by the Commission[4]. All certificates gave "Good" to "Very Good" energy efficiency ratings, and concluded that it performs better than the average building in their country.

For instance, according to the report, the Berlaymont is considered to be 45% better than the average of a group of air conditioned office buildings in Germany, 41% better than the minimum requirements of Portuguese legislation, 24.2% better than a new building in the Netherlands and 7% better than a new reference building in France. Speaking as someone who has been in the building, I can assure you it is a high quality environment, and that its energy-efficiency has not been achieved at the expense of comfort.

What are the features which contribute to this good energy performance? The key is the façade; the moving louvres optimise the transmission – or rejection – of solar heat and daylight. On warm days they reduce unwanted solar gain by 89%, on cold days they let in the maximum amount of the sun's warmth. As well as an intelligent façade there is intelligent lighting; with full sunlight only about 10% of artificial lighting will be used, and infra-red sensors switch lights off after 10-15 minutes if no-one is in a room. As a result of the large areas of glazing and the intelligent lighting, there is a reduction of 44% in electricity consumption compared to "constant" usage. A gas fired cogeneration station generates electricity and heat at the same time. The air conditioning in a room is automatically shut off when a window is opened. There is also the provision to install solar panels on the roof at a later date, for hot water production.

As the louvres are separately controlled, and because the facades are curved, there can be very interesting effects with louvres being at different angles on the same façade. At least it shows the façade really is intelligent!

Detail of external louvers, Berlaymont Building

Summary

1. Currently, there is little or no value attached by investors to energy-efficiency in commercial buildings.
2. Energy Certification is the key to establishing a link between energy-efficiency and marketability.
3. It is crucial that the EPBD is rigorously enforced to ensure Member States implement Certification.
4. Technologies exist to substantially improve the energy-efficiency of commercial buildings, whilst maintaining – or even enhancing – the quality of the indoor environment.

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Energy Efficiency, Costs and Comfort in Buildings of the Service Sector – A Comprehensive Cost and Benefit Evaluation

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Abstract
When trying to find the optimal balance between winter and summer energy demand, investment costs, life cycle costs and comfort, one is faced with numerous trade-offs and interactions. This is true for both the construction of new buildings and the renovation of existing ones. These include not only the well known trade-offs between energy-efficiency and investment costs, but also between different types of energy services (e.g. cooling and lighting, winter and summer energy demand) and between energy-efficiency and (thermal) comfort. For example, building insulation and glazing may lower the heating energy demand in winter, but can increase the cooling demand and decrease thermal comfort during sunny periods. Or a more frequent use and/or more effective solar protection may reduce the cooling demand but increase the demand for lighting. A priori, it is not evident that any one of these effects clearly dominates the others. This paper is based on an extensive case study of the buildings of the Swiss service sector that aimed to estimate the marginal costs of energy-efficiency and to undertake a comprehensive cost and benefit evaluation. In this paper a special focus to office buildings is given. A bundle of measures was defined for more than a dozen building types with varying utilisation. These measures aimed to reduce energy demand and costs and to increase the occupants' level of comfort, if possible, simultaneously. The measures cover different architectural concepts, thermal insulation standards, types of glazing, internal loads, lighting technologies including lighting management, cooling technologies, free cooling, ventilation including window management systems, natural ventilation, heating systems including heat pumps and renewable energies. Building simulation software was used to estimate the impact of these measures on the buildings' energy demand structure and on thermal comfort. In order to estimate the life cycle costs of the specific investments, a survey was made of cost data from different planning and building technology companies. Results are given on the energy structure (electricity and fuel), the thermal comfort (number of hours with indoor temperature above specific limits), and the life cycle costs. From these results, guidelines are derived for building planners and building standard developers and applicants.

Introduction
It is widely accepted that buildings in most countries within the temperate zone harbour large and mostly untapped energy-efficiency potentials. Due to its relative importance in terms of energy demand, (direct) CO_2 emissions and efficiency and mitigation potentials, the residential building sector has been the focus of many studies in the fields of building physics, energy policy and economics and of activities of both the public and the private sector. Thus, the state of knowledge regarding energy efficiency potentials, cost-curves, policy barriers, direct and indirect benefits is relatively high for this sector (Jakob and Madlener 2004, Banfi et al 2005, Jakob 2006). The common denominator of these studies and (legislation) activities is that reducing heating energy demand is a key element of energy and cost efficiency (although other efficiency measures and renewable energies should not be neglected, in particular, heat pumps). This is reflected in the techno-economic progress of the last three decades (leading to lower U-values at more or less constant costs) and in the respective codes and standards of the EU (EPBD), and in many of its member states[1]. In Switzerland the Swiss

[1] E.g. Germany: "Wärmeschutzverordnung, 1995" (Thermal Insulation Ordinance), "Passivhausstandard" (Passive House Standard)

Association of Engineers and Architects (SIA) defined and revised in 1970, 1988 and 1999 their standard SIA 180 restricting specific heat loss through the building envelope and specifying thermal comfort, and in 1988 and 2001 the standard SIA 380/1, restricting specific useful energy for space heating. These standards of the (private) association SIA were by-and-by included into the cantonal legal requirements. In 1995 a more advanced standard was defined by the association “Minergie” restricting final energy for heating, ventilation and hot water. Based on this standard, a label was created that promotes energy efficiency and additional comfort of living at moderate additional costs.

In recent years, more and more attention has been addressed to the buildings of the service sector. Indeed, due to its relatively high energy demand in terms of electricity, this sector should not be neglected in any energy and climate change policy. Buildings of the service sector have often been treated in the same way as residential buildings in policy analysis and energy modelling, but they actually differ in many ways from residential buildings. In particular, electricity-based energy services are of much higher relevance in the buildings of the service sector (see, e.g. Aebischer et al. 1998, SIA 1995, SIA 2006a, prEN 13790 (2005), SN EN 12464-1). In addition, improving the energy efficiency of these buildings is a much more complex issue than is the case in residential buildings. This is due to a larger variety of building-related energy services (ventilation, cooling, lighting, heating), a more intensive use of these buildings (spatial and temporal occupation density), more extensive requirements (air velocity, indoor temperatures, light level) and more constraints (window opening restrictions, occupants such as office staff, students, patients etc. may have to remain in rooms for long periods), resulting in a larger number trade-offs when trying to find an optimal balance between winter and summer energy demand, fuel-based and electricity-based energy demand, investment and life cycle costs and (thermal) comfort. Furthermore, in many building types of the service sector, there are many interactions between the different types of energy services (see Brunner et al 2003). Hence, the results of cost-benefit analyses cannot be simply transferred fromthe residential sector to the service sector.

When targeting an optimal balance between energy demand, costs and comfort, one also has to contend with a lack of updated, systematic and comprehensive data on cost-curves and the impacts of building measures on energy demand and (thermal) comfort and, as a consequence of this, on productivity. This is true at least for the Swiss case. Indeed, the most recent empirical data and studies on cost curves date from 1992 for heating energy demand reduction measures (Basler und Hofmann, 1992) and from 1995 for electricity demand reduction measures (Aebischer et al. 1998).

Scope and methodological approach

Scope

Against the above mentioned background, the Swiss Federal Office of Energy (SFOE[2]) initiated a research project with the following main goals (Jakob et al 2006):

1. Determine the average costs and the marginal costs of energy-efficiency measures concerning the building envelope (thermal insulation and summer heat protection), heat, ventilation, cooling and lighting energy services for the most relevant building types on an up-to-date empirical basis, for both new and existing buildings.
2. Estimate the impacts and co-benefits of the above mentioned energy-efficiency measures, where possible in quantitative terms, focusing on the (thermal) comfort of building users.
3. Derive conclusions and give recommendations for the relevant actors, in particular investors, architects and planners, construction and building technology companies, techno-economic and energy economic researchers, and last, but not least, policy makers.

This paper reports and summarizes the main results of this research project. Whereas the cost data relations of the different categories might differ in other European countries, the findings on building physics can be generalized to countries with a similar climate to Switzerland, such as France (w/o south), the Benelux countries, Germany, Austria, and others.

[2] The authors wish to express their gratitude to the energy policy fundamentals research programme (EWG) of the Swiss Federal Office of Energy (SFOE), the public utilities of Zurich and Basel and the Canton of Geneva for their financial support of this research project.

