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10 - 11 April 2008, Frankfurt am Main, Germany

Volume 1

Editors: Paolo BERTOLDI, Bogdan ATANASIU

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Contact information
Address: Via E. Fermi, 2749, I-21027 Ispra (VA), ITALY
E-mail: paolo.bertoldi@ec.europa.eu
Tel.: +39 (0)332 78 9299
Fax: +39 (0)332 78 9992

http://ie.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/
http://re.jrc.ec.europa.eu/energyefficiency/

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Preface

The commercial non-residential buildings sector is one of the fastest growing energy consuming sectors. This is mainly due to the growth of commercial and public activities and their associated demand for heating, cooling ventilation (HVAC) and lighting. Moreover in the new economy, with a wide dissemination of information and communication technologies, information technology equipment is also an important source of electricity consumption. For the tertiary sector space heating is responsible for more than 50% of total consumption of the sector, while energy consumption for lighting and office equipment and "other" (which is mainly office equipment) are 14% and 16%, respectively.

In its 2006 Action Plan on energy efficiency, the European Commission (EC) called for concrete measures to reduce growth in energy demand, mainly by promoting energy saving in buildings and the transport sector. According to the EU Green Paper, energy use in buildings could be reduced by at least a fifth by making greater use of available and economically viable energy-efficient technologies. Such savings would also improve the energy supply security and the EU's competitiveness, while creating job and raising the quality of life in buildings.

Greenhouse gas reduction is a common denominator of many countries' environmental policies and programmes. Commercial buildings are a key area to achieve the EU 2020 20% energy savings target, and this makes economic sense for the building owners and occupiers. As a consequence of the EU 2020 commitment, all actors need to take all necessary steps to disseminate good practice, foster investment in energy efficiency and provide technical solutions for the commercial building sector. Other regions of the world are also exploring potential programme and policy options to reduce commercial building energy waste.

Not only is every kWh saved avoiding pollution and CO2 emissions, but it is also reducing peak power requirements; a problem common to many countries. That is the reason why every achievement in the field of demand-side management (DSM), or more generally the improvement of energy efficiency has a direct effect on greenhouse gas emission reduction and on the security of energy supply. The European Directive on the Energy Performance of Buildings requires a major effort to improve building energy performance and will bring the energy performance of their buildings to the forefront of building market operators. This simultaneously presents an opportunity and challenge for energy efficiency.

The recent liberalisation of the electricity and gas markets could be an additional opportunity in the development of these efforts, as the competition eventually developing between the key players in the electricity and gas industry will not be focused only on prices but also on the service. In the long term there is the possibility that energy services and renewable energy sources (RES) would enable greater differentiation among utilities, Energy Service Companies (ESCOs), etc. Many property managers are now offered the services of ESCOs and facility management companies to manage and reduce the energy consumption in their buildings. A number of local, regional and national policies and programmes have recently been implemented to achieve a long lasting market transformation. The Directive on energy efficiency and energy services shall further contributes to the establishment of an energy efficiency market.

Low consumption commercial (office) buildings have been constructed and operated in the EU and elsewhere and they have proven that it is feasible to reach low consumption targets. There are some very good examples of low consumption commercial (office) buildings, especially in Germany. A major result is, that the reduction of consumption of primary energy is not only some percent, but new buildings have reduced consumption by a factor of 3 to 4 !

In many cases low energy office buildings have lower investment cost than conventional ones, especially where supply efficiency can be integrated or natural cooling is used. Where the initial cost of the efficient is greater than the normal market practise, these additional investment costs invariably turn out to be economical within the expected lifetime of the buildings, even on the assumption of constant energy pricing, a totally unrealistic assumption.

Furthermore energy efficient building owners and investors are happy. There is growing evidence on both sides of the Atlantic that the occupiers in high-efficiency buildings are happier, and significantly more productive. The value of the productivity normally outweighs the operating savings for the pure energy costs. Lower energy costs are combined with a good or even better comfort and substantially increased employee productivity. Thus investors and occupants are both happy with these buildings. The key question is why are such a kind of buildings still an exception and not the standard? And why cost effective building investments and retrofit do not take place.

The EU GreenLight and GreenBuilding Programme (GBP) programmes help to overcome some of the barriers to energy efficiency - in particular the lack of interest and information - by providing public recognition and information support to companies and public organisations whose top management is ready to show actual commitment to adopting energy efficient measures in buildings.

Following the success of the previous IEECB conferences (IEECB'98 in Amsterdam, IEECB'02 in Nice, IEECB'04 and IEECB'06 in Frankfurt), Messe Frankfurt with the scientific collaboration of the European Commission Joint Research Centre organised the fifth International conference on Improving Energy Efficiency in Commercial Buildings (IEECB'08) in conjunction with the Building Performance Congress (www.bp-congress.de). The IEECB'08 conference took place on 10 - 11 April 2008 in Frankfurt during Light+Building, the International Trade Fair for Architecture and Technology in Frankfurt, Germany.

The IEECB conference brought together all the key players from this sector, including commercial buildings' investors and property managers, energy efficiency experts, equipment manufacturers, service providers (ESCOs, utilities, facilities management companies) and policy makers, with a view to exchange information, to learn from each other and to network.

At the conference key representatives of leading organisations and companies, institutions and equipment industry presented the overall picture and give details of policies, recent advancements and examples of best practice.

The wide scope of topics covered during the IEECB'08 conference included: macro/micro approaches, state-of-the-art equipment and systems (lighting, HVAC auxiliary equipment, ICT & office equipment, miscellaneous equipment, BEMS, electricity on-site production, renewable energies, etc.) and the latest advances in R&D, tools, regulation & policy, demand-side and supply-side perspectives for all branches of activity (public and private sector, the commerce and retail sectors, hotels and restaurants, banks and insurance companies, local authorities, civil services & public bodies, education, universities & laboratories, hospitals, airport and stations, etc.)

We hope that the present proceedings could be a valuable contribution to disseminate information and best practices in policies, programmes and technologies to foster the penetration of highly efficient buildings in the commercial sector.

The Editors

Paolo Bertoldi
Bogdan Atanasiu

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IEECB'08

Policies

Non-residential buildings for combating climate change: Summary of the findings of the Intergovernmental Panel on Climate Change

Diana Ürge-Vorsatz, Central European University
Aleksandra Novikova, Central European University

Abstract

The challenge of climate change calls to reduce anthropogenic greenhouse gas emissions as soon as possible to avoid irreversible damage to the Planet. The non-residential buildings sector is one of the targets for these emission reductions. The paper presents the key conclusions of the Fourth Assessment Report of the Intergovernmental Panel of Climate Change on mitigation opportunities in the buildings sector with a focus on the non-residential buildings. A wide array of mature and emerging technologies can supply the substantial reductions in carbon emissions from energy use in the non-residential buildings. The analyzed literature attests that a significant portion of these emission savings is cost-effective in the short and medium term future. Numerous co-benefits take place while implementing GHG mitigation options in the non-residential buildings and provide significant value beyond direct saved costs of energy. If financially evaluated, these co-benefits help policymakers justify actions even in the absence of a strong climate commitment. A variety of government policies have been demonstrated in many countries to be successful in reducing energy-related carbon emissions in buildings. However, due to probably the highest, among energy use sectors, barriers for efficiency penetration in buildings, no single instrument can make a large impact. Therefore, packages of policy tools, which benefit from a synergy of advantages of individual instruments, tailored to local conditions, and combined with strong compliance and enforcement regimes, are needed.

1. Introduction

The challenge of anthropogenic climate change touches upon many aspects of the human kind. This is no more a question but an utmost urgency to reduce GHG emissions as soon as possible to the level of their concentration in the atmosphere which would stop the irreversible damage to the Planet. One of the targets for these emission reductions is the non-residential buildings sector.

The paper presents the key findings of the work on mitigation of greenhouse gas (GHG) emissions from energy use in buildings conducted under the framework of the Fourth Assessment Report (AR4) of the Intergovernmental Panel of Climate Change (IPCC) (Levine et al., 2007) with a focus on the non-residential buildings. The aim of the paper is to review the trends in carbon dioxide (CO_2) emissions from the non-residential buildings sector, to identify the key options to reduce these emissions, to assess the global potential for these emission reductions; to identify the co-benefits associated with realization of the potential as well as the barriers to unlocking the potential; and, finally, to review the policy options to remove these barriers. The sections frame the paper respectively to the outlined aims.

2. Past and future trends of CO_2 emissions of the non-residential buildings

A large share of CO_2 emissions in the buildings sector is associated with electricity use; therefore, it is useful to analyze these emissions and refer to them throughout the paper including those through the use of electricity. CO_2 emissions in the non-residential buildings grew from 1971 to 2004 at an annual rate 2.5% per year (an annual rate of the whole buildings sector is 2%) and reached 3.1 Gt/yr in 2004 (Price, *et al.*, 2006). During the last five years, CO_2 emissions in the non-residential buildings have grown faster (3.0% per year) than the 30-year trend (2.2%/yr.) (Price, *et al.*, 2006). The largest regional increases in CO_2 emissions for the non-residential buildings were from Developing Asia[1] (30%), North America (29%), and OECD Pacific (18%).

The projections of CO_2 emissions of the non-residential buildings sector to 2030 were coupled with those of the residential buildings. Nevertheless, the results of the projections (it terms of emission

[1] Centrally Planned and Other Asia.

growth implications) for the whole buildings sector could be partly replicated to the non-residential buildings, as a part of it. Scenarios A1B and B2 of the IPCC Special Report on Emissions Scenarios (SRES) (IPCC, 2000) show a range of projected buildings related CO_2 emissions: from 8.6 Gt CO_2 emissions in 2004 to 11.4 and 15.6 Gt CO_2 emissions in 2030 (B2 and A1B respectively), representing an app. 34% share of total CO_2 emissions in both scenarios. In Scenario B2, which has lower economic growth, especially in the developing world (except China), two regions account for the largest portion of increased CO_2 emissions from 2004 to 2030: North America and Centrally Planned Asia. In Scenario A1B (which shows rapid economic growth, especially in developing nations), all of the increase in CO_2 emissions occurs in the developing world: Centrally Planned Asia, Other Asia, Middle East/North Africa, Latin America, and Sub-Saharan Africa, in that order. Overall, average annual CO_2 emissions growth is 1.1% in Scenario B2 and 2.3% in Scenario A1B over the 26-year period.

Additionally, for the purpose of estimating the CO_2 mitigation potential in buildings (section 4), a baseline for the whole buildings sector was derived based on the review of several studies. This baseline represents an aggregation of national and regional baselines reported in the studies. This baseline shows emissions between the SRES B2 and A1B scenarios, with 11.1 Gt of CO2-eq. emissions in 2020, and 14.3 Gt in 2030.

3. Energy efficiency and CO_2 mitigation options

Measures to reduce CO_2 emissions from non-residential buildings fall into two categories: reducing energy consumption[2] and embodied energy in buildings and switching to low-carbon fuels including a higher share of renewable energy. Renewable and low-carbon energy can be supplied to buildings or generated on-site by distributed generation technologies. Steps to decarbonize electricity generation can eliminate a substantial share of present emissions in buildings. This paper devotes most attention to energy efficiency in new and existing buildings.

3.1. Overview of GHG mitigation options in the buildings sector

Table 1 summarizes selected key technological opportunities in buildings for CO_2 abatement in five world regions based on three criteria (the scope of the paper does not allow discussing the technological options in details; for the detail discussion please see Levine et al. (2007)). As economic and climatic conditions in regions largely determine the applicability and importance of technologies, countries were divided into three economic classes and two climatic types. The three criteria include the maturity of the technology, cost/effectiveness, and appropriateness. Appropriateness includes climatic, technological, and cultural applicability. For example, direct evaporative cooling is ranked as highly appropriate in dry and warm climates but it is not appropriate in humid and warm climates. The assessment of some technologies depends on other factors, too. For instance, the heat pump system depends on the energy source and whether it is applied to heating or cooling. In these cases, variable evaluation is indicated in the table.

3.2 Energy savings through conventional retrofits of existing non-residential buildings

There are numerous published studies showing that energy savings of 50 to 75% can be achieved in commercial buildings through aggressive implementation of integrated sets of measures. These savings can often be justified in terms of the energy-cost savings alone, although in other cases full justification requires consideration of a variety of less tangible benefits. In the early 1990s, a utility in California sponsored a 0 million US$ demonstration of advanced retrofits. In six of seven retrofit projects, an energy savings of 50% was obtained; in the seventh project, a 45% energy savings was achieved. For Rosenfeld (1999), the most interesting result was not that an alert, motivated team could achieve savings of 50% with conventional technology, but that it was very hard to find a team competent enough to achieve these results.

[2] This counts all forms of energy use in buildings, including electricity.

Table 1 Applicability of energy efficiency technologies in different regions. Selected are illustrative technologies, with an emphasis on advanced systems rating of which is different between countries

Energy Efficiency or Emission Reduction Technology	Developing Countries						OECD						Economies in Transition, Continental		
	Cold Climate			Warm Climate			Cold Climate			Warm Climate					
	Tech-nology stage	Cost/ Effectiveness	Appro-priateness	Tech-nology stage	Cost/ Effectiveness	Appro-priateness	Tech-nology stage	Cost/ Effectiveness	Appro-priateness	Tech-nology stage	Cost/ Effectiveness	Appro-priateness	Tech-nology stage	Cost/ Effectiveness	Appro-priateness
Structural Insulation panels	⬤	⬤	⬤	●	●	•	⬤	●	●	●	●	●	●	⬤	⬤
Multiple glazing layers	⬤	⬤	⬤	⬤	●	•[1]–●[2]	~	⬤	⬤	⬤	⬤	●	⬤	⬤	⬤
Passive solar heating	⬤	●	●	⬤	●	•	⬤	●	⬤	⬤	●	●	⬤	●	⬤
Heat Pumps	●[3]	•	•	●–⬤[4]	•[5]–●[6]	•[7]–●[8]	⬤[9]	●	●	~[10]–⬤[11]	●[12]–⬤[13]	●[14]–⬤[15]	⬤[16]	●	●
Biomass derived liquid fuel stove	⬤	●	⬤	●	•	•	~	●	⬤	~	●	•	~	⬤	⬤
High-reflectivity bldg. materials	•	•	•	●	⬤	●	⬤	●	●	~	●	⬤	⬤	●	●
Thermal mass to minimize daytime interior t° peaks	~	⬤	●	~	⬤	•[17]–⬤[18]	~	⬤	●	~	⬤	•[19]–⬤[20]	~	⬤	⬤
Direct evaporative cooler	•	•	•	~	⬤	•[21]–⬤[22]	•	•	•	~	⬤	•[23]–⬤[24]	•	•	•
Solar thermal water heater	~	⬤	⬤	⬤	⬤	⬤	~	⬤	⬤	~	⬤	⬤	~	⬤	⬤
Cogeneration	⬤	●	●	●	•	•	~	●	⬤	~	●	●	⬤	●	⬤
District Heating &Cooling System	⬤	●	●	•	•	•	~	●	⬤	⬤	●	●	⬤	●	⬤
PV	⬤	●	●	•	•	•	~	●	⬤	⬤	●	●	⬤	●	●

Air to air heat exchanger	🔵	🟢	🔵	🔵	🟢	🔵	🔵	🔵	🔵	🔵	🔵	🔵	🔵	🟢	🔵
High efficiency lightning (FL)	~	🟢	🔵	~	🟢	🔵	μ	🔴	🔵	μ	🔴	🔵	🔵	🟢	🔵
High efficiency lightning (LED)	~	🔴	🔵	~	🔴	🔵	🔴	🔴	🔵	🔴	🔴	🔵	🔴	🟢	🔵
Light shelves	🔵	🟢	🔵	🔵	🟢	🔵	🔵	🟢	🔵	🔵	🟢	🔵	🔵	🟢	🔵
HC-based domestic refrigerator	🟢	🟢	🔵	🟢	🟢	🔵	~	🔵	🔵	🔵	🟢	🔴[25] - 🔵[26]	🔵	🟢	🔵
HC or CO_2 air conditioners	🔴	~	μ	🔴	~	μ	🔴	🟢	🟢	🔴	🔴	μ[27] - 🟢[28]	🔴	~	🟢
Advance supermarket technologies	🔴	🔵	🔵	🔴	🔵	🔵	~	🔵	🔵	🟢	🔵	🔵	🟢	🔵	🔵
Variable speed drives for pumps and fans	~	🟢	🟢	~	🟢	🟢	~	🟢	🟢	~	🟢	🟢	~	🟢	🟢
Advanced control system based on BEMS	🔵	🟢	🟢	🔵	🟢	🟢	🔵	🟢	🟢	🔵	🟢	🟢	🔵	🟢	🟢

Notes: 1.For heat block type, 2.For Low-E, 3.Limited to ground heat source etc, 4.For air-conditioning, 5.For hot water, 6.For cooling, 7.For hot water, 8.For cooling, 9.Limited to ground heat source, etc., 10.For cooling, 11.For hot water, 12.For hot water, 13.For cooling, 14.For hot water, 15.For cooling, 16.Limited to ground heat source, etc, 17.In high humidity region., 18.In arid region, 19.In high humidity region, 20.In arid region, 21.In high humidity region, 22.In arid region, 23.In high humidity region, 24.In arid region, 25.United States, 26.South European Union, 27.United States, 28.South European Union.

Evaluation ranks:

Representation	Stage of technology	Cost/Effectiveness	Appropriateness
🔴	*Research phase (including laboratory and development) [R]*	*Expensive/Not effective [$$/-]*	*Not appropriate {-]*
🟢	*Demonstration phase [D]*	*Expensive/effective [$$/+]*	*Appropriate {+]*
🔵	*Economically feasible under specific conditions [E]*	*Cheap/Effective [$/+]*	*Highly appropriate {++]*
~	*Mature Market (widespread commercially available without specific governm. support) {M]*	*"~" Not evaluated [n/a]*	*"~" Not evaluated [n/a]*
μ	*No Mature Market (not necessarily available/not necessarily mature market)*		

Other, recent examples that are documented in the published literature include:

- A realized savings of 40% in heating plus cooling plus ventilation energy use in a Texas office building through conversion of the ventilation system from one with constant to one with variable air flow (Liu and Claridge, 1999);
- A realized savings of 40% of heating energy use through the retrofit of an 1865 two-story office building in Athens, where low-energy was achieved through some passive technologies that required the cooperation of the occupants (Balaras, 2001);
- A realized savings of 74% in cooling energy use in a one-story commercial building in Florida through duct sealing, chiller upgrade, and fan controls (Withers and Cummings, 1998);
- Realized savings of 50-70% in heating energy use through retrofits of schools in Europe and Australia (CADDET, 1997);
- Realized fan, cooling, and heating energy savings of 59%, 63%, and 90%, respectively, in buildings at a university in Texas, roughly half due to standard retrofit and half due to adjustment of the control-system settings (which were typical for North America) to optimal settings (Claridge et al., 2001).

3.3. Energy savings through solar retrofits of existing non-residential buildings

Solar retrofit performed in Europe under the IEA Solar and Cooling Program achieved savings in space heating of 25-80% (Harvey, 2006;). The retrofit examples described above, while achieving dramatic (35-75%) energy savings, rely on making incremental improvements to the existing building components and systems. More radical measures involve re-configuring the building so that it can make direct use of solar energy for heating, cooling, and ventilation. The now-completed Task 20 of the IEA's Solar Heating and Cooling (SHC) implementing agreement was devoted to solar retrofitting techniques.

3.4. Energy savings in new constructions

Examining the building as an entire system on the stage of building planning can lead to entirely different design solutions. The systems approach in turn requires an integrated design process (IDP), in which the building performance is optimized through an iterative process that involves all members of the design team from the beginning. The steps in the most basic IDP for a commercial building include (i) selecting a high-performance envelope and highly efficient equipment, properly sized; (ii) incorporating a building energy management system that optimises the equipment operation and human behaviour, and (iii) fully commissioning and maintaining the equipment (Todesco, 2004). These steps alone can usually achieve energy savings on the order of 35-50% for a new commercial building, compared to standard practice, while utilization of more advanced or less conventional approaches has often achieved savings on the order of 50-80% (Harvey, 2006).

4. Potential for and costs of greenhouse gas mitigation in buildings

The previous sections have demonstrated that there is already a plethora of technological, systemic, and management options available in buildings to substantially reduce CO_2 emissions. This section aims at quantifying the reduction potential these options represent, as well as the costs associated with their implementation.

4.1. Recent advances in potential estimations from around the world

There is a lack of literature that quantifies the global potential for CO_2 mitigation or energy-efficiency improvement in the buildings sector, and in the non-residential buildings particularly. Due to this reason, assessment of the global potential was conducted based on available regional and country-level studies for the whole buildings sector not separating it into the residential and non-residential purposes. For this assessment, the authors conducted a review of 80 recent buildings-oriented studies from 36 countries and 11 country groups, spanning all inhabited continents. Table 2 reviews the findings of a selection of major studies on CO_2 mitigation potential of the entire buildings sector (if not stated the opposite) from various countries around the world that could be characterized in a common framework. Since the studies apply a variety of assumptions and analytical methods, these results should be compared with caution.

Table 2 CO_2 emissions reduction potential for the buildings stock in 2020[a]

Economic region	Countries/ country groups reviewed for region	Potential as % of national baseline for buildings[b]	Measures covering the largest potential	Measures providing the cheapest mitigation options
Developed countries	USA, EU-15, Canada, Greece, Australia, Republic of Korea, United Kingdom, Germany, Japan	Technical: 21%-54%[c] Economic (<US$ 0/tCO_2-eq): 12%–25%[d] Market: 15%–37%	1. Shell retrofit, inc. insulation, esp. windows and walls; 2. Space heating systems; 3. Efficient lights, especially shift to compact fluorescent lamps (CFL) and efficient ballasts.	1. Appliances such as efficient TVs and peripherals (both on-mode and standby), refrigerators and freezers, ventilators and air-conditioners; 2.Water heating equipment; 3. Lighting best practices.
Economies in Transition	Hungary, Russia, Poland, Croatia, as a group: Latvia, Lithuania, Estonia, Slovakia, Slovenia, Hungary, Malta, Cyprus, Poland, the Czech Republic	Technical: 26%–47%[e] Economic (<US$ 0/tCO_2eq): 13%–37%[f] Market: 14%	1. Pre- and post- insulation and replacement of building components, esp. windows; 2. Efficient lighting, esp. shift to CFLs; 3. Efficient appliances such as refrigerators and water heaters.	1. Efficient lighting and its controls; 2. Water and space heating control systems; 3. Retrofit and replacement of building components, esp. windows.
Developing countries	Myanmar, India, Indonesia, Argentine, Brazil, China, Ecuador, Thailand, Pakistan, South Africa	Technical: 18%–41% Economic (<US$ 0/tCO_2eq): 13%–52%[g] Market: 23%	1. Efficient lights, esp. shift to CFLs, light retrofit, and kerosene lamps; 2. Various types of improved cooking stoves, esp. biomass stoves, followed by LPG and kerosene stoves; 3. Efficient appliances such as air-conditioners and refrigerators.	1. Improved lights, esp. shift to CFLs light retrofit, and efficient kerosene lamps; 2. Various types of improved cooking stoves, esp. biomass based, followed by kerosene stoves; 3. Efficient electric appliances such as refrigerators and air-conditioners.

Notes:
[a] Except for EU-15, Greece, Canada, India, and Russia, for which the target year was 2010, and Hungary, Ecuador and South Africa, for which the target was 2030.
[b] The fact that the market potential is higher than the economic potential for developed countries is explained by limitation of studies considering only one type of potential, so information for some studies likely having higher economic potential is missing.
[c] Both for 2010, if the approximate formula of $\text{Potential}_{2020} = (1 – (1 – \text{Potential}_{2010})^{20/10}$ is used to extrapolate the potential as percentage of the baseline into the future (the year 2000 is assumed as a start year), this interval would be 38%–79%.
[d] Both for 2010, if suggested extrapolation formula is used, this interval would be 22%–44%.
[e] The last figure is for 2010, corresponds to 72% in 2020 if the extrapolation formula is used.
[f] The first figure is for 2010, corresponds to 24% in 2020 if the extrapolation formula is used.
[g] The last figure is for 2030, corresponds to 38% in 2020 if the suggested extrapolation formula is applied to derive the intermediate potential.

4.2. The global estimate of the potential and costs for CO_2 mitigation in buildings

Our calculations based on the results of the reviewed studies (see Chapter 6 IPCC AR4 for the detailed methodology) suggest that, globally, appr. 29% of the projected baseline emissions by 2020[3] can be avoided cost-effectively through mitigation measures in the residential and commercial buildings. Additionally at least 3% of baseline emissions can be avoided at costs up to 20 USD/tCO_2, and 4% more if costs up to 100 USD/tCO_2 are considered. Although due to the large opportunities at low costs, the high-cost potential has been assessed to a limited extent, and thus this figure is an underestimate. These estimates represent a reduction of app. 3.2, 3.6, and 4.0 Gt of CO_2-eq. in 2020, at zero, 20 USD/tCO_2, and 100 USD/tCO_2, respectively. The summary of results is presented in Table 3. Due to the limited number of demand-side end-use efficiency options considered by the studies, the omission of non-technological options, the often significant co-benefits, as well as the

[3] The baseline CO_2 emission projections were calculated on the basis of the reviewed studies, and is a composite of business-as-usual and frozen efficiency baseline.

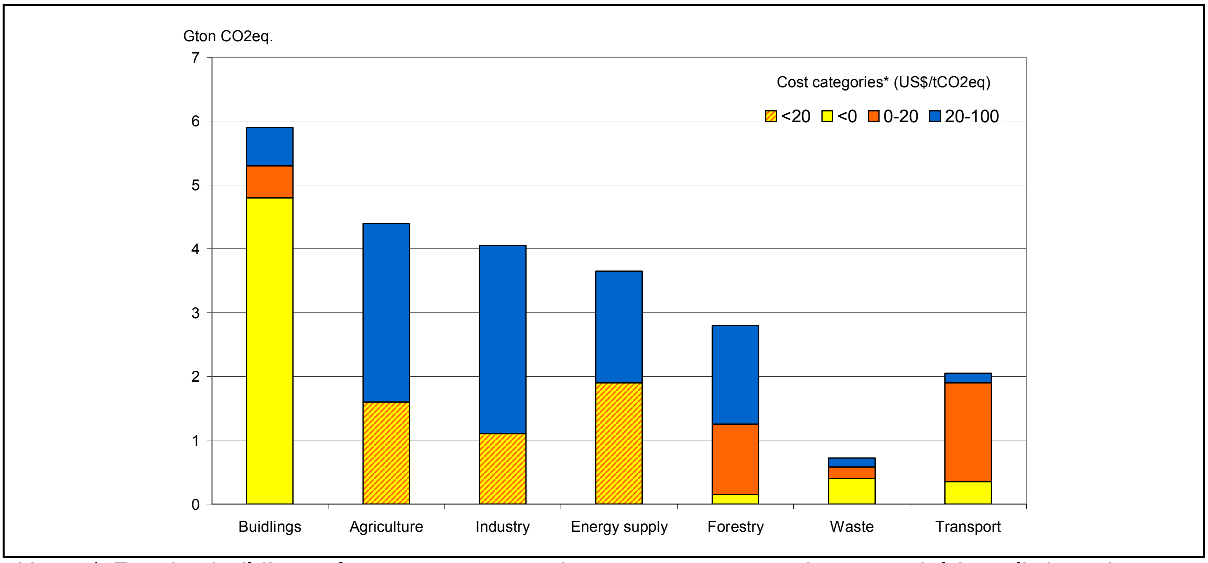
exclusion of advanced integrated highly efficiency buildings, the *real potential is likely to be higher*. While occupant behaviour, culture and consumer choice as well as use of technologies are also major determinants of energy consumption in buildings and play a fundamental role in determining CO_2 emissions, the potential reduction through non-technological options is not assessed.

Table 3 CO_2 mitigation potential projections in 2020 as a function of CO_2 cost

Region	Baseline emissions in 2020	CO_2 mitigation potentials as share of baseline CO_2 emission projections in cost categories in 2020 (costs in US$/t$CO_2$-eq)			CO_2 mitigation potentialsin absolute values in cost categories in 2020, GtCO_2-eq (costs in US$/t$CO_2$-eq)		
	GtCO_2-eq	<0	0-20	20–100	<0	0-20	20–100
Global	11.1	29%	3%	4%	3.2	0.4	0.5
OECD	4.8	27%	3%	2%	1.3	0.1	0.1
EIT	1.3	29%	12%	23%	0.40	0.2	0.3
Non OECD/ EIT	5.0	30%	2%	1%	1.5	0.1	0.0

For comparison with other sectors these potentials have been extrapolated to 2030. The robustness of these figures is significantly lower than those for 2020 due to the lack of research for this year. The results of the cross-sectoral comparison of the potentials are presented in Figure 1. The figure attests that low-cost potentials are highest in the building sector from all sectors.

Figure 1 Estimated potential for GHG mitigation at a sectoral level in 2030 in cost categories



Note: * For the buildings, forestry, waste and transport sectors, the potential is split into three cost categories: at net negative costs, at 0-20 US$/t$CO_2$, and 20-100 US$/tCO_2. For the industrial, forestry, and energy supply sectors, the potential is split into two categories: at costs below 20 US$/t$CO_2$ and at 20-100 US$/t$CO_2$.

The authors of the paper believe that the potential for CO_2 emission reduction in the non-residential buildings (as the share of their baseline emissions) is close to the range of that of the whole buildings stock. This is because the main factors determining the level of the potential such as the breakdown of energy use, efficiency principles and technologies, and the barriers for efficiency penetration in these the residential and non-residential types of buildings are similar.

4.3. Most attractive measures in buildings

Table 2 and Table 3 attest that opportunities for cost-effective and low-cost CO_2 mitigation in buildings are abundant in each world region. CO_2-saving options are largest from fuel use in developed countries and countries in transition due to their more northern locations and, thus, larger potential for heat-saving measures. Conversely, electricity savings constitute the largest potential in developing countries located in the south, where the majority of emissions in the buildings sector are associated with appliances and cooling. This distribution of the potential also explains the difference in mitigation costs between developing and developed countries. The shift to more efficient appliances quickly pays back, while building shell retrofits and fuel switching, together providing approximately half of the potential in developed countries, are more expensive.

While it is impossible to draw universal conclusions regarding individual measures and end-uses, Table 2 attests that efficient lighting technologies are among the most promising measures in buildings, in terms of both cost-effectiveness and size of potential savings in almost all countries. In developing countries, efficient cook stoves rank second, while the second-place measures differ in the industrialized countries by climatic and geographic region. Almost all studies examining economies in transition (typically in cooler climates) have found heating-related measures to be most cost-effective, including insulation of walls, roofs, windows, and floors, as well as improved heating controls for district heat. In developed countries, appliance-related measures are typically identified as the most cost-effective, with cooling-related equipment upgrades ranking high in the warmer climates.

In terms of the size of savings, improved insulation and district heating in the colder climates and efficiency measures related to space conditioning in the warmer climates come first in almost all studies,[4] along with cook stoves in developing countries. Other measures that rank high in terms of savings potential are solar water heating, efficient lighting, and efficient appliances, as well as building energy management systems.

The conclusions regarding the most attractive options in the non-residential buildings are similar to those for the whole buildings stock. The correction should be made to the applicability to certain technologies in the non-residential buildings (for instance, the domestic cooking stoves refer mainly to the residential sector).

5. Co-Benefits of CO_2 mitigation in the non-residential buildings

Investments in the buildings energy efficiency and renewable energy technologies can yield a wide spectrum of benefits well beyond the value of saved energy and reduced CO_2 emissions. However, these co-benefits are often not quantified, monetized, or perhaps even identified by the decision makers or economic modelers (Jochem and Madlener, 2003). If taken into account, they can play a crucial role in making decisions in policies and business (Jakob *et al.*, 2002; Mirasgedis *et al.*, 2004; Banfi *et al.*, 2006). Strategic alliances with other policy fields, such as employment, competitiveness, health, environment, social welfare, poverty alleviation, and energy security, can provide broader societal support for climate change mitigation goals, and may improve the economics of climate mitigation efforts substantially through sharing the costs or enhancing the dividends (European Commission, 2005). Further, we detail the most important co-benefits of GHG mitigation in the non-residential buildings.

First, the implementation of new technologies for GHG emissions mitigation achieves substantial learning and economies of scale, resulting in cost reductions. Jacob and Madlener (2004) analyzed the technological progress and marginal cost developments for energy efficiency measures related to the building envelope using data for the time period 1975-2001 in Switzerland. The analysis yields technical progress factors of around 3% per annum for wall insulation and 3.3% per annum for double glazing windows, while real prices decreases of 0.6% since 1985 for facades and 25% over the last 30 years for double glazing windows (Jacob and Madlener 2004).

Second, providing energy-efficiency services has proven to be a lucrative business opportunity. Experts estimate a market opportunity of 5-10 billion € (4.6-9.2 billion US$) in energy service markets in Europe (Butson, 1998). Also, there is increasing evidence that well-designed, energy efficient buildings often have the co-benefits of improving occupant productivity and health (Leaman and Bordass, 1999; Fisk, 2000; Fisk, 2002). Assessing these productivity gains is difficult (CIBSE (The Chartered Institution of Building Services Engineers), 1999) but in a study of 16 buildings in the UK, occupants estimated that their productivity was influenced by the environment by between -10% and +11% (Leaman and Bordass, 1999).

[4] Note that several studies covered only electricity-related measures, and thus excluded some heating options.

Third, most studies agree that energy-efficiency investments will have positive effects on employment, directly by creating new business opportunities and indirectly through the economic multiplier effects of spending in other ways the money saved on energy costs (Laitner, 1998; Jochem and Madlener, 2003). The European Commission (2005) estimates that a 20% reduction in EU energy consumption by 2020 can potentially create (directly or indirectly) as many as one million new jobs in Europe, especially in the area of semi-skilled labour in the buildings trades (Jeeninga *et al.*, 1999; European Commission, 2003).

Furthermore, the diffusion of new technologies for energy use and/or savings in non-residential buildings contributes to an improved quality of life and increases the value of buildings. Jakob (2006) lists examples of this type of co-benefit, such as improved thermal comfort (fewer cold surfaces such as windows), and the substantially reduced level of outdoor noise infiltration in buildings due to triple-glazed windows or high-performance wall and roof insulation. At noisy locations, an improvement of 10-15 dB could result in gross economic benefits up to the amount of 3-7% of the rental income from a building (Jakob, 2006). Last, better-insulated buildings eliminate moisture problems associated with, for example, thermal bridges and damp basements, and thus reduce the risk of mold build-up and associated health risks.

Additional co-benefits of building-level GHG mitigation include improved energy security and system reliability (IEA, 2004). Improving end-use energy efficiency is among the top priorities on the European Commission's agenda to increase energy security, with the recognition that energy efficiency is likely to generate additional macroeconomic benefits because reduced energy imports will improve the trade balances of importing countries (European Commission, 2003).

Finally, climate mitigation through energy efficiency in the non-residential buildings sector will improve local and regional air quality, particularly in large cities, contributing to improved public health (e.g., increased life expectancy, reduced emergency room visits, reduced asthma attacks, fewer lost work days) and avoidance of structural damage to buildings and public works.

6. Barriers for efficiency penetration in the non-residential buildings

Despite there is the significant cost-effective potential for CO_2 mitigation through energy efficiency in the non-residential buildings, it realization is slower than it could be even though accompanied with lucrative co-benefits. Certain characteristics of markets, technologies, and end-users can inhibit rational, energy-saving choices in building design, construction, and operation, as well as in the purchase and use of equipment and appliances. The most important barriers that pertain to the non-residential buildings sector are discussed below.

6.1. Barriers which relate to economics of energy-efficiency

The high ratio of investment costs to value of associated benefits creates one of the key barriers for penetration of energy efficient technologies and practices in the buildings sector. The common reasons for this phenomenon are energy subsidies and disregarded environmental, health, and other external losses/benefits downsizing the saved costs. In many countries, electricity historically has been subsidized to commercial or government customers (Gritsevich, 2000). However, the abrupt lifting of historically prevailing subsidies may also have adverse effects such as non-payment and electricity thefts (EIA (Energy Information Administration), 2004).

Other important economic barrier relates to higher up-front costs of the vast majority of energy efficiency technologies versus the business-as-usual technologies. Despite the saved operation costs of advanced technologies may justify the additional capital costs quickly, the limited availability of capital and limited access to capital markets of small businesses, especially in developing countries (Reddy 1991), shrink financing of expensive innovations.

Costs and risks due to potential incompatibilities, performance risks, transaction costs, and other reasons, which are not captured directly in financial flows, also reduce the penetration of efficiency technologies. Such barriers, for instance, include limited availability of energy-efficient equipment along the retail chain (Brown *et al.*, 1991); the case of poor power quality in some developing countries interfering with the operation of the electronics needed for energy efficient end use devices (EAP UNDP (Energy and Atmosphere Programme of United Nations Development Programme), 2000); and the inadequate levels of energy services (e.g., insufficient illumination levels in schools, or unsafe wiring) in many public buildings in developing countries and economies in transition.

Furthermore many energy-efficiency projects and ventures in buildings are too small to attract the attention of investors and financial institutions. Small project size, coupled with disproportionately high transaction costs – prevent some energy-efficiency investments. Small enterprises often receive higher returns on their investments into marketing or other business-related activities than investing their resources, including human resources, into energy-related activities. Conservative, asset-based lending practices of financial institutions, a limited understanding of energy-efficiency technologies on the part of both lenders and their consumers, lack of traditions in energy performance contracting, volatile prices for fuel (and in some markets, electricity), and small, non-diversified portfolios of energy projects all increase the perception of market and technology risk (Ostertag, 2003; Westling, 2003; Vine, 2005)..

6.2. Market failures

The second category of barriers for efficiency penetration is based on market failures that prevent the benefits of energy-efficiency investments. This is, for instance, the agent-principal barrier, which appears when intermediaries are involved in decisions to purchase energy-saving technologies, or agents responsible for investment decisions are different from those benefiting from the energy savings. This limits the consumer's role and often misplaces his/her incentives to invest in energy efficiency. For example, in many countries the energy bills of hospitals are paid from central public funds while investment expenditures must come either from the institution itself or from the local government (Rezessy *et al.*, 2006). Another example is that building designers may emphasize initial costs over life-cycle costs, hindering energy-efficiency choices (Lovins, 1992; Jones *et al.*, 2002).

Another significant barrier to energy-efficient building design is that buildings are complex systems: minimizing energy use requires optimizing the system as a whole by systematically addressing building form, orientation, envelope, glazing area, and a host of interaction and control issues involving the building's mechanical and electrical systems. At the same time, compounding the flaws in the typical design process is fragmented in the building industry and the typical design process is linear and sequential. Assuring the long-term energy performance and sustainability of buildings is all the more difficult when decisions at each stage of design, construction, and operation involve multiple stakeholders.

There is also a range of regulatory barriers hindering penetration of building-level distributed generation technologies such as PV, reciprocating engines, gas turbines, and fuel cells (Alderfer, 2000). In many countries, these barriers include variations in environmental permitting requirements, which impose significant burdens on project developers. Similar variations in metering policies cause confusion in the marketplace and represent barriers to distributed generation. Public procurement regulations often inhibit the involvement of ESCOs or the implementation of energy performance contracts.

Lastly, information about energy-efficiency options is often incomplete, unavailable, expensive, and difficult to obtain or trust. In addition, few small enterprises in the building industry have access to sufficient training in new technologies, new standards, new regulations, and best practices. A similar situation exists for building officers in local authorities. This insufficient knowledge is compounded by uncertainties associated with energy price fluctuations (Hassett and Metcalf, 1993).

6.3. Behavioural and organizational non-optimalities

Finally, the third broad category of barriers stems from the cultural and behavioural characteristics of individuals. The potential impact of lifestyle and tradition on energy use is most easily seen by cross-country comparisons. There are substantial differences among countries in lighting use, room temperatures considered comfortable, preferred temperatures of food or drink, the operating hours of commercial buildings, etc. (IEA, 1997; Chappells and Shove, 2004). Studies suggest that while lifestyle, traditions and culture can act as barriers, retaining and supporting lower-consuming lifestyles may be effective in constraining GHG emissions (e.g., (EEA (European Environment Agency), 2001).

The “rebound effect” has often been cited as a barrier to the implementation of energy-efficiency policies. This takes place when increased energy efficiency is accompanied by increased demand for energy services (Moezzi and Diamond, 2005). The literature is divided about the magnitude of this effect (Herring, 2006).

7. Policies to promote GHG mitigation in the non-residential buildings

The previous section has demonstrated that even the cost-effective part of the potential for reducing CO_2 emissions is unlikely to be captured by markets alone, due to the high number of barriers. Although there is no quantitative or qualitative evidence in the literature, it is possible that barriers to the implementation of economically attractive GHG reduction measures are the most numerous and strongest in the buildings sector. Since policies can reduce or eliminate barriers and associated transaction costs (Brown, 2001), special efforts targeted at removing the barriers in the buildings sector may be especially warranted for GHG mitigation efforts.

Table 4 reviews 16 of the key policy tools used in buildings grouped by four major categories using a typology synthesized from several sources (including (Grubb, 1991; Crossley *et al.*, 2000; Verbruggen and Bongaerts, 2003)): (i) control and regulatory mechanisms, (ii) economic and market-based instruments, (iii) financial instruments and incentives, and (iv) support and information programs and voluntary action. The effectiveness in achieving CO_2 reduction and cost-effectiveness were rated qualitatively based on 66 ex-post (with a few exceptions) policy evaluation studies from over 30 countries and country groups as well as quantitatively based on one or more selected case studies. Since any instrument can perform poorly if not designed carefully, or if its implementation and enforcement are compromised, the qualitative and quantitative comparisons are based on identified best practices, in order to demonstrate what impact an instrument can achieve if applied well. Finally, the table lists special conditions for success, major strengths and limitations, and co-benefits. Although a general caveat of comparative policy assessments is that policies act as parts of portfolios and therefore the impact of an individual instrument is difficult to delineate from those of other tools, this concern affects the assessment to a limited extent since the literature used already completed this disaggregation before evaluating individual instruments.

Table 4 The impact and effectiveness of selected policy instruments aimed at mitigating GHG emissions in the buildings sector using best practices

Policy instrument	Emission reduction Effectiveness[a]	Cost-effective-ness[b]	Special conditions for success, major strengths and limitations, co-benefits
Control and regulatory mechanisms			
Appliance standards	High	High	Factors for success: periodic update of standards, independent control, information, communication and education.
Building codes	High	Medium	No incentive to improve beyond target. Only effective if enforced.
Public leadership programmes, inc. procurement regulations	High	High/Medium	Can be used effectively to demonstrate new technologies and practices. Mandatory programmes have higher potential than voluntary ones. Factor for success: ambitious energy efficiency labelling and testing.
Energy efficiency obligations and quotas	High	High	Continuous improvements necessary: new EE measures, short term incentives to transform markets, etc.
Labelling and certification programmes	Medium/High	High	Mandatory programmes more effective than voluntary ones. Effectiveness can be boosted by combination with other instruments and regular updates.
Mandatory audit and energy management requirement	High, but variable	Medium	Most effective if combined with other measures such as financial incentives.
Demand-side management programmes	High	High	Tend to be more cost-effective for commercial sector than for residences.
Economic and market-based instruments			

Energy performance contracting/ESCO support[c]	High	Medium	Strength: no need for public spending or market intervention, co-benefit of improved competitiveness.
Energy efficiency certificate schemes	Medium	Medium	No long-term experience. Transaction costs can be high. Institutional structures needed. Profound interactions with existing policies. Benefits for employment.
Kyoto Protocol flexible mechanisms[d]	Low	Low	So far limited number of CDM &JI projects in buildings.
Financial instruments and incentives			
Taxation (on CO_2 or fuels)	Low	Low	Effect depends on price elasticity. Revenues can be earmarked for further efficiency. More effective when combined with other tools.
Tax exemptions/ reductions	High	High	If properly structured, stimulate introduction of highly efficient equipment and new buildings.
Capital subsidies, grants, subsidised loans	High	Low	Positive for low-income households, risk of free-riders, may induce pioneering investments.
Support, information and voluntary action			
Voluntary and negotiated agreements	Medium / High	Medium	Can be effective when regulations are difficult to enforce. Effective if combined with financial incentives, and threat of regulation.
Education and information programmes	Low / Medium	High	More applicable in residential sector than commercial. Success condition: best applied in combination with other measures.
Detailed billing and disclosure programmes	Medium	Medium	Success conditions: combination with other measures and periodic evaluation.