Methodological approach
To reach to above mentioned goals the following methodological procedure was followed:

- Several buildings types and configuration were defined in terms architecture, construction, applied building technologies, and use. These building types served as reference cases, representing the legally prescribed building standards or the currently typical construction (for new buildings), the building standard typically found at present (prior to renovation) and the usual repair and modernization measures (existing building stock).
- For each of the building types a (different) set of consecutive energy efficiency and comfort measures was defined in order to reduce electricity and/or fuel demand and/or to increase thermal comfort (in terms of overheating). The different sets of measures were defined in order to model different strategies that increase fuel or electricity efficiency or thermal comfort or a combination of these by different means (and by a different order). With this approach it should potentially be possible to differentiate the impact of the measures according to situation in which they are applied. Indeed it can be expected that the impact of some measures depends strongly on the initial situation (for instance, the impact of solar glazing might depend on the cooling and the lighting efficiency and their control system).
- For each of the defined building types and set of measures building simulations were performed for an entire year using the IDA-ICE programme. IDA-ICE is a building simulation programme which models the building physics phenomena (heat losses/gains and storage, lighting demand, electricity demand for cooling, air ventilation) for each (dynamic) time step as a function of the technical characteristics of the building components, the time schedules of users and building technologies, and the meteorological data.
- Cost figures in terms of unitary costs (per m^2, per kW, per m^3/h, etc.) for the above mentioned measures were obtained from engineering, planning and construction companies through specific surveys (spring/summer 2005). The building elements and technologies covered different levels of energy efficiency and sizes, power etc. to cover small and large buildings (economy of scale).
- The results from building simulations and from the cost survey were then combined to estimate the marginal and average costs of the energy efficiency measures. For the latter the above defined reference cases were used as a starting-point. Furthermore the total annual costs (life cycle costs including capital costs, and O&M, and energy costs) were estimated and assessed as a function of the energy demand and of the thermal comfort conditions of each state.

The scope of measures included construction and renovation measures and technologies in the area of windows, glazing, thermal insulation, lighting, ventilation, cooling, solar protection, control and regulation, fossil and renewable heat generation including heat pumps. Different levels of energy efficiency were considered, e.g. different values for thermal transmittance (U-value), solar heat gain coefficient (SHGC) and light transmittance (T_v), lighting of varying efficiency and different types of lighting control, “traditional” and hybrid heat exchangers (mixed dry and evaporative cooling towers), small air conditioning systems, supply air cooling, chilled ceilings, and chillers. The measures were then analysed in terms of their impact on the electricity and heat (fuel) energy demand of the buildings and on the thermal comfort. Note that in addition to the above mentioned measures two levels of internal thermal load resulting from appliances and persons serving as a parameter (and not as a variable) were defined (see Table 1). In particular, capital costs of appliances (of different efficiency levels) were not considered. However, electricity costs of appliances were included. High internal loads regarding persons and appliances are the buildings depicted with BN11, BN12, BN22, BB41, BB42, and BB1 (see e.g. Figure 1) whereas the others are with low internal loads. The internal load of lighting varies within a certain building type, depending on the set of measures defined (see Jakob et al. 2006 for further details on the methodological approach.

Table 1 Definition of building types: Internal load considered

	Internal load		full load hours	Resulting internal load (Wh/m^2d)	
	low	high		low	high
Persons	16 m^2/P (5 W/m^2)	10 m^2/P (8 W/m^2)	6 h/d	23	42
Appliances	5 W/m^2	15 W/m^2	5 h/d	40	120

Sources: SWKI 1995, Jakob et al 2006

Thermal comfort
The well-being of building occupants and the comfort conditions of buildings comprehend many dimensions, such as availability of daylight, quality of lighting, indoor air quality (relative humidity, concentration of CO_2 and pollutants), air velocities, and thermal conditions such as air and surface (radiant) temperatures. Many of these dimensions are well covered by research and conclusions and recommendations are available or even implemented in codes and standards, in particular for the cold season (e.g. required air exchange rates, minimal indoor temperature, and cold surfaces). For instance, due to insulation measures thermal comfort is improved during the heating period (because of higher surface temperature, see e.g. Fanger 1972, Charles 2003).

To make a long story short we assume that architects, planners and engineers have a good command of handling thermal comfort requirements during the cold season, last but not least due to the long tradition of heating buildings (although inadequate building configuration still might occur, in particular in relation with highly glazed buildings). However, thermal comfort in terms of overheating has often been neglected. Building users (in Switzerland) have been (and still are) quite tolerant regarding several days or weeks of overheated rooms during the summer period, but some trends might cause reconsideration. Increasing internal and external heat loads due to higher occupation density of persons and appliances, high glazing proportions, and an increasingly warmer climate (see Brunner et al, 2006, Frank 2005) might increase thermal discomfort considerably. Moreover expectations regarding comfortable conditions in buildings (in particular in the working environment) increase parallel to the diffusion of cooled trains, cars, and public space (shopping centres, cinemas).

Thus, in our quantitative analysis we focus in the following on the thermal comfort in terms of overheating. The level of thermal comfort (or discomfort) can be characterised by different quantitative measures (e.g. the number of hours with a PPD-value or an indoor temperature exceeding a certain threshold, e.g. 10% or 26°C, respectively, or the 90% or 95%-percentile of the PPD-value or of the indoor temperature). In Jakob et al 2006 we compared some of such measures. A percentile measure bares some advantages, but we follow the current (2005) revision of the Swiss calculation norm SIA 382/1 (SN EN13779), where thermal discomfort in terms overheating is characterized by the number of hours where the indoor temperature exceeds the so-called applicable upper temperature limit during the building occupation periods (see SIA 2006b). The applicable daily temperature limit depends on the daily outdoor temperature maximum, see Table 2. According SIA 2006b the T-limit should not be exceeded in less than 200 hours per year, if possible in less than 100 hours.

Table 2 Indoor temperature limit as a function of daily outdoor temperature maximum

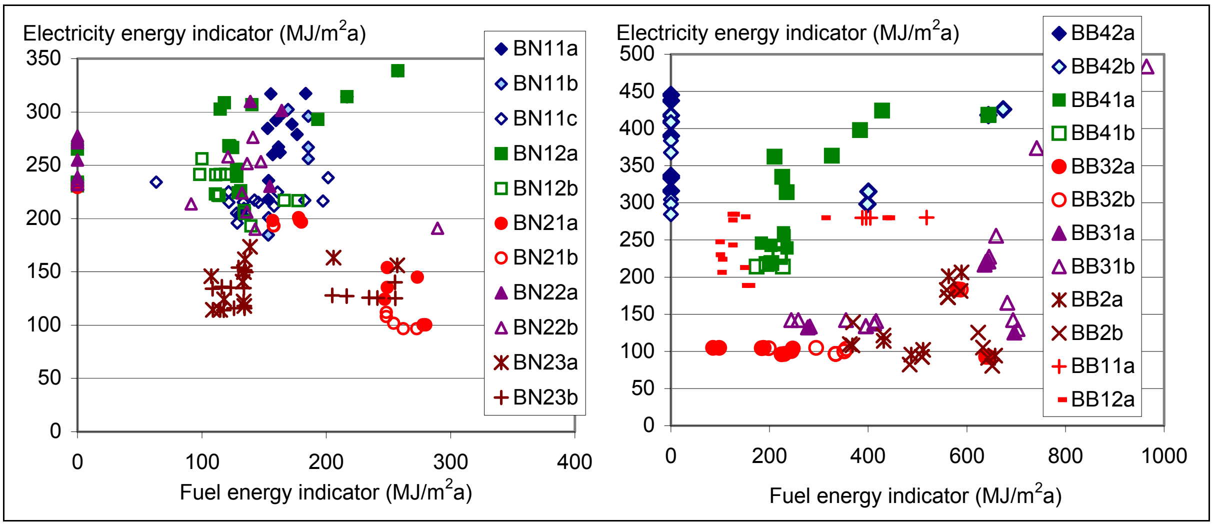
	Daily outdoor temperature maximum		
	<16.5°C	>16.5°C, <24.5°	>24.5°C
Indoor temperature limit	24.5°C	Linearly interpolated between 24.5°C and 26.5°C	26.5°C

Source: SIA 2006b

Electricity and fuel energy demand

Building types and their sets of measures
According to the simulation results the heating energy indicator varies between about 100 and 300 MJ/m^2a for new buildings and between 100 and almost 1000 MJ/m^2a in existing ones. The electricity indicator varies between 100 and 350 MJ/m^2a and between 80 and 450 MJ/m^2a for new and existing buildings respectively. The break down of electricity indicator is as follows: internal loads (appliances) typically lie between 40 and 120 MJ_{el}/m^2a, lighting between 40 and 100 MJ_{el}/m^2a in new buildings and up to 170 MJ_{el}/m^2a in existing ones, ventilation between 15 and 45 MJ_{el}/m^2a in new buildings and more than 150 MJ_{el}/m^2a (in existing buildings), and cooling between 10 and 110 MJ_{el}/m^2a. The influence of the building's users, extensive dehumidification or mediocre installations may have adverse effects on the cooling electricity indicator.