Notes:
[a] includes ease of implementation; feasibility and simplicity of enforcement; applicability in many locations; and other factors contributing to overall magnitude of realized savings
[b] Cost-effectiveness is related to specific societal cost per carbon emissions avoided.
[c] Energy service companies
[d] Joint Implementation, Clean Development Mechanism, International Emissions Trading (includes the Green Investment Scheme)

7.1. Control and regulatory instruments

Regulatory instruments are used in most countries with legislation on energy efficiency in buildings, but often in combination with other instruments. Main problems are the lack of enforcement and the rebound effect, but on the other hand, most of these policy instruments achieve high savings at low costs, often at negative costs to society. They can overcome many of the numerous barriers, in the buildings sector such as information barriers, market failures and financial/economic barriers as well as hidden costs. For example, regulatory instruments help to reduce transaction costs, one of the major problems in this sector, by simply imposing standards which eliminate the need for information-searching. Comparing different regulatory instruments is difficult, especially as many of them are usually used together since they concern partly different end-uses or target groups, for example appliance standards for appliances, building codes for buildings and procurement regulations for the public sector. The available case studies indicate that appliance standards are often easier to enforce than building codes because the industry is more concentrated and the products are standardized, while the building industry has many diverse trades and the products (buildings) are custom-built. However, if correctly enforced, building codes can achieve enormous savings as well.

7.2. Economic and market-based instruments

The four economic instruments presented in this section, energy performance contracting, cooperative procurement, energy efficiency certificate schemes and Kyoto flexibility mechanisms are very diverse. They can be applied simultaneously in one country as they target different end-users: energy performance contracting is a financing mechanism, cooperative procurement is used voluntarily by large buyers or groups of buyers in the public or private sector and the Kyoto flexibility mechanisms is the only international cooperation instrument specifically directed at developing countries. Energy performance contracting (EPC) and cooperative procurement are promising. However, due to the newness of two of the instruments, Kyoto mechanisms and white certificates, their effectiveness is still uncertain and limited. This might be due to problems with their current design such as a missing methodology for Kyoto mechanisms adapted to the buildings sector. For the same reason, ex-post evaluations are still rare and especially the cost-effectiveness of the instruments remains uncertain. However, there is a significant potential for energy and cost savings through these instruments in the future.

7.3. Financial instruments and incentives

According to the presented case studies the effectiveness of fiscal instruments varies considerably and depends strongly on the design of the instrument. For instance, in the short run, instruments which increase the energy price such as taxation are often less effective than fiscal incentives such as tax exemptions, loans and subsidies due to the limited price elasticity of households. The effectiveness of taxes depends, for instance, on the level of taxes or on the use of the tax revenue by the government. Tax exemptions are usually more effective and seem to be one of the most neglected, yet very useful instruments. Subsidies, grants, loans and rebates can be effective if designed well, and are especially needed in developing countries where lack of financing constitutes a major barrier. In these countries, tax exemptions are not enough. Fiscal instruments can help overcome the barriers under the categories financial costs versus benefit and market failures. In addition, fiscal incentives need to be high enough to attract attention.

7.4. Support, information and voluntary action

Although instruments in the category of support, information and voluntary action might be considered rather “soft” they can still achieve significant savings and successfully complement other instruments. However, they are usually less effective than regulatory and control measures. They are also often used at the outset of a country’s political engagement in energy efficiency policies either by the public sector or outside it. In general, the impact of instruments under this category is difficult to measure due to the frequent combination with other instruments. Public sector leadership programs seem to be the most effective instrument in this category. Voluntary labelling and agreements can be effective under certain conditions. Informational instruments can be effective in combination with suitable other instruments. Finally, instruments classified here can certainly help to overcome a number of the presented barriers, especially the information barrier, but also contribute to solving, for example, the political/ structural barriers.

7.5. Overall summary of policy tools

All of the instruments reviewed can achieve significant energy and CO_2 savings; however, the costs per ton of CO_2 saved diverge greatly. In our sample, appliance standard, building code, labelling, and tax exemption policies achieved the highest CO_2 emission reductions. Appliance standards, energy efficiency obligations, demand-side management programs, public benefit charges, and mandatory labelling were among the most cost-effective policy tools in the sample, all achieving significant energy savings at negative costs. Investment subsidies (as opposed to rebates for purchases of energy efficient appliances) were revealed as the least cost-effective instrument. Tax reductions for investments in energy efficiency appeared more effective than taxation. Labelling and voluntary programs can lead to large savings at low costs if they are combined with other policy instruments. Finally, information programs can also achieve significant savings and effectively accompany most other policy measures.

When comparing the four different categories of measures, the collected case studies indicate that regulatory and control measures are probably the most effective as well as the most cost-effective category, at least in developed countries. They all achieved ratings of high or medium (see Table 4) according to both criteria. Measures which can be designed both as voluntary and as mandatory, such as labeling or energy efficient public procurement policies, have been revealed as more effective when they are mandatory.

It also needs to be kept in mind that in developing countries the savings achieved by energy-efficiency policies may not fully or even partially materialize as reductions compared to even a business-as-usual baseline. This is because in the case of restricted energy services the purpose of energy saving policies is often not to reduce total energy consumption, as it is in many cases in developed countries, but rather to ensure that more energy services can be afforded from the available resources.

7.7. Policy packages

Every policy measure has its own advantages, ideal target groups and specific operational mechanisms. Each is tailored to overcome one or a few certain market barriers, but none can address all the barriers. Thus, none of them can alone capture the entire enormous potential for energy efficiency improvements even in a single location, nor can one instrument be singled out as a generally applicable best solution. The effectiveness of economic instruments, information programs, and regulation can be substantially enhanced if these are appropriately combined into policy packages that take advantage of synergistic effects (Ott et. al., 2005). Since climate change literacy, awareness of technological, cultural and behavioural choices and their impacts on emissions are important preconditions to fully operating policies, these policy approaches need to go hand in hand with programs that increase consumer access to information, awareness and knowledge.

A typical example of policy combination is the co-ordination of energy audit programs with economic instruments, such as energy taxes and capital subsidy schemes. In addition, ESCOs can flourish when public procurement legislation accommodates EPCs and includes ambitious energy-efficiency or renewable energy provisions, or in the presence of an energy-saving obligation. A promising combination of policy tools are public leadership programs and energy performance contracting. By improving its own energy efficiency, the public sector can not only save costs, but also demonstrate to the private sector the potential and feasibility of energy efficiency improvements and trigger market transformation. Energy performance contracting in the public sector is especially advantageous as the budget of many public administrations is limited. Executive orders which oblige public authorities to reduce their energy consumption by 30% and the federal energy management program in the US as well as the Energy Saving Partnership in Berlin, Germany, have significantly boosted the ESCO industry. However, significant barriers still hamper EPC in the public sector for example in China, India and other countries.

7.8. Section summary

During the last decades, many new policies targeted to the buildings sector have been initiated. However, so far only incremental progress has been achieved by these policies. In most developed countries, the energy consumption in buildings is still increasing (IEA, 2004). Although some of this growth is offset by increased efficiency of major energy-consuming appliances, overall consumption continues to increase due to the growing demand for amenities, such as new electric appliances and increased comfort. The limited overall impact of policies so far is due to several factors: (i) slow implementation processes (e.g., as of 2006, not all European countries are on time with the implementation of the EU Buildings Directive); (ii) the lack of regular updating of building codes (requirements of many policies are often close to common practices, despite the fact that CO_2-neutral construction without major financial sacrifices is already possible) and appliance standards and labelling; and (iii) insufficient enforcement. In addition, section 6 demonstrated that barriers in the building sector are numerous; diverse by region, sector, and end-user group and especially strong.

In summary, significant CO_2 can be achieved in buildings, often at net benefit to society (in addition to avoided climate change) and also meeting many other sustainable development and economic objectives, but this requires a stronger political commitment and more ambitious policy-making than today, including careful design of policies as well as enforcement and regular monitoring.

9. Conclusion

The IPCC SRES Scenarios project a significant CO_2 emissions growth is the buildings sector to the year 2030. The key conclusion of the paper is that substantial reductions in these emissions from energy use in the non-residential buildings can be achieved over the coming years using mature technologies for energy efficiency that already exist widely and that have been successfully used. A significant portion of these savings can be achieved in ways that reduce life-cycle costs, thus providing reductions in CO_2 emissions that have a net benefit rather than cost.

Our survey of the literature (80 studies) indicates that there is a global potential to reduce approximately 29% of the projected baseline emissions by 2020 cost-effectively in the residential and non-residential buildings sectors, the highest among all energy end-use sectors. Additionally at least

3% of baseline emissions can be avoided at costs up to 20 USD/t CO_2 and 4% more if costs up to 100 USD/t CO_2 are considered. However, due to the large opportunities at low costs, the high-cost potential has been assessed to a limited extent, and thus this figure is an underestimate. The authors of the paper believe that the potential for CO_2 emission reduction in the non-residential buildings (as the share of their baseline emissions) is close to the range of that of the whole buildings stock.

The great challenge is the development of effective strategies for retrofitting existing buildings due to their slow turnover. There are numerous published studies showing that energy savings of 50 to 75% can be achieved in the non-residential existing buildings through aggressive implementation of integrated sets of measures. These savings can often be justified in terms of the energy-cost savings alone, although in other cases full justification requires consideration of a variety of less tangible benefits. Applying an integrated design process to the new non-residential buildings has often achieved savings on the order of 50-80% compared to a standard practice. Over the whole building stock the largest portion of carbon savings by 2030 is in retrofitting existing buildings and replacing energy-using equipment due to the slow turnover of the stock.

Implementing carbon mitigation options in the non-residential buildings is associated with a wide range of co-benefits. While financial assessment has been limited, it is estimated that their overall value may be higher than those of the energy savings benefits. There are, however, substantial market barriers that need to be overcome and a faster pace of well-enforced policies and programs pursued for energy efficiency and decarbonization to achieve the high indicated negative and low-cost mitigation potential.

A variety of government policies have been demonstrated in many countries to be successful in reducing energy-related CO_2 emissions in buildings. Among these are continuously updated appliance standards and building energy codes and labeling, energy pricing measures and financial incentives, utility demand-side management programs, public sector energy leadership programs including procurement policies, education and training initiatives, and the promotion of energy service companies. Since climate change literacy, awareness of technological, cultural and behavioral choices are important preconditions to fully operating policies, applying these policy approaches needs to go hand in hand with programs that increase consumer access to information, and awareness and knowledge through education.

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Transforming UK non-residential buildings: achieving a 60% cut in CO2 emissions by 2050

Dr Mark Hinnells, Dr Russell Layberry, Daniel Curtis, Dr Andy Shea,
Environmental Change Institute, Oxford University.

Abstract

The UK Climate Change Bill will set in law a 60% cut in carbon emissions relative to 1990 levels by 2050. This paper describes the development of a model to explore the development of the UK non-domestic building stock, energy use and carbon emissions to 2050 under a range of scenarios. The paper discusses the data sources and modelling framework. The stock is undergoing significant evolution as the economy restructures towards a service economy, with strong underlying demographic, economic and social trends and drivers. At the same time there is significant scope for carbon reductions from technical and behavioural change, though this improvement is not being taken up for a range of reasons. The modeling and policy approach could provide the architecture for other countries (within or outside the EU) considering similar policy targets.

1 Introduction

The UK Climate Change Bill will set in law a 60% cut in carbon emissions relative to 1990 levels by 2050. The Bill will also set out a range of intermediate targets for carbon reduction, a budgeting process for successive 5 year periods, a process for independent assessment of progress, together with enabling powers for further policy implementation. The Bill is going through Parliament and is expected to become Law by summer 2008. Non-domestic buildings account for 19% of UK carbon emissions whereas residential buildings account for 27%. Buildings will become a key focus for policy.

This paper describes the development of a model to explore the development of the UK non-domestic building stock, energy use and carbon emissions, forward to 2050 under a range of scenarios.

The paper first discusses the data sources and modelling framework. The non-domestic stock model (NDSM) combines information about the stock, in terms of the number and floor area of buildings in a number of economic sectors, with energy use per square meter (m2) of floor area in 8 energy end use categories. Data is both historical (validated to the extent possible against known energy supplied at the UK level to different sectors) and projected to 2050 under a number of scenarios.

The paper then discusses how policy scenarios can be explored using the model. The stock is undergoing significant evolution as the economy restructures towards a service economy, with strong underlying demographic, economic and social trends and drivers. At the same time there is significant potential for carbon reductions from technical and behavioural perspectives, though reductions are not being taken up for a range of reasons.

4 sectors (offices, retail, warehousing and hotel and catering) have been presented here. Further work to complete the model is described. Even then, the model can only be considered interim, as there are many improvements to the modeling process which are needed (for example incorporation of a statistically significant number of buildings with Energy Performance Certificates and Display Energy Certificates) and these are outlined in the paper.

2 Description of the model

2.1 Envisioning the future

The future is clearly unknown, but will be influenced by a wide variety of factors such as:

- *Demographics* including population size, age, household structure
- *Socio-Economic Trends*. This may include the balance between private v public, and between industry v commerce). We have seen changing retail patterns (eg more out of town space, and

more use of the internet) and changing work-leisure patterns as populations get older and more wealthy with more disposable time and income.
- *Socio-Technological Trends* including changing perceptions about what constitutes thermal comfort (internal temperatures have been rising), hot water demand, and equipment use
- *Decision-Making Frameworks* which include both attitudinal factors as well as harder economic issues. Decisions may be influenced by fuel pricing and tariffs, access to capital, attitudes to return on investment, as well as tenant and landlord issues. Decisions may also be influenced by information, incentives and regulation, as well as by changing costs of technologies including through technology learning (the phenomena whereby costs come down in a relatively predictable way for each doubling of global installed capacity) and by innovative finance e.g. loans, mortgages or ESCOs.

Whilst these factors are too important to be ignored, they are difficult to include explicitly in a model, and more often than not, recent known trends and likely future directions explored off-model, and a simplified parameter included in the modeling, based on expert judgment.

2.2 Input parameters and calculation procedures

The non-domestic carbon scenario model (NDCSM) calculates the energy use and carbon emissions of the UK non-domestic stock yearly from 2004 to 2050. The main parameters are floor area and energy intensity. Data sources for these are as follows (Table 1).

Table 1 Data sources for modelling

	Floor area (m2)	**Energy intensity (kWh/m2/year)**
Historical	DCLG 1973-2004 CarB (1994-2004)	Sheffield Hallam 93-00
Reconciliation against historical	DTI Energy Trends and DUKES energy supplied data	
Projected	BMT	BMT

In 2004 the model has a fixed starting point based on survey data. In future years, the following are user-defined inputs:

- total area of each building class each year relative to 2004
- heating intensity, heating efficiency relative to 2004
- catering intensity and efficiency
- computing intensity and efficiency
- cooling intensity and efficiency
- domestic hot water intensity and efficiency
- lighting intensity and efficiency
- other end use intensity and efficiency
- process intensity and efficiency
- information about gains from each end use
- carbon intensities for each year of gas and electricity
- The potential for generation of heat and or power using building integrated renewables or CHP.

Of the 8 end uses, 4 can be considered electricity only and 4 electricity and gas. For mixed fuel end uses (catering, water heating, space heating and process heat) it is necessary to find the carbon intensity per kWh delivered and the efficiency (useful/delivered energy).

The model performs the processes described in Figure 1.

Figure 1 Structure of the non-domestic carbon scenario model

read in input data
1 – read in stock model [area in 2004 and energy for 8 end-uses in 2004]
2 – read in intensities [useful energy demand each year, each building class relative to 2004]
3 – read in efficiencies [useful/delivered each year, each building class (or relative to 2004 with 2004 = 1]
4 – read in emissions factors kgC/kWh] delivered [each year, each building class for the 4 mixed fuel end uses]
5 – read in emissions factors kgC/kWh] delivered for gas and grid electricity
6 – read in the area of Photo Voltaic and Solar Thermal [in terms of the fraction of floor area]
7 – read in the efficiency of PV and ST [in kWh/m2/year]

perform calculations for each year from 2004 to 2050 for each building class
1 – divide final end use energy by m2 to give final end use energy/m2
2 – multiply final end use energy/m2 by efficiency in 2004 to give useful energy/m2 in 2004
3 – multiply useful energy/m2 in 2004 by intensity to give useful energy/m2 in the current year
4 – calculate the difference in gains/m2 between current year and 2004 by adding together the difference in 6 end use useful energy/m2 between current year and 2004 (not including energy for space and water heating)
5 – multiply the gains difference by factor X (which represents how much of the gains coincide with the heating cycle/season) and add to useful heating demand/m2 and factor Y (which represents how much of the gains coincide with the cooling cycle/season) and add to useful cooling demand/m2
6 – calculate ST hot water and take off hot water heating demand
7 – divide useful energy/m2 by efficiency in current year to give fuel/m2
8 – multiply fuel/m2 by area intensity and area in 2004 to give end use fuel
9 – calculate carbon by multiplying each end use by kgC/kWh delivered in the current year and take off the carbon value of the PV generated electricity

write out data
1 file for each end use of total fuel delivered (GWh) for each year for each building class
1 file of the total carbon for each year for each building class

2.3 The effect of heat gains from lights and equipment in the model

End use electrical devices can be regarded as electric heaters. Less energy entering a building by heat from electrical appliances results in an increased need for space heating. It also results in potential reduction in space cooling need. Little is known about the time and the season of energy use in different building types, so significant assumptions have had to be made and this is a significant potential source of error. In the non-domestic, both heating and cooling needs are significant.

If lights and appliances are improved in terms of efficiency, the reduced gains that then have to be made up by the heating system is given by:

*lost heating = coincidence with heating cycle * coincidence with heating season,*

where the coincidence with the heating cycle is the proportion of the gains released when the heating system is attempting to meet a demand temperature.

The coincidence with the heating season is the proportion of gains emitted during the season where the heating system is operational. For example, lights may coincide with the heating cycle by 80% (they are on when the building is occupied) and with the heating season by 50% (6 months heating season). This means that 0.8*0.5 of the gains are 'useful' and must be replaced by the heating system. These numbers will change if an end use is preferentially on in the winter (e.g. lighting) or if it is on when the building is unoccupied (e.g. servers). The equivalent can be calculated for cooling. The cooling season is likely to be shorter, however. The lesser gains results in lesser cooling via an electric space cooling device by the missed gains divided by the coefficient of performance (COP) of the cooling device. Table 2 shows the assumptions made. In some sectors, a reduction in gains reduces cooling load to below zero. This is caught and these cooling (or heating) loads are set to zero.

Table 2 Assumptions in estimating useful and used gains from lights and equipment

	heating		**cooling**	
coincidence	**cycle**	**season**	**cycle**	**season**
heating	-99.9	-99.9	-99.9	-99.9
cooling	-99.9	-99.9	-99.9	-99.9
light	0.8	0.5	0.8	0.17
computing	0.6	0.5	0.6	0.17
Hot water	0.2	0.5	0.2	0.17
Catering	0.8	0.5	0.8	0.17
Other	0.5	0.5	0.5	0.17
Process	0.8	0.5	0.8	0.17

NB cycle = what percentage of the appliance load is within the heating/cooling cycle of the building (one number for now, but will be different for offices to hospitals for example)
season = what percentage of the cycle is within a heating or cooling period
heating season is assumed to be 6 months
cooling season is assumed to be 2 months

The remainder of the paper now sets out the major issues which drive the model, in particular floor area, and end use consumption and their impact in terms of future carbon emissions.

3 Modeling dynamic input parameters

3.1 Floor area data, current and projected

Floor area data are based on Valuation Office Agency (VOA) data for commercial premises (DCLG 2006). VOA collects data on commercial premises which is used as the basis for Business Rates and has published data since 1973. This is for England and Wales only, since there is central VOA data for Scotland and Northern Ireland. The England and Wales data has therefore been scaled up on a pro-rata population basis (i.e. by 12.5%) to represent the UK and the model for the UK is considered from here. CarB (2005) provided a more detailed breakdown of this data for two years, together with their own estimates or relied on other data sources for premises which are not rateable (eg public sector buildings).

Buildings are grouped by type. There are a total of 1.76 million buildings in 2004 in the non-domestic stock model (Table 3). By area, the commercial sector dominates, with industrial buildings accounting for 28% of floor area.

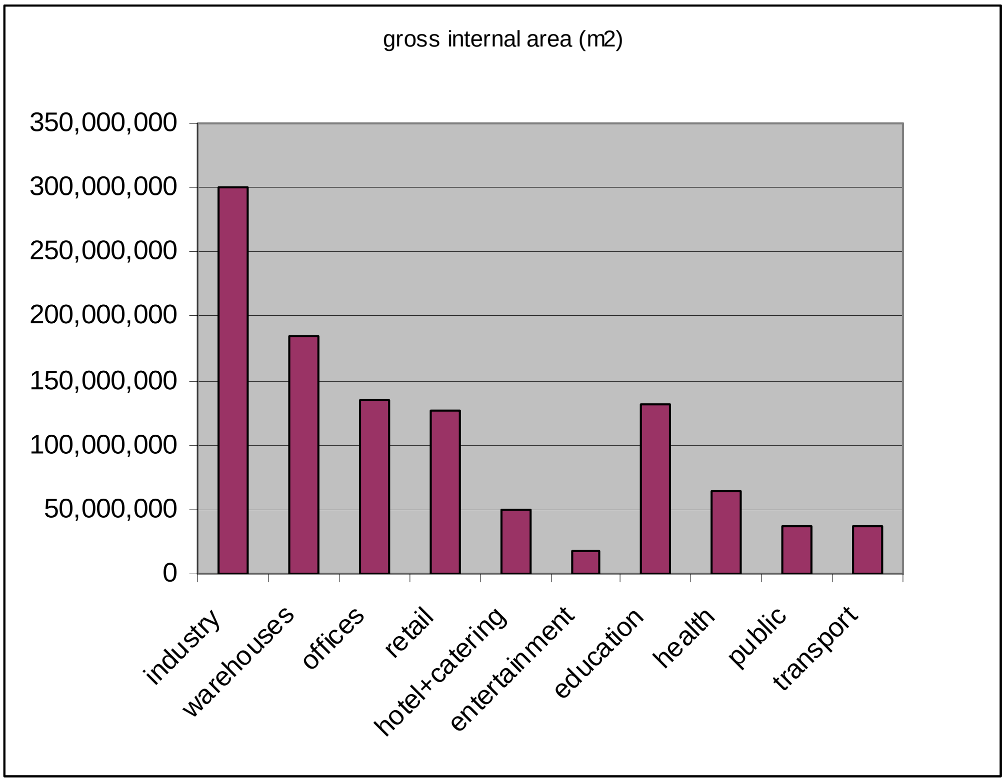
Offices and retail are urban or edge of urban in location. In dense urban areas they are often co-located within a given building. Edge of urban space retail can be shed like in structure. There is a huge variety in size of both office and retail, from small one or two person business to multi storey multi-tenanted structures. Retail is increasingly being dominated by malls and out of town centres.

Hotels cover large hotels down to bed and breakfast accommodation almost residential in style. Catering covers a range of fast food takeaways to restaurants, cafes bars and clubs. Entertainment (cinemas, bowling alleys, etc) is increasingly co-located in retail (eg in malls).

Industry and warehouses are similar in construction, and a given building can be interchangeable between functions. They are extra-urban in terms of location, broadly shed-like (i.e. often thin skin steel structures), often with large access doors, unlikely to be airtight, and unlikely to be maintained to comfort levels associated with other spaces. In industrial premises, much of the heating will be provided by process heat.

Education covers nursery, primary and secondary, as well as further and higher education. It covers both public and private provision. Health includes primary and tertiary sectors, again both public and private.

Figure 2 Gross internal floor area of the UK non-domestic Building stock in 2004



Source CarB 2005

Table 3 The UK non-domestic building stock in 2004

category	Number	gross internal area (m2)	% Floor area
industry	271,988	300,416,644	28%
warehouses	200,208	184,244,121	17%
offices	321,849	134,414,094	12%
retail	586,355	127,626,349	12%
hotel+catering	144,440	49,491,248	5%
entertainment	23,346	17,663,428	2%
education	40,737	130,999,233	12%
health	58,791	63,748,207	6%
public	60,549	36,706,958	3%
transport	58,211	37,436,612	3%
total	**1,766,474**	**1,082,746,894**	

Source: CarB 2005

3.2 The real estate market and projections of floor area needs

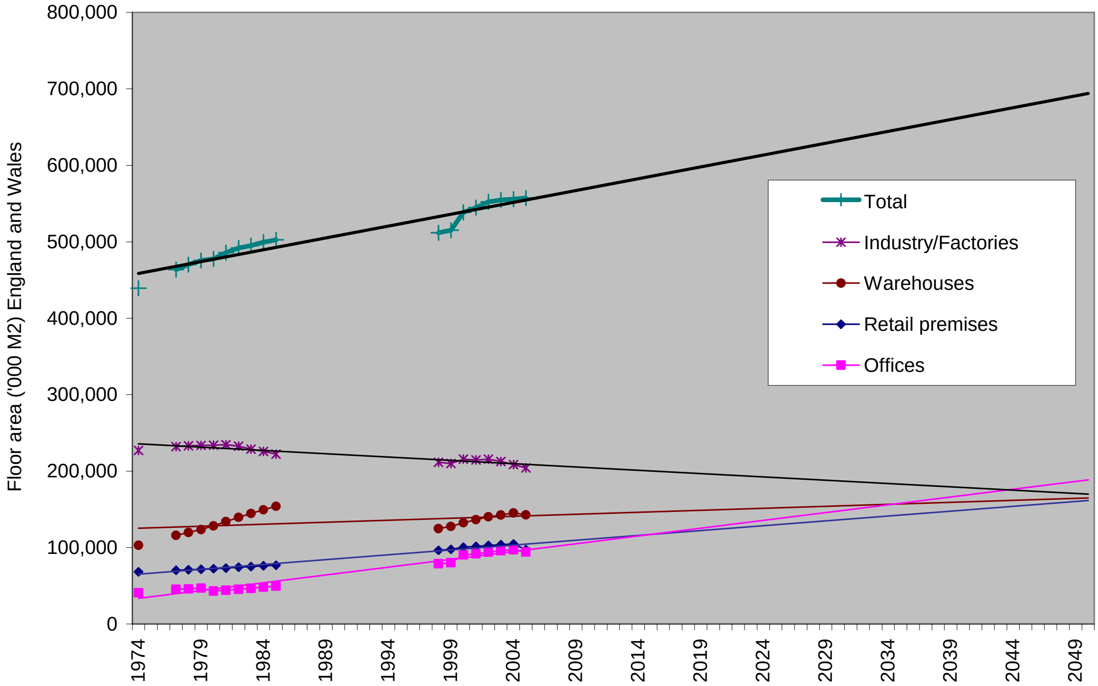
There are no existing projections for floor area needs, and so a coherent 'storyline' has been developed for each sector as part of the project. Projections are based on known trends n the stock, with data back to 1973 for most sectors. The real estate market mapping and market projections therefore form a major output of the project, and will have a variety of other important applications. Looking forward, there are public plans for expenditure in say health and education for the next 5-15 years, but building new commercial space (especially retail and offices) is highly speculative and based on local opportunity. Investors (landlords) anticipate likely demand from tenants (retailers and commercial business). Major trends identifies across the sectors include:

- A steady move from an industrial economy to a service economy meaning reduced factories, more offices and other service buildings.
- A move to larger out of town, shed based structures for both retail and for warehousing. Warehousing, the real estate arm of the logistics industry, in particular has changed enormously in character, size, age and location as supply chains have become much more international.
- A move to outsourcing Data Centres to large independent buildings, to ensure security of operation (including controlled conditions, power supply security and physical security.
- The development of real estate investment sector. Whilst some firms such as Grosvenor have invested in real estate for hundreds of years, there are many much newer players. There is a good degree of specialisation. Mixed portfolios of offices and retail are common, but sector such as hotels, food and drink, warehousing have specialist investor companies.
- The development of a real estate investment sector has been fuelled by a growing trend by remaining owner occupiers to sell their property and lease it back. Tesco, HSBC and BT are examples of businesses deciding that real estate management is not core business and they have outsourced the activity. According to Key and Law (2005) around 66% of retail, 63% of offices, and 24% of industrial property by value is owned by investors. Bright (2007) reports that of those properties on which the Valuation Office Agency have data 57% are leased (by number of properties). As the majority of UK commercial property is rented, any measures designed to reduce carbon emissions must reach not only developers and building owners but also those occupying as tenants. A key policy issue is therefore the development of Green Leases to reconnect landlord and tenant (Hinnells et al forthcoming).

The rate of new build can be strongly affected by prevailing economic conditions, but since new stock in any one year is around 1% of the total stock, the stock itself is relatively immune to economic conditions. Indeed the underlying driver of the stock over several decades appears to be population. In 1977 there was 23.3 M2 of commercial floorspace per person. By 2005 this was down to 21.6 M2. It could be expected to decline further with changes in industrial structure, increasing costs of real estate and pressure on planning consent. Nonetheless, the relationship with population is a useful basis for projections of the overall level of the stock, since population projections are available up to 2050, given relatively well understood drivers of birth rates, life expectancy and net migration. More detailed projections about the split of space between sectors can be made on the basis of expected employment patterns.

By 2050 total commercial floorspace is expected to have grown by 25% compared to 2005, consistent with trends over the last three decades. The importance of this increase in floor area, is that in order to get a 60% cut across the entire stock, either, every building must achieve not a 60% cut, but more like a 75% cut, or alternatively, new buildings need to be close to zero carbon, with existing buildings making a 60% reduction.

Figure 3 Floor area trends UK



Data: DCLG (2006)

3.3 Energy use per m2

Many countries have a time series of energy surveys with which to build a model of the stock (eg CBECS in the US). The UK is not in this position. The best available dataset of energy use across a portfolio of buildings is from Sheffield Hallam (Elsayed et al 2002), collected 1990-2002. This dataset has required significant work and has the following limitations:

- The overall number of buildings surveyed is small in comparison to the number of building classes.
- The survey was not representative of the UK non-domestic building stock – rather it intended to have a large coverage of building types. However, some major building classes have not been sampled at all (eg Universities).
- The survey is known to be biased in the direction of small buildings, because surveyors were paid by the piece, and small buildings are easier to survey.
- The surveys were carried out in the mid 1990s. Clearly, there will be many areas in which these data are outdated, for example with Information and Communication Technology (ICT), where the installed stock has changed rapidly.
- The energy uses are summarized in headings, e.g. “heating”, “lighting”, etc. Unfortunately, this does not provide sufficient detail on which to make future predictions. To take lighting as an example, it is impossible from this to know the lighting mix, and without this it is only possible to guess at the installed lumens per watt (L/W). If, in 2050, all premises were to have, say, 200 L/W of lighting, we need to know what that figure is now in order to calculate the magnitude of any savings. That figure could vary significantly, for instance, between an office with 90% fluorescent lighting, to a pub with 60% incandescent. In the former case, the installed L/W could be as high as 80, in the latter as low as 20. A 2.5 fold improvement in efficiency would be seen in offices versus a 10 fold improvement in pubs.

To address these two issues for equipment such as lights and appliances which have a rapid turnover in the stock, we have gone back to the original SHU data to build a new dataset representing energy consumption in premises at the median date of survey. Where feasible, this has been updated based on clear methodology (sales data, more up-to-date papers, etc.) to reflect conditions in 2004. This is then used as our starting point for both validation against energy supplied and for projections of energy use under different scenarios.

3.4 Validation of energy and carbon use

Comparison with data on energy actually supplied on a quarterly basis is important, first to understand the direction of trends over that time, and second to validate the model against actual consumption both in terms of the representation of seasonal and non-seasonal loads (Table 4). Seasonal loads are dominated by space heating (for fossil fuels) and lighting (for electricity). Other end-uses tend to be non-seasonal. In addition for longer term trends it is important to understand the impact of weather in any given quarter on consumption.

Unfortunately, published data aggregates a range of more detailed sectoral data into higher level descriptors of commercial and public administration, so limited conclusions can be drawn. In the commercial sector, seasonal fossil use is increasing at the same rate non-seasonal fossil is decreasing. Both electric seasonal and non-seasonal are increasing. This would indicate more lighting and computing. In public administration, non-seasonal fossil is decreasing strongly at almost 4% per year.

Table 4 Trends in seasonal and non-seasonal loads based on quarterly data 1998-2006

Fossil fuels	**weather normalized overall trend**		**Seasonal loads**		**Non-seasonal loads**	
	% change pa	TWh pa	% change pa	TWh pa	% change pa	TWh pa
domestic	0.39%	1.72	1.12%	3.73	-1.30%	-1.381
commercial	0.20%	0.32	0.25%	0.13	-0.29%	-0.31
public administration	-2.36%	-3.40	-0.35%	-0.22	-3.86%	-3.124
other industry	-0.11%	-0.64	5.07%	7.45	-1.74%	-7.905

electricity	**weather normalized overall trend**		**Seasonal loads**		**Non-seasonal loads**	
	% change pa	TWh pa	% change pa	TWh pa	% change pa	TWh pa
domestic	0.95%	1.11	-0.06%	-0.02	1.30%	1.0672
commercial	1.87%	1.35	2.26%	0.20	1.84%	1.1656
public administration	poor data	poor data	poor data	poor data	poor data	poor data
other industry	1.14%	1.23	-0.10%	-0.01	1.39%	1.4116

As well as exploring directions of change, model results can also be compared to absolute values of energy supplied. This work is ongoing and will be reported when all sectors are complete.

4 Developing scenarios

Once the model is validated a model against both trends and actual consumption, it is useful for exploration of forward looking scenarios. The scenarios take into account:

- **Estimates of saving potential** from improved fabric measures (better airtightness, improved insulation, and avoidance of cooling loads); from the installation of building integrated renewables (heat pumps, PV, solar thermal, micro wind etc) and combined heat and power; and from turnover in equipment and replacement with efficient equivalents (eg refrigeration and lighting). The saving potential is explored in both new build and in retrofit of existing buildings.
- **Analysis of the major points of intervention** to reduce carbon emissions from buildings. Turnover includes change in building through build and demolition, major refurbishment, change in use, and change in occupant. Perhaps surprisingly the commercial real estate sector does not have good market level statistics on turnover. Understanding stock turnover will help to estimate the rate at which change could be achieved over time. Importantly, the rate of change is different in

different sectors. Policy options will vary by sector. Commercial buildings are substantially owned by investors and leased by tenants (average length of leases has come down and is now thought to be around 7 years), though leased buildings are also bought and sold by investors (average length of ownership is now around 7 years). Refinancing of purchase and the creation of a lease are both opportunities for policy intervention, as are stamp duty (on both sale and lease) and business rates (annual on the occupant). Policy options for public buildings are different, public buildings may be under more direct influence, but with little sale or leasing (other than office space).

- **Policy options to drive market transformation.** Market Transformation has been seen elsewhere as a combination of information (eg Energy Performance Certificates and improved metering); incentives (eg tax reform) and regulation (eg use of building standards). The theory behind market transformation has been explained and developed in earlier publications by ECI with reference to theoretical understanding and evidence of how innovations are taken up (Hinnells and Boardman 2008). The first requirement is a reproducible measure of consumption and efficiency. Once efficiency can be measured, it can be influenced. Figure 4 (below) shows a distribution of efficiency on the UK market at different stages of transformation and how parts of that distribution may be affected. The three curves show:
  - **before intervention**: the baseline is the distribution of efficiency for all cold appliances offered by Scottish Hydro Electric prior to the introduction of labelling, when the average model was an F;
  - **after labelling**: the distribution of efficiency of models offered by Scottish Hydro after the introduction of labelling. The average model offered moved up to a D, with a overall improvement of 19% in a single year;
  - **market transformation**: a theoretical distribution is illustrated, combining a 15% efficiency standard plus rebates or tax differentials, to increase sales of more efficient products, and a procurement programme. The average appliance might become a B on the label, equal to a 40% improvement on the EU average in 1992 (GEA, 1993).
- **There are a range of markets to be transformed.** Market transformation will need to be achieved in energy markets, buildings, low and zero carbon technologies and in lights and appliances, and different measures needed for each (Table 5 overleaf). The focus for policy will need to include: new build standards (which may tend towards zero carbon new build in the UK by around 2016); refurbishment of existing buildings (including retrospective application of building regulations on change of occupant); reductions in consumption from lights and equipment (which as traded goods are driven by EU Directives); and removal of barriers to building integrated renewables and combined heat and power. Significant fiscal policy will be needed, since, there is currently little economic rationale for the more drastic changes explored. The buildings market is complex and market mapping shows there are many different actors whose behaviour will be altered in a transformed market (figure 5 overleaf).
- **Behavioural change will also need to be significant.** Collectively, the process of transforming markets will drive changed relationships in delivering and managing the built environment, changed costs and values, and changed contractual relationships (e.g. different lease arrangements).

Figure 4 Market Transformation

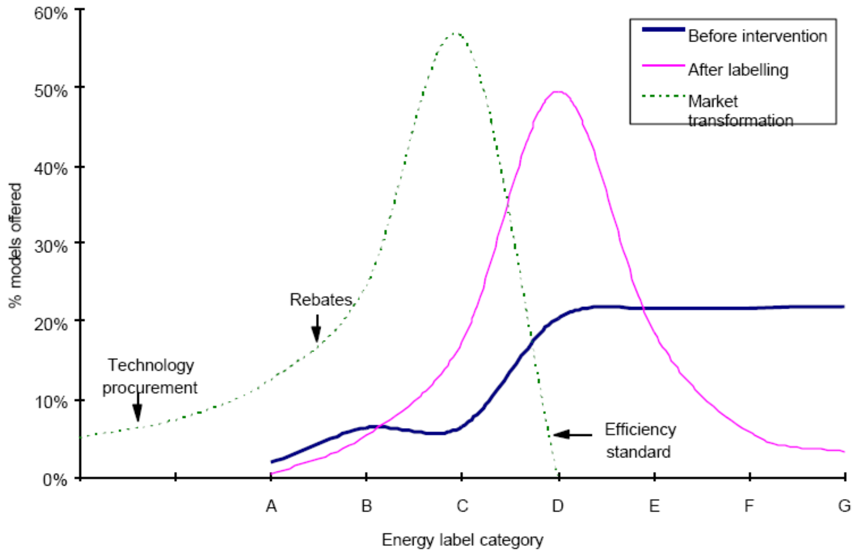
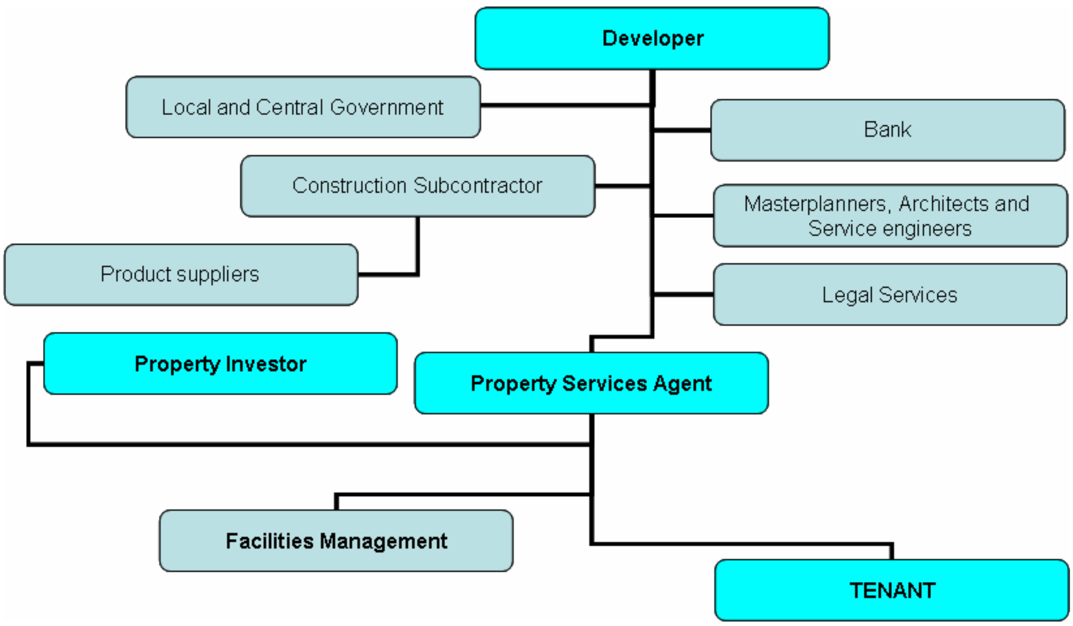


Table 5 Market to be transformed

overarching issues	buildings	LZC	Lights and equipment
Framework incentives eg • Personal Carbon Trading (PCT) • Governance: devolved targets and powers • Smart metering • Energy Service Companies (ESCOs) • Disclosure of energy and carbon emissions	• Government procurement • Labelling • Stamp duty reform • Building Regulations • Mandatory upgrade on sale	• Micro-generation obligation • Integrate LZC into building regulations and into Planning	• Mandatory energy labelling on all new products • Labels on consumption not efficiency X Minimum efficiency standards for a wide range of products

Figure 5 Market mapping of the buildings market



The definitions of scenarios are as follows:

- **Scenario A** represents a plausible scenario to illustrate what would happen if change was incremental. Scenario A reflects the continuation of current and near-term trends, technologies, policies and practices, with changes occurring slowly into the future. Society is assumed to continue along current trends with no restriction on consumption and any uptake of new energy-efficiency technology is slow. Consumer electronics is seen as a major growth area. The next 50 years would be similar in character to the last 30 years: whilst there have been (and will continue to be) significant energy efficiency and renewable energy programmes (eg Low Carbon Buildings Programme), improvements in efficiency would largely be outweighed by increasing demand for energy using products and services driven by an increasingly wealthy society. Outdoor spaces are used more so the definition of a building needs consideration.
- **Scenario B** investigates how the Government's target of a 60% reduction in carbon emissions in 2050 could be met. There is an implicit assumption that society becomes more carbon and energy aware, with technological change and societal choice driven by a need to reduce carbon emissions. There is substantial refurbishment and demolition of existing buildings, new buildings being built with near-zero space heating demand and with higher penetration of renewable energy and Low and Zero carbon technologies such as fuel cells. Where available, products use gas rather than electricity because of its lower carbon content. Products which are energy-profligate and non-essential (such as electric cooling) are installed less or technologies which have no net carbon implication (solar driven cooling) are deployed.
- **Scenario C** explores the options for a greater reduction in carbon emissions below 60% through higher uptake of renewables and energy efficiency measures and more fuel switching. Aiming for Scenario C may be necessary to ensure that a 60% reduction is achieved in practice, because some investments do not deliver the expected savings, or because of unexpected social trends (eg higher immigration). It may also be necessary to go beyond the 60% reduction to allow for failure to deliver in other sectors or if it is decided that the 60% target does not go far enough to stabilise atmospheric conditions.