Figure 1 shows the simulation results regarding the energy demand for each set of measures of the different building types, where energy demand is given as an indicator (energy per m^2 and per year, MJ/m^2a). The different building types considered are distinguished by the codes BN11a to BB12a, where the letter “a” depicts generally the cases with no controlled window opening (CWS) whereas the letter “b” depicts those with CWS. We distinguish between electricity and heating energy demand. Unless otherwise specified we use the terms heating energy demand and fuel energy demand as synonyms on the level of final energy (fuel energy could also mean fossil fuels, wood, district heating). Depending on the strategy followed in each set of measures, the electricity indicator increases, remains more or less constant or decreases as a function of a decreasing fuel energy indicator. Some strategies lead to a slight increase of the electricity demand when reducing the heating demand, in particular for buildings which are already efficient in terms of electricity demand. But the results also show that it is feasible to significantly reduce both electricity and heating demand simultaneously.



Source Jakob et al. 2006

Figure 1 Electricity demand as a function of heating energy demand for new buildings (left hand figure) and for existing buildings (right hand figure). The codes BN11a to BB12a depict the different building types considered.

Heating energy (fuel) demand can be reduced typically by 100 to 200 MJ/m^{2}a in the case of new buildings and by 500 MJ/m^{2}a or even more in the case of existing ones, by means of building envelope measures, heat recovery and increased energy efficiency of HVAC-systems. Fossil fuels or other final (fuel) energy sources are decreased accordingly. Using heat pumps to cover heating energy demand allows a complete substitution of fossil energies.

Gross electricity demand can be reduced typically by 50 to 150 MJ/m^{2}a in the case of new buildings and by up to 250 MJ/m^{2}a in the case of existing ones, by applying electricity efficiency measures. If heat demand reduction measures are implemented simultaneously, the achievable net electricity reduction is smaller (typically 30 to 100 MJ/m^{2}a) since some heat demand reduction measures use electricity as an input (e.g. ventilation systems with heat recovery) or reduce the internal heat load (e.g. lighting efficiency measures). If heat pumps are used to displace fuel energy, the result could even be a net increase of electricity demand.

Individual measures

In this subchapter we will have a closer look on each type of measure regarding their impact on the electricity and on the heating energy demand. In Figure 2 an according presentation of the simulation results is given. Note that some of the measures of a certain type can be cumulated (e.g. increasing insulation more and more). Further details and explanations can be found in Jakob et al. 2006.

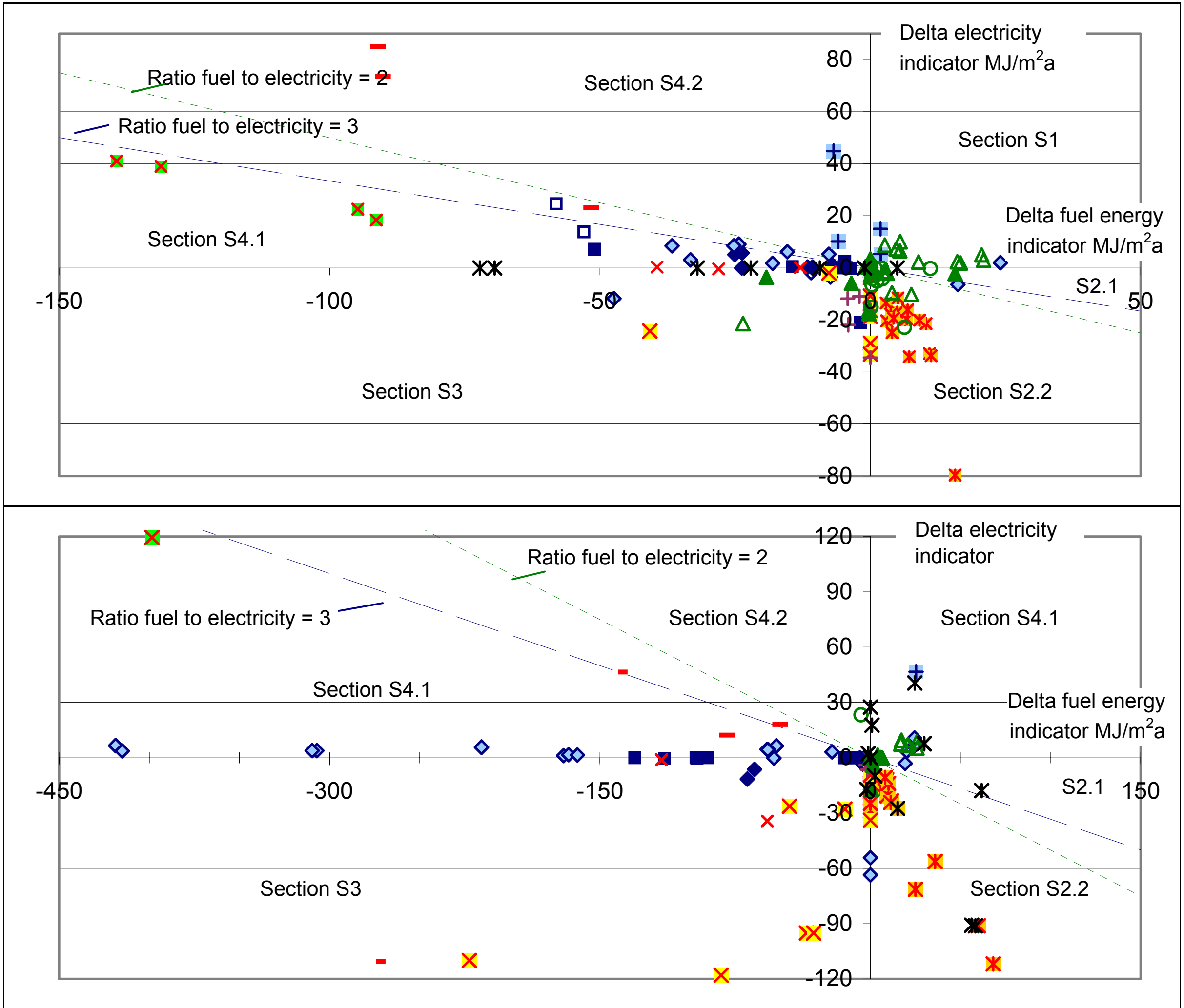
Thermal insulation of the building envelop reduces the heating energy demand substantially, especially if applied to a previously non-insulated building. Depending on the ratio façade area to conditioned floor area, an insulation of (the opaque part of) the façade reduces the heating energy indicator by up to 150 MJ/m^{2}a (assuming an U-value reduction from about 1 W/m^{2}K to current insulation standards of 0.3 W/m^{2}K) and replacing windows or façades with formerly uncoated glazing

by elements of up to date quality enables a reduction of the heating energy demand by up 400 MJ/m^2a (Ug from 3.0 to typically 1.1 W/m^2K), resulting in a relative reduction of 40% to 70%. In the case of new buildings there is also an energy efficiency potential that can be tapped by adopting standards beyond the legally required ones. This potential amounts typically up to 50 MJ/m^2a.
High energy efficiency potentials on both the heat and power side could be realized by modernizing ventilation systems in the building stock. Measures include the implementation of heat recovery devices with high thermal efficiency, the adjustment of the air exchange rates to the minimal hygienic requirements (30 m^3/h per person), and demand oriented operation schemes. The same principles are valid for new buildings. Depending on the reference case fuel energy demand can be reduced by 40 MJ/m^2a (new buildings) up to 600 MJ/m^2a (no heat recovery in the reference case, not shown in Figure 2). Furthermore the electricity demand for air ventilation can also be reduced by using more efficient fans, especially in the part-load operational range. As a result the electricity indicator is reduced by 30 MJ/m^2a (new buildings, reference thermal efficiency 65%) to 120 MJ/m^2a.

The installation of (new) mechanical ventilation systems with the sole aim of reducing the heating energy demand - should be viewed critically since the air exchange (of ventilation systems) is usually greater than in the case of (manual) ventilation using windows (even if air exchange rates of mechanical ventilations is adjusted to the minimal hygienic requirements). Hence, the net achievable efficiency gain is not as high as the nominal efficiency of the heat recovery system, but is only approx. half to two thirds of this (typically 50 to 100 MJ_{fuel}/m^2a). However, ventilation systems improve the indoor air quality and may also improve thermal comfort, i.e. they have an additional benefit besides reducing heating energy demand (as a matter of fact assuring indoor air quality should be viewed as the primary benefit of a ventilation system). In any case, care should be taken to have highly efficient fans and to keep pressure drops as low as possible (electricity demand for air ventilation = pressure loss * air volume flow rate * operating time / average fan efficiency).

The electricity demand for lighting can be reduced considerably: in new buildings by 15 – 40 MJ/m^2a with individual measures and up to 80 MJ/m^2a cumulatively, as compared to common practice, and in existing buildings by 20– 60 MJ/m^2a by individual measures and up to 120 MJ/m^2a cumulatively. These reductions of 50 % or more are possible thanks to reduced installed power per m^2 and lighting control. Indeed more efficient luminaries, lamps and ballasts, demand-tailored designs and appropriate planning allow for a power reduction from 15 – 18 W/m^2 to 9 to 12 W/m^2 and occupancy and daylight control allow for a reduction of the full load hours of 350 to more than 1000 h/a, strongly depending on the situation (office space orientation, glazing proportion, glazing and solar protection properties) and on the reference case (whether users are energy-efficient or not w/o lighting control).

On the level of useful energy (as demand before generation by heating or cooling system), cooling the building (100 to 250 MJ_{th}/m^2a) can have a comparable value to heating the building (150 to 250 MJ_{th}/m^2a for new buildings or reasonably well insulated existing buildings), see also Gasser and Kegel 2005. This applies in particular to buildings with high glazing proportions and high internal heat loads. Reducing the cooling demand and highly efficient cooling systems therefore have priority here. Measures include highly efficient cold supply and distribution (i.e. the lowest possible temperature difference between distribution and recooling, use of wet or hybrid cooling towers), exploitation of the "free cold" of the outside air (the lower outdoor temperatures compared to the temperatures inside the building). The cooling energy indicator can typically be reduced by a factor of 2 by doubling the annual COP, starting from a typical value of 2.5 (note that the annual COP could be raised to more than 20 (twenty, sic!), all auxiliary devices included, as showed by Ernst Basler und Partner 2005 and by Gasser and Kegel 2005). Combined with demand reducing measures such as adequate set point temperatures (25°C instead of 23°C) and solar protection, the cooling energy indicator is reduced from 100 MJ_{el}/m^2a to 30 MJ_{el}/m^2a or even below (with free cooling through controlled window opening) even in buildings with high internal load and high glazing proportions. Further measures include demand-oriented control/regulation, conservative dehumidification, and others.



■ m01 Thermal insulation wall (decreasing U-value)
◆ m02 Thermal insulation of windows (Ug decreasing or constant and SHGC constant or increasing)
◇ m03 Thermal insulation of windows (Ug decreasing or constant and SHGC decreasing)
◇ m04 Solar gain window or glazing (SHGC increasing, U-value constant or eventually slightly increasing)
m05 Lighting energy efficiency measures of various types
× m07 Increasing thermal efficiency of heat recovery
m08 Increasing electrical efficiency of ventilation and/or cooling
\+ m09 Less cooling
\+ m10 More cooling
△ m11 Increased solar protection (lower SHGC, controlled use, lower threshold)
▲ m12 Decreased solar protection (increased SHGC, higher threshold)
○ m13 More free-cooling through windows
● m14 Less free-cooling through windows
m15 Heat generation: higher share of heat-pumps
\- m16 Additional ventilation combined with heat-pumps
— m17 Additional ventilation with heat recovery
□ m18 Architectural measure: lower glazing share
m99 Combination of several measures

Source Jakob et al. 2006

Figure 2 **Electricity demand change as a function of the heating energy demand change for new buildings (upper figure) and for existing buildings (figure below).**

If the supply air was already being cooled prior to the reinvestment (and perhaps dehumidified), then a further efficiency potential can be exploited by reducing the air exchange rate when modernizing ventilation systems. The air exchange rates in the stock of installations are usually clearly above the air hygiene requirements (typically by two to three times as much) and reducing the air exchange rates also reduces the cooling energy demand in parallel The electricity demand of supply air cooling can be reduced from the values observed of over 50 MJ/m²a to 10 - 20 MJ/m²a.

Solar protection lies at the intersection between cooling energy and lighting demand and also influences heating energy demand. This is true for both static solar protection via glazing with lower SHGC and for dynamic solar protection (net curtains, blinds, shutters). The impact of solar protection measures on electricity largely depends on the building configuration considered: in cases without cooling or limited or very efficient cooling increased solar protection such as lower SHGC or lower set points increases the net electricity demand by 10 to 15 MJ/m^{2}a due to increased lighting demand (except of course in the cases where light is on during the whole occupation time). In contrast, net electricity is reduced in the case of buildings with noticeable cooling load, typically by 10 to 20 MJ/m^{2}a, in some cases by up to 60 MJ/m^{2}a. In these cases the effect on the cooling energy demand exceeds the one on lighting demand. Furthermore enhanced solar protection or glazing with lower SHGC increase the heating energy demand typically by 10 to 30 MJ/m^{2}a (unless set point criteria would be dynamic throughout the year).

Trade-off between electricity and fuel demand reduction
The case of solar protection with its impact both on electricity and heating energy demand that furthermore depend on the building configuration leads us to analyse more closely the impact of each individual measure on the electricity and on the fuel energy indicator (note that fuel energy could also mean district heating). From a primary energy point of view we distinguish between the following cases that are distinguished in Figure 2 by different sections, defined by the x- and y-axes and by the substitution ratio between fuel and electricity.

- Both electricity and fuel energy demand are increased simultaneously (section 1 in Figure 2, the least desirable section from an energy point of view)
- Both electricity and fuel demand are reduced simultaneously (section 3, the most desirable section from an energy point of view)
- Either electricity demand is increased while fuel energy demand is decreased or vice versa (sections S2.1, S2.2, S4.1, S4.2): measures in this section improve the overall efficiency of the energy economy (i.e. they reduce the primary energy requirement) if and only if the substitution ratio between fuel and electricity is above a certain threshold (i.e. if the measures are below the lines that depict this threshold, i.e. those in sections S2.2 or S4.1). The threshold is given by the inverse of the primary to final energy conversion factor of electricity generation and transportation.

At present, this factor is typically 3 in many European countries. Depending of the future renewal of the electricity generation park, this factor could decrease to 2 or even below, for instance if efficient combined cycle technologies are applied. Regarding the different sections we can we can present the following results for each type of measures:

- Many of the measures are on or close the x- or the y-axe (referring to Figure 2), i.e. either electricity or fuel energy is reduced. These are those with few interaction effects and either electricity or heat demand is reduced, as planned. Typical examples for measures on the x-axe are wall insulations. To a certain extent, also window insulations are on the x-axe (orientation north, strongly shaded, SHGC is not or, in relation to the U_g reduction, only marginally reduced). Measures on the y-axe are such that increase the electrical efficiency of HVAC-systems (e.g. reduction of pressure losses, low temperature differences, highly efficient fans, and others).
- Measures in section S3 imply a positive interaction effect (both electricity and fuel demand are reduced). Typical examples are a separation of the services cooling and ventilation, variable and user oriented operation schemes (adjusted air exchange rates, eventually based on occupancy, i.e. on CO_2-concentration). Further, some glazing types or increased solar protection (lower SHGC, controlled use, lower threshold) might be in S3, depending on the case: in highly glazed buildings with a moderate yearly cooling COP and high internal load glazing with lower U-value and lower SHGC might have a positive impact on both electricity and heat (fuel) demand.