In this context, particular issues are now explored with respect to ICT and lighting, particularly because they illustrate the risks of large scale and rapid increases in consumption that could be seen, and at the same time, the very rapid technical change that could be driven by the right policy framework.

5 Information and Communication Technology (ICT)

Technologies may be put in five categories: (1) Computers – desktops, notebooks, and future "Novel Computing Devices" (NCDs); (2) Monitors; (3) Imaging Equipment (multifunction devices, copiers, printers and fax machines); (4) Peripherals; (5) Data Centres – servers and associated infrastructure, be they for small offices or large data farms.

In constructing scenarios a variety of sources and assumptions have been used regarding items per head of working population (Dunn and Knight 2004; Fraunhofer/CEPE 2003; MTP 2007; own assumptions), consumption in varying modes of operation (MTP 2007; manufacturers' figures), and usage profiles (Nordman 2000; Webber 2001; Webber 2006). With data centres, a base year of 2006 is used together with the assumption that they consume 1.5% of the UK's electrical energy – the same proportion as that in the US described by (Koomey 2007).

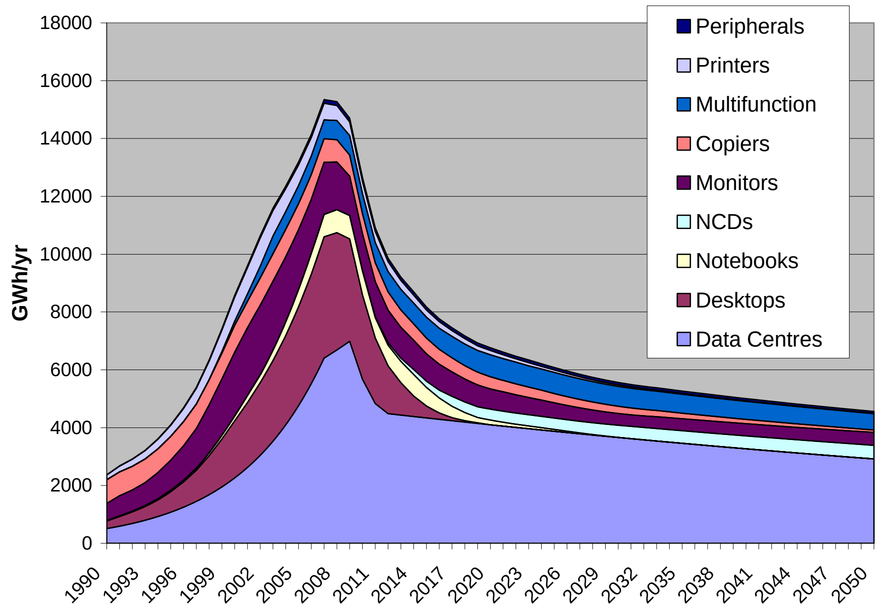
For the equipment in use in 2004, it is assumed that all meet the US Energy Star criteria of 2000. Under Scenario C, from July 2007 through to 2009, the Energy Star is updated to criteria that are far more stringent and compliant equipment becomes significantly more efficient in use. This is essential for the reductions in consumption of the first three of the above categories post 2009; in particular, power-management features are assumed to be utilised fully in all equipment. Dual-core processors are assumed in computers, and all monitors are assumed to be LCD by 2010 – becoming OLED (or similar solid-state technology) from 2020 on.

Over the period 2008 to 2013, it is assumed that virtualisation will be adopted in data centres such that server capacity is consolidated to the extent that energy consumption per nominal unit of computing power (server efficiency) is improved by two-thirds. From 2013 onward, it is assumed that demand for server capacity will continue to double every five years, and that the historic improvements (excluding virtualisation) in server efficiency will be maintained and augmented by an additional 17% year-on-year efficiency improvement through to 2050. In scenario A, without this additional improvement in efficiency, data centre energy consumption would experience the exponential growth rates seen between 1990 and 2008.

Computers are assumed to have moved on from the desktop/notebook by around 2020. By this time, it is assumed that “Novel Computing Devices” will have become the norm. Such devices may simply be more powerful versions of today’s PDAs – into which keyboard, mouse, and monitor will be connected. Annual energy consumption of such devices is assumed to fall to 3% of existing desktops – acting, to some extent, as thin-clients, the devices will have minimal onboard software and storage capacity needs.

Figure 6 shows ICT energy consumption in the UK non-domestic building sector 1990 to 2050 (Scenario C). Scenario C shows that whilst there has been significant, almost exponential growth in ICT consumption, this could be managed and even reduced in an extreme policy scenario. If intervention were not strong (Scenario A) consumption could expect to continue to double every five years.

Figure 6 ICT energy consumption in the UK non-domestic building sector 1990 to 2050 (Scenario C)

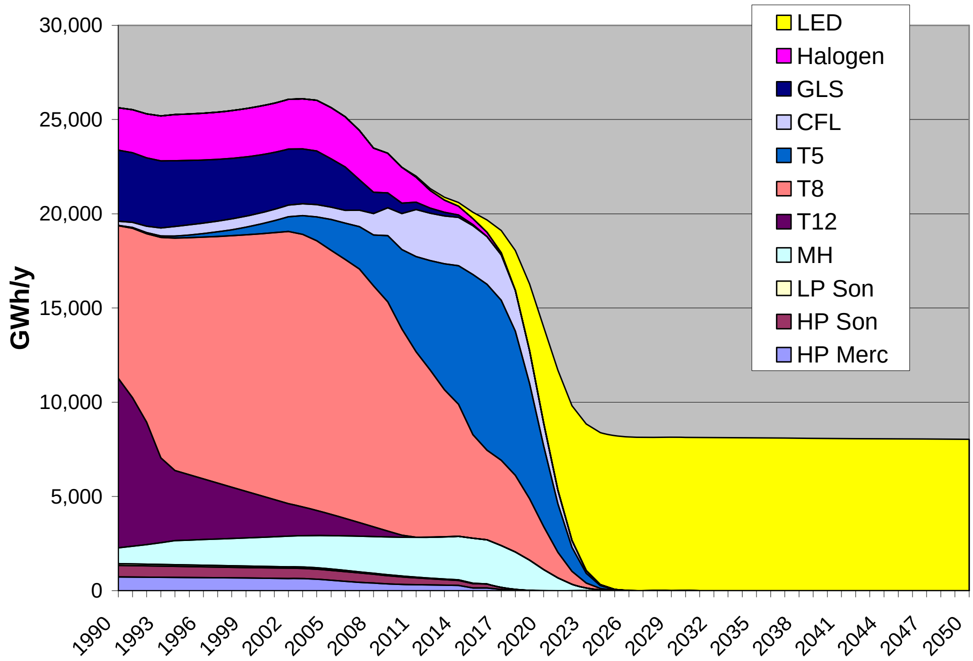


5.1 Lighting

The historical and predicted pattern of energy consumption by lighting in the UK non-domestic building sector can be seen in Figure 7. The data behind the chart are based on a detailed analysis of the stock of lighting equipment from Elsayed et al (2002). The survey dates used in the study range from 1992 to 2001, and a base year of 1994 (the median survey date) as a reference point for the lighting mix.

Forward projections of energy consumption are based on our estimates of changes to the lighting mix, and to changes in floor areas within the different sectors of the stock. Under Scenario C LED lighting is expected to become the dominant technology shortly after 2020 and this would result in a reduction of energy consumption of 70% over 2004 levels by 2050. Scenario A and B would see some LED, but slower uptake and less than complete uptake.

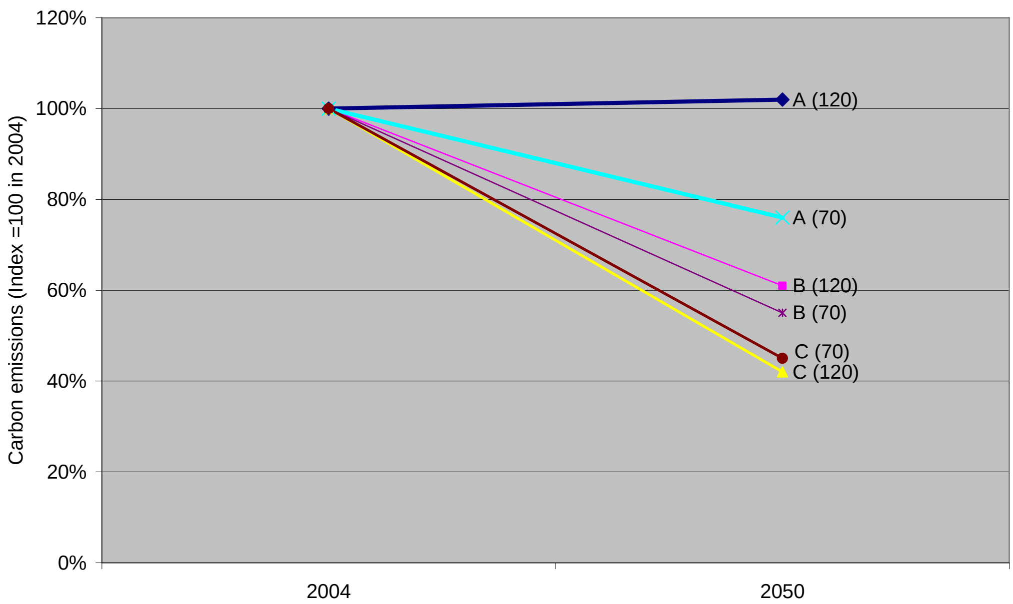
Figure 7 Lighting energy consumption in the UK non-domestic building sector 1990 to 2050



6 Scenario Results

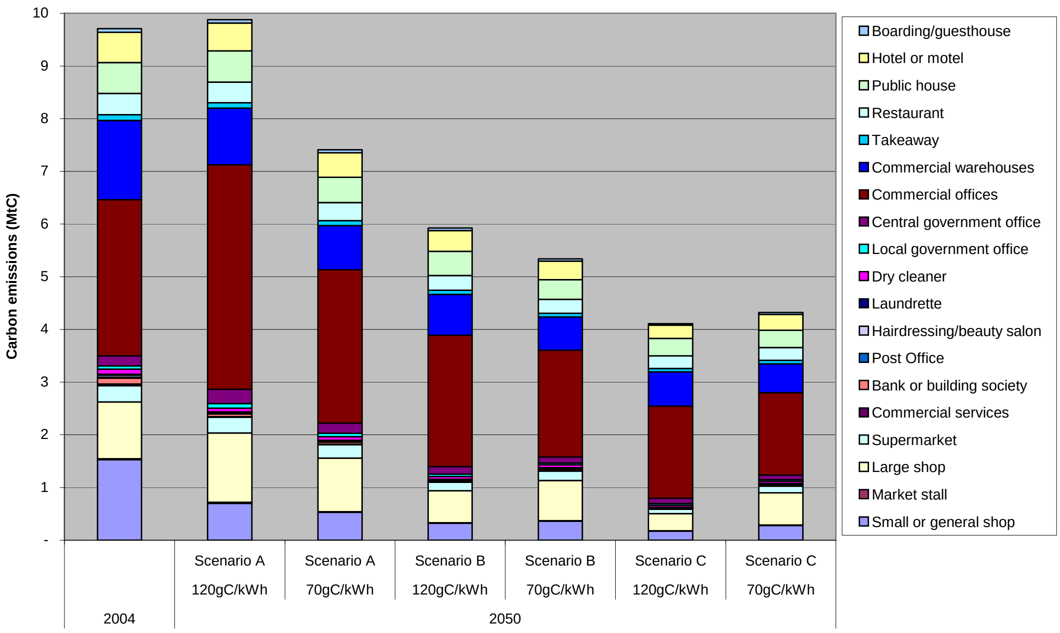
Scenario results are currently available for 4 sectors, offices, retail, warehousing and hotel and catering, and are shown in Figure 8. Results on the public sector and industrial buildings will follow. In addition, the scenarios at present exclude data centres. This is because data centres have traditionally been incorporated inside the buildings they serve, but they are increasingly being outsourced into separate buildings. Thus the technical solutions of managing space conditioning and energy supply become different than if they had remained part of the building they serve. It will be very difficult to constrain emissions from buildings once data centres are included.

Figure 8 Scenario Results



Together these scenarios describe a 'policy envelope' Infact to refine it slightly we have several policy envelopes, - Scenario A with different grid emissions, scenario B with different grid emissions and scenario C with different grid emissions. The scenario A envelope is the largest, and if we don't do anything to the building stock, then grid electricity emissions factors have a big effect. But if there is significant refurbishment of the stock, grid emissions factors are almost irrelevant. This is in part due to a larger uptake of LZC including CHP. In order to look at the feasibility of intermediate targets, we can refine the envelope eg by refining assumptions, exploring S –curve rates of uptake of kit, but it will basically remain the same shape. Emissions from different sectors and end uses can also be explored (Figure 9).

Figure 9 Scenario results by sector



7 Conclusions

7.1 Findings

A model has been developed based on data in many cases going back over 3 decades (floor area data and sales data), and in other cases on much more limited data (actual measured consumption in a significant sample of buildings). One of the difficulties in assembling the data in the model has been the poor correlation between definitions used and, thus, an inability to map one dataset onto another, even for datasets collected by government, but managed by different government departments.

The model is in the process of validation against trends in actual measured data over the period 1998-2006, and compares reasonably well (but arguably not well enough) against consumption in 2004.

The model can be extended to explore future scenarios, based on floor area trends, and energy use trends. Two example areas where change could be particularly remarkable (ICT and lighting) have been explored, and given more space, our analysis of trends and options in heating and cooling, and in renewables and combined heat and power, and in fabric and airtightness improvements would be explained.

The tool is a powerful one, and allows exploration of particular policy options for new build and refurbishment of buildings as well as assessment of policy options for equipment and lighting. Such options may be considered as a result of the UK passing the Climate Change Bill into law, with the consequent need to consider significant intervention in the market.

7.2 Improving the modeling

This paper reports on progress in modeling to date. However the model is far from complete and can be refined in a number of important ways in order to better support policy analysis, including:

- Completion of the additional sectors needed, including data centres, and exploration of trajectories between 2004 and 2050 using S curves.

- In two sectors, (retail and offices) we are validating the model (both current and potential, given the heat flux interactions described above) against SBEM (Simplified Building Energy Model, developed by BRE as a heat flux model for energy rating) as well as a dynamic simulation tool (ESP-r). University of Strathclyde, one of our partners, have been involved in the development of SBEM, and will provide particular support on this. This will inform our understanding of the interaction between measures, and particularly the impact of improved lights and equipment on additional space heating needs, and reduced cooling needs.
- The model needs much more measured data on a statistically significant number of buildings over a significant time period. Energy Performance Certificates will provide a much better understanding of the physical layout and condition of the stock, but not on how it is used. Additional data on metered consumption alongside the asset rating is needed. This could be in the form of a Landlords Energy Statement and Tenants Energy Review (LES-TER) or a Display Energy Certificate. It may be 5 years before statistically significant evidence is obtained and in the meantime, the current model is the best available tool.
- In due course, a much better assessment of the economic costs and benefits will be needed to inform policy. However, even a cursory explanation shows that for large scale carbon emissions reductions the benefits are significantly smaller than the costs when taken in direct energy terms. There may be additional health, performance and value benefits and significantly reduced external costs of change. However, significant policy requirements (either regulations or fiscal incentives) will be needed to trigger such change.
- Even with all of the above work, people do not appear fully rational in their decision-making in terms of the installation and use of equipment with an energy installation. A better understanding of people (and not least landlord and tenant relationships) will be needed to ensure that improvements in efficiency lead to reductions in carbon emissions rather than taken as increased service, or lost through seemingly ignorant or perverse behaviour (though probably quite rational viewed through the eyes of the occupier).

8 Acknowledgements

The work has been performed for the Building Market Transformation (BMT) project under the Carbon Vision Buildings (CVB) programme sponsored by the UK Engineering and Physical Sciences Research Council EPSCR) and the UK Carbon Trust. See www.eci.ox.ac.uk/research/energy/bmt.php for further information.

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Raising the efficiency of non-residential buildings through the GreenBuilding Programme: the experience of Spain

Núria Quince, Cécile Bonnet, Joan Carles Bruno, Alberto Coronas.

CREVER - Group of Applied Thermal Engineering
Universidad Rovira i Virgili, Dept. Ingeniería Mecánica,

Abstract

This paper presents the experience of CREVER - Group of Applied Thermal Engineering of the University Rovira i Virgili (URV) of Tarragona (Spain) in the implementation of the GreenBuilding programme. This programme was initiated in 2004 by the European Commission's Joint Research Centre. It complements, on a voluntary basis, the European Directive on the Energy Performance of Buildings (EPBD), implemented in Spain since 2006 through the new Building Technical Code (CTE), the Regulation of Thermal Facilities in Buildings (RITE) and the Building Certification Scheme. It encourages owner of non-residential buildings to introduce energy efficiency measures and/or renewable energy technologies in their buildings, providing them public recognition and technical support.

A two-year pilot phase has been implemented in ten countries until December 2006 in the frame of a project supported by the European Commission's EIE programme (TREN/DIR D/SUB/04-2003, EIE2003-057).

In this context, CREVER-URV, as national contact point for Spain, has been responsible for the set up of the required infrastructures for the successful development of the project at national level, offering support to interested buildings owners to become partner of the programme. The application consists of performance of an energy audit of the building(s), compilation of an action plan, and report on the results of the measures taken.

In this paper, besides the presentation of the work carried out to set-up the programme, different case studies for new and refurbished buildings in Spain along with other promotion actions pursued in Great Britain will be presented. The case studies include a description of the measures implemented and energy savings obtained in several types of buildings, mainly hotels, office buildings, hospitals, etc.

First Spanish partners claimed to be highly satisfied with their adhesion to the programme which provided them, besides substantial energy cost savings, acknowledgement of their actions and raised interest of their customers.

1. Brief introduction to the GreenBuilding Programme

In 2004 the European Commission launched the GreenBuilding Programme (GBP). GreenBuilding is a voluntary programme managed by Joint Research Centre. Its objective is to trigger investments in energy efficiency and renewable energy technologies in non-residential buildings in Europe with focus on existing premises. The programme encourages owners of non-residential buildings to carry out cost-effective measures -investment is supposed to pay back within 6 years- which enhance the energy efficiency of their buildings in one or more technical services. [1]

In a pilot phase, in the years 2005-2006, the GreenBuilding infrastructure has been set up in some European countries. In each participating country, a so called National Contact Point has been established for aiding organisations who may be considering participation in GreenBuilding. The GreenBuilding pilot phase is a project supported by the European Commission's Intelligent Energy for Europe Programme. [2]

The impact of the GreenBuilding project goes beyond the standards imposed by the European building directive and national building codes in force. The GreenBuilding project is designed to overcome socio-economic and market barriers – in particular lack of awareness, lack of know how and technical capabilities, lack of access to finance and energy service offerings – that are currently preventing investments in spite of high benefits and short payback times.

GBP cover both existing buildings and new buildings. The guiding principle for new buildings is that the building shall consume 25% less primary energy compared to the building standard in force at the time or of a “conventional” new building recently constructed. For existing building refurbishments, the building should consume at least 25% less primary energy, if economically viable, after refurbishment compared to before the refurbishment. The owner can choose a whole building energy approach or a modular approach (e.g. renovating only a specific end-use sector, e.g. air-conditioners, lighting, etc., provided the chosen module captures a large part of the potential energy savings). If only one specific subsystem (or module) is selected, then the 25% saving target is relative to the energy consumption of that subsystem.

Consideration for participation in the GBP starts with the submittal of an action plan defining the scope and nature of the owner’s commitment. Based on an initial energy audit, the action plan must define the buildings in which energy efficiency actions will be undertaken as well as the technical services (heating, lighting, water heating, ventilation, air-conditioning, office equipment, etc.) and the specific measures, to which the commitment applies. If the action plan is accepted by management entity, the company is granted Partner status.

GBP Partners derive direct benefits by saving money and in most cases by improving working conditions. They realise technically and economically feasible energy savings, thereby increasing their competitiveness and the value of their buildings. They also derive benefits resulting from the growing interest of consumers and investors in energy-efficient buildings. Their ability to deal successfully with environmental issues may indeed be considered as a credible measure of management quality. GreenBuilding provides support to the Partners in the form of information resources and public recognition, such as press coverage in newspapers and magazines, presentation at fairs and conferences across Europe, a regular newsletter, and a brochure and a catalogue of success stories. The GBP plaque allows Partners to show their responsible environmental entrepreneurship to their clients.

The application of GBP not only entails benefits for Partners, but also for public authorities in each country:

- No need for direct financial incentives to trigger energy efficiency/renewable projects
- Building up of building data set for case studies and benchmarking exercises
- Possibility to test/verify early versions of the integrated new measurement tests for building energy performance
- Early implementation of building Directive and possibility of testing of national building certification schemes. It goes beyond the Directive since small refurbishments are also included and specially targeted
- Establishment of effective public/private partnerships

Consequently, GBP is providing an important contribution for exploring the huge potential for raising the energy efficiency in the non-residential building sector. Actions are built on a solid infrastructure of National Contact Points, and a network of relevant actors (industry associations, local authorities etc.). The results of the GREENBUILDING project are providing the basis for designing concepts for national actions to promote energy efficiency in non-residential buildings.

2. Implementation of GBP in Spain

The Group of Applied Thermal Engineering (CREVER) of the URV, as a National Contact Point for Spain, was responsible for the implementation of an adapted infrastructure which should give the basis for the effective future development of the GBP in Spain. [3]

2.1 National GreenBuilding website

A national GreenBuilding website was compiled and is online on http://www.crever.urv.net/greenbuilding/. This website, in Spanish language, has the following contents:

- Presentation

- Description
- Document download (Synopsis, Partner guideline, Endorser Guideline and Energy Management Guideline translated in Spanish)
- Links (international websites, etc.)
- Contacts (NCP)

2.2 Best Practice examples

Five best practice examples from Spain have been published on the GreenBuilding main website and are also included on the actualised national Website.

2.3 National set of GBP guidelines

GreenBuilding Guidelines are the documents required to provide possible partners and endorsers of the GreenBuilding programme with the complete organisational and technical information necessary for a successful participation. The Partner Guideline, the Endorser Guideline and the Energy Management Guideline were translated into Spanish and are available on the national GreenBuilding website.

2.4 Additional documents

Within the implementation of the GreenBuilding infrastructures, some additional documents were compiled:

- Summary PowerPoint presentation providing a quick and concise overview of the programme with the key information
- Templates for energy audits and Action plan reports (in case of new building construction and building modernisation) including main information that each document should contain. These templates were compiled on request of some of the interested potential partners. They were sent to them, insisting on the fact that they are only guiding documents which can be adapted to each case.

2.5 National workshop

The Spanish national GreenBuilding workshop took place on the 24th of October 2006 in Tarragona. The objective was to present the GreenBuilding project results and to encourage potential partners and endorsers to join the programme in future.

2.6 Partners and Endorsers

An Excel Data base has been created for the internal management of the identified potential Partners and Endorsers. Identified potential partners comprise hotels, hospitals, municipalities, industries, service companies, investigation centres, private foundations, etc. 42 potential partner organisations have been contacted until now.
Identified potential endorsers are energy agencies, energy advisers, technical offices, consulters, etc. 20 potential endorsers have been identified until now.

Presently, nine organisations are already official GreenBuilding partners in Spain. The partner application of a tenth Spanish entity (Consejería de Empleo y Mujer de la Comunidad de Madrid) is about to be sent to the Commission but at this date they are not still official partner.

Therefore, at the moment, the official GBP Partners are: Servei Català de la Salut; La Vola; Fundación “Francisco Grande Covián”; Hospital Virgen de las Nieves; Hernández Cabeza Hoteles; Hotel Jakue; Coperfil Real State Group; Área hospitalaria Juan Ramón Jiménez; Bank of America.
Regarding endorsers, there is one Spanish endorser at the present: Escan S.A., which is an energy consultancy located in Madrid. They helped Hospital del Oriente to become a GreenBuilding Partner last year and now they have also performed the energy audit and developed the action plan for the Consejería de Empleo y Mujer. Levenger S.L, an enterprise devoted to cogeneration, renewable energies and environmental consulting, aided Hotel Jakue to be Partner last summer, and now they are planning to become endorsers too.

3. Results

The results of each building will be presented according the date they were acknowledged as official Partners. [1]
As shown in the following tables, the energy demand reference values for new buildings will be values that belong to a conventional building recently constructed with similar features but without any specific energy saving measures. For refurbished buildings, the expected energy demand after the implementation of measures will be compared to the current demand values (before measures), which have been determined by an energy audit.

Table 1. CAP Roger de Flor (Barcelona)

Organisation name	Servei Català de la Salut
Building name	CAP Roger de Flor
Building type	Primary care centre
Building description	It is a seven floor building with a useful area of 3000 m^2, including office-type, visiting rooms and public areas.
Type of actuation	New building
Year of construction	2006-2007
Main measures implemented / laid out in the action plan	Building envelope: - Passive solar strategies - High insulation level due to intermediate ventilation chamber in façades. - Natural ventilation Heating and cooling: - Heat by condensing boiler - Cold production by conventional electrical heat pump - Contribution to the heat demand by solar thermal panels - Low temperature radiant floor Lighting: - Fluorescent lamps - High frequency electronic ballasts Renewable energy sources: - 2 PV plant of 5 kW on the south-west façade and on the roof - Solar thermal plant covering the 60% of the DHW demand Building management system and monitoring

RESULTS

	Primary Energy Demand			CO_2 savings [t/y]
	Conventional building [kWh/m²y]	**Eco-building [kWh/m²y]**	**Savings [%]**	
Heating	83.1	47	43.4	53.3
Cooling	85.2	61.9	27.3	
Lighting	174	131.7	24.3	
DHW	27.2	13.5	50.4	
Others	24	24	0	
TOTAL	**393.5**	**278.1**	**29.3**	

Table 2. ECOEDIFICI (Manlleu, Barcelona)

Organisation name	La Vola			
Building name	ECOEDIFICI			
Building type	Office Building			
Building description	Net floor surface: 1114 m^2 Number of floors: 3			
Type of actuation	New building			
Year of construction	2006			
Main measures implemented / laid out in the action plan	Building Envelope: - South façade: Greenhouse / ventilated façade - West façade: Solar passive strategies - Green roof - Cross ventilation Heating and cooling: - Natural gas high efficiency boiler - Low temperature radiant floor for heat and cold distribution - Air preheating through greenhouse façade - Heat recovery system Lighting: - Fluorescent lamps and electronic ballast - Occupancy linking detectors in spaces of sporadic use Electrical Appliances: Low energy consuming lifts Renewable Energy Sources: - 5 m2 solar thermal collectors covering 60% of DHW demand - 18 m2 photovoltaic panels Building management system and monitoring			
RESULTS				
	Primary Energy Demand			**CO_2 savings [t/y]**
	Conventional building [kWh/m²y]	**Eco-building [kWh/m²y]**	**Savings [%]**	
Heating	95.9	58.4	39.1	18.5
Electrical equipments (cooling system included)	119.1	102.2	14.2	
Lighting	113.1	67.9	40	
DHW	2.6	0.8	69	
TOTAL	**330.7**	**229.3**	**30.7**	

This partner has already started the monitoring of the real energy savings achieved by the implemented measures. In Figure 1, it is shown the results of this monitoring from October 2006 to October 2007 and it is observed that the savings are even bigger than estimated in the action plan:

Figure 1. Real energy savings in ECOEDIFICI, La Vola

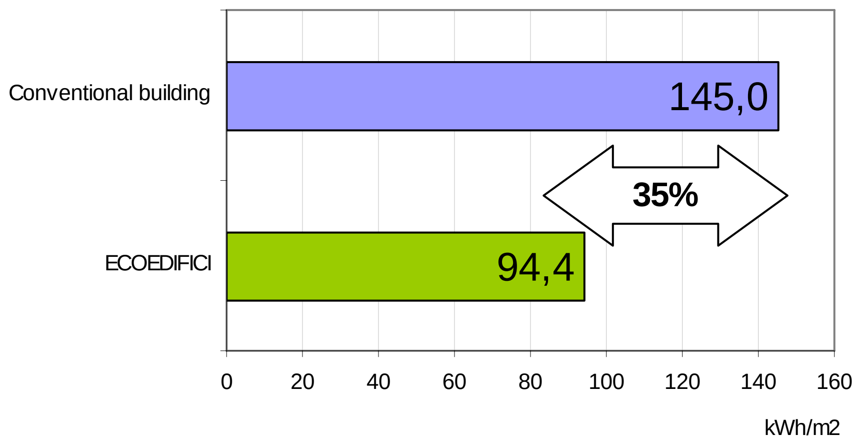


Table 3. Hospital del Oriente (Arriondas, Asturias)

Organisation name	Fundación "Francisco Grande Covián"			
Building name	Hospital del Oriente de Asturias			
Building type	Hospital			
Building description	Net floor surface: 10500 m^2 Number of floors: 4			
Type of actuation	Refurbishment			
Year of construction	1995			
Year of refurbishment	2005 - 2011			
Main measures implemented / laid out in the action plan	Renewable Energy Sources: - 225 m2 solar collectors on the roof for DHW production. Heating: - Substitute all the oil boilers with biomass boilers to cover the total heat demand (1660 kW) with renewable energy sources. Lighting: - Incorporation of hourly lighting programmers in zones with different uses along the day - Incorporation of luminosity sensors in the zones with sufficient natural lighting - Substitution of 200 fluorescent tubes with more efficient ones.			
RESULTS				
	Primary Energy Demand			**CO_2 savings [t/y]**
	Before measures [kWh/m²y]	**After measures [kWh/m²y]**	**Savings [%]**	
Electricity (Lighting)	424	409.1	3.5	420.1
Thermal	173	0 (biomass)	100	
TOTAL	**597**	**409.1**	**31.5**	

Table 4. Hospital Virgen de las Nieves (Granada)

Organisation name	Servicio Andaluz de la Salud			
Building name	Hospital Virgen de las Nieves			
Building type	Hospital			
Building description	Composed of 2 parts: *Caleta* / *Cartuja* Net floor surface: 91172m^2 / 38096m^2 Number of floors: 10 / 7			
Type of actuation	Refurbishment			
Year of construction	1953 / 1973			
Year of refurbishment	2007 - 2009			
Main measures implemented / laid out in the action plan	HVAC system: - Improve pipes insulation - Renovation of some parts of the installation - Incorporation of a control system Building envelope: - Improve external walls, windows and glazed façades insulation Lighting: - Fluorescent lamps and electronic ballast - Occupancy linking detectors in spaces of sporadic use - Luminosity sensors in the zones with sufficient natural lighting Renewable Energy Sources: - 630m2 solar thermal collectors to DHW production (425kW) - 40 m2 photovoltaic panels (20 kW) Energy management system and monitoring			
RESULTS				
	Primary Energy Demand			**CO_2 savings [t/y]**
	Before measures [kWh/m²y]	**After measures [kWh/m²y]**	**Savings [%]**	
Electricity	109.2	96.2	11.9	5048.7
Thermal	199.8	135	32.4	
TOTAL	**309**	**231.3**	**25.2**	

Table 5. Hotel ** Oviedo (Oviedo, Asturias)**

<table>
<tr><td>Organisation name</td><td colspan="4">Hernández Cabeza Hoteles</td></tr>
<tr><td>Building name</td><td colspan="4">Nap Hotel</td></tr>
<tr><td>Building type</td><td colspan="4">Hotel ****</td></tr>
<tr><td>Building description</td><td colspan="4">Net floor surface: 2500 m^2
Number of floors: 12</td></tr>
<tr><td>Type of actuation</td><td colspan="4">New building</td></tr>
<tr><td>Year of construction</td><td colspan="4">2006 - 2008</td></tr>
<tr><td>Main measures implemented / laid out in the action plan</td><td colspan="4"><u>Building envelope:</u>
- South-façade: ventilated and with PV solar followers integrated
- Reflective insulation

<u>Lighting:</u>
- Low consumption lamps
- Occupancy linking detectors in spaces of sporadic use
- Luminosity sensors in the zones with sufficient natural lighting
- Led lamps

<u>Electrical Appliances:</u>
- Low energy consuming lifts

<u>Renewable Energy Sources:</u>
- 300m2 solar thermal collectors to DHW production and for heating and refrigeration purposes
- 100m2 PV panels (on south façade)
- Aero-generators on the roof
- Hydraulic micro station to make the most of recycled water
- Geothermic

<u>Heating and cooling:</u>
- Heat recovery devices in the distribution and ventilation systems
- All heat and cool produced by means of clean energies

<u>Building management system and monitoring</u></td></tr>
<tr><td colspan="5">RESULTS</td></tr>
<tr><td rowspan="2"></td><td colspan="3">Primary Energy Demand</td><td rowspan="2">CO_2 Savings [t/y]</td></tr>
<tr><td>Conventional building [kWh/m²y]</td><td>Eco-building [kWh/m²y]</td><td>Savings [%]</td></tr>
<tr><td>Lighting</td><td>72.5</td><td>43.5</td><td>40</td><td rowspan="5">117.2</td></tr>
<tr><td>Electric equipments</td><td>88.6</td><td>62</td><td>30</td></tr>
<tr><td>Heating and cooling</td><td>116.9</td><td>40.9</td><td>65</td></tr>
<tr><td>DHW</td><td>120.9</td><td>32.6</td><td>70</td></tr>
<tr><td>TOTAL</td><td>403</td><td>179.1</td><td>55</td></tr>
</table>

Table 6. Hotel Jakue (Puente La Reina, Navarra)

Organisation name	Hotel Jakue			
Building name	Hotel Jakue			
Building type	Hotel			
Building description	Composed of 2 parts: main building / annex building Net floor surface: 2200 m^2 / 867 m^2 Number of floors: 5 / 2			
Type of actuation	Refurbishment			
Year of construction	1989			
Year of refurbishment	2007 - 2008			
Main measures implemented / laid out in the action plan	Renewable Energy Sources: - Engaging “Línea Verde” electricity supply: electricity is produced from 100% renewable energies sources. Heating and cooling: - Substitute all the oil boilers with 3 biomass boilers (pellets) - Incorporation of 2 heat pumps to supply heat and cold and for DHW production Lighting: - According the recommendations of CEI (Spanish Committee of Lighting)			
RESULTS				
	Primary Energy Demand			**CO_2 savings [t/y]**
	Before measures [kWh/m²y]	**After measures [kWh/m²y]**	**Savings [%]**	
Lighting	106.3	74.4	30	480.5
Electrical equipments (cooling system included)	159.5	17.1	89.3	
Heating	69.8	0 (biomass)	100	
DHW	29.1	0 (biomass)	100	
TOTAL	**365.5**	**91.5**	**75**	

Table 7. Logispark Meco (Meco, Madrid)

Organisation name	Coperfil Real State Group			
Building name	Logispark Meco			
Building type	Warehouse			
Building description	Composed of 2 parts: warehouse / office buildings Net floor surface: 31824 m^2 / 1971 m^2 Number of floors: 1 / 3			
Type of actuation	New building			
Year of construction	2008			
Main measures implemented / laid out in the action plan	Lighting: - Low consumption fluorescent lamps - Luminosity sensors in the zones with sufficient natural lighting - Skylights of 30% transmittance Renewable Energy Sources: - 346 MWh/y PV panels on the warehouse roof			
RESULTS				
	Primary Energy Demand			**CO_2 Savings [t/y]**
	Conventional building [kWh/m²y]	**Eco-building [kWh/m²y]**	**Savings [%]**	
Electricity	112.2	56.1	50	293.8
TOTAL	**112.2**	**56.1**	**50**	

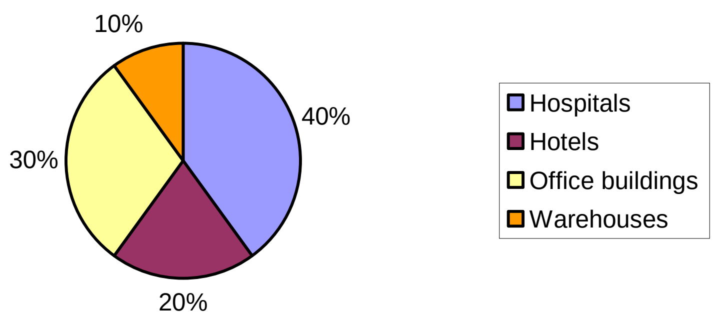
Table 8. Área Hospitalaria Juan Ramón Jiménez (Huelva)

Organisation name	Servicio Andaluz de la Salud			
Building name	Área Hospitalaria Juan Ramón Jiménez			
Building type	Hospital			
Building description	Composed of 3 buildings: *Juan Ramon Jiménez / Vázquez Díaz / Virgen de la Cinta* Net floor surface: 70249m^2 / 15200m^2 / 3862m^2 Number of floors: 5 / 8 / 6			
Type of actuation	Refurbishment			
Year of construction	1993 / 1962 / 1971			
Year of refurbishment	2007 - 2009			
Main measures implemented / laid out in the action plan	Building envelope: - Double glazing of south and southwest-oriented windows Lighting: - Substitution of incandescent lamps with low-consumption fluorescent lamps. Renewable Energy Sources: - 600m2 solar thermal collectors as a support for DHW production Heating and cooling: - Renovation of the cold production systems through substitution of 3 water-condensation cooling units and 3 cooling towers. - Optimisation of the boiling system (natural gas instead of oil) for heating and DWH production.			
RESULTS				
	Primary Energy Demand			**CO_2 savings [t/y]**
	Before measures [kWh/m^{2}y]	**After measures [kWh/m^{2}y]**	**Savings [%]**	
Electricity	461.4	295.9	35.9	7363.5
Thermal	240.9	229.7	4.6	
TOTAL	**702.3**	**525.6**	**25.2**	

As a summary of the previous tables, we can state the following:

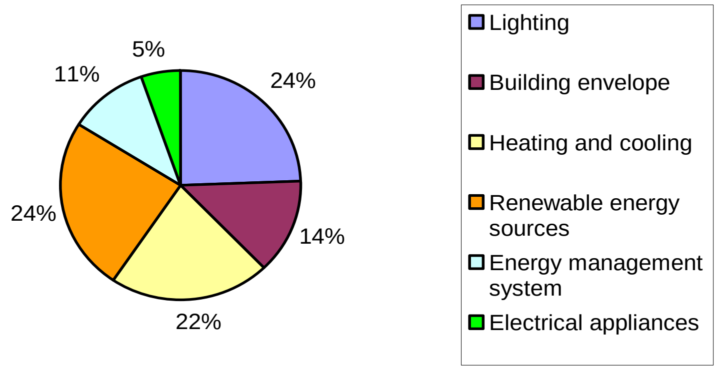
- Different types of building have become partners of the Programme. The distribution is presented in Figure 1:

Figure 1. Type of buildings that have become Partners of GBP in Spain



- Until now, a 60% of the GB Partners are for refurbishment and a 40% are for new buildings.
- The more common measures implemented are concerning lighting and renewable energy sources, as it can be checked in Figure 2:

Figure 2. Saving measures implemented



- The total energy saving in Spain thanks to the GBP are presented in Table 9:

Table 9. Total savings in Spain

Partners	**Primary energy savings (MWh/y)**	**CO_2 savings (t/y)**
CAP Roger de Flor	346	53
Ecoedifici La Vola	113	19
Hospital del Oriente	1973	420
Hospital Virgen de las Nieves	10044	5049
Nap Hotel	560	117
Hotel Jakue	840	481
Logispark Meco	1896	294
Área Hospitalaria Juan Ramón Jiménez	15781	7364
TOTAL	**31553**	**13796**

- The whole data related to savings are projected, not actual, since most of partners are still implementing the measures. After submitting the Action Plan and being accepted as GB Partners, all of them have to deliver a report to the European Comission once a year, in order to inform about their progress and the real saving results.
- The economics of the Partner buildings are reasonable. For example, Hospital del Oriente (Table 3), has a pay back period of 6.6 years for installing 460 kW of biomass boilers.
- For more detailed information, please refer to Partner Action Plans of the GB Programme.

4. Conclusions

This paper has presented the experience of CREVER - Group of Applied Thermal Engineering of the University Rovira i Virgili (URV) of Tarragona (Spain) in the implementation of the GreenBuilding programme as a National Contact Point in Spain.

Besides the presentation of the work carried out to set-up the programme, different case studies including new and refurbished buildings from Spain have been presented, including main measures implemented and corresponding energy savings achieved in several types of buildings, mainly hotels, office buildings, hospitals, etc.

Due to GreenBuilding Programme, Spain is projected to save 31553 MWh of primary energy and reduce release of 13796 tones of CO_2 per year.

The Spanish partners claim to be highly satisfied with their adhesion to the programme which has provided them, besides substantial energy cost savings, acknowledgement of their actions and increased interest of their customers.

5. References

[1] http://re.jrc.ec.europa.eu/energyefficiency/greenbuilding/index.htm

[2] AGRICOLA, Annegret-Cl.; HERMANN, Laurenz. *GreenBuilding: Enhancing the Energy Efficiency of Non-residential Buildings.* Proceedings of the International Conference IEECB'06. Frankfurt 26-27 April 2006, v. 2, 2006, P. 643-652

[3] http://www.crever.urv.net/greenbuilding/

Worldwide Status of Energy Standards for Buildings: A 2007 Update

Kathryn Janda, Environmental Change Institute, Oxford University

Abstract

The paper describes the worldwide status of energy standards for buildings in 80 countries keyed to the legal status (i.e., mandatory, voluntary, proposed) and building sector coverage (i.e., residential, commercial, or both) of such standards in different countries. It describes which countries have added new energy standards since 1993, when a similar study gathered information on this topic from 57 countries. The 1993 study used a 15-page mail survey distributed via post and fax; the current study relies mainly on a literature review to gather data. The paper present an international profile of activities and research issues related to energy standards for buildings. It includes a snapshot of the contents, development, and use of energy standards for buildings, with a particular focus on non-residential buildings in less-developed countries and economies in transition.

Introduction

In countries without effective energy-efficiency programs for their buildings, current building energy use trends are (or should be) cause for concern. The building sector consumes roughly one-third of the final energy used in most countries, and it absorbs an even more significant share of electricity. Electricity use in commercial buildings is driving peak demand in the United States, Japan, and in some of the wealthier less-developed countries (LDCs). As the people in LDCs raise their standards of living and services, building electricity use is expected to continue to increase, especially in the non-residential sector.

During the past three decades, governments in both industrialized countries and LDCs have initiated policies to reduce energy consumption in buildings. Most of these policies can be grouped into one of the following three categories: economic incentives (e.g., taxes, energy pricing), informational programs (e.g., energy awareness campaigns, energy audits), or regulatory requirements (e.g., codes or standards). More recently, growth in voluntary public-private partnerships (e.g., Energy Star in the US and the Energy Efficiency Accreditation Scheme in the UK) and award programs from non-governmental organizations (e.g., the US Green Building Council) have changed the landscape for improvement by setting stretch goals for the building industry and its clients.