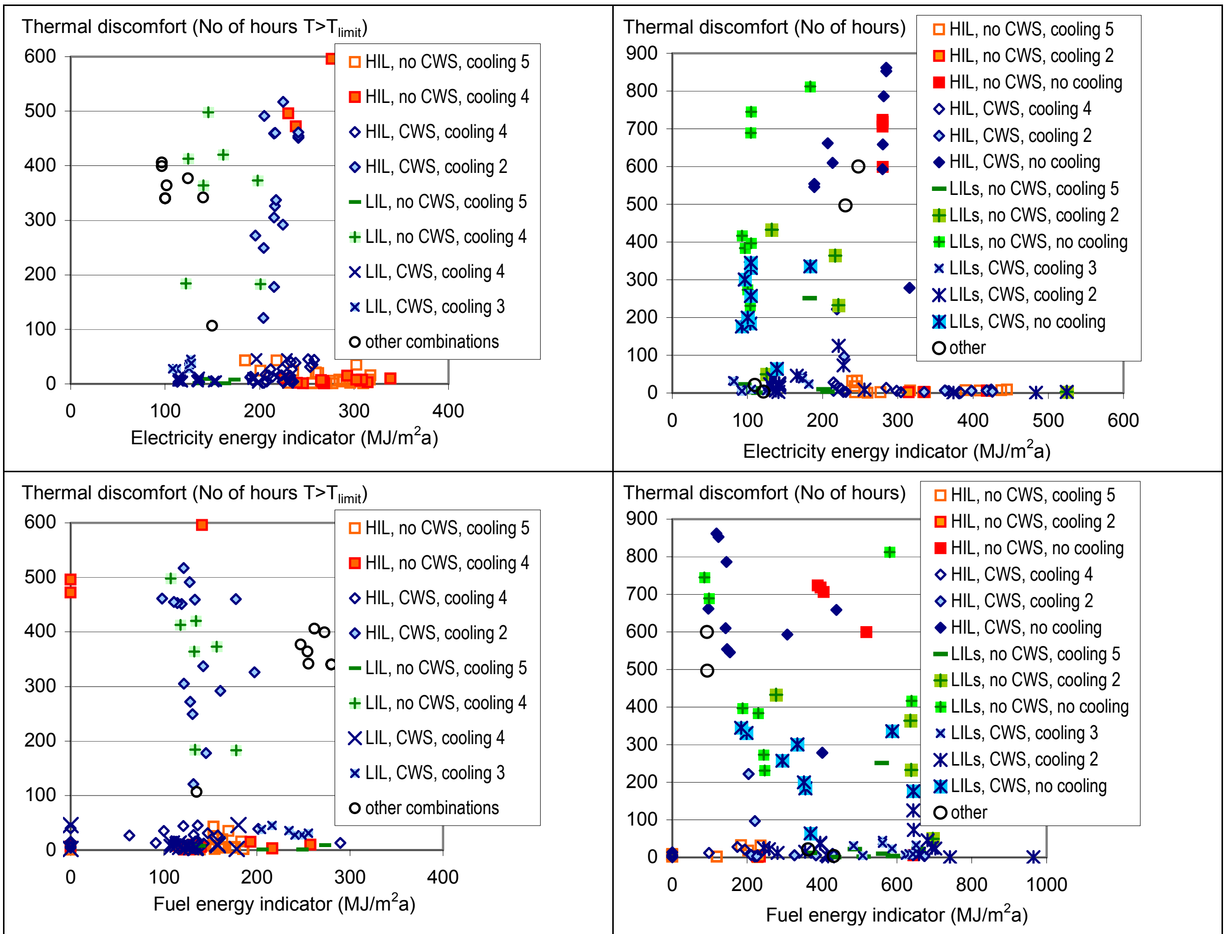
- However, in buildings with low internal load, very efficient cooling or free cooling through windows, increased solar protection or glazing with lower SHGC are rather in S2 (electricity is decreased, but fuel demand is increased) or even in S1 (both electricity and fuel demand are increased). Indeed, in these cases solar heat gains and daylight use are reduced and the associated increase of electricity for lighting is higher than the reduction in electricity for cooling.
- Lighting energy efficiency measures such as lighting renovation, optimisation of installed power per m^2, occupancy and daylight control are all clearly in section S2.2. The "price to pay" for more energy efficient lighting is an increase in heating energy demand, but the price is low enough to recommend energy efficient lighting from an primary energy point of view without any reservation: one kWh of electricity less needs at the most two third of an kWh of fuel more. This is much less than in any thermal or chemical power generation; where 1.7 kWh to about 3 kWh fuel are needed (based on the latest combined-cycle power plant and today's European mix respectively).
- Whereas in section S2, electricity substitutes for fuel, in section 4 the opposite is true: fuel energy is substitutes for electricity. Typical example are additional ventilation with heat recovery (or combined with exhaust air heat pumps) or heat pumps that displace fuel based heating generation. Some of these examples are in section 4.1 (the "good" one), other in section 4.2 (the fuel to electricity ratio is above the mentioned threshold of 3 or even 2). Whether additional ventilation is in section S4.2 or in S4.1 depends not only on the technology used (heat recovery and ventilation efficiency), but also on the reference case: if the air exchange rate in the case without ventilation is quite low (and thus associated heating demand low), the net fuel efficiency gain might be (considerably) lower than expected, i.e. much lower than the nominal efficiency of the heat recovery device. This is due to higher "gross" heating demand due to the higher air exchange rate of the ventilation. Unless ventilation is very electricity efficient a better alternative from an energy perspective may well be to ventilate using windows and to make up for any heat loss by heat generation using highly efficient heat pumps. Thus, to be "on the safe side" (in section 4.1) it is very important to design ventilation with a high electrical efficiency (pressure losses below 700 Pa, electricity demand below 0.22 to 0.34 $W/(m^3/h)$, see also SIA 380/4. The substitution ratio fuel to electricity is typically 2.5 to 3 for heat pumps using air as a heat source and 3 to 5 for well-designed and implemented heat pumps using ground or water as a heat source. Even higher values are achievable if the ground is used as a source for free cooling during the cooling period.
- Unsurprisingly, additional ventilation or additional cooling are in the upper part of the diagram, i.e. additional electricity is used. In some cases, additional cooling increases also heating energy demand, since "free" internal or external heat is less used. Also free cooling through windows increases heating energy demand. This can be called as the price to pay for additional thermal comfort (less overheating).

At this stage it is necessary to emphasise that, from the viewpoint of primary energy, resources and climate change, heat reduction measures are recommended only if their substitution ratio is higher than the inverse of the net efficiency of power generation and distribution. This means that heat pumps using air as a heat source (with a typical annual COP of 2.5 to 3) are at the lower threshold of this criterion at present. However, it can be expected that electricity will be generated with a higher net efficiency in the near future (>0.4).

Energy demand and comfort

Figure 3 shows thermal discomfort in terms of overheating (for an office space oriented south) as a function of the electricity indicator and as a function of the heating (fuel) energy indicator. Thermal discomfort is measured by the number of hours during building occupation (typically 11 hours per day) within the period of 16th of April to 15th of October. The cases are differentiated regarding their internal load, the presence or absence of free cooling and the type of active cooling. As a matter this configuration determines to a large extent electricity demand and thermal comfort (remember that high internal load was defined as 120 MJ/m^2a for appliances and low internal load as 40 MJ/m^2a). In Figure 3 the cases with high internal loads can clearly be discerned on the right hand side of the upper figures (high electricity indicator). The figures also show that thermal discomfort is within an acceptable range (less than 200 or 100 hours of overheating during the period considered) if "enough" cooling is being provided, i.e. if supply air is being cooled and cooling elements such as chilled ceilings or chillers are implemented and if the set point temperature of cooling elements is low enough (slightly lower than the limits specified in Table 2). In buildings with low internal loads free cooling (for instance with controlled window systems, CWS) is sufficient to prevent overheating in some cases.

Note that the number of hours with overheating might be high with the configuration “cooling 4” and “cooling 3” where the set point temperature is set to 25°C. This result can be called an “artefact” of the modelling approach: the set point temperature should have been to 24.5°C for days with a daily maximum outdoor temperature of 16.5°C to meet the comfort criterion according to Table 2. Actually, in the simulation results the indoor temperature does not exceed the set point temperature of 25°C, but nevertheless an indoor temperature of 25°C is accounted as overheating if the daily maximum outdoor temperature is below 18.5°C. The simulation results show that indoor temperatures exceed 25°C easily on sunny periods already during the winter and in particular during the transitional periods (spring, autumn) even if the maximum outdoor temperature is still below 18.5°C.



HIL: High internal load LIL: Low internal load CWS: Controlled window system
Cooling 5: cooling of supply air and cooling elements, set point temperature of cooling elements 23°C
Cooling 4: cooling of supply air and cooling elements, set point temperature of cooling elements 25°C
Cooling 3: only cooling elements (set point temperature 25°C)
Cooling 2: only cooling of supply air

Source Jakob et al. 2006

Figure 3 **Thermal discomfort in terms of overheating (No. of hours with indoor temperature above limit as defined above) as a function of the electricty energy indicator (figures above) and as a as a function of the fuel energy indicator (figures below) for new buildings (left-hand figures) and for existing ones (right-hand figures)**

Overall, thermal discomfort (overheating) is generally not increased if the electricity indicator is reduced or decreased if the electricity indicator is increased which one expect. In fact, to a certain extent rather the opposite is true (Figure 3, upper figures). This result might seem somewhat surprising because it is obvious that cooling decreases thermal discomfort (less overheating), but increases electricity demand (i.e. lower discomfort leads to higher electricity demand and vice versa). But obviously the effect of other electricity efficiency measures is stronger than that of cooling: some electricity efficiency measures have no impact on thermal comfort (e.g. more efficient ventilation) and others even have a positive impact (reducing the internal loads of appliances and/or lighting reduces both electricity demand and thermal discomfort). In some cases however thermal discomfort might be increased while reducing electricity demand. If for instance the air exchange rate in existing buildings is reduced in ventilation with supply air cooling, the thermal comfort situation may deteriorate (with regard to overheating). This may make compensatory measures necessary (e.g. reduction of internal loads, controlled window systems, increased solar protection, or, in buildings with high internal loads, radiant chilled-ceiling cooling or water to air heat exchangers).

The results further show that thermal discomfort in terms of overheating is increased to a certain extent along with lower heating energy demand for buildings with no or insufficient cooling (Figure 3, lower figures). This is a quite remarkable and somewhat surprising finding, but nevertheless plausible, as showed by the following considerations.

Indeed, a more detailed analysis showed that not all the energy efficiency measures lowering the fuel energy demand show this behaviour, but in particular those that involve thermal insulation of the building envelope. The phenomena is particularly pronounced in buildings with high internal loads (note however that these buildings do not satisfy comfort requirements already in their original, un-insulated state). In these buildings a large proportion of the cooling demand occurs during the transitional seasons. In these periods outdoor temperature is in a daily average significantly below indoor temperature and excessive heating load is dissipated through ventilation and the building envelope which can be viewed as a form of “free cooling”. Insulating and sealing the building envelope through thermal insulation and new windows reduces this form of free cooling. Thus, the price for the reduction in heating energy demand by building envelop insulation is a deterioration in the level of thermal comfort (in terms of overheating) on sunny periods as far as there are no compensatory measures already installed (e.g. cooling) or being taken in the building. Compensatory measures include e.g. reduction of the internal loads, ventilation, controlled window opening, overnight cooling, improved solar protection measures, glazing with lower SHGC. The compensatory measures mentioned can in turn also have an effect on the heat and power balance, which, however, can be limited by suitable control strategies. The effects described also occur in new buildings, but marginal effects are lower than when renovating an existing building.

The internal heat loads due to persons and electrical appliances have a large influence on comfort conditions, not just during the actual summer months but also for longer transitional periods. This applies not only to buildings with a high proportion of windows but also to the building stock with a construction design and geometric ratios similar to those of residential buildings. Given the decisive impact of the building configuration regarding internal load and the type cooling we conclude that a reduction of internal loads is an indispensable prerequisite in order to simultaneously achieve a substantial net reduction of electricity demand together with an increase of thermal comfort. Energy efficiency improvements for electrical appliances such as computers and energy efficient lighting help to reduce internal loads considerably. Indeed internal loads of lighting could be reduced from 200 Wh/m^2d (old lighting in existing buildings) or from 150 Wh/m^2d (new buildings) down to 100 Wh/m^2d. This is a substantial reduction of the potential total internal loads (compare with internal load of persons and appliances in Table 1). In buildings without cooling the number of hours with overheating can be reduced by 100 to 300 hours during the considered period (16th of April to 15 of October). If high occupancy density and an associated high density of appliances is given (for instance due to total building cost considerations), acceptable comfort conditions can only be achieved using compensatory measures (active cooling, ventilation systems incl. night cooling, automatic or maybe manual window opening).

As far as external loads are concerned we can retain the following: in buildings without cooling or moderate cooling glazing individual measures of increased solar protection reduce the number of hours with overheating by 100 to 200 hours during the considered period (at the price of a net electricity and heating energy demand increase, see previous chapter). Note that for glazing the effect could be opposite if there is a strong reduction of the Ug-value along with the SHGC reduction. In highly glazed rooms an increased solar protection not only reduces thermal load as such, but reduces also the glazing surface temperature which is perceived as comfortable.

Energy systems and their interplay in particular obviously do not behave as ideally under real conditions as they do in the simulation simulations. There may be rapid surges in electricity demand, especially in the case of building cooling, e.g. due to "suboptimal" or even faulty controls (values set too low or too high, simultaneous cooling and heating). Measures to optimise operation are therefore very important when putting systems into service during the construction of new buildings and when renovating buildings as well as at repeated regular intervals during their operation. For ventilation systems, for example, a reduction in pressure losses, which is decisive for reducing the energy demand, can also frequently be achieved by adjusting the air volume flow rate along with building and room occupation by means of CO_2-based control.

We conclude in retaining that considerable improvements can be made either in the level of comfort or in the reduction of the demand for heat or electricity respectively. Generally it is more challenging to simultaneously reduce both electricity and heat demand while satisfying comfort requirements by applying building envelop measures alone. Thus, highly efficient building technologies have to be included into the optimization process.

Cost-benefit analysis including energy and comfort criteria

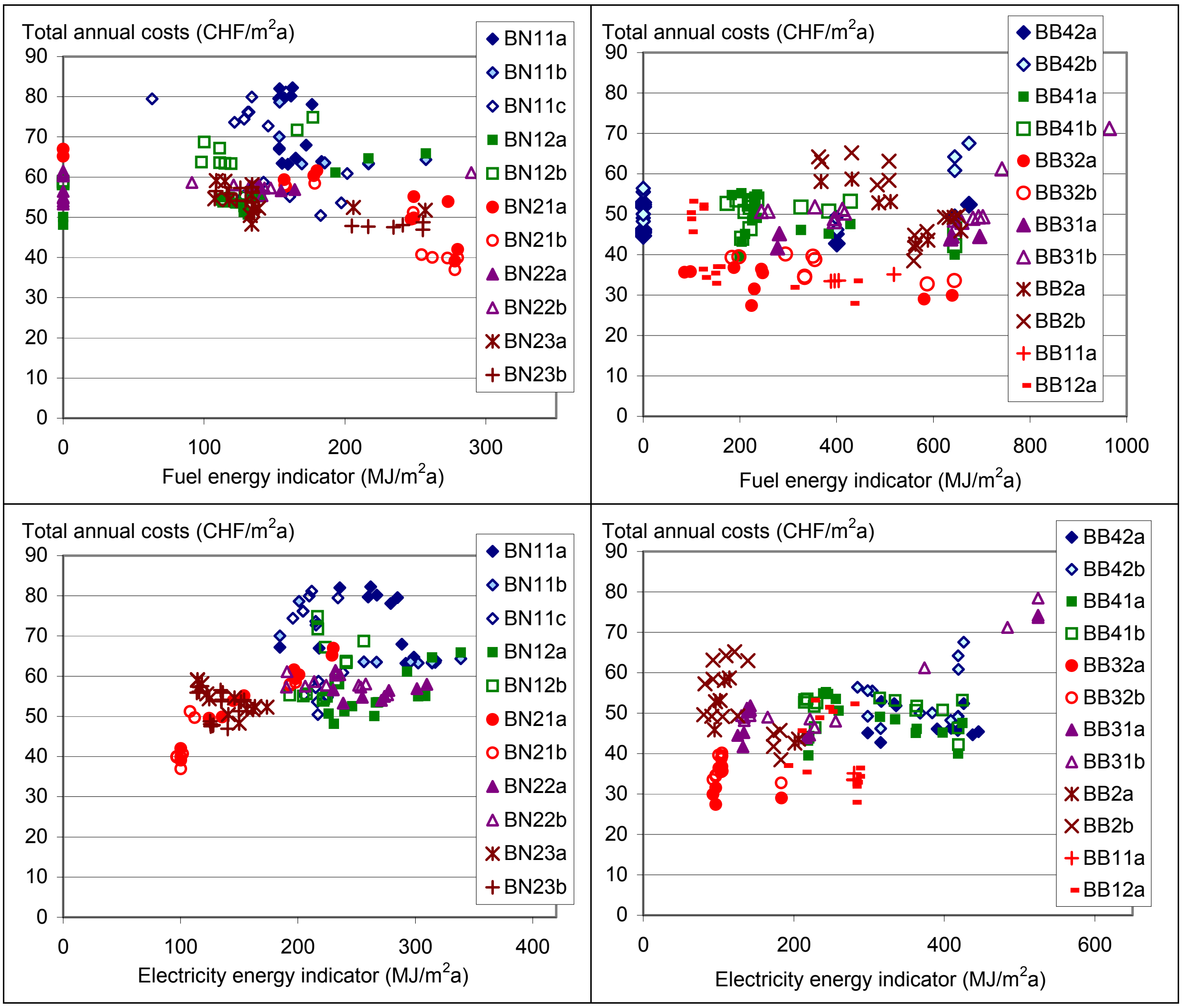
In this chapter we examine the relationship between costs, energy demand and thermal comfort for the different building types and configurations, using indicators. We define the cost indicator as the total annual costs (also called life cycle costs) per conditioned area. Total annual costs include capital costs and operation and maintenance costs of the building envelope and the building energy technologies, and fuel and electricity costs. The latter include also electricity costs of internal loads (of appliances). To compute capital costs from investment cost we assume a real interest rate of 3% and a mid to long term fuel energy prices of 0.07 CHF/kWh and an electricity price of 0.17 CHF/kWh[3].