In this paper, we focus mainly on energy standards for buildings1, which are a widely pursued but sparsely documented approach to limiting energy consumption in buildings. Existing energy standards range from voluntary guidelines to mandatory requirements, which may apply to one or many building types. Their development is typically a complex decision-making process that can involve any combination of participants from a range of institutions, including government, academia, utilities, industry groups, and professional associations. Once a standard's basic structure has been developed and tailored to fit a country's building practices and climate, it can be augmented and tightened to reflect technological development and changes in construction practice. Well-suited to influence new construction, standards can help avoid "lost opportunities" by capturing the long term savings associated with buildings' long life-cycles and low turnover rate. Moreover, they can help overcome barriers to energy-efficient products by heightening awareness and stimulating the market. They are also increasingly being used, particularly in Europe, to address energy concerns in existing buildings undergoing major renovations.

Although standards can be a flexible and low-cost approach to energy conservation, they are complicated to develop and difficult to assess. Published information about energy standards is limited, and most existing international studies focus on residential standards in industrialized

[1] We use the word "standard" to refer interchangeably to what also might be called codes, criteria, guidelines, norms, laws, protocols, provisions, recommendations, requirements, regulations, rules, or standards. Depending on the country, the "standard" may be contained in one document, be part of another larger document (such as a general building code), or comprise several documents.

countries. Policy makers considering energy standards for non-residential buildings2 or in less-developed countries have few avenues through which to gain insight into their development, contents, use, or effectiveness. To explore these under-represented areas of research, in the early 1990s we developed a mail survey to gather more detailed information about activities undertaken to increase the energy-efficiency of buildings, particularly non-residential buildings. The results of this survey are available at several levels of detail, including a pair of government research laboratory reports (Kathryn B Janda & Busch, 1993) and a peer-reviewed journal article (Kathryn B. Janda & Busch, 1994).

This paper reviews the original survey results and presents initial results of an ongoing update of the original survey. The original study—which we will call the 1994 study— provided a snapshot of the legal status and coverage of energy standards in 57 countries and used results of the survey to characterize the contents, development, implementation, and assessments of specific countries. The current update—which we will call the 2007 update—expands the scope of the original study, gathering information on information in 80 countries. Plans to launch a web-based survey—which we will call the 2008 study—are underway. The 2007 update relies upon a literature review of existing documents available in print and through the internet. This change in research method from survey to document review has several implications for this report. First, it means that the 2007 update hinges on documents and websites available in the native language of the researcher (English), whereas the work in 1994 relied on country experts. These experts were able to gather information in the native language of the relevant country and translate the information into English as necessary to answer the survey, ensuring broader coverage than an English-only endeavor. Second, the current work is subject to the level of information publicly presented rather than the level of information available directly from country experts. The 1994 survey format provided an important template that channeled information from the country experts, ensuring that the same types of questions were addressed by all respondents. Because of these methodological concerns, we plan to fully update the 1994 study with a web-based survey in 2008 hosted by the Environmental Change Institute at Oxford University. Due to methodological issues, we are unable to characterize the standards in 2007 at the same level we did in 1994. However, this paper identifies and discusses trends over the past 15 years in their development, orientation, and governance. We conclude with a summary discussion of the comparative advantages of the various approaches to increasing efficiency of energy use in buildings through standards.

Background

As a background for the study results, we briefly review the development of energy standards over time, describe research issues which complicate the analysis of both building energy use and building energy standards, and suggest topic areas where international information on energy standards could be shared.

As with other energy-efficiency policies, interest in energy standards was fueled by the oil shocks of the 1970s. Prior to that time, only a few countries had regulations affecting the energy use of buildings. These were simple, prescriptive insulation requirements that bear little resemblance to the multi-faceted performance standards used in many countries today. Over the last three decades, improvements in calculation methods, computer modeling, and building energy research have provided the means for many countries to revise their original standards and develop more comprehensive versions.

Although energy standard activities are frequently mentioned in the literature, the standards themselves are rarely described in any detail. The lack of basic information about the contents of standards reflects and perpetuates an international information gap surrounding the development, use, and effectiveness of energy standards. The demand for information is most apparent for non-residential buildings and in LDCs. A handful of studies have pulled together detailed information about energy standards across national boundaries, but they do not represent the full breadth of energy standards activities or issues. The limited coverage of the literature on energy standards reflects complexities inherent in analyzing both building energy use and building energy standards,

[2] The term "non-residential" is used to refer to buildings that could be classified in the commercial, public, or service sectors.

especially in the service sector. These intricacies pose serious barriers to building energy research and complicate comparative assessments of energy standards.

Building energy use & efficiency

Understanding even a single building's energy use is an analytical challenge. A building's energy consumption depends on its physical structure and design components, but it is significantly influenced by other less tractable factors such as occupant use, equipment operation and maintenance, and climate variation. Without the aid of detailed monitoring equipment, it may be difficult to determine how much energy use is due to building functions (heating, cooling, ventilation, lighting), how much emanates from occupant use (computers, refrigerators, stoves), and how these activities influence each other. While efficient light bulbs, refrigerators, and cars undergo prototype testing before they are mass-produced, buildings are custom-built. Testing procedures for buildings are typically limited to computer simulations or scale models. Like an appliance or an automobile, a building's performance will vary over its life-cycle, which is on the order of about 50 years. Technological development and ongoing changes in building practice further compound the complications in characterizing building energy use. Uncertainties about energy use in buildings are echoed in the lack of adequate data for the building sector. Compared to industry and transportation, the other two major energy consuming sectors, international and country sources for energy statistics give little detailed information about buildings. Buildings often fall into the "other" category which lumps together the residential, commercial, public service, and agricultural sectors. The International Energy Association publishes separate figures for residential and commercial use, but the differences between these sub-sectors are more significant than a single pair of numbers can convey.

Energy use in the residential sector is more homogeneous, more clearly defined, and better understood than energy use in the service or commercial sectors. Residential buildings are used predominantly to provide shelter, but commercial buildings span twelve International Standard Industrial Classification divisions. Uses for buildings constructed for service, commercial, or other "non-residential" purposes can range from caring for the sick to treatment of sewage.'" Residences vary in size, shape, and fuel use, but not to the same extent that non-residential buildings do. The floor area of most new residences in the United States, for instance, varies from about 1500 to 2500 square feet, but the floor area of a new commercial building could be less than 5000 square feet or more than 100,000. Residential and non-residential buildings even have different energy conservation needs. Most office buildings are internal load dominated, and they can require some cooling even in winter. Residences tend not to contain enough operating equipment or people to generate a net internal heat gain during the colder months. As a result, the heat added by a few incandescent light bulbs might be negligible or beneficial in residences, but over-lighting in an office can increase an already significant cooling load.

Building energy standards

Because a thorough understanding of the existing building stock and its energy use is essential to standards development, it follows that the less variable and better documented residential sector has been the primary focus of building energy analysis and energy standards development. In addition to being less technically complex, there are political and practical reasons which may account for the residential focus of many building energy-efficiency efforts. Many countries have governmental housing programs which make regulation in the residential sector more politically feasible than in the commercial sector. In industrialized countries, the residential sector tends to use a higher overall percent of energy than the commercial sector, so it assumed higher priority during earlier energy crises. On a per building basis, however, energy-intensive commercial buildings present a ripe target for further savings.

As a regulatory option, building energy standards might be considered similar to standards for materials or appliances, but their development, usefulness, and assessment face greater uncertainties. Parameters used in the standard must be set by professional judgment or computer models because full-size prototypes are too expensive to construct and test for each building type, let alone each design or component. Whether a standard is successful, however, may have very little to do with the provisions it codifies. Without appropriate educational programs and implementation mechanisms for the construction community, even a well designed, mandatory standard will not save energy. Even with full compliance, poor data about energy trends in existing buildings or careless monitoring of new buildings could camouflage the real impact of a stringent and otherwise successful standard.

All of these issues apply to the assessment of energy standards in any one country, but additional barriers stand in the way of cross-national comparisons. Energy standards are difficult to classify because no established nomenclature clearly identifies policies that might be considered “energy standards.” A single country may have several such standards published by different entities, and they may be self-contained or subsumed within another document (such as a general building code). Whereas a standard set for efficient refrigerators in the U.S. could be used in Singapore or Sweden, standards for energy-efficient buildings are much less transferable. Building energy standards that are stringent for one country may be ineffective in another country, depending on climate conditions, occupant behavior, existing building stock, and construction practices. To make reasonable judgments about the impact of existing standards in different countries, all of these variables plus the turnover of old buildings and rate of new construction would need to be gathered, normalized. and compared. Such an analysis would be valuable, but it is beyond the scope of most studies, including ours.

1994 Survey: Review of Past Trends

As a possible framework for an international descriptive reference, and in response to the highly variable published information available on energy standards, we developed a 15 page informal survey to gather information about activities undertaken specifically for the purpose of increasing energy-efficiency in buildings. Responses regarding standards for non-residential buildings were specifically encouraged, but the survey did not assume all respondent countries would have energy standards in place for any building sector. Although several sections were standard-specific, the survey also asked general questions about the status of non-energy building standards, energy-efficiency testing facilities, and other programs designed to increase energy-efficiency in buildings.

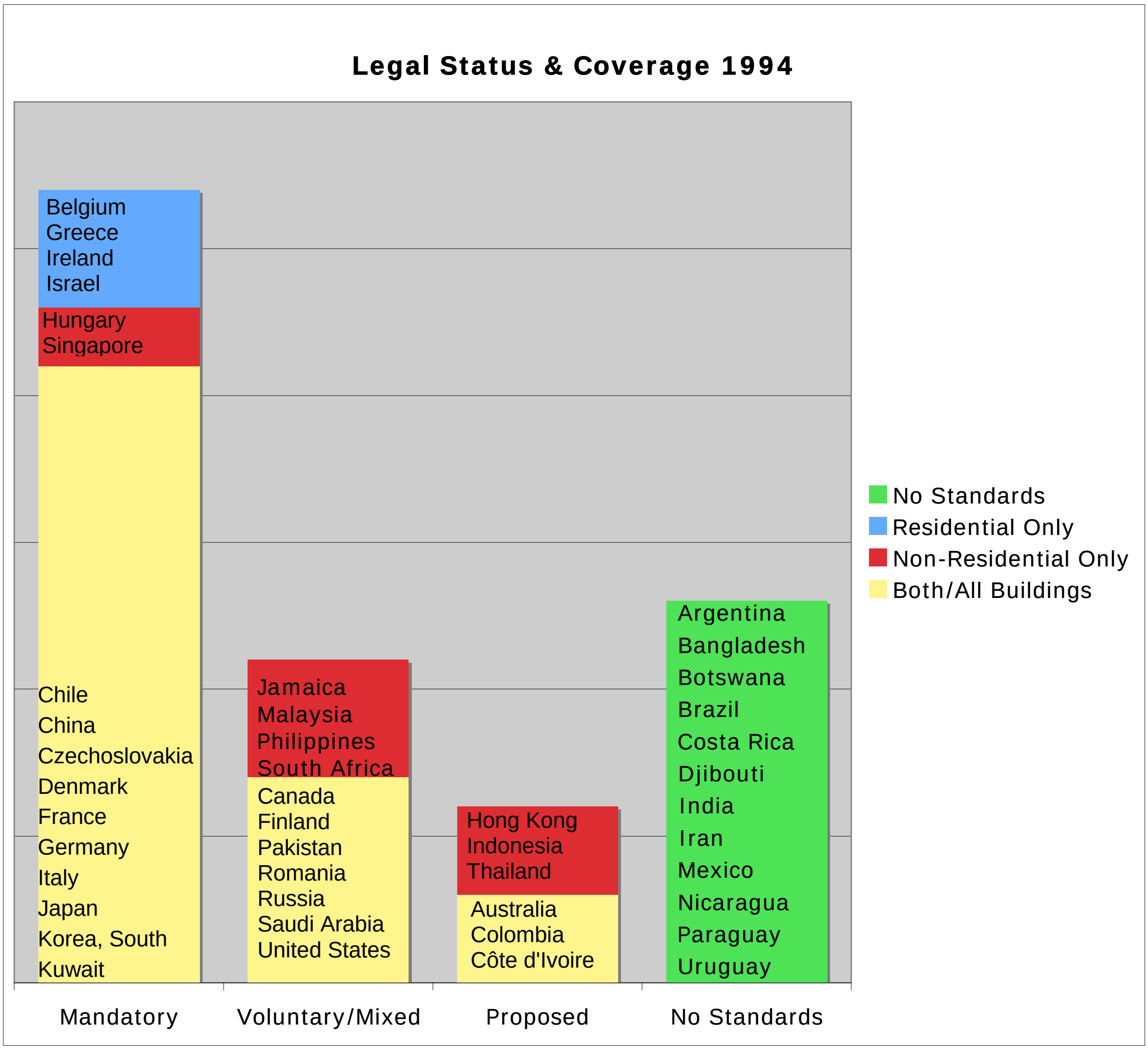
To broadly characterize the worldwide status of energy standards for buildings, we combined previously published information with results of the survey. Figure 1 shows a general overview of the legal status and coverage of energy standards in 57 countries. Thirteen of the countries for which information was gathered had no energy standards for any building sector; four countries had standards only for the residential sector; nine countries developed standards exclusively for non-residential buildings; and 31 countries had standards for both. At the national level, 27 countries have mandatory energy standards for at least one building sector, and 11 have voluntary standards. Three of the 11 voluntary standards are “mixed,” meaning that they are voluntary guidelines but mandatory in limited regions or for specific building types. Six more countries have proposed but not yet adopted energy standards; half of these are non-residential standards and the rest are for both or all buildings.

Summaries of energy standards from each country did not fit easily even into these simple categories. Many countries have more than one kind of standard, depending on the building sector and issuing organization. Each of these standards may have different legal applicability and original versions may have been updated and changed several times since their introduction. We attempted to include the most up-to-date information available for this table, but we did not project into the future. A recently passed energy bill might push the United States into the ranks of countries with mandatory national energy standards for buildings in 1994,” but until then the U.S. remains a patchwork of various state-initiated policies, many of which are based upon standards developed by ASHRAE.

Because of these complexities, we did not ask survey respondents to attempt a synthesis of the entire energy standard situation in their country. Instead, respondents from countries with existing (or proposed) energy standards named a specific standard and answered several sections of the survey with respect to this standard. They were asked to specify the standard’s geographic coverage and legal status; identify the applicable building types and vintages; and note its provisions for specific building elements. Respondents were also asked to indicate the entities involved in the process of developing and revising this standard, and to describe issues pertaining to its implementation and enforcement.

The survey was sent to approximately 175 contacts in government, research, and professional positions in 65 countries. The number and distribution of these contacts reflects recommendations solicited from researchers knowledgeable about energy standards rather than a specific selection criteria or sampling methodology. Contacts in countries where published information about energy standards does not exist were pursued more vigorously than contacts in countries covered by previous reports. Given the survey's length and the need for specific expertise in several areas, the response rate of 33% (59 surveys from 42 countries) was better than anticipated.

Figure 1. Worldwide Status of Standards, 1994 (after Janda & Busch 1994)



Information from survey respondents countries was organized into a database of information containing: (1) the status of energy standards for buildings in each country; (2) basic provisions of existing energy standards; (3) approaches to standards development; (4) implementation and compliance; and (5) other methods of increasing energy-efficiency in buildings. Coverage of the topics in the database depends upon the extent to which respondents in individual countries filled out our surveys. We reiterate that the database itself and information gathered is not definitive. Although efforts were made to define the researcher's sense of what an "energy standard for buildings" is, a few respondents answered with respect to a different type of standard than expected, such as a national electric code; if determined, these responses were not used for further analysis. In most cases only one survey from each country was received, but in cases where multiple surveys were returned we did not attempt to verify the information given or "correct" discrepancies between respondents from the same country.3 Instead, we selected the survey which seemed to contain the

[3] In South Africa, for instance, two respondents said there were no energy standards of any kind, while a third mentioned a voluntary standard for offices, government facilities, and hotels. All three

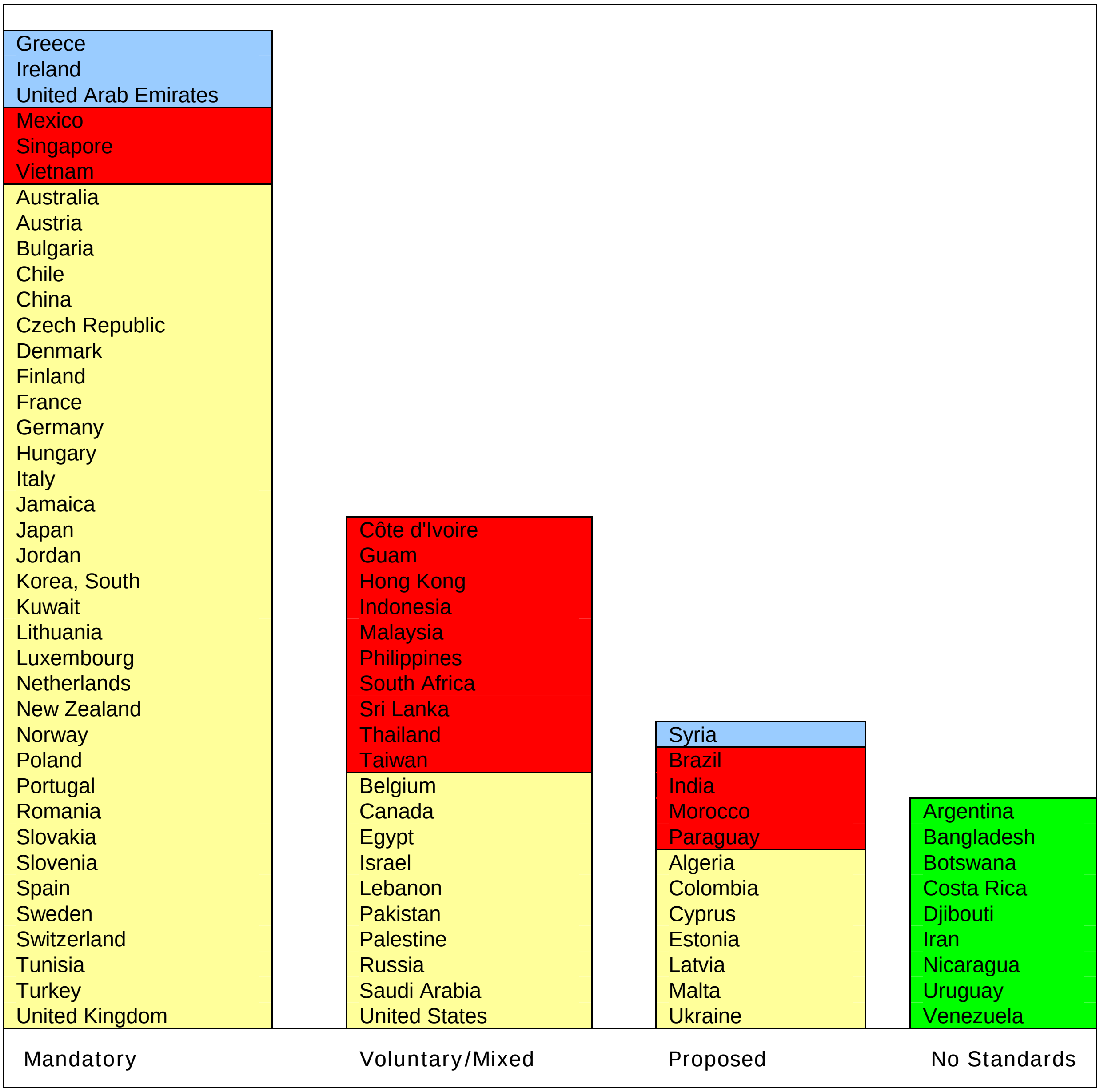
most reliable information for our comparative analysis set. The results below cover only a few highlights from the database of surveyed information.

Reflecting our initial sampling methodology, 26 of the 42 countries responding to the survey do not belong to the Organization for Economic Cooperation and Development (OECD). Seven of these countries do not have energy standards for buildings, although all seven have implemented programs to reduce energy consumption in buildings and most have devoted some attention to standards development.

2007 Update: Review of Current Trends

In 2007, we found that 59 countries have some form of mandatory or voluntary existing standard, twelve countries had proposed standards, and nine countries did not have standards.

Figure 2: Status of Energy Standards in 80 countries



respondents were certain, however, that energy efficiency was not a high priority, given current excess electric capacity and indigenous energy supplies.

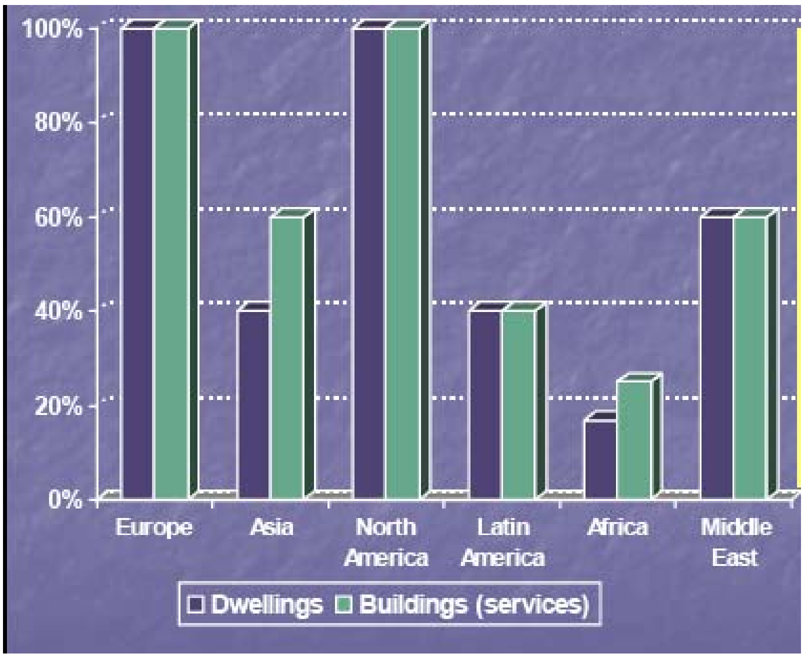
Primary data for the update was gathered through reports and websites (e.g., CLASP, 2005; Deringer, 2006; IEA, 2006; Koeppel & Ürge-Vorsatz, 2007; RICS, 2007) This growth in the number of standards is due to a number of factors, including geopolitical transitions, international agreements, international assistance, and concerns about development, energy security, and climate change.

Since the original survey, which was started in 1992, many geopolitical changes have occurred. Some countries have divided (e.g., Czechoslovakia into the Czech Republic and Slovakia in 1993, Yugoslavia into six different countries over the period 1991-2006) and others have changed their political affiliations (e.g., Hong Kong from crown colony of the United Kingdom to special administrative region of China). It is important to note that a few of the increases in the number of countries with standards has to do with this redistribution of nation-states.

Countries with Standards

At the national level, there is evidence of energy standards activity in countries on almost every continent. The World Energy Council conducted a survey of 63 countries and found that there were mandatory efficiency standards for new dwellings and buildings in all European countries (Moisan, 2005). The study found regular and recent revisions in more than half of European countries. In other regions, it found that few countries had standards for new dwellings, but approximately 60% of countries outside Europe had mandatory or voluntary standards in the non-residential sector.

Figure 3. Thermal Building Regulations (Moisan, 2005, p. 12)



From Proposed to Adopted

Many of the countries with proposed standards in 1994 actually took the steps to adopt these standards into law, sometimes changing the standards along the way. In1994, Hong Kong's proposed standard was to have applied to office buildings and hotels. The standard Hong Kong actually passed in 1995 was different in scope than the proposed standard, applying somewhat more broadly to commercial buildings *except* for hotels and schools (Hong Kong Government, 1995). Other countries such as Australia, for example, moved from a set of proposed standards to mandatory standards for all buildings, plus a coordinated set of voluntary initiatives designed to encourage best practices in building design, construction and operation (Australian Government, 2008).

From Nothing to Something

Of the thirteen countries without standards in 1994, three (Brazil, India and Paraguay) have since proposed standards and Mexico has adopted mandatory standards for non-residential buildings (Huang, Warner, Wiel, Rivas, & de Buen, 1998).

Countries Without Standards

Even though many countries do not have energy standards for buildings, there is evidence of other kinds of programs that promote energy efficiency or energy conservation in buildings. Many countries without energy standards at the building level are participating in standards and labeling activities for appliances. The Collaborative Labeling and Appliance Standards Program (CLASP) has activities in over 27 countries, including: Argentina, Australia, Bahrain, Belize, Brazil, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Ghana, Guatemala, Honduras, India, Mexico, Nepal, Nicaragua, Panama, Poland, South Africa, Sri Lanka, Thailand, Tunisia, Uruguay (UNDESA, 2008). For countries without energy standards for their buildings, appliance and labeling standards offer some protection from end-use extravagance. Other countries without standards, like Iran, have developed energy efficiency offices and a range of programs designed to improve energy efficiency (IEEO-SABA, 2008).

International Standards

In addition to energy standards activity at the national level, similar activities are also taking place in international arenas. There has long been interest within the European Community to develop a European building energy standard. The Directorate General for Energy of the European Economic Community (EEC) commissioned studies in 1975, 1980, and 1987 regarding thermal insulation requirements in EEC member states. Although the International Standards Organization (ISO) did not have a technical committee on the topic of building energy standards in 1994, the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) had proposed that the ISO develop one that could encompass broader issues of energy use. By 2007, this institutional change had been implemented, and TOC 205 on "Building Environment Design" is currently developing eight different projects, four of which are directly related to energy performance or energy efficiency (ISO, 2008). However, only one standard in this TOC area (ISO 16813:2006, "Building environment design -- Indoor environment -- General principles") has been published at present.

Most importantly in the international arena, the European Parliament and Council approved in December 2002 a comprehensive directive on the energy performance of buildings (EPDB). The directive requires member countries to:

(1) develop a comprehensive methodology for calculation of the integrated energy performance of buildings and HVAC systems including heating, cooling, ventilation and lighting;
(2) set minimum requirements for energy performance of new buildings;
(3) apply requirements in existing buildings;
(4) develop an energy certification system for buildings;
(5) have heating and air-conditioning systems inspected regularly.

Although a recent report by European Energy Network suggests that the EPBD is not delivering completely on its promise (EnR, 2008), EPBD has certainly made a bold statement about not just energy standards themselves but the broader policy and market context in which they occur. The next section will develop these ideas in greater detail.

Beyond Standards: Review of Ongoing Policy Initiatives & Market Transformation

Recent work assessing policy effectiveness for energy efficiency in buildings has emphasized that although energy standards for buildings are frequently used, their effectiveness varies greatly from country to country (Koeppel & Ürge-Vorsatz, 2007). Koeppel & Urge-Vorsatz note that effectiveness of energy standards may be particularly low in developing countries, given difficulties with enforcement and even corruption. Even in developed countries, the estimated savings from energy codes range from 15-16% in the US to 60% in some countries in the EU. These authors and other proponents of market transformation stress that a combination of policy instruments (regulatory instruments, information instruments, financial/fiscal incentives, and voluntary agreements) is the key to achieving real reductions in the building sector. The idea behind market transformation, as the name suggests, is to use a coordinated suite of tools to transform the market in which building design, construction, and operation occurs. In practice, it is difficult to discern exactly how to coordinate these policy tools, but the idea of a multi-pronged approach does seem to fit with the diverse interests and elements in the building industry.

In addition to policy initiatives undertaken by governments, a host of non-state actors have started to engage in promoting energy efficiency in buildings. The extent to which cities, regions, and businesses have started to play a role in climate change mitigation has been the subject of several books and numerous articles on the changing nature of governance in a global world (Newell, 2000; Newell & Levy, 2005). Within this context, non-governmental organizations such as the US Green Building Council are experiencing immense growth, both in the US and around the world (USGBC; WGB, 2008). Similarly, the Clinton Climate Initiative (CCI) has chosen to partner with the 40 largest cities in the world rather than the governments of the nations in which those cities reside. Finally, the World Business Council for Sustainable Development is also focusing its attention on energy efficiency in buildings (WBCSD, 2007). Although they are not the usual originators of energy efficiency policies, cities, businesses, and non-governmental organizations are increasingly playing a voluntary role in transforming the market towards a lower-carbon future.

While some might argue that the voluntary initiatives are the way of the future, we assert that setting a stringent standard for building performance will always be of assistance by setting a floor for the market. It also serves as an enduring reminder to architects, engineers, owners, operators, and others in the building industry that certain basic elements of building performance should be included in every new design and retrofit.

Recommendations for Further Research

Although the complexities associated with both building research and energy standards obstruct meaningful comparative analysis and information transfer, they do not preclude it. Greater access to the methodology, tools, and information used to support existing standards would give countries without standards a basis to choose between revising research and re-inventing it. The current information gap is already spanned by calculation methodologies, and other useful connections might be forged through an international comparison of non-residential buildings or by the development of a comprehensive reference for technical and administrative requirements of energy standards.

A historical precedent for information sharing has been set by the cooperative use of methodology and tools for calculating building energy consumption. In the 1960s France was credited with developing the first criteria that were oriented toward the performance of a whole building rather than specifying materials for its parts.' By 1975 these calculations were updated to include infiltration losses, and Germany had developed similar expressions of its own which spread across Greece, Spain, Belgium, and the Netherlands. In 1980, another iteration of standard calculations appeared in Europe and added heat gains (from solar and internal sources) to the accepted methodology. In the United States, the term “Overall Thermal Transfer Value” (OTTV) has been coined to describe this concept of determining heat gains and losses to a building (either as a whole or particular components). OTTV calculations are performance-based criteria that have been employed in both the U.S. and in Southeast Asia. Like these calculation methods, predictive computer models have also been developed for one country and used effectively in others.

Much as some research methods have crossed national boundaries, some research topics are intuitively international. Although the authors of most multi-country studies on energy standards have pursued a residential focus, comparative international analysis of some non-residential building types and standards might provide more transferable information. Residential energy use patterns within a single country may be more homogeneous than those of its service sector, but the perceived homogeneity shifts when making international comparisons about building design, construction practice, and energy use. Consider, for example, the probable appearance and pattern of energy use in two new high-rise office buildings, one in Bangkok and the other in New York. Then visualize the construction and likely energy patterns of two residences in those cities. While styles of living and types of housing vary tremendously from country to country, modern urban workplaces tend to follow a more uniform pattern. In particular, large offices and hotels share general physical characteristics, equipment requirements, and energy consumption patterns that might make comparative analysis of standards for these buildings useful. There is an international market in commercial buildings and building systems, and there are unclaimed opportunities to explore energy use, efficiency potential, and efficiency methods for this sector.

Although further study of methods or special topics would help to fill in the information gap, the key to bridging it may lie in making basic information about existing building energy standards more readily accessible. In 1994, we proposed a directory with information compiled from different countries to enable exchanges between countries with effective existing standards and countries seeking to update their standards or develop new ones. As a model for this kind of work, we pointed to an annual report done in the United States by the National Conference of States on Building Codes and Standards (NCSBCS, 1991). Internationally the same need for detailed information exists but no equivalent descriptive source for energy standards information fills the gap. Today, creating an online database of energy codes and regulations would be the obvious next step towards this goal.

CONCLUSIONS

All signs point to the conclusion that energy standards, particularly for non-residential buildings, will play an increasingly significant role in the future of national and possibly international energy-efficiency policies. The information gathered here is another step toward fostering cooperation among countries with standards and those contemplating standards or other policies for increasing energy-efficiency in buildings. While it is difficult to generalize, our work to date and proposed database provides a basis for further inquiry into the development, structure, and implementation of energy standards throughout the world. This information may be particularly useful to countries at similar stages of development, countries with common cultural roots, and/or those in comparable climates. While energy standards for buildings have been developed and adopted in at least one-third of the world's countries, the other two-thirds have few ways of learning about the existence of information on this topic, and all countries currently face barriers to accessing it. Our project does not establish a complete international reference for building energy standards, but it submits a possible framework for further inquiry. It is our hope that this project will draw attention to the need to further define the field of energy standards research and support increased communication within it.

Acknowledgements

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Australia's Path to Energy Efficiency in Commercial Buildings – '*Your Building*' Best Practice Programme

Jodie Pipkorn, Stephen Berry Department of the Environment, Water, Heritage and the Arts
Department of the Environment, Water, Heritage and the Arts, Australia
Tony Stapledon, CRC for Construction Innovation

Abstract:

The role of government as a regulator of the building industry is well understood, but government can do more to address the market failure by promoting best practice to industry and consumers.

Since June 2005 the Australian Government, in partnership with the Cooperative Research Centre for Construction Innovation (CRC-CI) and the Australian Sustainable Built Environment Council (ASBEC), have been developing a web-based information and decision system that allows stakeholders in the building, construction and property sector to understand and communicate the commercial and economic benefits of environmentally sustainable commercial buildings.

On 28 September 2007, the innovative new best practice tool titled ***'Your Building'*** was launched. Using interactive web-based technology, *Your Building* provides a comprehensive guide on sustainability for commercial buildings and consolidates industry knowledge, provides links to leading organisations and reference materials and, through practical case studies and research findings, demonstrates the economic, environmental and social benefits of creating sustainable buildings

This paper will outline the path for developing and improving energy efficiency in commercial buildings, and the role of the Australian Government in promoting industry best practice in building markets, through information dissemination and interactive web-based tools.

Introduction

Buildings have a significant impact on the natural environment, particularly the production of greenhouse gas emissions contributing to climate change. Around 20 percent of the total greenhouse gas emissions in Australia come from the building sector (Australian Greenhouse Office, 2007) and research indicates emissions from commercial buildings are expected to double between 1990 and 2010 (Australian Greenhouse Office, 1999). With more recent figures indicating these predictions may be underestimated (Wilkenfeld 2007), it is critical that the energy and greenhouse impact of commercial buildings in Australia be addressed.

To cost effectively address the energy and greenhouse impact of commercial buildings, the Australian Government has developed a comprehensive strategy of programmes. These include:

- locking in minimum standards with new **building energy performance regulations**;
- creating market recognition of building energy performance through **mandatory disclosure at point of sale and lease**;
- encouraging commitments to improving ongoing operational performance by **green leases**;
- developing opportunities to give Australian companies the technical expertise and incentives to fund, design, build and operate better performing buildings through **industry capacity building**.

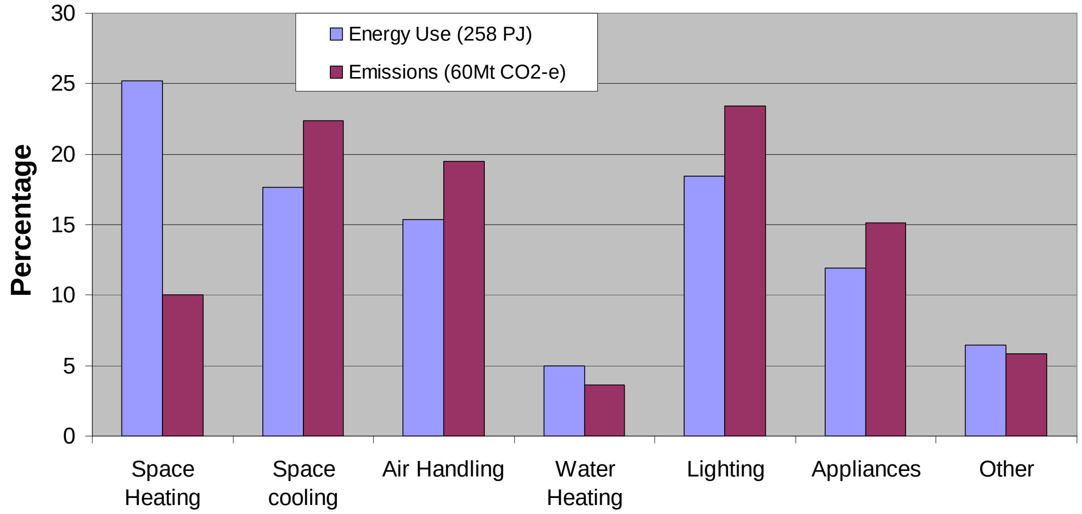
While the role of government as a regulator of the building industry is well understood, through industry capacity building the government can make it quicker and easier for the building industry to go beyond minimum standards.

Since June 2005 the Australian Government has been working in partnership with industry (through the Australian Sustainable Built Environment Council (ASBEC)) and with the Cooperative Research Centre for Construction Innovation (CRC-CI), to develop an interactive web-based information and decision system. This innovative new best practice tool titled '***Your Building***' consolidates industry knowledge and helps those in the building, construction and property sector to understand and communicate the commercial and economic benefits of environmentally sustainable commercial buildings.

Australia's Commercial Building Energy Use and Greenhouse Impact

Energy use in Australian 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, lighting and space cooling become the highest impacts at around 23 per cent and 22 per cent of emissions respectively (see Figure 1).

Figure 1 End Use Analysis Of Energy Emissions (Wilkenfeld 2007).



The overall increase of the commercial building sector greenhouse gas emissions in Australia has been driven by economic growth. This growth has driven the need for new buildings and increased electricity consumption, mainly due to increased comfort expectations leading to additional air conditioning use, rapidly increasing retail lighting levels, and rising standby loads.

Not only is this annual growth in energy consumption and consequent greenhouse gas emissions 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 and supply systems. As air conditioner prices have fallen and comfort expectations risen, the number of businesses and households with air conditioners has dramatically increased, which further increases the demand for energy in the form of electricity at peak times.

The greenhouse impact of buildings is further exacerbated by the generation of electricity. Around 77 per cent of electricity comes from coal-fired power stations (Department of Industry, Tourism and Resources, 2005), which gives electricity a carbon intensity of 0.8 tonnes CO_2 per MWh (Australian Greenhouse Office, 2005). It is estimated that Australia 's net electricity demand will rise by around 50 per cent by 2020 (ABARE, 2003).

With Australia's climate being relatively mild and electricity being internationally competitively priced, as the availability of cooling technologies have increased and product prices have fallen, developers have become even less likely to construct buildings to naturally maintain thermal comfort during periods of higher temperatures. Consequently, to effectively address the energy and greenhouse impact of commercial buildings, substantial changes are required in the commercial building sector.

Australian Government Policy Approach

Australia has had a recent change in government and dealing with the climate change challenge is one of the highest priorities of the new Australian Government. In his first act as Prime Minister, the Hon Kevin Rudd MP committed Australia to play its part by ratifying the Kyoto Protocol and leading the Australian delegation to the Bali climate change negotiations. Australia was instrumental in securing agreement on the Bali roadmap for the international community to agree on post-2012 action on climate change.

The Australian Government is also moving quickly to implement its comprehensive framework for tackling climate change in Australia, by:

- setting a target to reduce emissions by sixty per cent on 2000 levels by 2050, with analysis underway to set interim targets;
- establishing a national emissions trading scheme by 2010;
- setting a twenty per cent target for renewable energy by 2020 to dramatically expand the use of renewable energy sources such as solar and wind;
- improving energy efficiency in Australian homes, schools and businesses; and
- investing in sustainable agriculture and protecting biodiversity.

This framework will create new opportunities for Australia to lead the way in tackling climate change and deliver positive outcomes for the economy.

At this stage, after extensive consultation with the building and construction industry, the Australian Government has implemented a range of programs to cost effectively address the energy and greenhouse impact of commercial buildings. An overview of these are:

Building Regulation

Building regulation in Australia, although implemented by regional governments, is collectively developed as the Building Code of Australia (BCA). As of May 2006 the BCA included minimum energy performance standards for all classes of buildings and has established standards for commercial buildings that include: the building fabric, lighting systems and controls, and the heating, cooling and ventilation system. A system of regular reviews allows these standards to be upgraded in line with community expectations.

Mandatory Disclosure

Markets always work more efficiently with improved 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. Mandatory energy performance disclosure was established for residential buildings in the Australian Capital Territory in 1999, and research undertaken for the Australian Greenhouse Office 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). Research scoping the potential for mandatory energy performance disclosure for commercial buildings has commenced and is expected that by the second half of 2008 the Governments of Australia will have a roadmap for this initiative.

Green Leases

The Australian Government has developed 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.

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 of information on both the financial benefits of building green, and how to design, build and maintain green buildings. Branded "*Your Building*" (www.yourbuilding.org), this guide is the commercial building companion to the very popular "*Your Home*" guide to environmentally sustainable residential buildings (www.yourhome.gov.au).

While the role of government as a regulator of the building industry is well understood, government can make it quicker and easier for the building industry to go beyond minimum standards. The following part of this paper will therefore outline the path taken to develop and improve energy efficiency in commercial buildings, and the role of the Australian Government in promoting industry best practice in building markets through information dissemination and the interactive web-based tool: *Your Building*.

What is *Your Building*?

Your Building is a web portal designed to help those in the building, construction and property sector reach for higher environmental performance. By demonstrating the business case for sustainable commercial buildings, *Your Building* is helping those in the sector better understand and communicate the commercial and economic benefits of environmentally sustainable commercial buildings and is providing the foundation for a host of further industry resources for training, education and research.

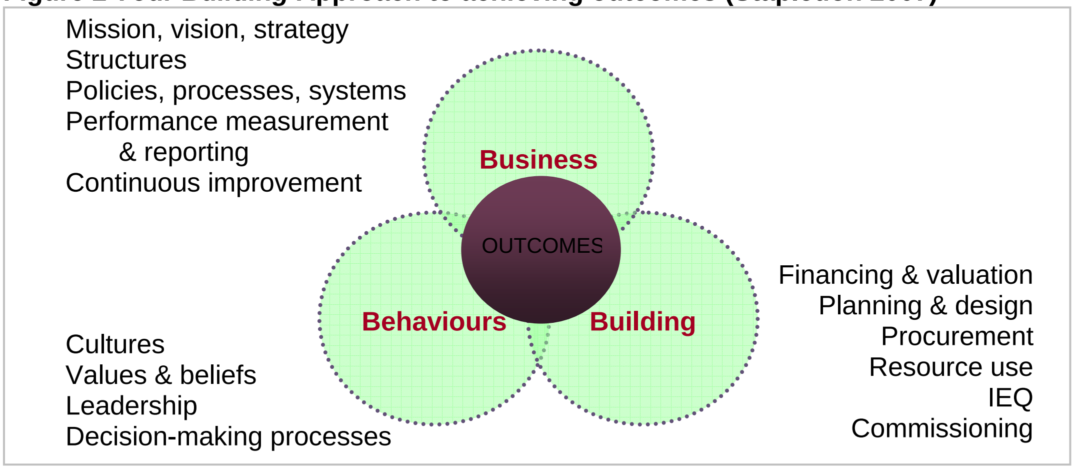
Developed as an interactive and easy-to-use provider of up-to-date information, *Your Building* consolidates the vast quantity of available industry knowledge, provides information about all stages of the building process – including funding, designing, building and operating commercial buildings – provides information to a range of audiences – including investors and developers, owners and occupiers, or builders, designers and facility managers – and most importantly, provides the Government stamp of authority.

The challenge that was set at the project inception was to change market behaviours, as sustainable commercial buildings are an outcome of what is done now and how it is done:

Actions + Behavior = Outcome

However to really change behaviours and not just achieve the occasional success, change needs to be tackled at various levels (Stapledon 2007), including the underlying level of behaviours of stated goals and philosophies, and the level below these of beliefs and feelings. *Your Building* addresses changes in behaviour at all levels and at all stages (see Figure 2).

Figure 2 *Your Building* Approach to achieving outcomes (Stapledon 2007)



Your Building also recognises there is already a lot of information available in various forms that already address sustainability issues, but that much of it is quite specialised, technical and not easily understood by non-experts, or located in dispersed knowledge areas that may not present an integrated view of sustainability and the systemic nature of sustainable solutions.

Your Building is therefore Australia's 'one-stop-shop' national online resource that:

- Consolidates this information into one accessible location;
- Justifies sustainable commercial buildings;
- Provides access to the tools for sustainable performance; and
- Creates a resource for education and training programs; and
- Provides real answers to questions about sustainable commercial buildings.