Figure 4 shows the total annual costs as a function of the fuel energy indicator for the different building types. Four main findings are identified: First, we notice that within a certain building type the total annual costs are - apart from some exceptions – more or less constant or even decreasing along with a decreasing fuel energy indicator. Second, some fuel energy reduction measures involve a significant increase of the annual costs. Third, there are some increasing cost steps without a noticeable reduction of the fuel energy indicator. And fourth, the cost level of the different building types and sets of measures is quite different.

These main findings can be explained and interpreted as follows. First, most of the energy efficiency measures reducing heating energy demand are economically viable or they are at the border of economic viability. This is valid in particular for many envelope insulation measures including windows, but also for heat recovery systems with higher efficiency (if there is ventilation already in the reference case), and for adjusting operation schemes. Second, a closer analysis of the results shows that some significant cost steps in relation with reduced fuel demand are caused either by heat pumps that replace fossil fuel heating systems or by additional ventilation system (including heat recovery). This is the case for instance for the building types BN21 or BB2. Note that the primary purpose of a ventilation system is to assure adequate air renewal and that energy efficiency (heat recovery) is a secondary benefit. Third, cost increases without a reduction of fuel energy demand are caused by comfort measures such as additional cooling or CWS. Forth, the different cost levels of the different building types are in addition to the already mentioned factors strongly determined by architectural concepts and material choices (glazing proportion, type of façade and type of solar protection).

[3] 1 CHF equals about 0.65 Euro (2005/2006)

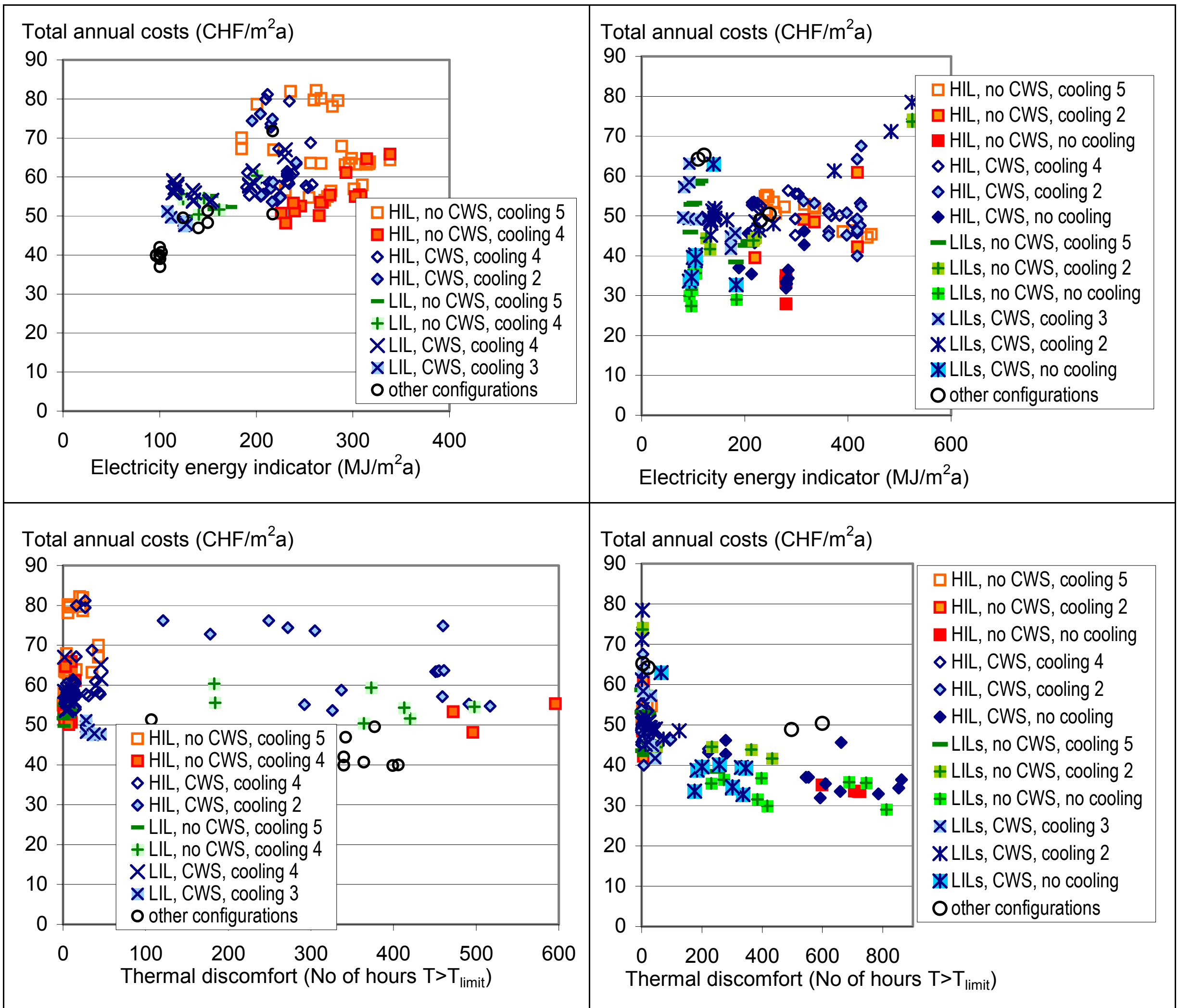
To a certain extent similar statements can be made for the relationship between the total annual costs and the electricity indicator (Figure 4, lower figures): Total annual costs are more or less constant to increased electricity efficiency (lower electricity indicator) or they entail only moderate additional annual costs (typically 0 to 2 CHF/m^{2}a). Be aware that in this representation of the results the cases without cooling and/or ventilation are rather in the lower left section of the charts (low costs, low electricity indicator) which explains some of the declining course of some cases (from the upper right to the lower left. The building type BN21 is such an example. Note that some of these cases would not meet comfort requirements (less than 100 or 200 h of overheating), i.e. costs and electricity demand are low at the price of insufficient thermal comfort conditions. Also other measures such as heat pumps replacing fossil fuel heating systems have higher costs and a higher electricity indicator. Other measures have higher (or lower) costs at a constant electricity indicator. These are fuel efficiency measures or conceptual changes (e.g. less expensive glazing façade with external solar protection instead of solar protection in-between the glazing).



Source Jakob et al. 2006

Figure 4 **Annual costs as a function of the fuel energy indicator (upper figures) and as a function of the electricity energy indicator (lower figures) for new buildings (left-hand figures) and for existing ones (right-hand figures). The codes BN11a to BB12a depict the different building types considered.**

Other factors influencing the total costs and/or the electricity indicator in either way are the glazing proportions, the type of façade, the internal loads, and others, see upper part Figure 5 where the annual costs as a function of the electricity indicator are differentiated by the configuration regarding internal load, window control, and cooling. These configurations (including the glazing proportions) largely determine the total annual costs and the electricity indicator. This becomes apparent by a break down of the cost indicators. The annual costs of additional active cooling typically amount to 10 CHF/m^{2}a and the costs of additional ventilation or of controlled window systems are at about the same level. Internal loads affect the total annual cost directly (direct electricity costs are 5.5 CHF/m^{2}a instead of 1.8 CHF/m^{2}a for low internal loads) and indirectly through additional cooling technology and electricity costs for cooling (the latter amount to up to 5 CHF/m^{2}a in highly glazed buildings). Finally a reduction of the glazing share from 80% to 50% (referred to the façade area) reduces the capital costs by about 10 CHF/m^{2}a (the total of electricity and fuel costs is more or less constant).



HIL: High internal load LIL: Low internal load CWS: Controlled window system
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Cooling 3: only cooling elements (set point temperature 25°C)
Cooling 2: only cooling of supply air

Source Jakob et al. 2006

Figure 5 **Annual costs as a function of the electricity energy indicator (figures above), and as a function of thermal discomfort (figures below) for new buildings (left-hand figures) and for existing ones (right-hand figures)**

From the lower part of Figure 5 it becomes apparent that at the bottom line the total annual costs are strongly determined by the level of thermal comfort. The total annual costs of the cases that satisfy comfort requirements (less than 100 h) are clearly higher than the ones that don't satisfy the comfort requirements. This is particularly true for existing buildings. For the new buildings the picture appears less clear-cut, but let us remind at this stage that "cooling 4" involves modelling "artefact" (with "cooling 4" the number of hours above the defined temperature limit as defined in Table 2 might be high, but the indoor temperature is only exceeded slightly, i.e. the set point is only slightly higher than the defined limit). Actually with "cooling 4" the comfort requirements are almost met and thus, high annual costs are within the picture Also "other configurations" are within the picture knowing that these configurations include "cooling 3" (only cooling elements, set point temperature 25°C), "cooling 2" (only cooling of supply air) or no cooling. Hence, the configuration "high internal load, CWS, cooling 2 (cooling of supply air)" is an exception to a certain extent, but an interesting one: total annual cost are generally quite high but nevertheless thermal comfort requirements are not satisfied in most of the cases. It is almost satisfied for a bundle of measures including night cooling through controlled window opening (including controlled window opening during the day).

Summary, conclusions and recommendations

The paper summarizes an extensive study where costs and benefits of energy efficiency and comfort measures of new and existing buildings of the service sector with a special focus on office buildings were analysed. The impacts of these measures on the energy demand and on the thermal comfort were estimated with dynamic building simulation software and the costs of the different measures were obtained through surveys from specialized planning and building technology companies.

Heating energy (fuel) demand can be reduced typically by 100 to 200 MJ/m^2a in the case of new buildings and by up to 500 MJ/m^2a or even more in the case of existing ones, by means of building envelope measures, heat recovery systems and increased energy efficiency of HVAC-systems. Fossil fuels or other final (fuel) energy sources are decreased accordingly. Using heat pumps to cover heating energy demand allows a complete substitution of fossil energies. Gross electricity demand can be reduced typically by 50 to 150 MJ/m^2a in the case of new buildings and by up to 250 MJ/m^2a, rarely by up to 400 MJ/m^2a, in the case of existing ones, by applying electricity efficiency measures, in particular by efficient lighting (luminaries, ballast, and control), ventilation and cooling (adjustment of operation schedules and air flows, reducing pressure drops, using efficient fans). If heat demand reduction measures are implemented simultaneously, the achievable net electricity reduction is smaller (typically 30 to 100 MJ/m^2a) since some heat demand reduction measures use electricity as an input (e.g. ventilation systems with heat recovery) or reduce the internal heat load (e.g. lighting efficiency measures). If heat pumps are used to displace fuel energy, the result could even be a net increase of electricity demand. In relative terms the heating energy efficiency potential is up to two thirds for new buildings and up to three quarters for existing ones and the (net) electricity efficiency potential is up to one half for new buildings and up to two thirds for existing buildings.

A considerable part of the measures considered have an impact on both the electricity and the heating energy demand. For instance, thermal insulation and solar protection measures alter the building envelope's properties (e.g. decreased heat loss and thus decreased night cooling, reduced solar gains and daylight inlet, decreased air infiltration). These property changes might create or intensify benefits or drawbacks. Further, due to building physics phenomena, there are interaction effects between the different types of building measures. Typically, glazing has an impact on lighting, heating and cooling demand. In some cases, the interaction may be even greater than the targeted primary effect. Furthermore, the direction of the impact on this two types of electricity demand differs considerably. Some measures reduce electricity and heating energy demand simultaneously (e.g. adjustment of the air exchange rates to specific needs), others reduce electricity demand, but increase heating energy demand (e.g. more efficient lighting) or vice versa (e.g. envelope insulation, implementation of ventilation with heat recovery, heat pumps replacing fuel heating) and some of them increase even both (increased solar protection in efficiently cooled or not cooled buildings). Mostly the ratio of decreased fuel to increased electricity is above 3 and the ratio of decreased electricity to increased fuel clearly more than one third, mostly more than 1 (see Figure 2 for details). From an energy efficiency and primary energy point of view, it is reasonable to replace fossil fuels by electricity if the substitution ratio is more than 3 or electricity by fuels if the substitution ratio is more than 1/3. This is the case for instance for heat pumps that replace fossil fuelled heating systems since the average annual COP is 3 or more, or, if its provided efficiently, for additional cooling that compensates for adverse effects that building insulation might have on thermal comfort.

High occupancy densities which are becoming increasingly common and the associated density of appliances result in high internal heat loads. This causes – together with the heat load of lighting – thermal discomfort in terms of overheating of several hundred hours per year, particularly in rooms that are south-facing (note that only building occupation periods are accounted). This is true for both new and existing buildings. Insulating the building envelope of existing buildings improves thermal comfort during the cold periods, but may aggravate thermal discomfort due to overheating during sunny periods in the summer or the transitional seasons. Although a moderate glazing to floor ratio, energy efficient lighting, low internal loads, and excellent solar protection quality and management help to reduce overheating; comfort requirements (which are mandatory for new buildings) are not satisfied in most of the cases without some cooling measures. Hence cooling is gaining in increasing importance in buildings of the service sector. Cooling measures could include active cooling through chilled ceilings or chillers, cooling of supply air, thermally activated construction elements, or controlled window systems including night cooling or façade devices with similar functionality. From an energy demand point of view cooling should be set in relation to other electricity based energy services. Indeed, despite of additional cooling total electricity demand can still be reduced if cooling is provided efficiently and if other electricity efficiency measures are taken. Thermal comfort might be ameliorated by a bundle of measures and the resulting co-benefits may help to promote energy efficient building renovation.

In both new and existing buildings, energy efficiency measures such as additional insulation, efficient lighting, additional ventilation efficiency etc. are either economically viable or entail only moderate additional annual costs (typically 0 to 2 CHF/m^{2}a). Within a large range, energy demand can vary considerably at quite similar annual costs. Indeed, at today's standards of design, construction and implementation, more energy efficient alternatives often have higher initial investment costs, but lower energy costs that more or less compensate the higher capital cost over the lifetime of the devices. However, this statement is only valid if a methodologically suitable approach has been taken (e.g. life cycle cost considerations rather than investment cost comparisons or low payback time postulation)

In contrast to energy efficiency measures, fundamental architectonic decisions (construction type, material choice, share of glazing, positioning of solar protection etc.) and specific comfort measures that generate extra benefits (ventilation, cooling) have a much larger impact on life cycle costs (they also might have a large impact on energy demand). This impact amounts to 10 up to some few 10 CHF/m^{2}a. For comparison: complete buildings' life cycle costs are roughly between 300 to 400 CHF/m^{2}a and labour costs between 5000 and 10000 CHF/m^{2}a. If labour productivity is influenced only slightly by building measures (energy efficiency or other) in one direction or the other, this would completely alter every cost-benefit analysis which focuses only on energy considerations. Against this background it becomes obvious that energy efficiency measures have to at least maintain, or better, increase comfort levels. Installing ventilation may not pay off from an energy cost point of view, but may do so from an indoor air quality and thermal comfort point of view.

As a result from the analysis the following measures can recommended from a point of view of energy efficiency, thermal comfort and economics (no or only few net additional annual costs):

- Thermal insulation of the building envelop down to a U-value of 0.2 W/m^{2}K and replacement of non-coated glazing or windows. It might be wise to take additional measures that improve thermal comfort to meet current requirement and increasing expectations.
- Energy efficient lighting in new and in existing buildings including efficient luminaries, ballasts and presence and daylight control.
- Use of highly efficient heat recovery (>80%), low pressure loss (<700 Pa), and highly efficient fans in ventilations, leading to low specific electricity demand (less than 0.22 to 0.34 W/(m^3/h))
- Separate cooling and ventilation services. Use of highly efficient cooling including low temperature differences, highly efficient fans and chillers. Annual COP should exceed 4 to 5.
- Adjust cooling and ventilation services to specific needs (including adjustment of operation schedules, presence and CO_2-sensors)

- According to the simulation results controlled window systems showed a considerable positive impact regarding the reduction of overheating and the energy demand of cooling. In the real world application care should be taken to prevent thermal discomfort due to cold air infiltration.
- The more efficiently cooling is provided, the less recommended is increased solar protection that reduces daylight use and increases lighting demand, i.e. set points that control solar protection should be dynamic throughout the year and adequate products with high visible transmittance should be used. The latter also applies for glazing.

A profound policy analysis was not a main goal of the research project this paper is reporting on (Jakob et al. 2006). The conducted surveys of cost and technical data from numerous companies revealed numerous barriers that hinder energy efficiency. Some recommendations for energy and innovation policy makers that were able to be derived from the analysis are given in Jakob et al. 2006.

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Abstract
This book contains the Proceedings of the 4th International Conference on Improving Energy Efficiency in Commercial Buildings - IEECB'06 which was held in Frankfurt, Germany, 26 - 27 April 2006. The IEECB'06 conference has been very successful in attracting a large international audience, representing a wide variety of stakeholders involved in policy implementation and development, research and programme implementation, investments and property management of energy efficient commercial buildings. IEECB'06 has provided an unique forum to discuss and debate the latest developments in energy and environmental impact of commercial buildings and the installed equipment and lighting. The presentations were made by the leading experts coming from virtually every corner of the world. The presentations covered policies and programmes adopted and planned in several geographical areas and countries, as well as technical and commercial advances in the dissemination and penetration of energy efficient commercial buildings.

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