How was Your Building developed?

Since 2001, the successful Australian Government initiative *Your Home* has been providing information and justification for sustainable building in the residential sector. In 2004 industry indicated that a similar resource for the commercial sector should be developed and a partnership was formed between the Australian Government, industry and a research and development (R&D) contractor.

The role of each partner included:

Australian Government (AG): Department of the Environment, Water, Heritage and the Arts

- Client;
- Primary source of funding; and
- Member of the Project Steering committee.

Industry: The Australian Sustainable Built Environment Council (ASBEC):

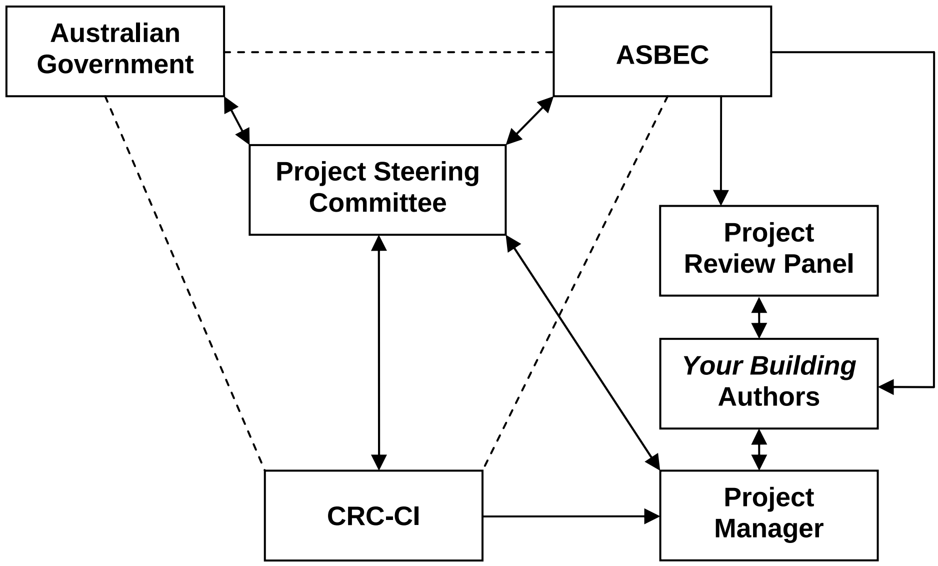
- The 30+ members supported the project;
- Endorsed the governance model;
- Suggested potential authors;
- Provided peer reviews of sections of reports relevant to their members; and
- Provided publicity through their associations, newsletter, website, etc.

Contractor: Cooperative Research Centre for Construction Innovation (CRC-CI) :

- Provided R&D;
- Were responsible for project delivery;
- Contributed cash and in-kind resources to the project;
- Were responsible for appointing the Project Manager;
- Approved the Project Steering Committee;
- Negotiated intellectual property (IP) from those providing information;
- Appointed *Your Building* authors; and
- Own the IP, but make all information assembled under the contract in *Your Building* publicly available to Government for unlimited access and non-commercial use.

Importantly the Australian building industry was to have strong ownership of the project through actively participating in its design, management, development and use. A structure (as shown in Figure 3) was therefore developed, with overarching leadership coming from the Steering Committee formed by the project partners and day to day management handled by a Project Leader (CRC-CI) on behalf of the Steering Committee.

Figure 3 *Your Building* Structure



Strategies developed and incorporated within this structure included:

Creation of a Project Steering Committee (PSC):

— This committee comprised of representatives from the Australian Government (1), CRC-CI (2, including chair for Committee) and four ASBEC members (comprising ASBEC Chair plus 3 members elected by ASBEC members). Regular meetings between the PSC and Project Manager provided guidance on scope, structure and content in respect of the industry needs as reflected by ASBEC members and allowed opportunities for PSC to recommend appointees to the Project Review Panel (PRP), receive and respond to report(s) from the PRP about the quality of product received from the Project Manager (authors) and an opportunity to report and monitor progress to the partners (AG, ASBEC, CRC-CI).

Inclusion of a skilled and independent Project Manager:

— Selected by a 3 member panel comprising of an AG nominee, the chair of ASBEC and the CEO of CRC-CI, the successful applicant was chosen from an open advertisement and had demonstrated ability to deliver a high quality, technically validated product, and was able to devote 3 days/week on average over a 2-3 year period.

Utilisation of specialist expert *Your Building* Authors:

— A team of authors comprising of sets (one research, one practitioner) of highly qualified individuals related to key aspects of Commercial Building performance (refer to *Your Building* scope in the following pages) were used to provide the content for *Your Building*. Authors were selected from an advertisement seeking 50:50 (money paid to author: in-kind contributions from authors) and appointed under (sub)contract by CRC-CI.

Creation of a Project Review Panel:

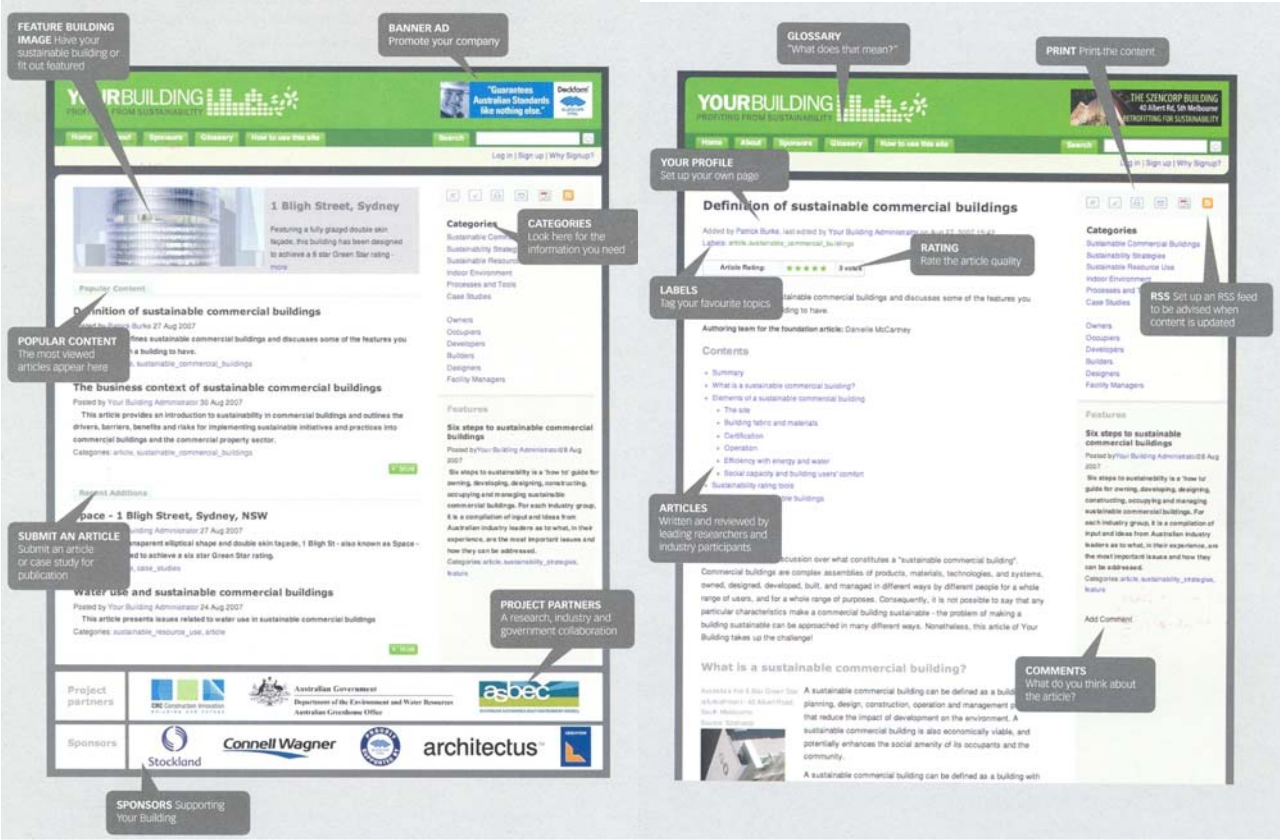
— This panel comprised of technically knowledgeable representatives from industry associations and professional institutes, governments and research organisations – invited to provide peer review of drafts of *Your Building*.
— Members of the review panel were recommended by the Project Steering Committee and appointed by CRC.
— The Project Review Panel reports were provided to the Project Steering Committee.

To ensure the content and information on the *Your Building* web portal was relevant for the audience, in addition to the structure outlined above, research and extensive industry consultation was conducted through industry surveys, industry focus groups and workshops across the country.

How does *Your Building* work?

To meet the diverse needs of those in the commercial building industry, remain up-to-date and continually provide relevant information, *Your Building* was designed as a fully interactive web portal built on a wiki platform. This provides the capabilities for social adding and editing of material that is achieved with wikipedia – such as approved contributors being able to post articles, comment, and edit all content (see figure 3).

Figure 3 *Your Building* Home Page & Article Page



The types of content on *Your Building* includes:

- Site editorial (authoritative)
- User editorial (interactive)
- Third party content
  - Case studies
  - Sponsor information
  - Links to articles, sites, etc
- Links to existing web based materials & information
- Information specific for the six user groups (refer to following sections)
- Educational resources for CPD, industry training programs, universities and TAFEs

With the intention of having a fully accessible resource, not only is the information free, but it is made available in the most useable form and in the way busy people need it when they are working – by both knowledge area and user group.

Knowledge Areas

Six knowledge area selection categories have been used for quick navigation around the web portal:

- Sustainable Commercial Buildings
- Sustainability Strategies
- Sustainable Resource Use
- Indoor Environment
- Processes and Tools
- Case Studies

The scope of topics covered by *Your Building* were designed to include the impact that each stage of the building's lifecycle has on the environment, and the full range of major environmental impacts (see Table 1). The scope of topics range from the building's development in its local environment context, to the key design features that reduce its impact over its effective life, to construction impacts, operational strategies and refurbishment impacts.

Table 1 Scope of Topics

Building Context:	➢ Microclimate		
	➢ Biodiversity Impact		
	➢ Site Management	— Emissions to air — Noise	— Congestion — Disturbance to infrastructure
	➢ Travel Demand	— Relationship to public transport — Walking/cycling facilities	— Parking access — Mobility plans
Facades and Envelopes	➢ Windows		
	➢ Indoor – Outdoor exchange		
Indoor Environment	➢ Energy & Greenhouse Efficiency	— Operational energy consumption Daylighting & artificial lighting o Thermal performance o HVAC o Appliance efficiency (plug loads) — Application of renewable technologies	
	➢ Water efficiency	— Embodied water content — Rainwater harvesting — Grey water recycling	— Black water recycling — Appliance efficiency
	➢ Indoor Air Quality	— Material selection — Ventilation cycles/filtering systems	
	➢ Acoustics		
	➢ Indoor Ecology		
	➢ Sensing and Automation		
	➢ Occupant Health, Productivity		
	➢ Layout Flexibility and Adaptability		
Materials and Appliance selection	➢ Environment performance		
	➢ Energy and water embodied in the materials		
	➢ Service life performance		
	➢ Reusability and recyclability		
Performance Assessment and Benchmarking	➢ Checklists		
	➢ Rating Tools (GreenStar, NABERS, ABGR)		
	➢ Design Tools (LCA Design, Ecospecifier)		
	➢ Ecological Footprint		
	➢ Performance Metrics		
	➢ Case Studies		
Building Commissioning			
Performance Management	➢ Occupant Behaviour		
	➢ Facility Management	— Green leases — Energy Plans — Energy Performance Contracting	— Pre-commitment agreements — Monitoring systems — Safety & Security
Building Regeneration	➢ Refits		
	➢ Major Refurbishments		
De-construction			

Although the scope of topics is relatively extensive, *Your Building* has ensured the information consolidates and builds on existing knowledge by:

- Simplifying information
  - Providing definitions of what commercial buildings are
  - Using common language, measurements and calculation standards
  - Giving practical tools
  - Making sure articles are readable and easy to digest
- Integrating and collaborating information
  - Linking together topic areas, such as water/materials, water/energy, etc
  - Incorporating information for the various disciplines involved
  - Utilising supply chain management to provide relevant and practical information
- Justifying information
  - Addressing critical sustainability issues
  - Addressing the barriers for change
- Contextualising information
  - Considering and structuring for different audiences

- Providing global context
- Addressing inter and intra-generational contexts
- Discussing political and legislative frameworks

User Groups

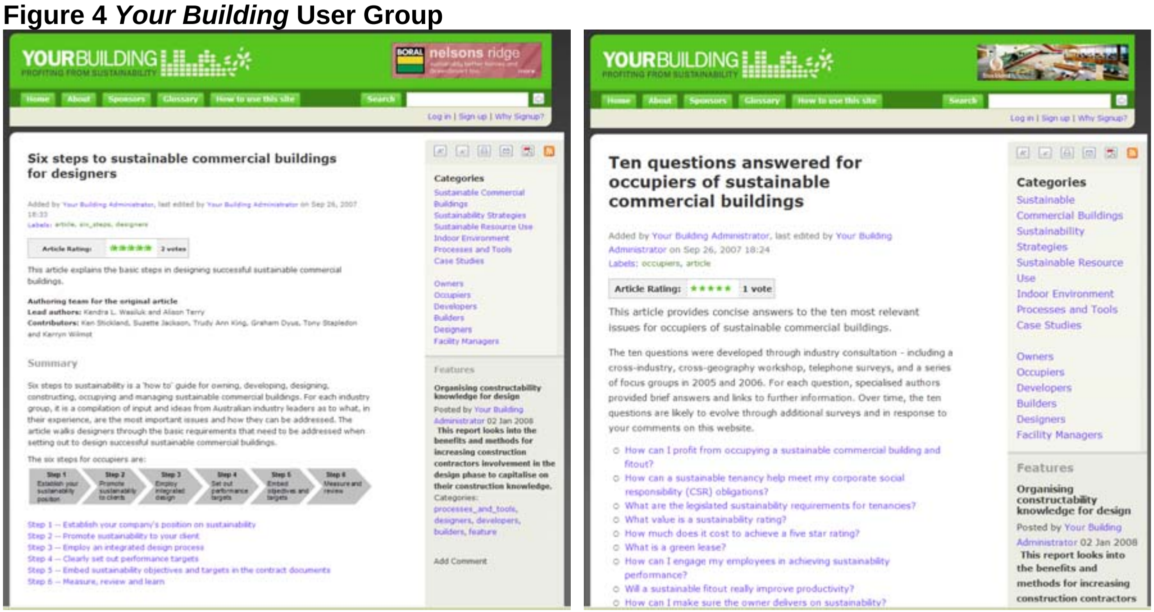
The initial scoping study for *Your Building* identified fifteen different groups in the property and buildings industry who may use the portal. These were consolidated into six user groups and used for quick navigation within the web portal:

- Owners
- Occupiers
- Developers
- Builders
- Designers
- Facility Managers

Within each user group information and articles are collated that are relevant for the particular user group (see Figure 4). However a number of common articles are provided for each user group that are written specifically for that group. These include:

- **The business case for sustainable commercial buildings** – This highlights the key business case value factors for the user group and suggests how sustainable commercial buildings may provide benefits in each instance.
- **Six steps to sustainable commercial buildings** – This provides a 'how to' guide from leaders in the specific user group industry.
- **Ten questions answered for sustainable commercial buildings** – This provides the most important ten questions that each group wanted answered and was identified during consultation. The answers provided are short, easy to understand and linked to more detail elsewhere on the web portal.

Figure 4 *Your Building* User Group



In these early stages of the *Your Building* release, due to some concern about product manufacturer's or consultant's adding inappropriate or misleading information, the level of interaction has been reduced on the website and it is only possible for people to comment on and submit articles. However, with good management and an active audience, bad content should be quickly corrected and the future level of interaction may be increased.

How has *Your Building* been introduced to industry?

In September 2007 *Your Building* was officially launched. This was followed in September and October 2007 with a range of industry seminars across the country (run by the CRC-CI), introducing the various user groups to the *Your Building* web portal and explaining how it could be used.

Following these successful industry seminars, and by utilising the information on *Your Building*, the CRC-CI then presented a series of practical training workshops. These workshops were designed to give industry the 'What', 'Why', and 'How' of the business case for sustainable commercial buildings by developing attendees capacity to:

- Identify business case drivers and value factors
- Justify the value of sustainability in commercial terms
- Create and present the business case for a project
- Influence and communicate with senior management, clients and key decision makers
- Employ practical sustainability tools, models and concepts

Further workshops are planned for 2008, including:

- Developing a Brief
- Facility Management
- Life Cycle Costing
- Valuing a Sustainable Building

Where to now?

The *Your Building* web portal is on-line and free for everyone to use. Between October and December 2007 the site received about 47 000 hits and at this stage there is the equivalent of nearly 1500 A4 sized pages of information (Stapledon 2007) on the web portal. If this commercial building resource continues like the residential building resource *Your Home*, this content could double over the next five years.

To make the most of this new information source, *Your Building* will be maintained and continually developing more content, in conjunction with education and training programmes.

Conclusion

Energy consumption and greenhouse gas emissions by commercial buildings sector in Australia is an important issue, as it is large and growing fast. To effectively address this problem substantial changes are required from the sector.

The Australian Government's commercial buildings programme has been designed to cost effectively address energy and greenhouse issues, while encouraging innovation within the industry, building market recognition of performance, and eliminating practices that are wasteful.

Your Building is a web portal designed to help those in the building, construction and property sector understanding the economic and technical opportunities to reach for higher environmental performance and go beyond minimum standards. Using a wiki-style web portal this resource has the potential to be interactive, in addition to evolving and developing in-line with changing industry needs.

Through industry capacity building programmes like *Your Building*, the Australian Government is improving the knowledge base of the Australian construction industry to improve the environmental and economic performance of commercial buildings, and contribute to the longer-term national target of significantly lower greenhouse emissions.

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Reducing CO_2 Emissions Through Refurbishment of Non-Domestic UKk Buildings

A. Peacock, The Energy Academy, Heriot Watt University
P.F. Banfill, S. Turan D. Jenkins, M. Ahadzi, G. Bowles, School of the Built Environment, Heriot Watt University
D. Kane, School of Engineering and Physical Sciences
M. Newborough, ITM Power
P.C. Eames, H. Singh, University of Warwick
T. Jackson , A. Berry, University of Surrey

Abstract

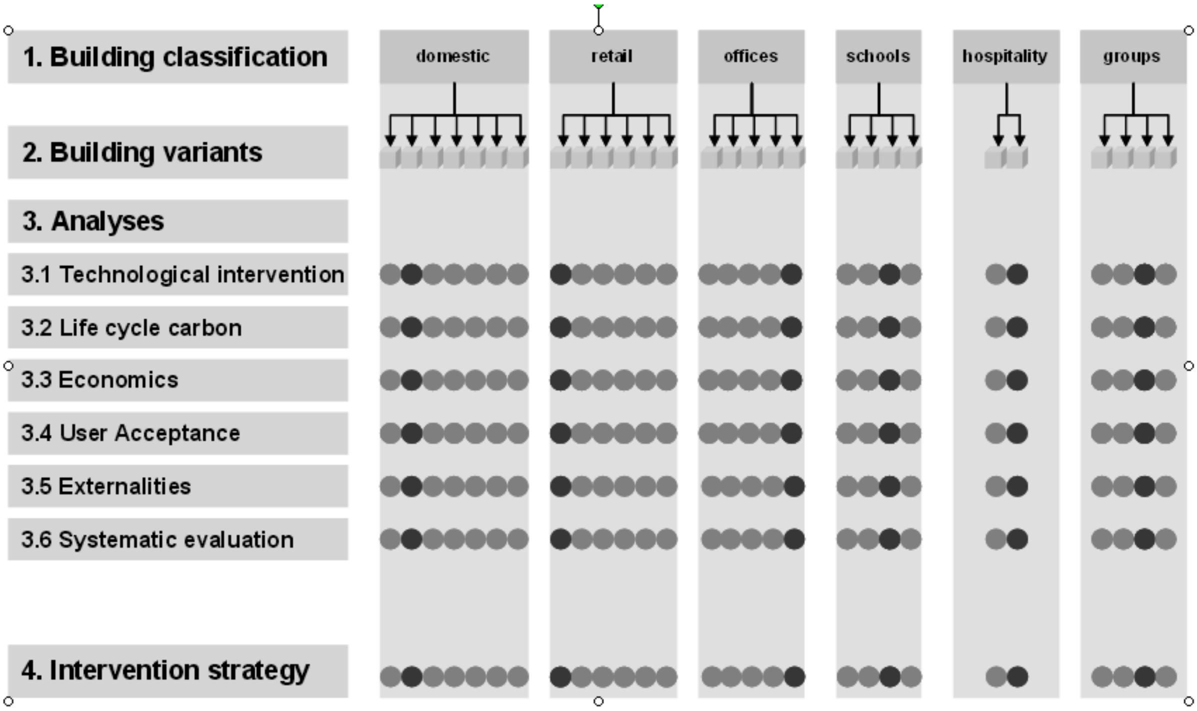
Recent research by the Tyndall Centre in the UK has suggested that a 70% reduction in CO_2 emissions will be required by 2030 to mitigate the worst impacts of global climate change. In the UK, approximately 11% of CO_2 emissions are attributable to non-domestic buildings. Of the UK non-domestic stock that will be present in 2030, approximately 75% will have been constructed before 2005. Consequently, refurbishment of existing buildings is likely to strongly influence whether these emissions reduction targets are met. This paper catalogues interim research outcomes from a research project (TARBASE) whose aim is to identify technological pathways for delivering a 50% reduction in CO_2 emissions of existing UK buildings by 2030. This investigation describes the approach as applied to the non-domestic sector. The approach taken was to describe a series of non-domestic building variants, chosen due to their prominence in the stock as a whole and also by their ability when taken together to describe the range of construction methods found in UK buildings. Technological interventions, grouped by building fabric, ventilation, appliances and on-site generation (of both heat and power) as applied to the building variants were investigated. Their applicability was determined with respect to energy and CO_2 emission savings. Emerging research findings from the application of this deployment methodology to mitigation and adaptation strategies for the existing built environment are discussed.

1. Introduction

Recent research by the Tyndall Centre in the UK has suggested that a 70% reduction in CO_2 emissions will be required by 2030 to mitigate the worst impacts of global climate change [1]. In the UK, approximately 11% of CO_2 emissions are attributable to non-domestic buildings [2]. Of the UK existing stock that will be present in 2030, approximately 70% will have been constructed before 2005. Consequently, refurbishment of existing buildings is likely to strongly influence whether these emissions reduction targets are met. The aim of the TARBASE project is to deliver technological solutions which will allow a radical, visible, step change input to policies and programmes designed to reduce the carbon footprint of the existing UK building stock. Developing technological interventions to reduce the energy consumption of existing buildings is a well researched pathway and the findings have been incorporated into the legislative process both in the UK and abroad. Given the weight of knowledge in this field, the results, in terms of take up of technologies has been disappointing and energy consumption so that energy consumption and CO_2 emissions attributable to existing buildings have continued to grow. There are numerous reasons why this has occurred but one possible cause may however lie in the character and quality of the data itself. The Sustainable Construction Task Group [3] suggested that one of the reasons for this market failure was that the costs and benefits of refurbishment options are often complex to determine. Following an assessment of the available data on refurbishment interventions for reducing carbon emissions they concluded that, while there is a wealth of guidance and literature regarding technological intervention strategies for reducing carbon emissions in existing buildings, the data is disparate, too specific or not specific enough. TARBASE aims to contribute to the bridging of these gaps by developing a methodology for assessing technological intervention strategies which attempts to (Figure 1):

- Characterise energy flows for specific buildings, the choice of which is informed by a thorough understanding of the data describing the existing stock. It is not incumbent upon Tarbase to select buildings that could be described as average. The aim is to choose buildings that are prominent in the stock from the perspective of CO_2 emissions and that the buildings when taken as a whole reflect variables that are fundamental in describing the wealth of buildings found in each classification. In the UK schools sector for instance, the Government has committed to either refurbishing or replacing the entire stock before 2020. Choice of buildings from this sector has, therefore to be heavily influenced by this policy resulting in choices that have been constructed relatively recently.

Figure 1: TARBASE Project Flowchart



- Produce an assessment vehicle or methodology to develop intervention strategies for these buildings that will provide an understanding of their suitability from the perspective of CO_2 savings, engineering veracity, externalities (near term climate change and carbon intensity of network electricity), economics and user acceptance.

2. Scope of the Paper

The aim of this paper is twofold; (a) to provide a broad overview of the methodological approach that has been taken in assessing technological interventions in existing UK non-domestic buildings and (b) to provide an overview of some of the key findings emerging from the work in the non-domestic sector.

3. Methodology

The methodological approach taken is shown in Figure 2. Following choice of the appropriate building by close analysis of the relevant stock model [4] the construction detailing, likely occupancy characteristics and HVAC plant specification was developed in conjunction with the practitioner community to ensure that 2005 baseline building design described possibilities that were recognisable. A description of the variants in each of the non-domestic sectors considered is given in Table 1. The project as described is a modelling study that builds upon research carried out by the principal authors who applied a similar approach to the assessment of the UK domestic sector [5]. A key finding of this work was the importance in defining the electrical and thermal demand of buildings at a temporal precision sufficient to capture the load diversity. In the domestic sector, this temporal precision was found to be 5 minutes or less, chiefly as a consequence of the wide and disparate nature of domestic electrical loads resulting in whole building electrical demand signatures with daily load factors as low as 7% [6]. In the non-domestic sector load diversity of this nature is less evident and electrical and thermal demand of the building can be represented at hourly intervals with much reduced risk of misrepresenting the data. For instance, Figure 3 shows monitored data from a typical UK office with a floor area of 3,350m^2 in an urban location with 400 staff where the daily load factor is approximately 48% [7]. It has also been reported that office load factors can be as high as 69% with schools found to be 33% [8]. By considering the occupancy characteristics, IT equipment and lighting requirements and behaviour the electrical load of the building was estimated using bottom up modelling techniques. From this, a series of incidental gains profiles could be developed for each building studied.

The building description and small gains profiles were then imported into a building simulation environment [9] and using CIBSE TRY climate files for specific locations, the idealised energy requirement of the buildings was estimated using assumed specific thermal comfort limits. The final energy demand of each building was then characterised using bespoke modelling software that allowed transient performance of HVAC equipment in delivering the idealised energy requirements to be characterised. At each step of this process, the energy requirement was compared to published data and benchmarks to ensure that the energy flows were commensurate with those expected.

Table 1: Tarbase Non-Domestic Variants

Variant Number	Description	Age	Floor Area	Construction
VO1	4 Storey Office	1981-85	4000m^2	Concrete panel/blockwork
VO2	5 Storey Office	1991 conversion of a Victorian warehouse	3000m^2	Solid wall with additional internal insulation
VO3	6 Storey Office (Deep)	1986-1990	5400m^2	Curtain wall
VO4	6 Storey Office (Shallow)	1986-1990	5400m^2	Curtain wall
VO5	Small Office	Pre-1900	120m^2	Solid wall
VR1	Estate Agent	Pre 1900	60m^2	Solid wall
VR2	Convenience Store	Pre 1900	150m^2	Solid wall
VR3	Clothes Shop	1986-1990	450m^2	Concrete panel/blockwork
VR4	Supermarket	1986-1990	4000m^2	Concrete/insulated brick
VS1	Primary school	2000	840m^2	Cavity wall
VS2	Primary School	Pre-1900	1196m^2	Solid wall
VS3	Secondary School	2000	7735m^2	Cavity wall
VS4	Secondary School	2004	9679m^2	Cavity wall
VH1	2 Star City Centre Hotel	Pre 1900	2902m^2	Solid wall
VH2	Budget Airport Hotel	1986-1990	3500m^2	Cavity wall

Figure 2: TARBASE Methodological Approach

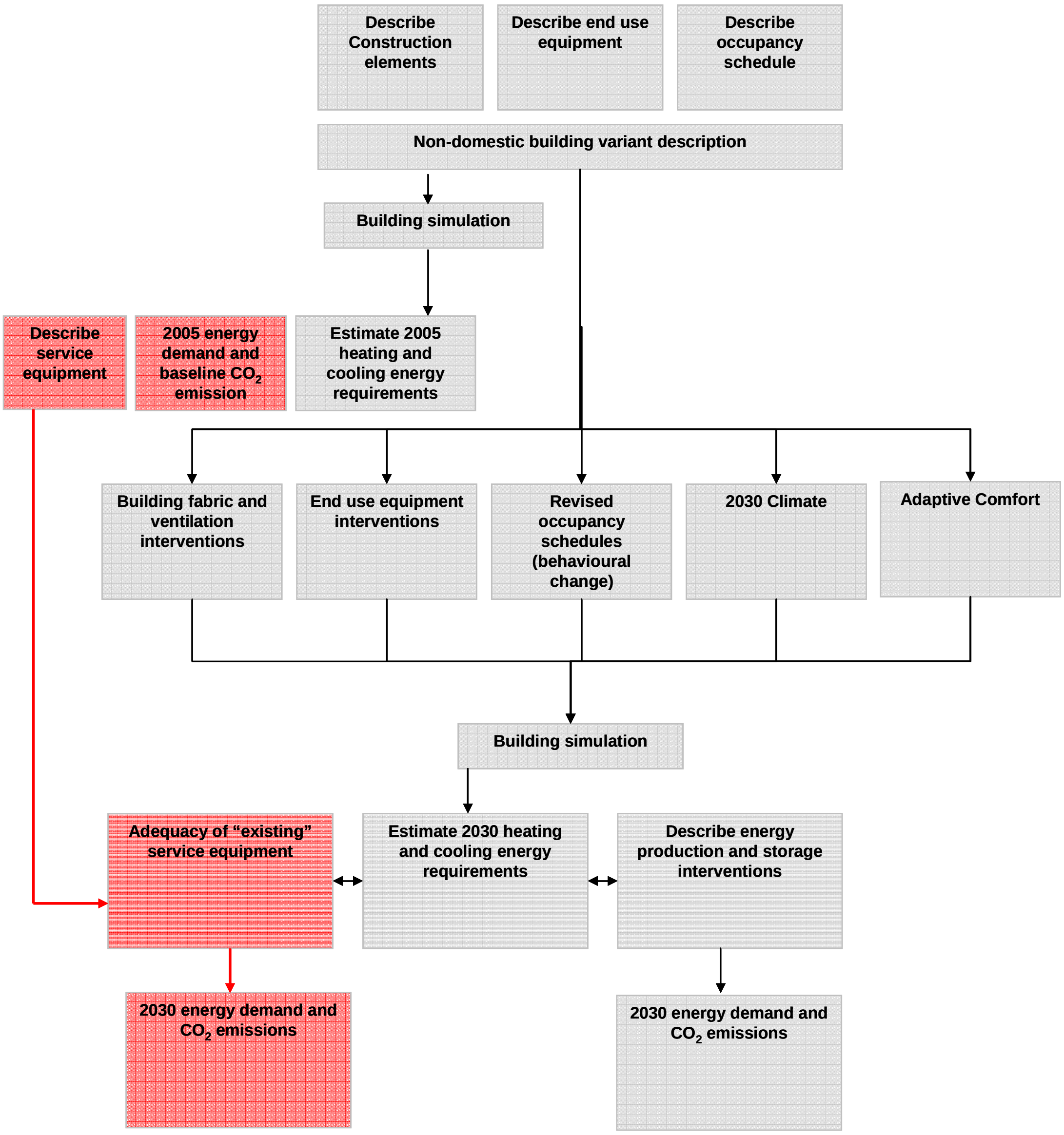
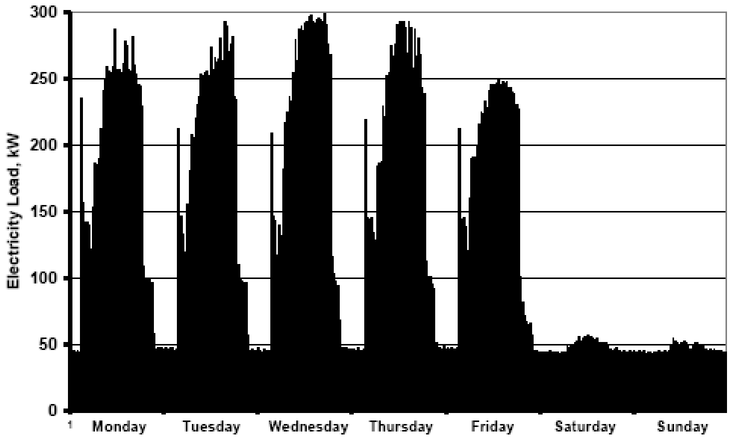


Figure 3: Monitored electrical demand of an UK office



4. Emerging Outcomes

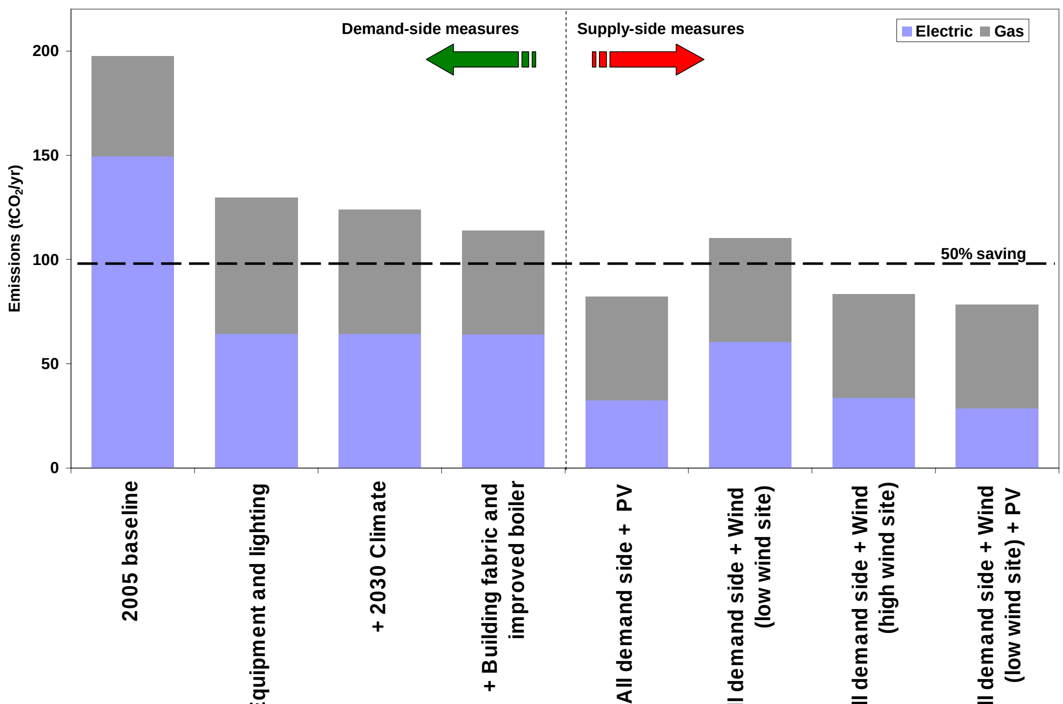
4.1 Intervention sets

Full intervention sets have been developed for each of the buildings outlined in Table 1. Technologies were grouped in end use equipment, building fabric, HVAC and on-site generation categories. An example of an intervention set developed for Building Variant SV4 (secondary school) is shown in Figure 4. The demand side measures included improved lighting (with a luminous efficacy of 150lu/W), increased penetration of IT equipment (in line with UK commitment for 1 computer per pupil) but this in conjunction with efficiency improvement such that current best practise laptop efficiency is assumed and external wall insulation to reduce heat loss of wall to a u-value of 0.15W/m^{2}K. The CIBSE TRY climate files for 2005 were modified using UKCIP02 co-efficients (for 2010-2040) and the Belcher algorithm [10] to produce a climate file indicative of 2030 and the building re-simulated to study the effect of near term warming of climate on energy demand. This further reduced the CO_2 emissions attributable to UK schools if it is assumed that no cooling requirement exists. As a consequence of these and several other less significant measures the aspirational target of 50% was approached.

Supply side alternatives would have to be developed if this target or indeed the higher target posited by the Tyndall centre were to be achieved in this school. The supply side options considered were wind and PV sized appropriately for the size of the school grounds and roof and also taking into account potential concerns regarding the vulnerability of PV systems to vandalism. Wind yield for specific turbines was estimated using wind speed data monitored at a temporal precision of 10 minutes for a full calendar year at sites typical of urban and suburban sites. The applicability of wind energy in urban areas is extremely questionable due to the effect of increased surface roughness slowing wind speeds. The wind turbines investigated would not be in operation for greater than 60% of the year on either wind speed sites and capacity factors of below 10% would be typical. Yield from the PV system was estimated using the CIBSE Test Reference Year Climate file for Birmingham where this school was assumed to be located. An appropriately sized mono-crystalline cell with a system efficiency of 14% was found to deliver approximately 25% of the revised 2030 electrical demand of the school. However, approximately 20% of the available generation is likely to fall during the summer holiday period, all of which would have to exported to the grid. Similar, though less extreme supply demand matching characteristics were found to occur during occupied periods of the summer.

It is possible then, for the school buildings to produce intervention sets that could result in the 50% savings. It is likely that they would have to come from both supply and demand side fixes with attendant issues surrounding security of deployed systems and supply demand matching characteristics of the electricity generated. The study described only took account of behavioural or occupancy change with respect to IT equipment usage.

Figure 4: Intervention sets for Building Variant VS4 - Secondary School

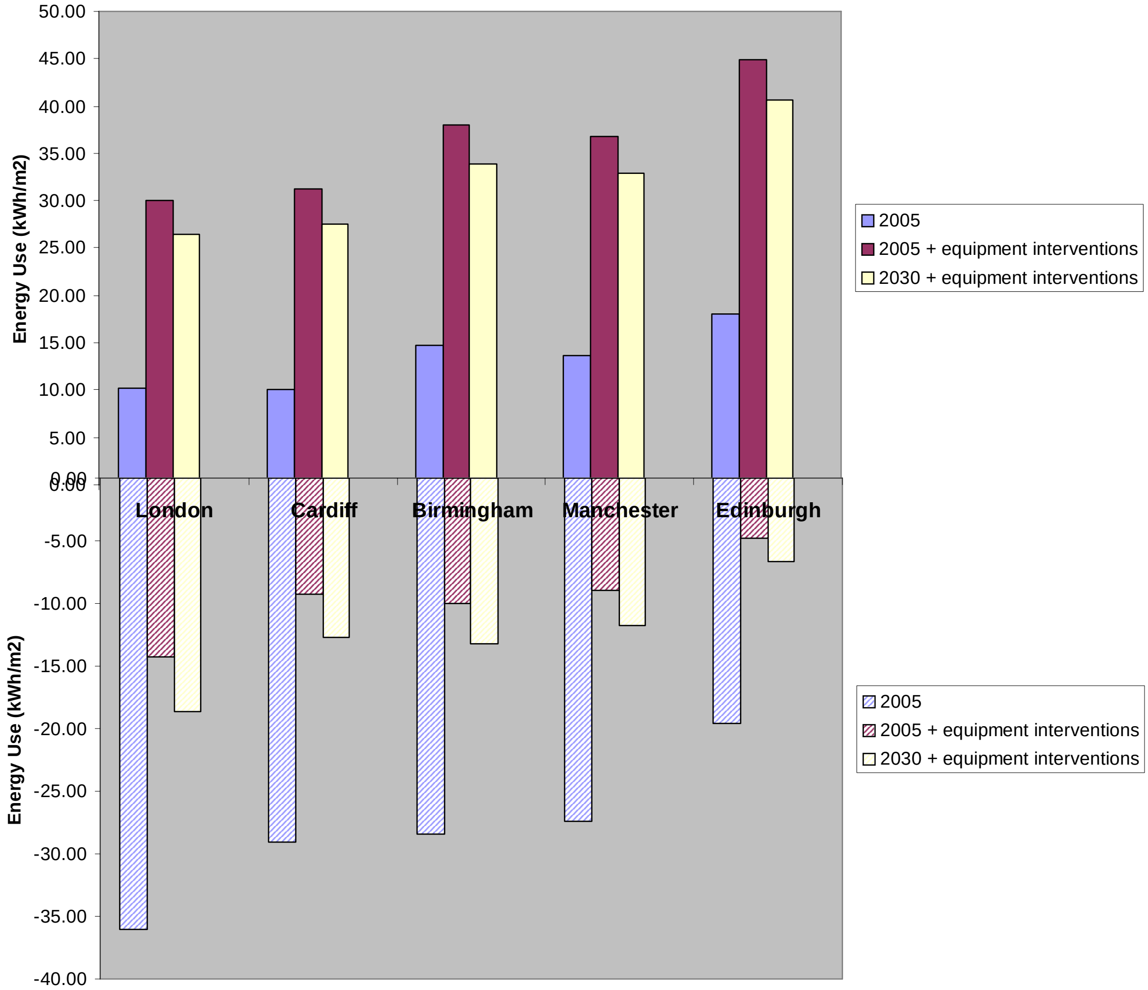


4.2 Gains and Thermal Comfort [10]

The co-incidence of solar and incidental gain in a building is a primary determinant of the ratio of heating and cooling required in an office building. The effect of dramatically reducing the incidental gain in an office building was investigated by (a) applying similar lighting interventions as those outlined above in schools and (b) IT equipment interventions that coupled highly efficient monitors and processors with energy management software that ensured that systems were not needlessly left on. The small power load of the Building Variant OV2 (4 storey office) was found to fall from approximately 60kWh/m^2 to 24kWh/m. In addition to this substantial fall in electricity consumption, it also has a dramatic effect on the heating and cooling requirement. The result of interventions to end use equipment only is to switch the office from being a heating dominated to a cooling dominated office [Figure 3]. This raises substantial issues as to how regulation might proceed with respect to refurbishment in the future. Small power loads in offices are not regulated in the UK and are seen as the sole responsibility of the building occupiers (rather than the owners or Maintenance Company). A number of studies have identified the issues and barriers associated with the tenant occupant relationship in commercial buildings and the effect of this tension on the uptake of technical interventions aimed at reducing building energy consumption and commensurate CO_2 emissions. However, the concept that the actions of the building occupier can switch completely the energy efficiency vector that needs to be chosen also has to be taken into account when devising mitigation and adaptation strategies for a specific building. This blurs the lines considerably between a regulatory approach involving building regulations and an approach that seeks for a specific building a reduction in CO_2 emission commensurate with aspirational targets.

The end use equipment interventions can also be viewed as acting as a quasi adaptation strategy to deal with predicted near term warming of the UK climate as the resultant switch to an office that is heating rather than cooling dominated is maintained when the office is simulated using a climate file modified to reflect a 2030 climate.

Figure 5: Effect of end use equipment interventions on building variant VO1 – 4 storey office with and without end use equipment interventions and 2005 and 2030 climate for 5 UK locations



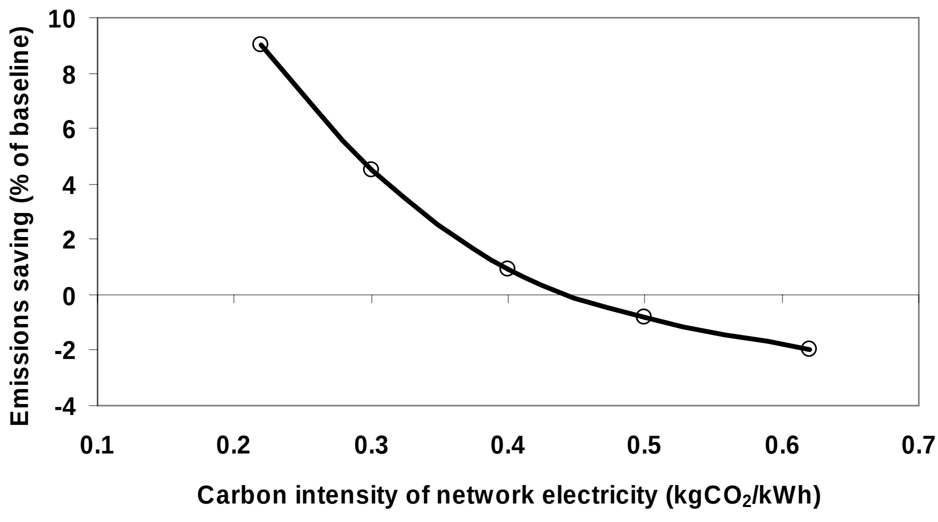
4.3 Interventions and Network Electricity Futures [11]

Policy and intervention that aims to reduce the CO_2 emissions attributable to the built environment is concurrent with efforts to decarbonise the power sector. In the UK, in common with most developed countries, the age of the electricity generation infrastructure is such that as much as 58% (50GW) of currently installed generation sets may have to be replaced in the next 3 decades [12]. At a network scale, the technologies that could be considered as replacement alternatives in this time frame are likely to be high efficiency coal plant, CCGT, thermal plant with carbon sequestration, nuclear and wind. The TARBASE research group considered the deployment of these alternatives at different levels taking account of the feasible deployment over the timescale identified to fill the looming 'generation gap'. Experimental design techniques were used to investigate different penetrations and combinations of each technology. Using emission data for each fuel type and estimated annual plant efficiency figures the range of potential annual carbon intensities possible in a future UK electricity network was estimated. These ranged from 0.22kgCO_2/kWh to 0.62kgCO_2/kWh where for instance the lower figure included a fuel mix scenario that included 28GW of wind, 5GW nuclear, and 5GW of coal with carbon sequestration with CCGT plant acting to take up the marginal plant capacity.

This range of possible electricity futures attaches significant risk to the decision making process associated with deploying supply side emission reduction measures in the built environment. Amelioration of this risk is limited as the mechanisms and decision making process by which plant will be deployed are likely to be largely at the behest of market forces with private companies seeking to minimise their capital outlay risks. It is possible for instance to see at present a favouring of new coal plant over new CCGT plant at present in the UK as a consequence of the substantial price volatility attached to wholesale gas markets over the last 5 years. It is therefore by no means certain that the a network carbon intensity at the low end of the range indicated will be achieved.

As intimated, the emissions efficacy of deploying certain supply side technologies is compromised by rising network electricity carbon intensity. To provide an example of this, the deployment of an air source heat pump was modelled taking account of system COP variation and part load performance [10] to meet the heating and cooling requirements of Building Variant OV1 (4 storey office) was considered. The results are shown in Figure 6 for the heating and cooling requirements in its 2005 baseline state. The comparative baseline condition was for heating to be supplied by a condensing boiler and cooling by existing specification cooling equipment – central chiller with distributed fan coil units [9]. The air source heat pump was found to be carbon neutral when the carbon intensity of network electricity was approximately 0.43kgCO_2/kWh i.e. at current assumed UK network condition with savings only attributable to the technology when electricity generation involving large scale deployment of low carbon systems is realised.

Figure 6: Effect of carbon intensity of network electricity on the emission reduction efficacy of air source heat pumps as applied to building variant VO4 – 4 storey office

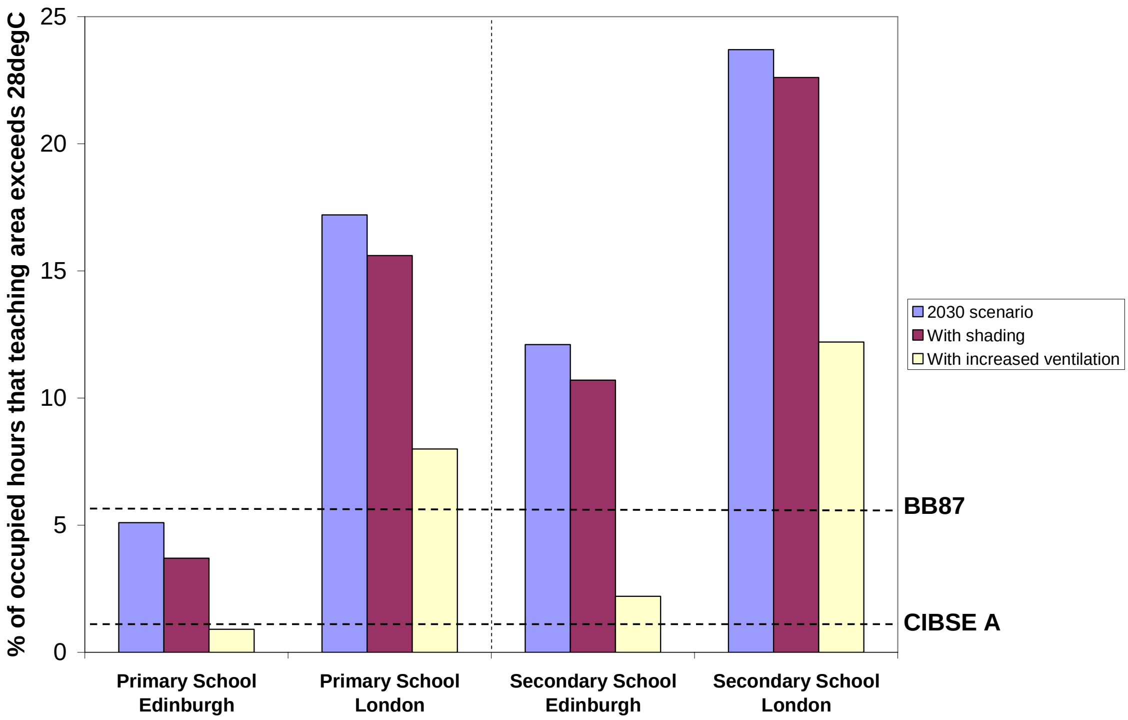


4.4 Overheating and warming climates

Although the TARBASE research project fundamentally aims to develop mitigation strategies for the existing built environment, it is becoming increasingly apparent that adaptation strategies will also be required to ensure that buildings are future proofed against extant climate change. As shown in 4.2 synergies exist between the mitigation strategy adopted and the resultant response of the building to near term climate change. However, this example considered the responsiveness of a building which already had a defined cooling requirement.

Meeting thermal comfort and internal air quality standards for schools can be difficult for buildings that, traditionally in the UK, have not used mechanical ventilation and air-conditioning. With a change in internal gains, and global warming predicted to cause a significant rise in temperatures, this issue becomes more problematic. Considering this within the context of low-carbon buildings creates an added hurdle – can low-carbon schools be produced that will provide suitable teaching environments in the future? The effect that future small power and lighting energy use as described in 4.1 could have on reducing the overheating of school teaching areas was investigated using the 2030 climate. The conclusion was reached that, to contribute towards the prevention of mechanical cooling systems in schools, the increase in school IT equipment and lighting should be monitored and regulated. An analogy can be made to the large rise in IT equipment in offices since the 1980's which subsequently drove the need for office air-conditioning as standard in modern offices. However, a cooling requirement would still persist based on regulatory guidelines. Introducing external shading and increasing ventilation in classrooms can reduce overheating significantly but, for many cases, the risk that the school building cannot cope with the overheating problem might still remain. The modelling predicted that classroom temperatures greater than 28°C would be found for more than 8% of teaching hours in both the primary and secondary schools located in London even after reduced lighting, ventilation and shading options had been deployed (Figure 7). Additional passive or mechanical means are required for existing school buildings to avoid overheating in the future. Alternatively, the results may point to the need for flexibility in teaching timing and seasons as a potentially more benign adaptation strategy.

Figure 7: Effect of shading and increased ventilation on overheating in building variant VS1 and VS4 (primary and secondary schools) with end use intervention strategies using 2030 climate scenario



4.5 Onsite generation

Consideration has been given to the proportion of electrical demand a building can meet through the deployment of on-site generation. This conceptually has interesting potential as an individual building could move towards autonomy. This concept is being discussed in the UK under the banner of net zero carbon buildings, a concept that is now reaching out to Europe through the secretariat of the European Council for an Energy Efficient Economy (eceee) [13]. To exploring this concept further, Building Variant OV1 (the 4 store office) was used as a template to estimate the proportion of electrical demand that could be met by low carbon, on-site generation.

The chosen onsite generation technologies are photovoltaic (PV), micro-wind. CCHP was also considered but the prime mover electrical efficiency required to ensure that the low (not zero) carbon electricity consequently produced CO_2 savings was found to be approximately 47% i.e. medium to long term SOFC systems. As a consequence it was discounted. PV and wind were sized based on the largest systems likely to be situated on Building Variant OV1. So, for example, while larger wind turbines might be installed in a car-park area, a rooftop turbine is unlikely to be larger than 1.5kW due to structural and building planning issues. Similarly, while large PV systems currently exist for non-domestic buildings (e.g. PV Pergola Shell Building in Rijswijk, Netherlands), it is unlikely that an installation of greater than 50% of the roof area would be carried out (due to the physical area actually available on most non-domestic roofs as well as the economic constraints).

Using bespoke PV and micro-wind models the potential yield from on site generation was estimated. For the 4 storey office, using the assumptions indicated above, the potential yield would be approximately 87MWh of electrical generation per year assuming that the building is located in London near a favourable wind site. This would drop to approximately 51MWh if (as is likely) the wind site were not applicable and only PV was deployed. However, the lighting and small power demand of the office assuming no further growth in requirement and 2030 end use equipment interventions would be approximately 143MWh pa. With PV only then, on-site generation would be able to generate enough electricity to offset approximately 1.4 floors of the small power and lighting demand of the 4 storey office. It should be noted that this demand figure does not include electrical demand associated with other aspects of the building e.g. ventilation and air cooling requirements.

Conclusions and Further Work

The TARBASE project has developed a methodology that allows the effect of intervention sets to be assessed for a range of UK non-domestic buildings. It has also assessed the impact of these interventions on the responsiveness of the buildings to two key externalities namely carbon intensity of network electricity and the certainty of a near term warming climate. For intervention sets to be developed for the sectors considered will require further assessment of the robustness such that both mitigation and adaptation can be accommodated within the same intervention strategy.

Acknowledgements

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Barriers to energy efficiency in buildings and some routes to overcoming them

Constant Van Aerschot, Lafarge & WBCSD "Energy Efficiency in Buildings" project.

Abstract

This paper presents an analysis of the market failures and behavioural barriers which stand in the way of more energy-efficient buildings, and identifies three broad approaches to overcoming those barriers.

The paper reports research and analysis carried out during the first year's work of the Energy Efficiency in Buildings (EEB) project of the World Business Council for Sustainable Development, which has a vision of zero net energy buildings. International market research commissioned by EEB sheds light on the attitudes and understanding of building sector decision-makers, identifying a lack of leadership on energy efficiency and serious gaps in knowledge among building professionals.

The analysis is based on EEB research which covered eight countries – Japan, China, India, Brazil, the US, Spain, France and Germany. It combined qualitative and quantitative research to gauge the level of support for energy efficiency among opinion leaders, policymakers and the business people who finance, design, build and occupy buildings. The paper reports encouraging findings, eg a broad awareness of the importance of energy in most of the countries covered. In many countries, however, respondents underestimated the impact of buildings on climate change, and overestimated the costs of improving energy use.

The paper analyses complexities in the structure of and relationships in the building industry which inhibit action on energy efficiency. It identifies three areas where action is needed to overcome barriers to improved energy efficiency in buildings, and briefly explores the two which are most relevant to the building industry: a holistic design approach and financial mechanisms and relationships

The analysis suggests that these components of change, underpinned by a supportive policy framework, can achieve progress towards the EEB vision of zero net energy buildings.

1. Introduction

Technology available today can achieve dramatic improvements in building energy efficiency, but market failures and behavioral barriers are blocking progress. This paper presents an analysis of the personal and market barriers which stand in the way of more energy-efficient buildings, and proposes three broad approaches to overcoming those barriers.

The paper reports the first year's work of the Energy Efficiency in Buildings (EEB) project of the World Business Council for Sustainable Development, which has a vision of zero net energy buildings[1]. The project continues into 2009, so this paper presents only preliminary conclusions. It presents the findings of the project's international market research into the attitudes and understanding of building sector decision-makers, which identifies a lack of leadership on energy efficiency and serious gaps in knowledge among building professionals that inhibit their greater involvement in reducing the energy used by buildings.

The EEB has also analyzed the barriers inherent in the structure of the industry and its common practices. The analysis suggests there are three key business levers which can break down the barriers: holistic design, new financial mechanisms and relationships, and changes in users' behavior. This paper briefly explores the first two, which are the most directly relevant to the building industry.

[1] The full report of the project's work is available at www.wbcsd.org

2. Personal Barriers to energy efficiency – attitudes and perceptions of building industry professionals

Progress on energy efficiency depends on people in the building industry being aware of the importance of the issue, and then being able and willing to act on it. The EEB project commissioned research to investigate these two aspects. It found that awareness is high in most countries covered, but there are significant barriers preventing widespread involvement – serious gaps in knowledge about energy efficiency among building professionals, as well as a lack of leadership throughout the industry.

The research

The EEB Project research included both qualitative and quantitative elements. It covered eight countries – Japan, China, India, Brazil, the US, Spain, France and Germany – and was designed to investigate perceptions of and attitudes to building sustainability.

Researchers carried out qualitative research with three groups:

- Opinion leaders – architects, journalists, NGOs, academics
- Regulators – policymakers, politicians, regulators
- The finance community – analysts, financiers, property investment companies

They conducted in-depth interviews between October 2006 and January 2007, either face-to-face or by phone, with 45 people.

The quantitative research covered three broad sub-groups of building professionals:

- Specifiers and developers – including architects, engineers, builders and contractors
- Agents and professional landlords – including corporate building owners
- Corporate tenants

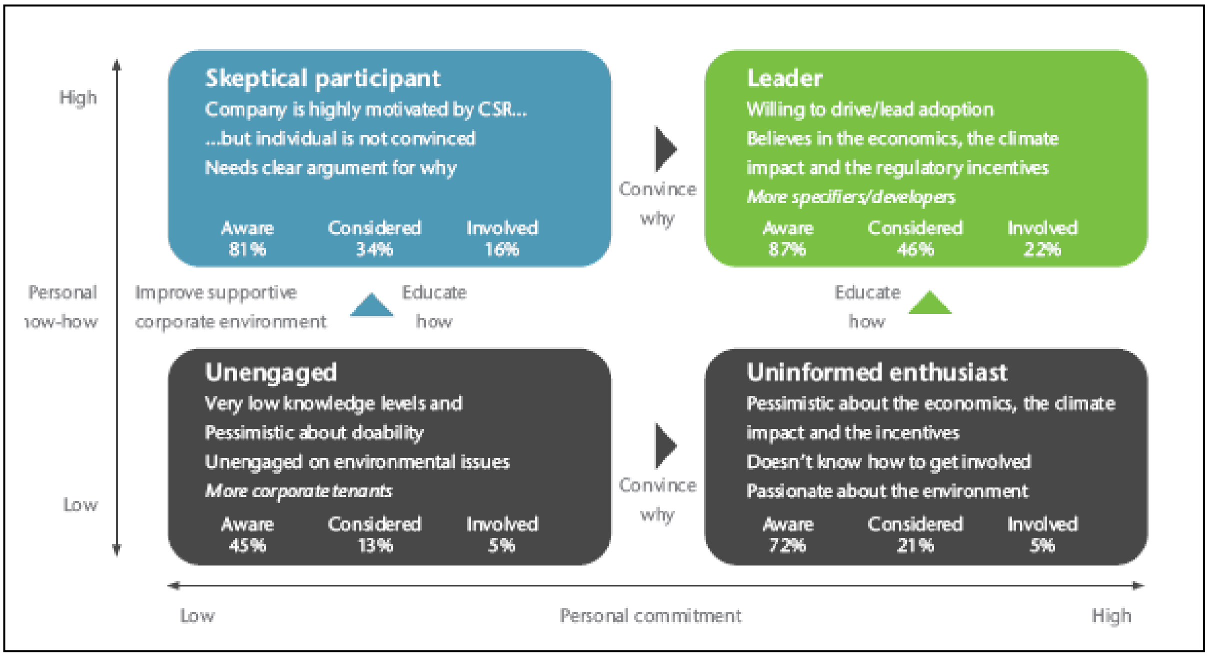
Researchers interviewed 1,423 people using a telephone questionnaire between November 2006 and February 2007.

Attitudinal segments

The research identified four broad attitudinal segments among building professionals (see Figure 1). The segmentation is based on personal knowhow and the extent of personal conviction or commitment to sustainable buildings. Each box in the Figure shows the characteristics of the segment, including the awareness of and involvement in sustainable buildings. (The figures relate to the "purchase funnel" in Figure 2) Thus the Leadership group (the top right quadrant) consists of the respondents who have high personal commitment and knowhow. They are the most aware of sustainable building, have considered it most and been involved the most in sustainable building

projects. Diametrically opposite, the Unengaged group have low levels of commitment and knowhow. They are least aware and have been least involved in sustainable building.

Figure 1: Attitudinal segments among building professionals



The Figure also indicates the key requirements to move groups towards the "Leader" quadrant. Thus it will be necessary to convince the unengaged group why sustainable building is important and how it can be achieved. The Uninformed Enthusiasts need educating about sustainable building; the skeptics need convincing why it is important.

Awareness and involvement

Awareness of environmental building issues was relatively high in all markets and across the three broad professional sub-groups. But in most markets the numbers drop fairly sharply on questions about involvement in green building activity (see figure 2). Typically only a third of those who said they were aware of green building had considered involvement, and only a third of those had actually been involved (11% of the total).

The highest awareness was among specifiers and developers and in western Europe. The lowest awareness was among corporate tenants in Japan and India.

Results in Japan appear to be anomalous: the 13% level of awareness of green/sustainable buildings contrasts to an average 84% overall awareness in the other surveyed countries. Japan's unusually low awareness response is odd given building energy use, per capita and per floor area, is the lowest of the developed countries.

Overall, only 13% of those questioned have been involved in green or sustainable building, although this figure ranges from 45% in Germany to just 5% in India, and from 20% among specifiers and developers to just 9% among owners and tenants.

The majority of respondents say they would be likely to consider involvement in a sustainable building in the future.

Figure 2: Awareness and involvement of building professionals

Professionals' sustainable building knowledge

Respondents generally recognized that sustainable buildings are important for the environment, but they underestimate buildings' contribution to greenhouse gas levels (see figures 3 and 4). They also generally overestimate the likely cost premium, which is likely to be under 10% in developed countries (although the estimates from China, Brazil and India may be more appropriate to those countries). This cost differential is discussed in more detail later.

Fig 3: Estimates of buildings' contribution to emissions

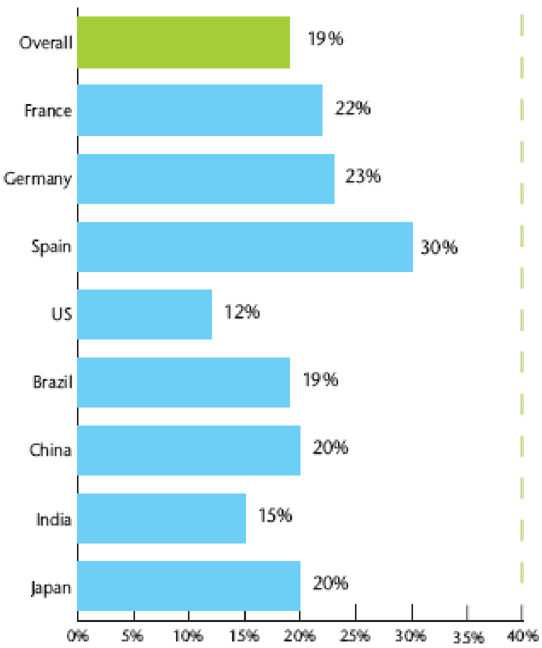
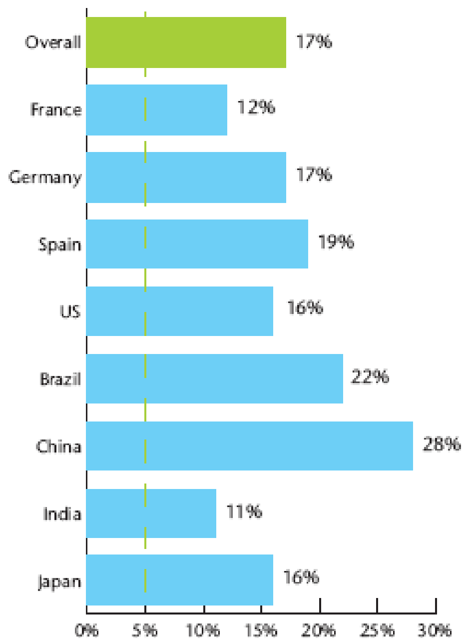


Fig 4 Estimates of cost premium



Note: the dotted lines indicate the EEB's assessment of the actual levels

Barriers to progress[2]

The quantitative research identified eight factors that influence decision-makers about sustainable buildings. Four of these emerge as the main barriers to greater consideration and adoption by building professionals and are the most significant in influencing respondents' consideration of "sustainable building":

1. Personal know-how - whether people understand how to improve a building's environmental performance and where to go for good advice.

2. Business community acceptance – whether people think the business community in their market sees sustainable buildings as a priority.

3. **A supportive corporate environment** – whether people think their company's leaders will support them in decisions to build sustainably.

4. **Personal commitment –** whether action on the environment is important personally

It is interesting to note that building attractiveness, the actual climate impact of action, and economic demand were considered much less significant influencing factors.

The ranking of these barriers is broadly consistent across the groups of professionals, with two exceptions. The specifier/developer group scored much higher than the other two groups on know-how and business community acceptance, while corporate tenants scored much higher on the supportive corporate environment. This suggests there is potential for demand and competent supply, but a fragmented discontinuity between the two.

Leadership

Qualitative research found that people believe financiers and developers are the main barriers to more sustainable approaches in the building value chain. It is interesting that landlords and tenants come low down in this ranking, while builders and contractors are seen as more significant than owners.

When asked about their responsibility in driving change, very few of the decision-makers saw their task as leading the move to sustainable building. The answers suggest some willingness to adopt new practices, but also hint at the conservatism for which the industry is renowned.

3. Market barriers – the structure of the building industry

While the personal attitudes and knowledge of individuals are important in inhibiting the move towards more energy efficient buildings, the way the industry is organized and projects are carried out also creates significant barriers. The EEB project has developed the following analysis of the complexities in the structure of the building industry and relationships within it, concluding that they are likely to reinforce a tendency for short-term financial criteria to dominate decision-making.

Fragmentation

The sector is characterized by fragmentation within sections of the value chain and non-integration between them. Fragmentation is a significant issue in the building sector. Even the largest players in the supply of buildings are small by international business standards, for example the largest construction group in the FT Global 500 in spring 2006 (the French company VINCI) appears in the bottom 20%. The largest construction companies are international, but barely multinational (they do not tend to operate in all continents). Property developers and investment companies, architects and engineers tend to be even less international. One consequence is that research and development spending within the industry is significantly low (less than 1% in the US[3]) as a proportion of the revenues generated.

The value chain

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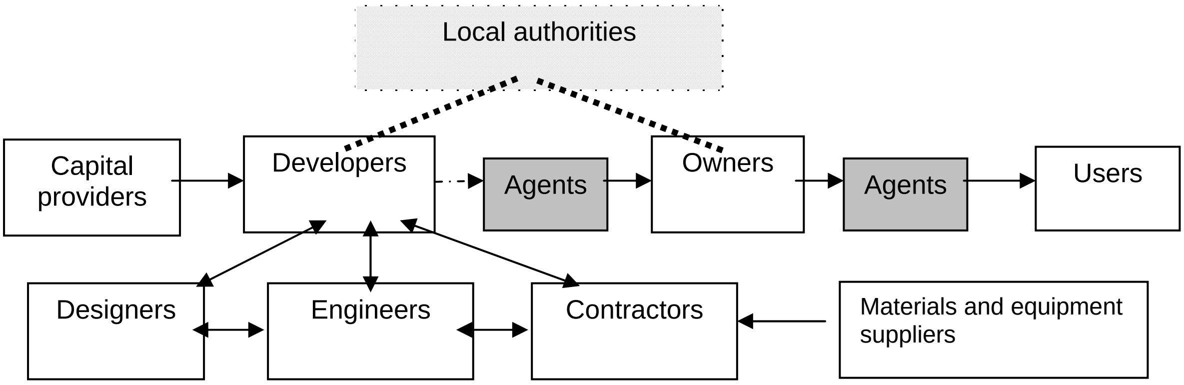
[2] **Technical note:** The statements connected with each barrier are grouped together based on statistical analysis of responses. These four deficiencies were identified as the most significant contributors to barriers out of the eight dimensions because of their importance in influencing respondents' consideration of "sustainable building."

[3] US Department of Energy, Office of Energy Efficiency and Renewable Energy

There are many stakeholders in the building supply chain. The main commercial relationships are illustrated in Figure 5. The complexity of interaction between these stakeholders is one of the greatest barriers to energy efficient buildings.

Local authorities influence the value chain through building policies for their area, which are typically layered over national regulations. While the local authorities set codes and standards for buildings, they typically are a compromise between high levels of energy performance and cost considerations. [4]

Fig 5 Relationships in the building value chain



Capital providers – as lenders or investors they are overwhelmingly concerned with the risk and return equation. This is often over a short time period, although mortgage lending clearly involves longer timescales. Their decision-making is dominated by financial criteria, and as chapter 5.3 describes, energy is not normally sufficiently significant to influence decisions.

Developers are the primary actors in commercial construction and are frequently speculative, making capital gains rather than holding the property to reap returns from rental income. This inevitably results in a short-term focus on buildings' value, and value being dominated by estimates of potential rental income. Once a project has the necessary commercial and regulatory backing, there is usually intense pressure to complete construction as quickly as possible, which can squeeze out consideration of any aspects considered non-essential.

Speculative developers have only a short-term interest in a property, which is quickly sold on to an owner or investor. Their concern is with the attractiveness of the property to potential buyers. Only if energy efficiency was a significant factor in the buying decision would it concern the developer.

Developers who hold property to receive income from tenants have a longer-term view. They are likely to be concerned with long-term operating costs, possibly for as long as 50 years. This perspective makes energy-saving investments potentially attractive, even if the payback period is relatively lengthy. But in many countries it may not be possible for developers to reap the benefits of such investments – the energy saving goes to the occupier, even though the developer incurs the investment cost.

Developers are typically conservative. They are naturally reluctant to take technical risks given the scale of commercial risk involved in major projects and the perceived conservatism of potential occupiers. This makes it difficult for architects to incorporate new ideas in many developments.

Developers commission *designers (or architects), engineers and construction companies* – who have the most expertise in technical aspects of construction, including energy efficiency, but who usually have only limited influence on key decisions. Architects, engineers and contractors often work in relative isolation, even if they all work for the same firm. Financial pressures can mean that proposed

[4] "Who Plays and Who Decides," Innovologie LLC, US DOE, page xiii

enhancements such as energy-efficient features are eliminated in a value-engineering exercise in later design stages.

The role of *agents* can be important. They often stand between developers and tenants, and between owners and occupiers. Their interests are typically short-term and financial, eg the agents who act for developers and tenants in a commercial transaction are interested primarily in the lease agreement, focusing mainly on price. Developers complain that this intermediation makes it more difficult to talk to potential tenants about the longer-term, non-financial aspects of buildings, including energy efficiency.

Owners are frequently not the same as *end users* in residential or commercial buildings. The owner may lease the property to occupiers, sometimes with timescales of only a few months. Agents or property managers may stand between owners and end users, without knowing or communicating the benefits of energy efficiency to either side.

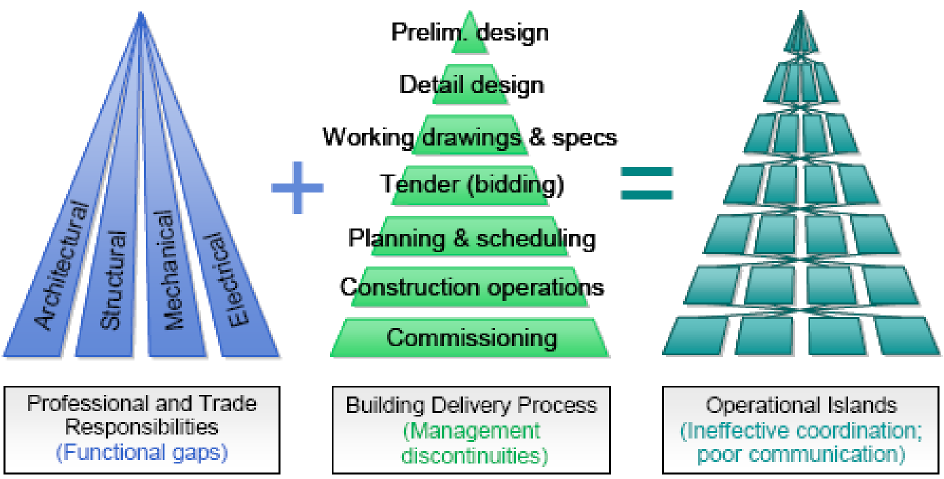
Owners may have a short-term or long-term perspective, depending on their objectives. Some owners buy to sell on (and make a capital return), others buy to lease (as an investment), or buy to occupy. The latter group is in the best position to consider investments which may have lengthy pay-backs. Owners of investment properties are in a similar position to long-term developers. They may be able to consider investments with lengthy payback periods, but may be inhibited by split incentives, which mean that they cannot reap the benefit of the investments.

Users – are likely to be in the best position to benefit from energy savings, but may not be able to make the necessary investments (the reverse of the owner/developer position). More significantly, as described later in this paper, energy costs are likely to be a small proportion of their total occupancy costs, and may therefore not receive enough attention to drive energy-saving activity.

The design process
The design process is another significant aspect of complexity which stands in the way of greater energy efficiency.

One way to visualize the complexity of interaction between project participants is shown in Figure 6. The first pyramid describes the various technical disciplines involved in the building sector. The second pyramid describes the building delivery process. Combined, the third pyramid highlights the ineffective coordination that exists between the functional gaps and management discontinuities. For example, there are often lengthy delays between the design stages, due to differences with planning permission, project financing or signing up anchor tenants for commercial property.

Fig 6 players and practices in the building market [5]



[5] Mattar, S.G. "Buildability and Building Envelope Design". Proceedings, Second Canadian Conference on Building Science and Technology, Waterloo, Nov. 1983.

More prevalent vertical integration in the supply chain could improve energy efficiency in buildings. Property developers may prefer not to integrate because they believe competition within each specialty generates value (ie results in lower bids in a tendering process).

A more directly integrated relationship exists in the public sector, where the state may finance, develop and own property such as schools, hospitals and other public buildings, including public housing. The residential sector is in any case more integrated. Housing developers typically design and build properties and sell them directly to owners, who are also often the end customers.

The individual roles and ineffective coordination between participants in the value chain have two important consequences:

- incentives to reduce energy use are usually split between different players and not matched to those who can invest in energy-saving measures
- there is normally very little opportunity for users to provide feedback through the market to developers or designers.

This aspect is exacerbated by the one-off nature of property transactions. The market consists of a relatively small number of large transactions. In most business sub-sectors, buyers seldom have the opportunity to return to the same seller.

4. Overcoming the barriers – three approaches

This paper has presented research which identifies personal barriers to greater involvement of building professionals in energy efficiency, and an analysis of the market structure which also presents a substantial barrier.

The EEB's preliminary analysis suggests that there are three key components of change, underpinned by a supportive policy framework, which can achieve progress towards the EEB vision of zero net energy buildings. They are:

- a holistic design approach
- financial mechanisms and relationships
- behavioral changes by property users

The third of these - behavior – is beyond the scope of this paper, which now sets out some preliminary conclusion on the other two aspects which can help to overcome the barriers to improved energy efficiency in buildings which we have identified.

Holistic design

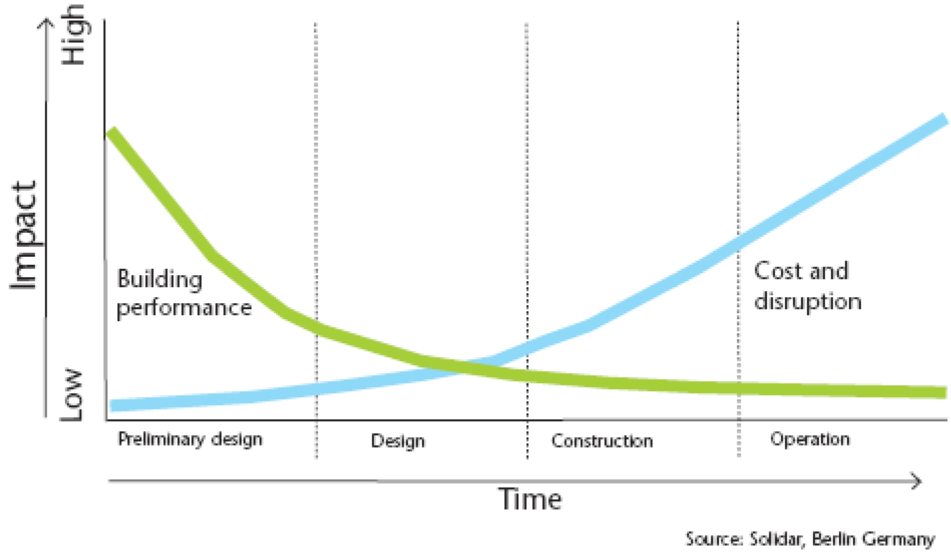
Each individual player in the building sector needs to make a contribution towards zero net energy buildings using an approach which integrates all the individual aspects – a holistic approach. The holistic concept should begin with master planning, which is crucial to optimize urban centers and reduce their total ecological footprint, but in this paper we restrict ourselves to integrated building design. It is important to note, however, that Master Planning extends beyond buildings to include energy supply (production, transmission, distribution and in some cases storage), transport systems, working and living conditions.

The performance of a building depends not only on the performance of individual elements, but on how they work together. Many factors need to be taken into account to design a high-performance building, such as climate, comfort levels, materials, building shape, health and security, structural security, architecture. Designers need to carry out extra design iterations to optimize all those factors, but firms traditionally wish to avoid the extra work because the fee structure is not adapted to this approach. Most buildings therefore follow a conventional design approach, operating on a sequential basis. But there is great potential in multi-disciplinary working, bringing together architects, engineers and others responsible for creating the building.

Unless barriers are removed, professionals will tend to continue working in isolation and buildings will continue to miss the benefits of using a multi-disciplinary approach.

An Integrated Design Process (IDP) involves participants from the various value stream stakeholders in the design phases of the project. It is often suggested that the benefits of an IDP are increased building performance and lower downstream cost and disruptions. As shown in Figure 7, the earlier in the process that IDP occurs, the bigger the impacts.

Fig 7: the benefits of early integration



Integrated components of energy efficiency
Several components work together to create an energy-efficient building. The building "envelope" is particularly important. It is the starting point of energy efficient buildings and the main determinant of the amount of energy required to heat, cool, and ventilate. Specifically, it determines how airtight a building is and how much heat is transmitted through "thermal bridges" which breach insulation and allow heat to flow in or out.

There are five broad categories of product or service that can influence a building's energy efficiency.
Design*: shade, orientation, ventilation, 'envelope'* – these factors affect the extent of heating from sunlight, the airtightness of the building, and therefore the internal cooling or heating requirements, and the need for artificial ventilation.
***Materials* –** Structural materials affect the building's thermal mass and therefore its ability to store heat and moderate temperature swings. Other construction materials affect the airtightness and insulation of the building and the extent to which it absorbs heat from sunlight.
***Equipment* –** Improved equipment such as heat pump dryers, and improved use of equipment, such as power management on office equipment, can save substantial energy during a building's use.
***Energy generation* –** Heat pumps, combined heat and power systems, solar panels and wind turbines can generate energy on-site, possibly with the potential to feed unused energy into an intelligent grid.
***Services* –** New approaches such as retro-commissioning can ensure that a building's potential energy efficiency is achieved through fine-tuning building systems so they perform effectively.

These different aspects need to be considered together rather than in a fragmented way. Most categories of energy use are affected by more than one influence. For example, all five elements affect the energy needs for heating, ventilation and air conditioning (HVAC).

Financial mechanisms
Financial considerations are critical to property development and investment in general, but they appear to be limiting progress on energy efficiency. Financial pressures have become more powerful, especially in the US, because of the rise of real estate as an investment class alongside equities and bonds and a decline in the number of owner-occupied buildings. Owner-occupiers are in the best position to make long-term investment decisions about their buildings. They will tend to have a longer term perspective and stand to benefit directly from energy savings. This applies both to owners specifying a new building that they will occupy as well as to existing owner-occupiers considering retrofitting. Investors' time horizons are likely to be shorter. This increases the importance for their

investment calculations of the property's residual value when they sell compared with operational returns during their ownership. In any case, energy costs are often hidden in operational costs and not considered by most investors.

Attention to energy efficiency is also hampered by the fact that energy costs are a small proportion of total occupancy costs, especially in commercial properties. For example, real estate managers at the EEB's financial hearing in Zurich in March 2007said that energy costs were too low to be a driver for energy efficiency. For example, in a high-quality office building in Germany, heating and electricity made up less than 5% of the total running cost of the building - about 1.1 of out of every 23.3 Euro spent. The budget for energy in a medium-sized office building in the US typically equals approximately 1% of total business costs, while salaries represent about 80%. Energy therefore tends to receive too little attention from developers, investors, owners and occupiers. This is made worse by uncertainty and lack of information about the energy efficiency value equation – decision makers may find it difficult to get adequate information about potential returns from energy-saving investments.

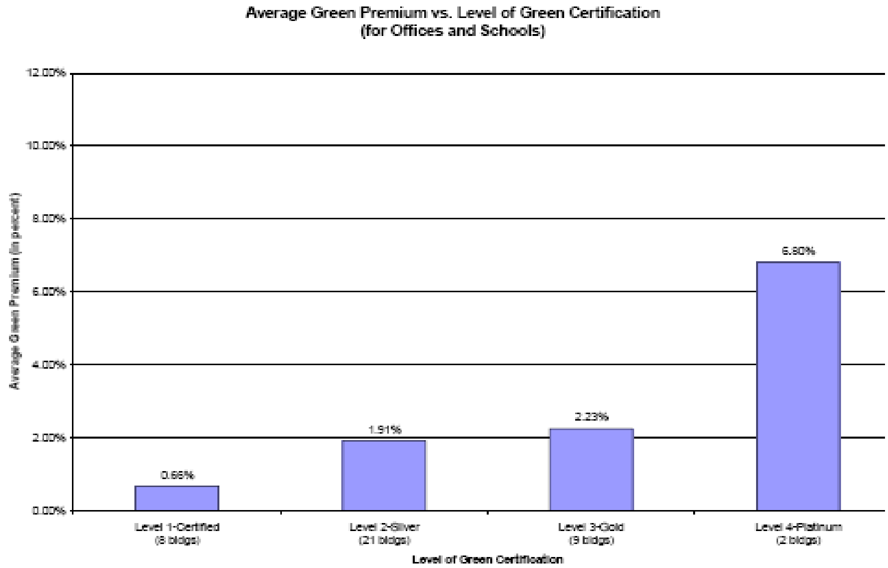
Value of energy-efficient buildings
There is emerging evidence that an energy-efficient building can command a premium, and this may grow as awareness of the link to climate change and expectations of rising energy costs leads more people and organizations to attach more value to energy efficiency. One US study[6] found that professionals expect greener buildings to achieve an average increase in value of 7.5% over comparable standard buildings, together with a 6.6% improved return on investment. Average rents were expected to be 3% higher. The financial research firm Innovest has found that Real Estate Investment Trusts (REITs) in the US considered to have the highest green credentials outperformed the index over several years.

The cost of achieving energy efficiency
The market research commissioned by the EEB Project has found that perceptions of the cost necessary to achieve greener buildings are likely to be significantly higher than the actual cost. The average perception was that a 17% premium would be necessary to reach a "certified" level of sustainability but cost studies on actual properties have come up with much lower figures. The Fraunhofer Institute has shown that the energy demand of new office buildings can be reduced by 50% compared to the building stock (limiting primary energy use to 100 kWh/m²a for most buildings) without enhancing building construction costs compared to the average[7].

The US Green Building Council (USGBC) has performed numerous studies and concluded that the cost of reaching certification under its LEED standards system is between zero and 3%, while the cost of reaching the highest level of LEED (platinum) comes at a cost premium of less then 10%. These figures are supported by a study of 40 offices and schools which found cost premiums substantially lower than the estimates reported in the EEB research (16% for the USA). (See Figure 10)

Fig 10: the green cost premium

[6] McGraw-Hill Construction:Green Building SmartMarket Report 2006
[7] Herkel et al. Energy efficient office buildings – results and experiences from a research and demonstration program in Germany. Building Performance Congress 2006 www.enbaumonitor.de



Source: Greg Katz, CapitalE, Economic Costs and Benefits of Green Buildings

A more comprehensive study of a broad selection of buildings, by Davis Langdon Adamson (a construction management firm) confirmed these broad conclusions but with an important caveat: location and climate are more important than the level of energy efficiency as an influence on ultimate cost. The study looked at over 600 cases in 19 US States. It found that the variations between LEED and non-LEED buildings are not significantly different when considering the impact of location and climate, especially for heating and cooling costs. The implication is that building developers and owners considering a green building should be aware that the costs can be influenced more by local factors and conditions than by sustainable design requirements.

Energy cost information and analysis

While energy costs are a relatively small part of total occupancy costs, they can still be a significant factor in motivating energy efficiency action. But profitable opportunities for energy savings are often overlooked because of inadequate cost information. Despite real estate managers' stated interest in energy efficiency, a study in 2007 found that only two thirds of companies tracked energy data and only 60% tracked energy costs[8].

Where data was collected, it was used mostly by facilities managers, rarely by real estate managers and seldom passed on to property evaluators. In the US, only 30% of real estate managers or facilities managers claimed to have included energy efficiency requirements into requests for proposals. Despite these findings, the study surprisingly suggested that energy costs are the most important driver for energy efficiency, both currently and in the future.

The EEB market research confirms these findings in all six regions. Three of the four attitudinal segments defined in the research (Skeptical participant, Unengaged, Uninformed Enthusiast) may be characterized by inaction in pursuing energy savings.

New business models

Appropriate commercial relationships can increase the focus on energy costs by altering commercial relationships, removing the split incentives problem and introducing more effective incentives for reducing energy use and costs. Energy performance contracting (EPC) is one example .

EPC is an arrangement between a property owner and an Energy Service Company (ESCO) which covers both the financing and management of energy-related costs. It involves a variety of mechanisms to help property owners use the knowledge of energy professionals to reduce their energy costs. Specifically, first-cost and performance risk considerations are taken on by the ESCO.

[8] CoreNet Global 2007

ESCOs generally act as project developers, installers and operators over a 7 – 10 year time period. They assume the technical and performance risk associated with the project. The services offered are bundled into the project's cost and are repaid through the operational savings generated, with the ESCO's profit coming from a proportion of cost savings or a fixed fee based on projected energy savings. As an additional service in most contracts, the ESCO provides any specialized training needed so that the customer's maintenance staff can take over at the end of the contract period.[9] ESCOs have placed great emphasis on measurement and verification and have led the way to verify, rather than estimate energy savings.[10] One of the most accurate means of measurement is the relatively new practice of metering, which is direct tracking of energy savings according to sanctioned engineering protocols.[11]

A Lawrence Berkeley National Labs 2003 research study[12] on International ESCO's found that the bulk of activity today is in the US, but ESCO's exist in varying degrees in other countries - ranging from just a few in Belgium, Thailand, and South Africa to over 50 in Brazil, Germany, Korea and Switzerland. Hong Kong has seen an emergence of ESCO's to serve the growing Chinese marketplace. In Japan, ESCO's have grown significantly during this decade, with the recent emphasis on performance contracting, as the charts show below. The retrofit markets for environmental load decrease and energy savings are forecast to grow by 90% and 60% respectively during 2000-2015.The total amount of ESCO activity is estimated to be $3bn, with two-thirds of that in the US (adjusting for estimated growth projections from 2001 information).

Financial instruments[13]
Financial incentives are beginning to play a key role in helping energy-efficient buildings make business sense. New tax breaks and emerging markets for renewable power and energy efficiency can help firms overcome internal financial hurdle rates and are expected to promote further investment in energy-efficient buildings.

Reducing Initial Costs
Tax incentives at the federal, state, and local levels can help overcome initial cost barriers to energy efficiency upgrades or development. The Energy Policy Act of 2005 (EPAct 2005) provides a federal tax deduction of US$0.30 to US$1.80 per square foot for energy-efficient commercial buildings, depending on the technology and energy savings. A growing number of cities and states are offering tax credits for commercial buildings that meet certain energy efficiency or sustainability standards. EPAct 2005 also established a 10 to 30 percent tax credit for commercial and industrial clean energy projects and states and municipalities have established similar incentives to promote renewable (e.g., solar and geothermal) or efficient (e.g., combined heat and power) energy sources.

Renewables Can Deliver Revenues
Expanding market-based energy regulations are also creating financial opportunities for high-performance buildings. More than 20 states have adopted renewable portfolio standards requiring electric utilities to meet a percentage of demand with renewable energy sources. In many cases, states allow third parties (e.g. commercial and industrial facilities) that generate renewable energy to register and sell renewable energy credits (RECs) to utilities seeking to meet their mandated targets. The value of RECs in these compliance markets can range from US$10 to US$200 per megawatt hour (MWh) or more, depending on the state and energy source, and can be an important revenue stream that, when combined with energy cost savings, can offset installation and operational costs for renewable energy systems.

A Market for Efficiency Credits?
More than 10 US states have also developed energy efficiency resources standards, which set utility requirements for energy efficiency and are expected to create a market for energy efficiency credits (EECs). In 2007, Connecticut became the first state to launch a market for trading in energy

[9] *Ibid.*
[10] IEA DSM Task X Performance Contracting – Summary Report, Final, May 2003
[11] *Ibid.*
[12] *Review of US ESCO Industry Market Trends: An Empirical Analysis of Project Data*, Enerst Orlando Lawrence Berkely National Laboratory, Charles Goldman et al, January 2005.
[13] Based on information provided by *Eliot Metzger, World Resources Institute*

efficiency, where EECs will be valued between US$10 and US$31 per MWh. As the market develops and utility efficiency requirements become more stringent in 2008 and 2009, commercial and industrial facilities are expected to benefit from demand for EECs and generate revenue through qualifying efficiency projects (e.g., combined heat and power generation and lighting and HVAC upgrades).

Conclusion

Building professionals and decision-makers must be deeply involved if we are to substantially improve buildings' energy efficiency and move towards the EEB vision of zero net energy buildings. Yet the EEB research has found only limited involvement and understanding, and a lack of leadership. Our analysis has also identified impediments in the structure of the industry and the relationships between building professionals.

This paper has suggested that holistic design approaches and new financial mechanisms, relationships and instruments may help to overcome these barriers, along with changes in users' behavior and a supportive policy environment.

Sustainability in Commercial Buildings – Bridging the Gap from Design to Operations

Adam Hinge, Sustainable Energy Partnerships, USA
Om Taneja, U. S. General Services Administration, New York, New York, USA
Michael Bobker, Building Performance Laboratory, City University of New York, USA

Abstract

Green building development has rapidly evolved in the United States with notable efforts by property developers, designers, constructors and buildings operations and maintenance managers. Green, or high performance, buildings provide many benefits to building owners, occupants, and all other members of the building design and construction marketplace. A variety of reports have stated the energy cost savings benefits of green buildings, and often energy cost savings are cited as offsetting any additional first costs of green buildings. Most of the cited energy benefits, though, are based on predicted, not measured, savings. Because interest in green buildings is growing, at least in part based on expectations of improved performance and reduced operating costs, it is important to understand the actual performance after the buildings have been in operation for some time. In some cases, actual energy performance is often quite different from predicted performance, particularly for the first years of operation.

An important link toward delivering sustainability and energy savings targets that has been too often missing is the role of building operations staff. In order to get newer green buildings operating at the efficiency level near where predicted in the design process, the role and active involvement of Building Operators and Facility Management staff are critical. Bridging the gap between great intentions in design and construction, toward building performance at the desired levels, is a major challenge. This paper outlines some approaches for promoting an improved team approach for design, commissioning, systems turnover and periodic tune-ups to ensure that performance is restored to original design parameters. Field measurements of performance and understanding operational problems can lead to adaptive changes and can increase accountability amongst the design, build and buildings management groups. Benchmarking can be further used to assess which technologies and methods work and which do not. Feedback from Tenant Satisfaction Surveys can facilitate further in making changes for improved benchmarking outcome. From concept through operation, the buildings' design and operating performance can be improved through such iterative processes. This can particularly help public and private organizations with a large portfolio of buildings whose integrated approach and benchmarking processes can improve overall assets' performance and reduce building related environmental impacts.

Introduction

The green, high performance buildings industry has seen exponential growth in recent years. A plethora of new technologies and practices have rapidly evolved with the intent of reducing buildings' impacts on the environment and improve the indoor air quality and worker productivity. An overwhelming amount of information is flooding the buildings trade literature with claims about improved performance.

Unfortunately, most of this information is based on expected performance, instead of actual measured or demonstrated performance. While initial concepts and design documents express a modeled performance, too often that is not effectively translated into commensurate operations, maintenance, refurbishment or user awareness and acceptance.

How much variance there is between expected performance and actual, measured performance during occupancy/operation is not completely clear. One of the more comprehensive studies looking at 121 buildings certified through the US Green Building Council's "Leadership in Energy & Environmental Design (USGBC's LEED) program found that, on average, LEED buildings are 25-30% more energy efficient than non-LEED buildings (NBI 2008). It also found that in these 121 buildings, 30% perform better than expected, about 25% perform worse than expected, and a handful of buildings have serious energy consumption problems.

These findings are encouraging, though a major caveat to the report and data is that it only reports on a self-selected 121 buildings out of 552 LEED certified buildings; it is unclear whether this portion of the buildings are representative of the broader set of certified buildings, or not. Anecdotal information suggests that a much higher percentage of buildings are operating at significantly higher energy use than predicted – much more study is needed to understand the true performance gap.

A recent study reported by World Resources Institute indicated that for buildings in New Zealand, during the life-cycle, only 10% of energy is used during initial construction, and remaining one third each is used during Operations, Maintenance/Refurbishment and Transportation (Camilleri & Jaques 2001). Therefore, how well we transition from design/construction to occupancy, and then operations and maintenance, makes the most significant impact on environmental performance. There is a tremendous need for more information on "lessons learned," where practitioners can explain what worked: what went right, what didn't work so well, and what they might do differently if given the chance (Learning from Our Buildings 2001) Having the Operating and Maintenance ("O&M") Managers participate in design, and timely and ongoing training of O&M Staff, can obviate some of the hurdles that adversely impact the performance. Increasing the feedback from building operators to the design and construction community is critical.

Managing Expectations and Getting to Better Predictions

The road to high-performing buildings is paved with high expectations—but, ultimately, it is measured performance that shows how energy efficient a building really is. All too often a building's energy performance does not meet design expectations, particularly expectations set by a new building's energy savings projection that may overstate achievable performance. Across the high-performing building industry, unrealistic energy performance goals have come from such things as:

- inadequate modeling practices
- unreliable controls and control systems and inadequate monitoring
- significant changes in space usage and processes during occupancy and tenant improvements,
- failure to include operations staff in goal setting or accurately communicate the design intent to the staff, and
- lack of adequate budgets for commissioning, evaluation and ongoing benchmarking.

In any rapidly growing industry, performance expectations are reported at a rate that outpaces publication of actual results. Therefore designers' base of knowledge is limited. Poor feedback of results further hinders the accuracy of design projections. In the case of green buildings and their actual operating performance, potential savings seem to be often over-stated. Some of this may be due to a lack of precision about what is being measured and expressed.

In one recent example, the new Seattle City Hall, which received a U.S. Green Building Council (USGBC) LEED® Gold rating in 2003, became front-page news in the *Seattle Post-Intelligencer*: "Seattle's New City Hall is an Energy Hog: Higher Utility Bills Take the Glow Off Its 'Green' Designation" (*Seattle Post-Intelligencer*, July 5, 2005). The new City Hall *does* use more energy than the old City Hall, for a variety of valid reasons including much greater ventilation levels, different uses between the two buildings, and vacancy levels in the old City Hall. But this press coverage clearly indicates the need to better manage expectations to avoid damaging news stories. This type of out-of-context information can erode confidence in the industry and discourage other owners and managers of high-profile high-performing buildings from releasing actual energy performance data.

As more actual energy performance data on high-performing buildings becomes available, clearer and more realistic expectations will help to establish confidence within the building design and construction industry about costs and savings. Especially because energy cost savings are often cited as offsetting additional first costs of green buildings, it is important to narrow the gap between the predicted energy benefits and actual measured, savings. Accurate reporting of the actual performance of green buildings is important will help the industry to calibrate its expectations and move towards more consistent results and confidence in projections. Sharing operating results and lessons learned earlier rather than later can avoid repeating potential mistakes as the green buildings movement proceeds.

What do we know About Sources of Under-Performance?

Operations – Tenant Use

Tenants are not always made aware of how their use of spaces and equipment affect the energy use and environment. Tenants use ancillary equipment, such as heaters, fans and task lights, if proper air flow and services are not effectively delivered. Without their active participation and commitments, some of their actions inadvertently negate the benefits of high performance design elements. Encouraging tenants not to use space heaters and fans, and to turn off equipment during off hours, making sure to shutting off lights, power down everything - such as computers, monitors, copiers, kitchen equipment and task lights, can significantly reduce plug loads. In U.S. companies alone, more than $1 billion a year is wasted on electricity for computer monitors that are left on when they shouldn't be.

Cleaning and security personnel can be trained to turn off miscellaneous items such as coffee pots, kitchen equipment and individual office lights. Office equipment that is left in stand-by mode continues to draw significant power on a 24X7 basis and degrades the energy performance. It is important to adjust building operating hours, and the provision of heating and air-conditioning levels, to reflect actual tenant usage and needs.

Operations – Systems and Operators

Many high performance buildings are designed with state of the art efficient and complex equipment, particularly controls, which can be very difficult to operate optimally. While these systems may be the best from a design perspective, the realities of commercial operation are often not adequately considered in establishing design intent that is realistic and achievable.. Complex building systems (in any building, not just green or high performance buildings) often require improvements and iterative adjustments over multiple seasons to ultimately operate as designed. Complicating this situation is the fact that design intent is not well communicated to operators and rarely if ever in a quantified manner that can be readily checked against accessible building data.

For example, discharge air temperature sensors are often found to be reading several degrees higher than the actual temperature. This results in significant excess cooling plant energy use. Generally, only a small sample of sensing elements is validated, leading to inaccurate control. Further, in actual practice, many control loops are unstable as installed. Careful testing and monitoring of system performance under actual load is essential to identify and correct instabilities inherent in the systems as installed. Most complex buildings can easily take three years (or three seasonal cycles) to be brought up to optimal operation. Unfortunately clients are hesitant to pay designers to return after occupancy, and designers have generally moved on to the next urgent project deadline.

Another element that can result in low building performance is a disconnect between design and operation—at the time of design and modeling predicted energy performance, optimal control strategies and schedules often are assumed which do not occur in operation. For example, daylighting strategies would normally assume that artificial lighting is dimmed or turned off but operators or occupants often do not understand this and may well not recognize if the controls are not working properly. Lack of commissioning can result in systems that are not operating as designed, frustrating operators and occupants. Improper function that results in unacceptable indoor environment conditions will often result in by-passed control routines. To manage expectations for energy performance, the design team must consider operational needs, situations, and responses from the beginning of the project.

Modeling

Modeling can be one major issue in understanding why energy expectations are not being met. Potential inaccuracies of energy modeling are well known, nonetheless common errors persist. Most energy modeling tools are very good at modeling standard HVAC systems, but it can be more of a challenge for less experienced modelers to predict the energy use of advanced green building components such as natural ventilation, atria, displacement ventilation, chilled beams, and double facades, among others.

As noted above, with sophisticated systems and new technologies, actual energy performance is often quite different from predicted performance, particularly for the first years of operation. The issue of predicted energy performance differing from actual is not unique to green buildings; the challenges of accurately modeling and predicting building energy use apply to all buildings, though the same scrutiny about performance is usually not applied to the general building stock.

What's in the Metrics

Many earlier energy codes and rating schemes did not take "process energy" (sometimes called "unregulated energy") into consideration, defined in ANSI/ASHRAE/IESNA Standard 90.1-1999, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, as "energy consumed in support of a manufacturing, industrial, or commercial process other than conditioning spaces and maintaining comfort and amenities for the occupants of a building."

As an example, many design teams will gather energy performance data for energy-efficient buildings, and make performance predictions, by comparing only the systems that the design team controls—such as envelope insulation value, percentage glazing, solar shading, chiller and boiler efficiency, fan and pump motor efficiency, installed lighting power density, and system selections. This excludes the "process energy" elements, often some of the biggest end users in new buildings, such as server rooms, lab equipment, cooking or restaurant equipment, security systems, building control systems, fire safety systems, computers, printers, copiers and some plug loads.

Many of these excluded loads operate 24 hours a day, seven days a week; while an energy savings calculation will state significant energy savings, the real energy use of a new building may be much higher. These details need to be considered when setting goals and reporting both projected and actual energy performance.

Keeping Score: Getting to an Appropriate Set of Metrics

Energy performance in buildings can mean many different things. Energy intensity, or energy use per unit of floor area, is one common measure of building energy performance. The US EPA ENERGY STAR™ Buildings program, with its *Portfolio Manager* rating system, measures and compares building energy performance through adjusted energy intensity.

As a starting point, developing a simple energy intensity indicator, such as BTU/Gross Square Foot or MJ (or kWh all fuels)/Square Meter, as a benchmark allows for comparing performance of buildings in a region. A variety of other annual energy cost or use benchmarking reports, such as the "Experience Exchange Reports" published by the Building Owners & Managers Administration (BOMA), provide another source of energy cost benchmark data. Prescriptive energy codes, generally based on ASHRAE 90.1 and 90.2, only indirectly produce an energy intensity, via the modeling of a prescribed set of construction elements meeting minimum requirements. In setting up a model, certain environmental design conditions must be held constant; improving energy performance by curtailing levels of service is not allowed nor would it result in acceptable outcomes.

Energy intensity, then, must be balanced against other performance criteria and project requirements—for example, a building with no lights, air-conditioning or mechanical ventilation will have extremely low energy intensity, but will not adequately serve the needs of building occupants. Sometimes this is taken to mean that all occupant complaints about environmental conditions (heating, lighting etc) can only be addressed by higher levels of energy use. This is demonstrably incorrect. Complaints frequently arise from system imbalances, over-conditioning of supply air, or glare from excessive light – all conditions that involve waste of energy. The need to balance the energy intensity indicator with occupant comfort has led some investigators to attempt development of more complex, multi-dimensional building performance metrics that are based on physical parameters and/or surveyed expressions of occupant satisfaction. Such measurement may ultimately provide us with a way of tracking how well the building and its operation is meeting the full set of design expectations.

A challenge in understanding the performance of green buildings is that there is a delicate interaction and balance between the different goals of green buildings. If energy conservation is the only goal in the building, that priority may preclude other environmental attributes that are important, but can result in higher energy usage. For example, extra outdoor air ventilation generally requires additional fan energy to move the air, as well as energy use for conditioning that outdoor air, although use of heat recovery technology can minimize this latter effect Similarly, the fans/pumps used for water reclamation and recycling require more electricity consuming equipment than is typical in most buildings.

An Effort to Bridge the Gap: The US General Services Administration

The US Department of Energy has determined that effective O&M is one of the most cost-effective methods for ensuring reliability, safety, and energy efficiency. As the largest single "landlord" in the United States, the federal government oversees about 500,000 federal buildings. More than $20 billion is spent annually on acquiring or substantially renovating federal facilities, more than $3.5 billion for energy for these facilities, and almost $200 billion for personnel compensation and benefits for civilian employees. This represents an enormous opportunity to transfer the sustainable technologies and practices on a large scale and help transform the marketplace.

With so much to gain in terms of energy, environmental, and economic benefits, it is not surprising that many federal agencies have developed policies to promote sustainable design and operation.
The US Departments of Energy's Federal Energy Management Program (FEMP) has estimated that O&M programs targeting energy efficiency can save 5% to 20% on energy bills without a significant capital investment. Just for federal facilities, operational efficiencies can lower energy costs between US$175 million to 700 million with concomitant reductions in release of greenhouse gases. From small to large sites, these savings can represent thousands to hundreds-of-thousands of dollars each year, and many can be achieved with minimal cash outlays.

For proper use of metered information and effective operations and maintenance of state-of-the-art equipment and controls, industry needs aggressive, structured training programs for operations and maintenance staff and performance ratings of facility managers to become related to energy efficient operations and maintenance programs

Inadequate maintenance of energy-using systems is a major cause of energy waste in both the Federal government and the private sector. Energy losses from steam, water and air leaks, un-insulated lines, maladjusted or inoperable controls, and other losses from poor maintenance are often considerable. Good maintenance practices can generate substantial energy savings and should be considered a resource.

In addition, O&M program operating at its peak "operational efficiency" has other important implications:

- A well-functioning O&M program is a safe O&M program. Equipment is maintained properly mitigating any potential hazard arising from deferred maintenance.
- In most Federal buildings, the O&M staff are not only responsible for the comfort, but also for the health and safety of the occupants. Of increasing productivity (and legal) concern are indoor air quality (IAQ) issues within these buildings. Proper O&M reduces the risks associated with the development of dangerous and costly IAQ situations.
- Properly performed O&M ensures that the design life expectancy of equipment will be achieved, and in some cases exceeded. Conversely, the costs associated with early equipment failure are usually not budgeted for, and often come at the expense of other planned O&M activities.
- An effective O&M program more easily complies with Federal laws such as the Clean Air Act and the Clean Water Act.
- A well functioning O&M program means not always answering complaints. Rather, it is proactive in its response and corrects situations before they become problems. This model

minimizes callbacks and keeps occupants satisfied while allowing more time for scheduled maintenance.

For US Federal Government Buildings, benchmarking is mandated by Federal Executive Orders and Local Laws that require public buildings to lower energy use by 3% per year over the next ten years.

Bridging the Gap between Design and Operations

High-performing buildings need to provide healthy, productive and safe places in which to live and work. Occupants require energy efficiency, improved indoor environment and innovative design and it is an undeniable fact that there are trade-offs between these performance demands. Clearly the most effective way of advancing the building construction industry towards a sustainable balance is through rational analysis of the actual performance.

Getting Quantifiable Design Intent into Operations

A major cause for discrepancy between design predictions and actual performance is the divide between building operators, tenants, and building designers. Only the rarest of projects will include operating personnel in design development phase. “Optimum” design often fails to take into account realities of commercial operation, including elements such as standard practices, O&M budget cuts, labor costs, union jurisdiction, or the final operating program of the building. Design intent must be carefully vetted with the owner’s operating personnel, and tenants to ensure that the design takes into account the intended method of operation.

In addition, this communication loop must be closed at the end of the commissioning process, when the design intent must be shared with the operating personnel in order for them to ensure that the building operates as close to the design intent as possible. Bringing designers back on board after occupancy to review and comment on operations happens even less frequently then integrating operators into the design process. This should continue beyond commissioning as even commissioning is not 100% effective. A seasonal or annual review by the original design team can pick up small issues like errors in critical sensors or control elements that greatly impact energy performance.

Each successive project phase -- from concept development through design to construction, Tenant Improvements, and finally hand-over to ongoing building operations -- embodies the previous phase’s Intent and Requirements. Yet how well articulated is this at each phase? Can better attention to clear statements of intent help us to consistently realize our project goals? Are there ways to articulate Intent and Requirements systematically and in terms of quantifiable outcomes? Perspectives from various project phases need to discuss their approaches to, and experiences with, statement of Intent and Owner Requirements.

Understanding the metrics for building environmental performance, and then measuring performance against those “yardsticks” is key to performance improvement. What are key metrics for building energy performance measurement? How are new buildings doing toward targets? Are there major reasons for differences between anticipated and actual performance? What are water use/conservation baselines and metrics, and are new technologies delivering savings? What is a “carbon footprint”, and how does one accurately and repeatably quantify and reduce that footprint?

Advanced metering, with appropriate sub-metering for different end-uses and tenants, is an effective means to determine energy usage and measure savings as well as hold different users accountable for their installation of ancillary and process equipment.

Improving Feedback: Incorporating Experience into Design

Our operation and use of buildings tells us a lot about how they really work, what the ultimate users really like and appreciate, and what doesn’t work as we might have thought. Capturing this kind of information in a type of “post-occupancy evaluation” is fairly new to the field. And getting it fed back into the design process is even newer. A few firms and organizations have been leading on this –

incorporating iterative learning from projects and even getting operational staff involved in the design phase. Their stories are enlightening and instructive.

It is critical to understand the delicate balance between energy use, indoor environmental quality, and other desired built environment features such as water conservation and recycling. The primary function of buildings is to provide healthy, productive and safe places in which to live and work. Clients require energy efficiency, improved environment, and innovative design, but often struggle to balance the trade-offs between them. Reducing the performance expectations for lighting levels, temperature control, daylight, ventilation rates, and redundancy will reduce energy consumption, but too often following design and construction those reduced performance levels are not accepted by occupants.

Performance and comfort concerns often exclude the use of passive systems such as natural ventilation or optimal thermal mass. Operable windows are generally not considered in the design of new buildings because of performance requirements of acoustics, humidity control and air filtration, even if the operational and first cost hurdles can be overcome. There has been a trend over a number of years of increasing the glazing area of buildings due to both client requirements and architectural preference. A common solution to optimize the sometimes contradictory goals of improved indoor environment and reduced energy consumption is a complex set of controls and systems to minimize energy use wherever possible.

However, the often challenging to operate technology and design concepts sometimes fail to deliver on their promised improvements in function and efficiency, and in some cases it has been shown that these concepts and technologies consume more energy initially than the mature technology they replaced. There is a need to better test new technologies in research laboratories and through repeated demonstration projects before they are widely implemented, along with need for monitoring and performance guarantees.

The growing number of initiatives toward building energy performance labeling and benchmarking will help significantly in providing feedback to design teams about what is working (or not). Too often the teams doing the innovative design are never aware of issues that affect operating building energy/environmental performance, so assume that everything works as expected. With more widespread “operational” energy labeling that shows measured performance, and policy moves toward mandatory benchmarking and performance disclosure, the feedback process will become more common place.

Another innovative initiative that holds great promise toward bridging this challenging gap, and deliver measured results in building performance improvements, is the “Green Lease Schedule” effort in Australia. The Green Lease Schedule (GLS) provides for mutual contract lease obligations for tenants and owners to achieve energy efficiency targets, as well as other environmental obligations if agreed (Woodford 2007). The GLS initiative provides a way for tenants to make owners accountable for building energy performance, and also let building owners make tenants accountable for their energy usage. While the effort is relatively new, preliminary findings are extremely encouraging, and this lease structure will likely be a powerful tool in getting feedback about actual energy performance to key design and construction decision makers.

Conclusion

There is growing awareness about the potential gap between expected and actual performance, and a variety of initiatives are underway to better quantify, and then bridge, this gap.

As there is more activity and push to disclose performance data and lessons learned about projects, designers and operators can help to move each other forward on the road to high-performing buildings—with both good intentions and high performance. As more actual energy performance data become available on high-performing buildings, clearer and more realistic expectations will help establish confidence within the building design and construction industry about costs and savings.

Some initiatives such as mandatory operational energy performance benchmarking, and structured feedback activities like the Australian Green Lease program, hold great promise, and will likely spawn other innovative activities that bridge the energy performance gap.

With growing efforts toward building energy labeling and in some cases, mandatory energy performance disclosure, there is great opportunity for combining both the "asset" rating of a building, where the physical properties and predicted optimal performance are calculated, together with the "operational" rating, which measures how the building actually performs. Through a combination of these two ratings: how the building should perform, and how it actually is consuming energy, operators and designers will be able to learn what works, and where there are opportunities for significant savings.

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Life Cycle Assessment Measures of Energy Efficient Projects

Om Taneja, U. S. General Services Administration, New York, New York, USA
Adam Hinge, Sustainable Energy Partnerships, USA

Abstract

There is growing interest in the public and private sectors, supported by the financial community, in energy and water conservation projects. Such projects are evaluated and justified based on vague "environmental or need-based criteria" or "payback-analysis" that generally includes short term benefits and cost considerations. However, to sustain the momentum with such activities, it is not going to be enough just to show initial or immediate beneficial outcomes, but there is a need to demonstrate sufficient benefits over many years of operations, maintenance, aging and building-use changes. The cumulative impact of a facility project with regards to its total impact on environment, energy use and costs over the life-cycle requires due considerations of many other interrelated factors. A simple payback analysis could under or overestimate the environmental impact of a project due to unaccounted impact of types of energy and other materials use during production, installation, commissioning, operations, maintenance and decommissioning and disposal.

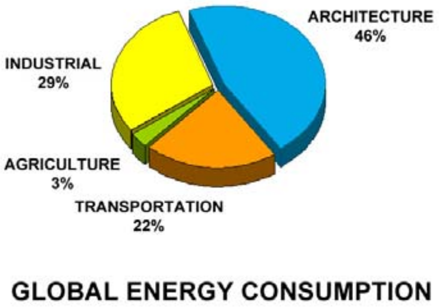
This paper outlines a framework for making a life-cycle qualitative or quantitative analysis of facility systems or projects so as to guide the decision-making process by cradle-to-grave total impact analysis. Beyond analytical analysis, it also emphasizes the need for performance monitoring, benchmarking, retro-commissioning and making adaptive changes to buildings systems to suit changing uses, or external factors such as new codes, standards and security requirements. It also emphasizes how industry professional and trade organizations can foster cross-training and templates for modeling systems to address life-cycle impacts and thereby make the industry more socially and environmentally accountable. With industry becoming increasingly sensitive to higher sustainability goals, such a conceptual framework can be helpful.

Background, and Need for Resource Conservation in the Buildings & Construction Sector

Buildings have a staggering impact on the natural environment. The U.S. construction industry, for example, is responsible for only 8 percent of gross domestic product, but accounts for more than 40 percent of the total materials harvested from the environment each year [(4)]. It becomes a significant factor impacting the environment throughout the life-cycle of facilities – from early planning, through design, construction, occupancy and use, operation and maintenance, and eventual decommissioning, reuse or disposal. Even though the scientific community continues to have some disagreements regarding the direct role of such activities on global warming due to other offsetting factors, there is consensus that buildings and structures are major parts of the economic, social and ecological footprint of society [(16)].

The construction and real-estate development sector is comprised of investors, planners, architects and engineers, contractors, owners and managers, who engage in the development and construction of (a) housing, buildings and service facilities and land development, and (b) heavy construction, such as highways and bridges, power and process plants, pipelines, etc. By its very process, land development and associated construction and operational activities have a wide range of negative impacts on the environment, energy and materials, promoting wasteful transportation patterns, and quality of life for the current and future generations.

For example, the United States, with less than 5% of the world's population, produces about 25% of all CO_2 emissions. In North America, 48% of all energy consumption (Fig 1) is used directly or indirectly for buildings[(6,7)]. Buildings in urban areas come up as giant slabs of concrete and fenestration without full regard to their impact on the ecosystems. Construction and operation of buildings account for 37% of all United States CO_2 emissions, and 25% of all wood is harvested for use in residential and commercial buildings. Buildings are also the locus of consumption; it is in the homes, schools and workplaces, where consumers use and eventually dispose of equipment, appliances, furniture, carpeting, computers, paper, chemicals, metals, etc.



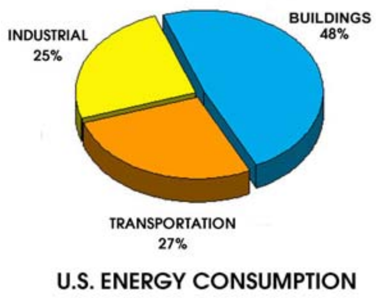


Fig 1, Global & US Energy Use Patterns – Source US Energy Information Administration Statistics

In the buildings industry, less than 0.5% is spent on basic research and development to improve the performance of buildings. Therefore, for a long time, traditional thinking of planning, design, construction and operation, refurbishment and decommissioning of such buildings and structures has been continuing without due regard to energy, materials and resource use. Even though there have been spurts of progress towards more efficient lighting, low-emissivity windows, and better controlled heating and cooling, the CO_2 emissions from sources within the United States continue to escalate, and the developing countries are catching up (3). Particularly, the impact of buildings on the environment is noteworthy:

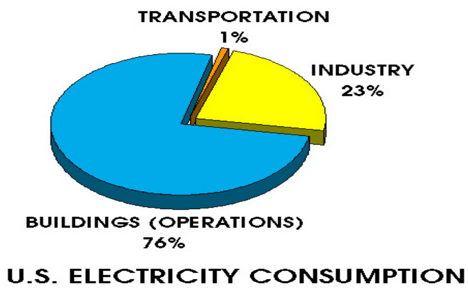


FIGURE 2

Buildings use 48% of all US Energy and 76% of electric power generated (Figure 2).

People spend a significant part of their daily lives commuting to and working in buildings. Buildings account for approximately 75% of CO2 release into atmosphere. Concentration on consumer awareness, better design, more efficient use of energy and resources, and better operation and maintenance can help reduce environmental impact, global warming, improve working environment and thereby improve productivity.

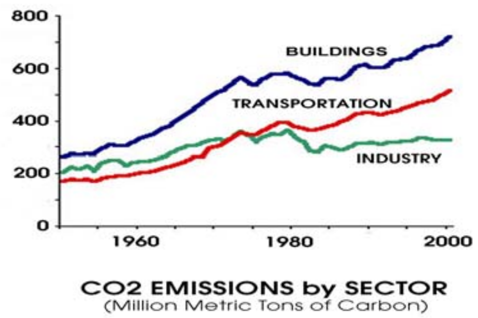
It is very important to understand the energy and resource use patterns for every stage in the life-cycle of a building and develop actions that would streamline each phase to a sustainable process. At the planning stage, we need green investors, planners, and architects to build houses and buildings that are more in balance with nature. During construction and occupancy phases, we must consider aspects of substantial embedded energy that goes into the materials for construction, furnishings, operations and servicing of buildings, and ensure that such energy is not wasted by disposal after a single use. Therefore, we not only need to recycle materials, but get to the more basic aspects of using biodegradable or reusable construction materials and furnishings labeled as green materials, benefiting from daylight, natural ventilation and renewable energy sources, conserving water, shifting focus away from long, automobile based transportation, and ultimately reusing all the parts and buildings elements at the end of a building's life. The largest impact on environment results from the operations and maintenance of facilities and how efficiently these services are provided determines the carbon footprint and environmental impact over the life of a facility. The economies of such greening effort may seem unjustified with traditional thinking process, but it can gradually and steadily be justified when considered in the spirit of innovative ideas and environmental harmony.

Discussion

Framework for a Systems Approach – Construction and Buildings Sector

In an effort to better understand use and consumption patterns, it is suggested that we develop a systems approach that takes a holistic view to globally sustainable design with due consideration of needs and characteristics of the surrounding community. Here, we take buildings construction and usage as an example to outline the approach. As indicated before, residential and commercial buildings release 37% of all CO_2 emissions in North America and industrial facilities release an additional 30% [6].

Buildings and structures are the centers of human consumption. Residential facilities are where we live, commercial buildings are where we work, shop and enjoy entertainment, and industrial facilities provide energy and materials for our economic and social life. Thus, increasingly, we are less and less out in nature and more and more living, working and enjoying in enclosed buildings requiring lighting, heating, cooling, and support services. In addition, how and where we develop the land for residential, commercial and industrial complexes sets up the transport needs and modes for the employees and other users, which creates its own environmental impact. In this context, it is helpful to understand the relative contribution of various buildings towards emission of the greenhouse gases based on available estimates for the year 2000 [10] For example, in the United States, 76% of all energy used for buildings comes from electric power sources and the relative release of carbon-dioxide emissions that can be attributed to each end-user for such use are shown in Figure 3:

Sector	Total CO_2 emissions (in million metric tons)	% of US energy related CO_2 emissions	% annual growth since 1990
 FIGURE 3 Residential	313.4	20	1.9
Commercial	267.8	17	2.4
Industrial	465.7	30	0.3
Transportation	514.8	33	1.8

It should be noted that despite economic prosperity in the United States during the period from 1990 to 2000, amounting to an average growth of 3.2% per year, energy related CO_2 emissions grew by an average of 1.6% annually due to lesser manufacturing sector activity as a result of imports and energy conservation and efficiency measures pursued [(6)].

Buildings are the ecosystems with huge inputs of materials, resources and energy that the occupants and processes consume, yielding enormous outputs of greenhouse gases and waste. Therefore, development, construction and use of buildings are the processes that are the ideal candidates for buildings information modeling (BIM), simulation and systems analyses, with regard to their use of energy and resources and consequent impact on the environment.

Based on the above, the residential, commercial and industrial sectors contribute a significant portion of CO_2 emissions directly and also indirectly by their impacts on transportation. Therefore, any intent to reduce emissions of greenhouse gases cannot just be based on policies to burn less fossil fuel. We must review, analyze and address the energy and resource uses through the individual phases in the life-cycle of buildings and focus on facilitating a shift in each of the phases towards more renewable and sustainable energy and resource use patterns. It is difficult to make a significant change without moving from traditional design and use patterns to significantly new grass root initiatives in buildings' site selection, construction and operation.

Drivers for Movement Toward Sustainable Design of Buildings

A variety of factors are now driving dramatic changes in interest toward environmentally sustainable buildings, including:

- Public awareness and public demand;
- Observed impacts of global warming and associated climate changes and respiratory diseases;
- Political inter-governmental agreements, such as the Montreal Protocol and Kyoto Protocol;
- Scientific knowledge and growing consensus regarding release of greenhouse gases, global warming and climatic changes;
- Emerging technologies for cost-effective carbon-saving, greening and more efficient operations;
- Likely insurance company requirements for greening;
- Increasing asset value of efficient buildings versus liability of inefficient buildings; and
- Stockholders' interest in investing in companies that promote greening and sustainability in their products and services and in their workplaces.

More environmentally preferable materials are available, in areas like paints, finishes, carpets, windows, furniture, roofing, glass, plumbing fixtures, lighting and cladding. Building Teams should be able to specify 90-95% of the basic green products and materials they need for their jobs, usually at prices competitive with conventional products. Many projects achieve sustainable design within their initial budget, while many government office buildings experience a premium of 1.4% for LEED Certified Projects to 8.3% for LEED Gold rated buildings with minimum façade work. Using integrated design and off-the-shelf solutions – such as low e-glazing, "cool" or vegetated roofs, energy-conserving lighting, dual-flush toilets, low-demand landscaping, and gray water irrigation – could readily bring in even the most sophisticated projects at a cost most owners and developers could be happy with.

Environmental Impact Assessment Criteria

Consumption of manufactured products has an effect on resources and environment. These effects occur at every stage in a product's life-cycle from the extraction of the raw materials from the ground through the processing, manufacturing, and transportation phases, ending with use and disposal or recycling – aim is to quantify such direct and indirect effects of products and processes. The pending energy crisis and the need for alternative, environmentally safe energy sources go hand in hand with such life-cycle assessment.

Environmental impact criteria should include items, such as the following [12] (more substantive details are listed in the reference):

- Quantity and Types of Resource Uses
- Embodied Energy –energy used in manufacture, transport and construction
- Embodied Pollution – caused during manufacture, transport and construction
- Recyclability
- Material Efficiency for the use intended
- Product Life
- Global Warming potential
- Tropospheric ozone potential
- Ecological Toxicity
- Human Toxicity
- Acid Rain
- Resource Depletion
- Socio-economic impacts
- Balancing economic and environmental impacts

Energy Conservation & Sustainability Benchmarks, Ratings & Standards

A variety of standards and guidelines have evolved to provide guidance to various building industry market actors. These include the following.

Energy Conservation Standards

- ASHRAE 90.1 – published by the American Society of Heating, Refrigerating, and Air Conditioning Engineers, provides guidelines for building energy models and benchmarks for energy use that efficient buildings can match or exceed. This Standard has advanced to much greater requirements for energy efficiency in its 2004 and 2007 version. Some State and Federal Governments are further requiring government buildings to be designed and operated with Energy Use 30% below ASHRAE 90.1 Standard.
- International Energy Conservation Code (IECC), developed by the US based International Code Council
- ENERGY STAR- a US DOE & EPA government-backed program helping businesses and individuals protect the environment through use of superior energy efficient appliances and buildings systems.
- US Energy Policy Act 2005

Sustainability Rating Standards

- LEED Green Building Rating System - A comprehensive rating system has been developed by the US Green Building Council (USGBC), gaining widespread acceptance in the US and Overseas. This rating standard is now placing greater emphasis on energy efficiency.
- Green Globe Progran – provides benchmarking and certification program to promote better business, better environment and better communities.
- BREEAM – Building Research Establishment Environmental Assessment, widely used in UK and Canada, and a forerunner to LEED.
- WHOLE BUILDING DESIGN (WBD) focuses on an integrated approach to design of sustainable facilities.
- Building Owners & Managers Administration (BOMA) Experience Exchange Reports

The USGBC has developed a ranking system called "Leadership in Energy & Environmental Design (LEED)" for new buildings, with relative weights along the following lines:

Factor	*No. of Points for New Buildings NC*	*No of Points for Existing Buildings – O&M*
Sustainable Sites	14	14
Water Efficiency	5	5
Energy and Atmosphere	17	23
Materials and Resources	13	16
Indoor Environmental Quality	15	22
Innovation and Design Process	5	5
TOTAL	69	85

USGBC rates buildings for sustainability, as follows:

Rating	*Score for New Building*	*Score for Existing Building – O&M*
Certified	26-32	32-39
Silver	33-38	40-47
Gold	39-51	48-63
Platinum	52-69	64-85

From the above ranking system, highest considerations are given to energy and atmosphere, followed by air quality and sustainable sites. With the current technologies for the existing buildings, approximately 30% to 35% energy use reductions and silver ratings are manageable, while higher energy savings and gold or platinum ratings require strategically innovative ideas and operations that are easier under new buildings construction or major refurbishments.

Need for Life-Cycle Assessment

In a survey conducted by *Building Design + Construction* magazine in August 2006, as well as in in 2003 and 2004, respondents felt very strongly (4.4 on a scale of 5) that green products and building materials should be evaluated on the basis of life-cycle analysis, operational longevity and safe maintenance potential, and not just environmental impact and energy savings(11) . The article found that:

- Most current approaches look at features of a system while taking a snap shot during design, construction or operations
- Life Cycle approach first dissects a facility into various phases of its life and further dissects each phase into materials, energy and services used and their individual environmental impacts
- It then looks at each individual element and analyze what changes can be made and at what cost to reduce the overall adverse environmental impact
- This can be an objective process to evaluate the environmental burdens associated with a product, process or activity and implement opportunities to affect environmental improvements.
- Issues of reducing waste at the source, Air & Water quality, Climate Change, resources usage, and Landfill Disposal sites are paramount.
- The process allows structuring of the problem with both objective and subjective inputs which are inevitable in life cycle impact assessment

Common Approach proposed by the Society of Environmental Toxicology and Chemistry & International ISO Standards is to dissect the building into components' or systems' effects at each phase:

- *LIFE CYCLE INVENTORY* (LCI)– Process for quantifying the energy, water and natural resources used to extract, produce, and distribute the product, and the resulting air emissions, effluents and solid wastes
- *LIFE CYCLE IMPACT ANALYSIS* – process to assess the ecological and human-health effects of the environmental loadings identified in inventory.
- *LIFE CYCLE IMPROVEMENT ANALYSIS* – process to reduce the environmental burden associated with energy and raw materials use and environmental releases throughout a product's entire life cycle.

ISO Standards pertaining to Life-Cycle Analysis are:

- ISO 14040 – Environmental Management – Life Cycle Assessment – Principles & Framework
- ISO 14041 – Environmental Management – Life Cycle Assessment – Goal Scope & Definition and Inventory Analysis
- ISO 14042 – Environmental Management- Life Cycle Assessment – Life Cycle impact assessment
- ISO 14043 – Environmental Management – Life Cycle Assessment – Life Cycle Interpretation

Phases in the Life of a Building and Their Impact On the Environment

The most direct effect of buildings on climate change is from their release of greenhouse gas emissions at different stages of a building's life, from initial land development, components manufacture and construction, to occupancy, operations and maintenance, and demolition and disposal/reuse. Greenhouse gas emissions largely result from fuels consumed for energy and transport, and chlorofluorocarbon leakages from heating and cooling equipment and imbedded energy in resource processing, such as for cement, steel, aluminum, asphalt, carpets, computers, etc [13, 14, 16] . A recent study for the United Nations Environment Program's Sustainable Buildings and Construction Initiative reviewed a wide range of research and found that while the most significant environmental impacts result from the building's operation and maintenance phase, the impacts during the construction phase can be from 5 to nearly 20% of building lifetime energy use [16].

The life-cycle stages and related aspects suggested for consideration are the following, based on their environmental impact:

- Land development and planning, which affects removing trees, greenery, soil with impervious surfaces, roads, walkways, parking and transport needs (recurring impact);
- Initial supply of materials, furnishings, and construction and occupancy (one-time impact);
- Operations with energy use, heating and cooling systems releases, and services for performing functions (recurring daily, major impact);
- Maintenance, alterations, improvements, and refurbishments (periodic impact);
- Transport of workers, visitors, goods and services (recurring daily, major impact); and
- Demolition (one-time impact, reduced by reusing the shell and recycling materials).

The stages in the life cycle of a material used are

- Extraction
- Manufacture
- Transportation
- Use as a construction or systems material
- Use during occupancy, operations and maintenance
- Recycle or Disposal

The detailed analysis for each of the phases requires substantive analytical focus and is very much a function of local weather, buildings use and operational considerations. However, considering the average life-span of buildings of 50 years, and comparing to total life-span energy use and greenhouse gases release, the contribution of demolition is negligible, and that of initial construction is relatively small; transport, operations and maintenance and land development impacts are the major factor. One of the recent studies regarding buildings in New Zealand [13] indicates approximately 10% impact of initial construction, and one-third each for transport and operational recurring factors; the remaining impact is from land development and maintenance/refurbishment activities.

Buildings thus become both the cause and effect for climate change. They cause adverse impact on the environment and climate by release of enormous quantities of greenhouse gases. They are also adversely affected by climate and weather changes, global warming, water tides and winds. Inclement weather, storms and hurricanes increase the operational shelter costs of buildings as well as affect insurance and worker access and productivity. Therefore, it not only makes environmental sense to control the release of greenhouse gases, but also makes strong economic and social sense.

Bearing in mind such economic, social and operational consequences, sustainability with regard to built environment must focus on meeting the present needs in an efficient manner synchronized with nature, without causing further damage and thereby sacrificing the ability of future generations to meet their needs. Therefore, the buildings of tomorrow should include a wide range of concerted actions to reduce the impact of built environment on natural environment by use of renewable resources, conservation and efficient management of facilities.

Sustainability is promoted by pursuing the following principles:

- Land use and site selection – to minimize damage to the natural landscape, with ease of public transport and local use of materials and services (brownfields development, storm water management, reduction of heat and light loads, erosion and sedimentation controls, etc.);
- Planning, design and commissioning – to use renewable energy and materials, and emphasize source and waste reduction;
- Use natural and renewable means for healthy indoor environment – to use day lighting, natural ventilation, natural noise barriers, solar, wind, bio-mass or geothermal energy sources, and bio-degradable and recyclable materials;
- Conservation – to limit use of spaces and resources for essential needs; and
- Operations and maintenance – to use efficient equipment and systems so as to be able to do more with less (less use of chemicals or other harmful substances). More importantly, it is important to train the Operations & Maintenance staff to perform these functions in a high performance manner, to monitor and correct deficiencies promptly and invest in periodic re-commissioning and self-assessment. The actual performance of such buildings need to measured regularly and compared against benchmark industry standards.
- Recycling, reuse or eco-friendly disposal

Life Cycle Environmental vs. Life Cycle Economic Cost Analysis

- All activities cause some environmental impact
- To bring improvements costs money, sometimes small, sometimes large
- Improvements that can be achieved with lowest socio-economic costs should be favored.
- US DOE is developing an integrated model, including LCACCESS Website, that uses LCA Methodology, but also overlays economic considerations to assess the implications of an LCA analysis and determine the best method to reduce environmental impact
- It is required to develop measures for total cost burden, total environmental burden, total energy use burden, and thereafter take a ratio of Environmental Burden per unit cost or Energy use per unit cost. Depending on the priorities, one may be favored over the other – but both are important. Where water or other resources are scarce, the impact of such a resource use per unit cost need to be considered

Life Cycle Environmental & Cost Impact Assessment Tools:

- The US DOE's "Federal Energy Management Program's (FEMP's) Building Life Cycle Cost (BLCC) software can help calculate life-cycle costs, net savings, savings to investment ratio, internal rate of return and payback period for Federal Energy and Water Conservation projects. The BLCC programs also estimate emissions and emissions reductions.
- BEES (The Building for Environmental and Economic Sustainability) software tool measures the environmental performance of Building Products. BEES analyzes a product's life cycle, including raw material acquisition, manufacture, transportation, installation, use, recycling and

waste management. It was developed by National Institute of Standards and Technology (NIST) with support from the US Environmental Protection Agency, Environmentally Preferable Purchasing Program and the Partnership for Advancing Technology in Housing

- ATHENA™ - Assessment tool developed by the ATHENA Sustainable Materials Institute of Canada allows to look at the life cycle environmental impact of complete structures or individual assemblies so as to experiment with alternative designs and different materials mixes
- LCAccess – an internet site based searchable global directory to potential data sources , that provides access to and greater awareness of life cycle inventory data sources along with more comprehensive understanding of their overall quality – Access through EPA Website epa.gov
- **ENVEST** is a UK software tool that simplifies the otherwise very complex process of designing buildings with low environmental impact and whole life costs. Envest 2 allows both environmental and financial tradeoffs to be made explicit in the design process, allowing the client to optimise the concept of best value according to their own priorities.

Advantages & Problems/ Limitations of Life Cycle Assessment

Advantages

There is a critical need to identify areas within a product's life cycle where the greatest reduction in environmental burdens can be achieved. Thus LCA is a valuable engineering tool to dissect all direct and indirect impacts on pollution caused by products and processes. The use of eco-labeling with the LCA of products at the heart appears to be the most logical approach to encourage consumer's participation in reducing environmental impact. Increased emphasis is being placed on certification standards in both ASTM and ISO estimates.

This can be an objective process to evaluate the environmental burdens associated with a product, process or activity and implement opportunities to affect environmental improvements. Issues of reducing waste at the source, Air & Water quality, Climate Change, resources usage, and Landfill Disposal sites are paramount. The process allows structuring of the problem with both objective and subjective inputs which are inevitable in life cycle impact assessment

Limitations

LCA is a data intensive methodology. In many cases two similar analyses will not arrive at the same level of environmental burdens because of lack of reliable data for all elements. Concerns arise due to out of date of information, omission of certain phases, and omission of packaging, forming, filling and transportation stages that can skew results. Most LCA studies conducted by experts rely on accumulated databases that are not available for peer review. Databases need to be dynamic as fabrication and packaging processes change. Effective use of LCA at this stage is cumbersome for construction industry [(15)].

Conclusion

This paper outlines an input-output type of systems analysis framework for the buildings and construction sector to understand the impact on the environment during different phases in the life span of buildings, and thereby develop innovative measures, education and training to promote efficiency and sustainability. Buildings' location, design and operations are the chief determinates of buildings' costs and environmental impact [(16)]. The more in-depth understanding we have of factors affecting the environment, the more likely there will be progress towards sustainable and green buildings.

Future survivability and quality of life of the habitants of earth is in the hands of the current generation. How we redirect our energies from the behaviors and economic-social lifestyle of ignoring the environment towards an environment-friendly life-style and economy would determine our future on earth. In the end, buildings' location, design and operations are the chief determinates of buildings' costs and environmental impacts. The more in-depth understanding we have of factors affecting the environment, the more likely there will be progress towards sustainable and green buildings. Similar analysis can be applied to other sectors with focus on individual phases in the life-span of an enterprise.

There is hope. Federal, State and City Governments all across the United States are slowly, but steadily, promoting policies, local laws and standards to require Green Buildings Design, renovations and construction. The performance of Property Managers and Operators is being judged by how well they manage buildings in an environmentally responsible manner. The Private Sector increasingly finds merit in building Green since such buildings have only a minimal incremental construction cost [(11)] while making the buildings more attractive to tenants and to the financing and insurance industry. Public policies coupled with private interests are starting to show green investments and favorable results. Federal Energy Policy Act of 2005, New York City's Local Law 86 and adoption of LEED Green Globe and Whole Building Design (WBD) are movements towards energy and water efficiency and towards sustainable buildings.

For Example, General Services Administration, Northeast & Caribbean Region promotes "Building Information Modeling", "monitoring of energy use and benchmarking on an annual basis" and an aggressive recycling and hazardous materials management program along with following noteworthy recent energy efficiency & Sustainability initiatives:

- Energy use at regional federal facilities in FY2005 was reduced by approximately 33.5% compared to the amount of energy used in FY1985 - and this is despite the tremendous increase in the use of office automation equipment that everyone has experienced during the same period.
- In FY2006 the region awarded a contract to provide 100% wind power to the nation's most popular tourist attractions on the east coast, the Statue of Liberty and Ellis Island. In this contract GSA's New Jersey Service Center will also buy over 1 million kWh of renewable energy for its 22 facilities, including the Peter Rodino Federal Building in Newark, New Jersey.
- In FY2005 the region was presented with GSA's Achievement Award for Real Property Innovation for "Offsetting Environmental Hazardous Emissions from Energy 2004"- the U.S Government's premier national energy conference. In that same fiscal year the region was presented with the Department of Energy's 2005 Federal Energy and Water Management Award for exceptional accomplishments in the efficient use of green power in the Federal Sector.
- Four of the region's federal facilities have received Energy Star Label designations from both the Department of Energy and the Environmental Protection Agency.
- Two federal facilities, located in Binghamton and Utica, NY, meet 100% of their energy needs through wind power.

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Experiences on the programmatic approach under Joint Implementation – new opportunities for the building sector

Markus Rothe, FutureCamp GmbH

1. Introduction

1st January 2005 marked the beginning of European emissions trading; for the first time CO_2 emissions within the EU had been given a value. In addition it created a fast-growing transnational market for emissions credits; in other words, emissions reductions from projects abroad also have value. In this regard projects in developing countries and countries in transition (Clean Development Mechanisms) are particularly interesting because, the resulting credits can be used in emissions trading throughout the EU, starting in 2005. Joint projects involving industrialized countries (Joint Implementation), can be generated and exploited from 2008 on.

Emissions reduction projects received another boost when the Kyoto Protocol went into force on 16 February 2005, with its emission targets that are binding under international law. The possibility of offsetting reductions via projects abroad creates significant flexibility for every entity with reduction obligations, no matter whether state or company.

Until now over 900 CDM projects are registered and over 100 JI projects are submitted for acceptance at the JI Supervisory Committee. Nevertheless there is still a high emission reduction potential in the sector of “energy efficiency” so far untapped. One problem is, that the emission reduction volume in every single source is often too small to justify the implementation as a separate project.

To overcome this barrier, the programmatic approach was developed under the CDM framework. Under JI such regulations are still missing. Currently first experiences are being made in Germany with the programmatic approach under JI 1 Track (project development in dependence on the requirements of the CDM regulations).

Aim of this paper is to give an overview of the experiences made in Germany to strengthen programmatic JI approaches.

2. Background: the Kyoto mechanisms

2.1. Kyoto Protocol

The Protocol, drafted during the Berlin Mandate process, requires countries listed in its Annex B (developed countries) to meet differentiated reduction targets for their emissions of a ‘basket’ of greenhouse gases relative to 1990 levels by 2008–12. There are six greenhouse gases covered under the Kyoto Protocol - carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The arrangement allows for high flexibility. Any Party is free to increase emissions of any gas in the ‘basket’ provided it generates commensurate reductions of another gas in the ‘basket’.

It was adopted by all Parties to the UNFCCC in Kyoto, Japan, in December 1997 and entered into force on 16 February 2005.

2.2. Kyoto Mechanisms

In addition to already existing eco-political instruments like taxes and regulatory law, the Kyoto Protocol allows Annex B Parties to meet their commitments based on actions outside their own borders. These so-called market-based mechanisms have the potential to reduce the economic impacts of greenhouse gas emission-reduction requirements.

- Joint Implementation (Article 6),
- Clean Development Mechanism (Article 12) and
- Emissions Trading (Article 17)

Joint Implementation (JI) and Clean Development Mechanism (CDM) can be used to generate certificates by implementing emission reduction projects that lead to certifiable emissions reductions (which would otherwise not occur). Article 17 of the Kyoto Protocol allows Annex B countries to exchange emissions obligations (Assigned Amount Units, AAU). Domestic implementing regulations determine the extent to which companies and other actors may be allowed to participate.

The main goal of the Kyoto Mechanisms is the worldwide and cost-effective reduction of greenhouse gas emissions.

2.3. JI and CDM

JI and CDM are project-related instruments for emissions reduction measures in other developed (JI) or developing countries (CDM) and encompass all "Kyoto-Greenhouse-Gases". If emission reductions are made by the implemented project, the project owner will receive emissions credits for this work. Credits can be used for compliance with respective emissions targets or can be sold to other market participants. Any private or legal person (e.g. company) can be project owner.

Table 1: Differences of JI and CDM

	Joint Implementation	**Clean Development Mechanism**
Host country	Developed countries	Developing countries or countries in transition
Generation of	ERUs (Emissions Reduction Units)	CERs (Certified Emissions Reductions)
Generation of credits possible	From 2008 on	Since 2000
Can be used in EU emissions trading	Starting in 2008	Starting in 2005
Process and criteria	Regulated internationally, but generally more dependent on the respective national regulations	Are internationally strictly regulated
International Board	JI Supervisory Committee	CDM Executive Board

The crucial factor for all JI/CDM project ideas is the verification of the additionality of the emission reductions. According to the Kyoto Protocol a project is considered "additional" if the emissions after execution of the project are lower than the emissions that would have occurred in the absence of the project. Reduction measures that are anyhow required due to existing national environmental regulations categorically do not satisfy the criteria of additionality.

The idea is that previously untouched emissions reduction potential shall be tapped as the mechanisms provide the needed incentive (emissions credits) for doing so. Any overlap with projects that are carried out without the incentive of emissions credits ("business as usual") is to be avoided. Consequently reduction measures that extend beyond the "business as usual" case are designated as "additional". Additionality is verified by establishing a reference case (baseline), which reflects the "business as usual" case. Then the emission reductions achieved by the JI/CDM project can be calculated by comparing the anticipated project emissions to the emissions in the reference case.

2.4. European Emissions Trading Scheme (ETS)

In addition to Emissions Trading (Article 17), the European Emissions Trading Scheme (ETS) was developed. The ETS started on 1st January 2005 as an important step for the EU-compliance with the Kyoto emission reduction targets.

Therefore emissions trading can take place on two levels: on Federal State level as regulated in the Kyoto Protocol and Scheme (ETS) and on installation level within the European Union. For the first time CO_2 emissions within the EU have been given a value.

The ETS covers large CO_2 emitting installations within the European Union. Each country within the European Union has a National Allocation Plan which provides installations in covered sectors with an allocation of tradeable allowances for their respective CO_2 emissions.

On 13th November 2004, the "Linking Directive" was adopted. The central element of the Linking Directive is the recognition of JI and CDM credits for EU-emissions trading (as compliance tools). This makes the other flexible mechanisms relevant for the future of the EU ETS.

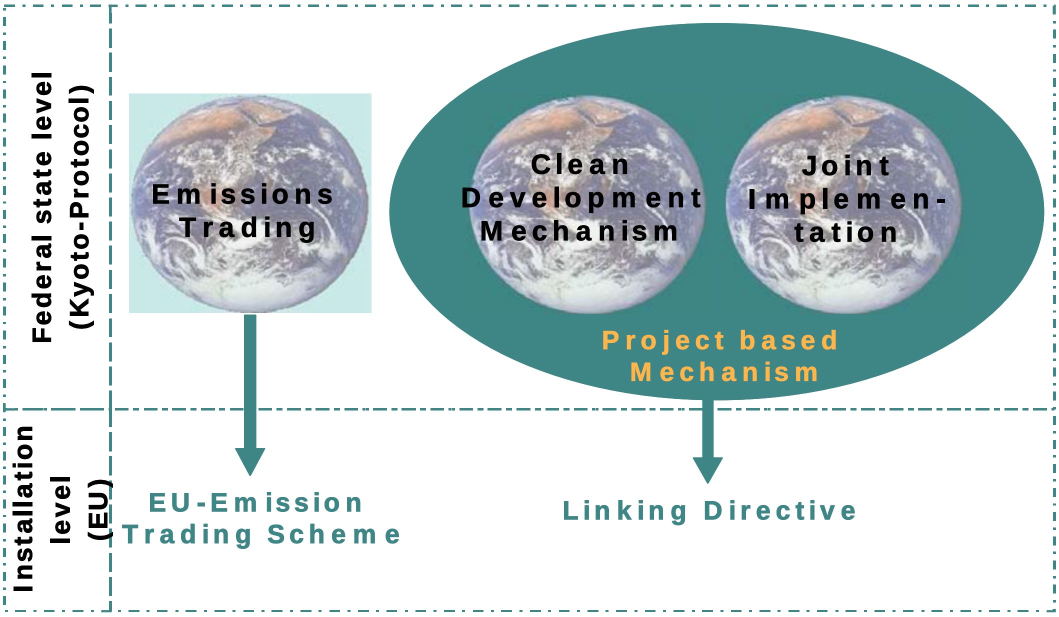


Figure 1: Linking Kyoto Mechanisms with Installation level

3. Challenges for small-scale projects under the Kyoto project-based Mechanisms

To generate and use emission credits a lot of regulations have to be taken into account, particularly the detailed rules for project definition and implementation on the international level. For planning and execution of a JI/CDM project some process steps have to be completed which can cause relevant costs and other expenses. The procedure for a JI/CDM project includes the steps of project design documentation, approval, validation, registration, implementation & monitoring, verification as well as the issuing of emission credits. At least 9-12 months should be considered for the steps preceding the registration.

Transaction costs include those associated with internal and external efforts such as search of relevant information, negotiations, determination, registration, monitoring, verification and implementation. Depending on the size and complexity of a JI/CDM project, costs range between a total of 50,000 up to 150,000 Euro. The bigger part of these costs are related to project development.

Revenues can even be achieved in an early project stage, when emission credits have not yet been generated. This involves the sale of future emission credits as futures-trading (forwards/futures). The prices range between 5-10 Euro/ERU-forward and 5-18 Euro/CER-forward (Source: Point Carbon). When the spot market will be implemented, the prices will converge with those paid for EU emission allowances (21.05 €/EUA on the EEX, as of 28 March2008, Source: www.eex.de).

As the number of approved methodologies and registered projects increases, the costs for new JI/CDM projects will tend to decrease, since in many cases development costs do not accrue for new methodologies. For small scale JI/CDM projects it is possible to employ simplified modalities and processes.

Nevertheless, although there are simplified modalities for small scale JI/CDM projects available, a lot of barriers to develop of emission reduction activities with lower reduction potential do persist. First of all these barriers are transaction costs and matters of inadequate time scales.

4. Programmatic approach: window for JI

Within JI the programmatic approach has a high potential to foster single types of technologies (e.g. energy-efficient light-bulbs) or entire sectors (e.g. private households or transport) which are not yet regulated or included in the carbon market and lack so far facilities for monetarization of emission reductions; by tapping these potentials additional GHG emission reductions could be achieved. Usually such projects involve technical or other measures at a large number of very small, direct or indirect, emission sources.

The potential emission reduction volume in every single source is often too small to justify the implementation as a separate project. This gives reasons for the assumption that in many cases reduction measures without the programmatic approachwould be delayed, if not foreclosed in general.

The programmatic approach has evolved under the CDM framework in recent years. Today CDM project activities using the programmatic approach are quite common.

But there is not just potential under the CDM but also under JI. There are many small emission sources also in industrialized countries, which are not included in the EU Emissions Trading Scheme. Incentives for such sources to reduce GHG emissions can be set under a JI programme of activities.

Bundling[1]	**Programme of Activities**[2]
Number of project activities defined at the beginning	Number of project activities unlimited
New project activities cannot join the project	Every new project activity requires an additional PDD
Calculated / approximated amount of emission reductions	Assumed amount of emission reductions
Project examples	
CDM: Umbrella Fuel-Switching Project in Bogotá and Cundinamarca, Colombia ER = 32,667 t CO_2 p.a. 8 local companies, located in the Colombian Department	**JI**: Pilot programmatic Joint Implementation project in North Rhine-Westphalia (JIM.NRW) - Energy efficiency measures in steam production and heat production Emission reduction: approx. 244,400 t CO_2 (08-12) Measures expected: ~ 110

[1] General principles for bundling, Annex 21, EB 21

[2] Guidance on registration of project activities under a programme of activities as a single CDM project activity, Annex 38, EB 32

Figure 2: CDM Bundling and Programme of Activities (PoA)

5. Experiences with programmatic approach to JI in Germany

To develop programmatic JI projects Track 1 procedure has to be chosen at present. This is because the JI Supervisory Committee (JISC) argues that it lacks the mandate to accept Programme of Activities under JI. Therefore, Track 2 procedure is currently not being available, which means that Programmes of Activities under JI can only be developed bilaterally on Federal State level.

Germans Designated Focal Point (DEHSt) allows JI projects in Germany and supports Track 1 procedures for Programme of Activities. Therefore, some programmatic JI projects have already been developed and implemented in Germany.

DEHSt sets the formal requirements:

- Annex 38 / EB 32 para. 63 decisions from CDM applicable for Programme of Activities under JI in Germany
- In general, formal requirements for CDM shall be used (documents: PoA-DD, CPA-DDs, Real Case CPA-DDs)

Being possible under JI, DEHSt also alleviates some procedures:

- Combination of two different measures under one Programme of Activities is possible
- No further validation of a JI programme activity (= JI project activity under a PoA) is required; procedures are done in course of verification
- Monitoring:
  - Only verification of control samples (10%) is required

JIM.NRW - First German programmatic JI-project

Within the scope of the concrete application of the project-based Kyoto-mechanism, the Ministry of Economics of the Federal State of North Rhine-Westphalia intends to implement a pilot programmatic Joint Implementation (JI) project for this federal state. This is supposed to offer an incentive for the advanced renewal and modernization of heating and steam boilers, both with and without fuel switch, which is not covered by the EU-Emission Trading Scheme (EU-ETS)

Target groups are small and medium sized companies as well as public facilities in North Rhine-Westphalia. Thus energy savings are incentivised in steam and heat production in the industry, manufacturing as well as office buildings.

The implementation of the JI-project is effected in accordance with the Track1- procedure and in the terms of the “Programmatic CDM”. In this manner, new participants can be admitted continuously to the JI-project, provided that they comply with the participation criteria – without the need for passing through the (JI-) authorisation process again.

This means that the applicant of the programme is credited the proceeds of emission reductions, which are the result of actual measures, in the form of ERUs.

Emission reductions can be achieved by:

- efficiency increase due to improvement of the annual use efficiency of the boiler plant

- reduced CO_2-emissions due to lower specific emission values in case of fuel switch

The EnergieAgentur.NRW (www.energieagentur.nrw.de), which also functions as project applicant, conducts the entire procedure. The participants in the JI-project put specific reduction measures into practice and receive a refund according to their reduction achievements. An impartial monitoring determines the actual reduction volume.

The final approval for JIM.NRW was issued by the competent national authority on 24 January 2008.

6. Future outlook and prospects of programmatic approach to JI

FutureCamp has developed several programmatic JI projects for conversion of heating systems by fuel switching, rehabilitation of buildings, and efficiency increase in heat production and use in the industrial/manufacturing and the private and commercial sectors in Germany. These projects are in different stages of development.

Table 2: Examples of programmatic JI projects in Germany

Title	Target group	Supported technology	Emission reduction 2008-12 (in tCO2e)	Status
JIM.NRW	Business /industry	Renewal of heat and steam boilers	250.000	approved
„Klimabonusprogramm Heat Pumps“ of RWE WWE	Households & Business /industry	Electric heat pump	112.000	endorsed
„Ökobonusprogramm Business/Industry Customers“ of Bayerngas	Business /industry	Gas powered heat pump & renewal of heat and steam boilers with fuel switch	160.000	endorsed

If approved by the relevant authorities all have the potential to be replicated by other actors – in Germany as well as in other Annex B countries.

We believe that the main potential for programmatic JI projects in Europe lies in:

- Measures for energy efficiency and fuel switching in the housing sector and business enterprises;
- Measures for new heating technologies in the housing sector and business enterprises;

Against the background of the potential for programmatic JI projects and the positive first experiences made in Germany, we suppose that other Annex B countries will also set up regulations for the development of programmatic JI projects.

7. Conclusion

The implementation of JI projects can be an interesting part of a company's climate strategy. Still this has to be tested in a case-by-case study. Furthermore JI projects also provide valuable information regarding blind spots in the incentive structure of the existing instruments.

Particularly the programmatic approach is an interesting option from a governmental point of view, as it allows for giving incentives for the implementation of many small emission reduction activities.

First experiences made in Germany are very positive. As long as the JI Supervisory Committee (JISC) argues that it does not have the mandate to accept Programme of Activities under JI, the so far gathered German experiences will still serve as a model for other JI host countries to set up national regulations to accept programmatic approaches under Track 1.

8. Reference

CDM EB 21, Annex 21: General principles for bundling

CDM EB 32, Annex 38: Guidance on registration of project activities under a programme of activities as a single CDM project activity

Directive of the European Parlament 2004/101/EG (Linking Directive)

ProMechG (Linking Flexible Mechanisms Act) of Federal Republic of Germany 2007

Operational Rating vs Asset Rating vs Detailed Ssimulation

Ljiljana Marjanovic-Halburd,
Department of Built Environment, Faculty of Science and Technology, Anglia Ruskin University, Chelmsford, UK

Ivan Korolija, Rob Liddia, Andrew Wright
Institute of Energy and Sustainable Development, De Montfort University, , Leicester, UK

Abstract

It is widely acknowledged that carbon dioxide emission is one of the primary causes of global warming. The Kyoto protocol, to which the European Union (EU) is a signatory, has an objective to reduce emissions of six key greenhouses gasses. This objective is unlikely to be met without the introduction of more primary legislation. Throughout the EU, the building stock is responsible for around 45% of all carbon emissions and this sector is clearly a primary target for legislative actions. This has led to the introduction of the Energy Performance of Building Directive (EPBD).

The EPBD requires several different measures to achieve prudent and rational use of energy resources and to reduce the environmental impact of the energy use in buildings. The three main components for implementation of the Directive are: calculation methodology, energy certificate and inspections of boilers and air-conditioning. This paper is concerned with energy certificates of buildings.

The principal categories for the energy certificate scheme are Asset rating, based on calculated energy use and Operational rating, based on metered energy. The Asset rating is determined by modelling the building under a defined set of standard conditions of occupancy, climate, environment and use. Asset rating includes energy use of heating, cooling, hot water, ventilation and lighting for non-domestic buildings. It will apply to both new and existing buildings. In the case of existing buildings, the calculation methodology for Asset rating will have to take into account that design data is unlikely to be available in existing buildings. In contrast, the Operational rating, will be based on metered energy. The metered energy consumption includes energy uses for all purposes. These intrinsic differences opened a debate about if these two ratings are at all comparable, and if so under which circumstances.

This paper, as part of the UK research project "Carbon reduction in buildings", investigates the issues surrounding the application of Asset rating on existing buildings and its compatibility with Operational Rating, but also with detailed simulation software. The case study is a typical narrow plan office building hosting University estate built in early 1970 with treated floor area of 1280m^2 on 4 flours. The methodology used for the Asset rating is UK national calculation methodology SBEM, while the detailed simulation program used is DesignBuilder. In absence of a UK national methodology for Operation rating, EPLabel software has been applied, although the building energy consumption has been compared with UK design guide for office buildings. The significant differences in results (for gas 207kWh/m^2 vs 276kWh/m^2 vs 164kWh/m^2) suggest that great care and understanding must in employed while producing and interpreting building energy certification.

Introduction

Promoting energy efficiency in buildings in the European Union has gained prominence with the adoption of the Directive on Energy Performance of Buildings (EPBD) in 2002. The EPBD requires several different measures to achieve prudent and rational use of energy resources and to reduce the environmental impact of the energy use in buildings. The three main components for implementation of the Directive are:

1. calculation methodology,
2. energy certificate and
3. inspections of boilers and air-conditioning.

The calculation methodology is used to determine the data for energy certificate of buildings and it allows for different levels of complexity:
1. simplified hourly or monthly calculation or
2. detailed calculations.

The principal categories for energy certificate scheme are:
1. Asset rating, based on calculated energy use under standardized occupancy conditions and
2. Operational rating, based on metered energy.

Long before EPBD, ever since 1993, various EU documents were clearly indicating the importance of the energy reduction in building sector. Over the last decade building energy performance standardization and legislation is in many EU member states considered to be an attractive strategy for increasing the energy efficiency of new and existing buildings in both domestic and non-domestic building sectors since energy regulation and energy certification are two main mechanisms to control the energy consumption in buildings.

The calculation methodology for Asset rating has to be based on the characteristics of a building and its installed equipment assuming standard conditions for occupancy, climate , environment and use. Operational rating is based on metered energy consumption which includes energy uses for all purposes and in actual conditions. Some authors, like in (Roulet, 2006), suggest that Asset and Operational ratings should not be compared at all. However, if they are to if not increase then at least inform on building sector energy efficiency, at least these two mechanisms must complement each other.

Energy certification of buildings requires a method that is applicable to both new and existing buildings and should treat them in an equivalent way. However a design data is unlikely to be available in the case of existing buildings. A methodology for providing “missing” data in order to calculate energy use for heating and cooling, ventilation, domestic hot water and lighting might be of at least equal importance as calculation engine itself.

This paper investigates the issues surrounding the application of Asset rating on existing buildings and its compatibility with Operational Rating, but also with detailed simulation software. The presented research is part of UK Carbon reduction in buildings, CaRB, research project, http://www.carb.org.uk/.

The case study

The Building

The case study, Southgate House, is a typical narrow plan office building leased by De Montfort University and hosting the University Estates Department. It is built in early 1970 with floor area of 1280m^2 on 4 flours. The example building is one of the first buildings to be surveyed in Leicester for the CaRB project. Surveying is the essential part of CaRB project since good quality data on buildings and the energy they use is vital to understanding and reducing carbon emissions. The building images are presented in Figure 1.

Figure 1 Southgate building outside and inside corridor view

The building is five stories high. Typical stories are 11m wide and 27m long with 3m between floor levels. The ground floor is largely open to the air, being a car park, with a small untreated entrance lobby, plus an electricity substation. Above the ground floor are four floors of office space, heated by hot water radiators and cooled by air. The air-conditioning system is Variable Refrigerant Flow, VRF, system. Two LTHW boilers using natural gas are used for the heating and hot water. Also heat recovery ventilators are used, one per floor. Since there was no available information on their type, it was assumed with certain level of confidence that they are plate type heat exchangers. Northern and southern facades are concrete without insulation. All external walls at ground level are concrete without insulation. Western and eastern facades are concrete with internal insulation. Twenty windows of 1.2m width and 1.8m high are mounted at west and east façade. The windows are single glazed with aluminum frame.

Southgate's building metered energy consumption for 2004 together with the UK design guide for offices, ECON 19, is presented in Table 1

Table 1 Building metered energy consumption and ECON Guide benchmarks

	Building metered energy use	**ECON 19 "Typical" building benchmark**	**ECON 19 "Good practice" building benchmark**
Gas	247.72kWh/m^2/year	178 kWh/m^2/year	97 kWh/m^2/year
Electricity	111.69kWh/m^2/year	226 kWh/m^2/year	128 kWh/m^2/year

According to the CIBSE energy benchmarks for office buildings, the Southgate building is as almost good as "good practice" category for electricity consumption and worse than "typical practice" for gas consumption (*, 2000).

Building Operational Rating

In the UK the Operational Rating is indroduced by Display Energy Certificates (DECs) scheme. A DEC is always accompanied by an Advisory Report that lists cost effective measures to improve the energy rating of the building. Display Energy Certificates are only required for buildings that are occupied by a public authority or an institution providing a public service to a large number of persons with a total useful area greater than 1000m^2. Display Energy Certificates are valid for one year. The accompanying Advisory Report is valid for 7 years. The requirement for Display Energy Certificates comes into effect from 1 October 2008. In the longer term, the UK Government has announced its intention to consult on whether this requirement should be extended to include private sector buildings occupied by commercial organisations where large numbers of members of the public regularly visit the building. Such an extension would be subject to separate legislation.

In the absence of national method, the EPLabel on-line web tool using UK national sets of parameters, (*, 2007), have been used to produce the Operational rating for the Case Study building. The results are presented in Figures 2 and 3.

Figure 2 EPLabel on-line tool results

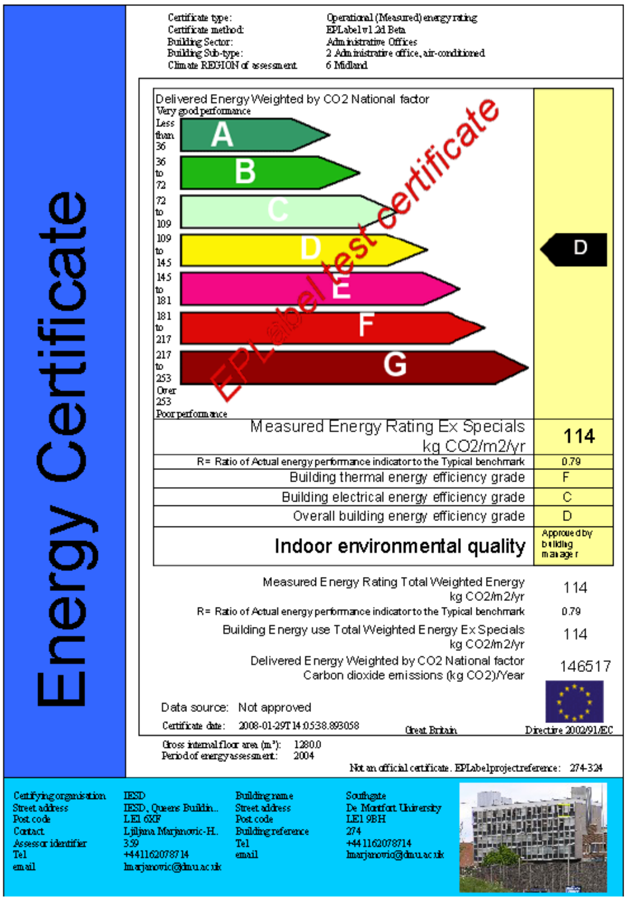
Measured Energy Rating (MER)

Electricity										
Delivered Energy Carriers	Supplied kWh/yr	Specials kWh/yr	Weather Correction kWh/yr	Supplied at Regional Climate kWh/yr	Ex Specials at Regional Climate kWh/yr	Energy Weighting Factor kg CO2/kWh	Total Weighted Energy kg CO2/m2/yr	Ex Specials kg CO2/m2/yr	Good kg CO2/m2/yr	Typical kg CO2/m2/yr
Grid electricity	*167175*	*0*	*0*	*167175*	*167175*	*0.568*	*74.184*	*74.184*		
Fuel/Thermal										
Delivered Energy Carriers	Supplied kWh/yr	Specials kWh/yr	Weather Correction kWh/yr	Supplied at Regional Climate kWh/yr	Ex Specials at Regional Climate kWh/yr	Energy Weighting Factor kg CO2/kWh	Total Weighted Energy kg CO2/m2/yr	Ex Specialskg CO2/m2/yr	Good kg CO2/m2/yr	Typical kg CO2/m2/yr
Natural gas	*265781*	*0*	*0*	*265781*	*265781*	*0.194*	*40.282*	*40.282*		
Overall Total							**114.466**	**114.466**	**72.359**	**144.718**
MER Grade							D	(R = 0.79)		
MER Grade Ex Specials								D	(R = 0.79)	

Building Energy Use (BEU)

Electricity									
All Energy Carriers	Supplied kWh/yr	Specials kWh/yr	Weather Correction kWh/yr	Supplied at Regional Climate kWh/yr	Ex Specials at Regional Climate kWh/yr	Energy Weighting Factor kg CO2/kWh	Total Weighted Energy ex Specials kg CO2/m2/yr	Good kg CO2/m2/yr	Typical kg CO2/m2/yr
Grid electricity	*167175*	*0*	*0*	*167175*	*167175*	*0.568*	*74.184*		
Total Electricity							*74.184*	*57.652*	*115.304*
BEU Electricity Grade							C	(R = 0.64)	
Fuel/Thermal									
All Energy Carriers	Supplied kWh/yr	Specials kWh/yr	Weather Correction kWh/yr	Supplied at Regional Climate kWh/yr	Ex Specials at Regional Climate kWh/yr	Energy Weighting Factor kg CO2/kWh	Total Weighted Energy ex Specials kg CO2/m2/yr	Good kg CO2/m2/yr	Typical kg CO2/m2/yr
Natural gas	*265781*	*0*	*0*	*265781*	*265781*	*0.194*	*40.282*		
Total Fuel/Thermal							*40.282*	*14.707*	*29.414*
BEU Thermal Grade							F	(R = 1.37)	
Overall Total							**114.466**	**72.359**	**144.718**
BEU Grade							D	(R = 0.79)	

Figure 3 EPLabel Operational Rating certificate



If the results from the ECON 19 and EPLabel are compared it can been seen that both methods have indicated that the buidling gas consumption is "worse" than it's electrical energy consumption. The overall Operation Rating of D can be considered a good result for at least 35 years old building bult in time when prcatically no buidling regulation covering non-domestic building stock in the UK has existed.

Building Asset Rating

The UK National Calculation Method (NCM) for the EPBD is defined by the department for Communities and Local Government (CLG). The procedure for demonstrating compliance with the Building Regulations for buildings other than dwellings is by calculating the annual energy use for a proposed building and comparing it with the energy use of a comparable 'notional' building. Both calculations make use of standard sets of data for different activity areas and call on common databases of construction and service elements. A similar process is used to produce an 'asset rating' in accordance with the EPBD. The NCM therefore comprises the underlying method plus the standard data sets. The implementation for the Asset Rating Certificates also comes into effect by October 2008.

The NCM allows the actual calculation to be carried out either by an approved simulation software, or by a new simplified tool based on a set of CEN standards. That tool has been developed for CLG by BRE and is called SBEM **-** Simplified Building Energy Model. It is accompanied by a basic user interface **-** iSBEM**.** SBEM is a computer program that provides an analysis of a building's energy consumption. SBEM calculates monthly energy use and carbon dioxide emissions of a building given a description of the building geometry, construction, use and HVAC and lighting equipment. It was originally based on the Dutch methodology NEN 2916:1998 (Energy Performance of Non-Residential Buildings) and has since been modified to comply with the emerging CEN Standards.

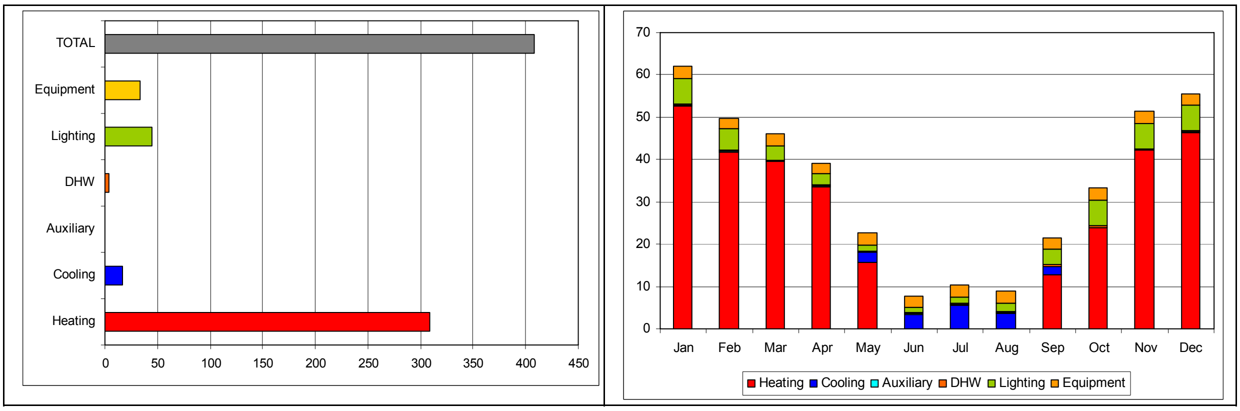
As already mentioned, for the existing building the issue of available design data is very important. Table 2 gives the listing of construction and glazing characteristics for the Southgate building according to SBEM database.

Table 2 Building fabrics characteristics based on SBEM

PROJECT DATABASE				
Name	Generally used in walls that connect the zone to:	Construction from the library		U-value
		Category	Library	[W/m²K]
Walls				
External wall N/S	Exterior	Solid (masonry) wall	Solid concrete wall, uninsulated	1.7
External wall W/E	Exterior	Solid (masonry) wall	Cast concrete wall, internal insulation	0.83
Internal wall ground	Unheated adjoining space	Curtain wall	Curtain wall, pre-1981	2.3
Internal wall	Conditioned adjoining space	Curtain wall	Curtain wall, pre-1981	2.3
Roofs				
Roof	Exterior	Flat roof	Flat roof, pre-1981	1.8
Floors				
Floor	Underground	Solid ground floor	Solid ground floor, uninsulated	0.53
Floor ext.	Exterior	Solid ground floor	Solid ground floor, uninsulated	0.53
Floor internal 1	Unheated adjoining space	Solid ground floor	Uninsulated floor	1
Floor internal and ceiling	Conditioned adjoining space	Solid ground floor	Uninsulated floor	1
Doors				
Door		Personnel door	Uninsulated personnel door	3
Garage door		Vehicle access door	Vehicle access door, pre 1995	
Glazing				
Glazing		4 mm single glazing (clear glass)	Metal frame, thermal break, conventional glazing spacer, Aluminium window frame	5.264

In order to apply SBEM calculation engine, the building had to be zoned. Following SMEB zoning guidelines, each floor from 1st to 3rd was divided into two zones, west and east, while the fourth floor remained one single zone. SBEM HVAC systems Template dos not recognize the combination of systems existing in the Southgate building: boiler radiation heating system and VRF cooling system. To only way around this was to apply SBEM twice: first time as if the building has only radiator heating system and second time as if the building has only VRF system. The combined output is presented in Figure 4.

Figure 4 Buildings Energy end uses, SBEM results



The solution existing in the Case Study building, where the building is retrofitted with the air-conditioning system decades after it is built, is not un-common, especially for the heavily glazed buildings such as Southgate House. Considering the current limitation of SBEM that the building can have only one central system, it is difficult to see how this building can be certificated. The Asset Ratings for the Southgate House assuming only radiator heating or only VRF air-conditioning system are presented in Figures 5 and 6 respectively.

Figure 5 SBEM rating for radiator heating only with VRF system and with only

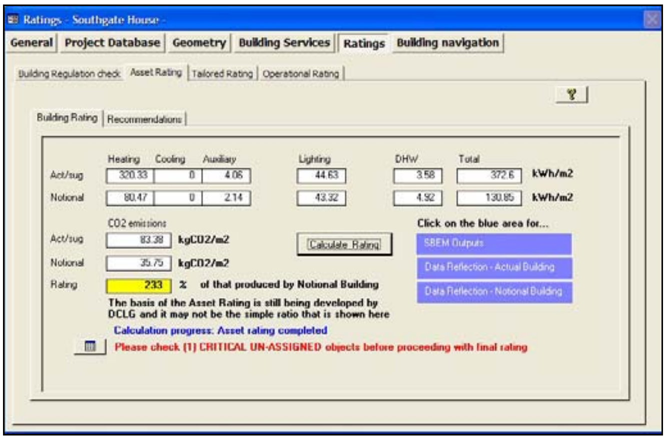
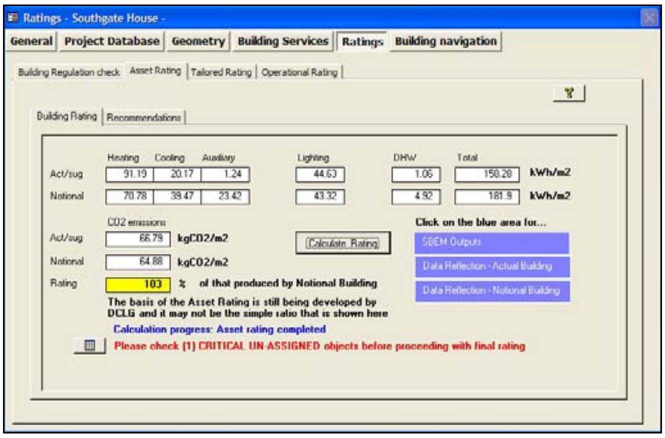


Figure 6 SBEM rating for VRF air-conditioning system only



One way to interpret these two certificates would be that the building can improve its energy efficiency in winter months when only radiator heating system is used, whilst in summer months, when the VRF system is used for cooling, is almost as energy efficient as notional building.

Detailed Simulation

The use of detailed simulation software will almost certainly be the way of providing Asset Rating for the new buildings when all of the design parameters are know. However it is of interest to explore how would detailed simulation software deal with the existing buildings when no design parameters are available. For these purposes the DesignBuilder detailed simulation software has been used. The survey information about the Southgate House translated into DesignBuilder parameters is presented in Table 3.

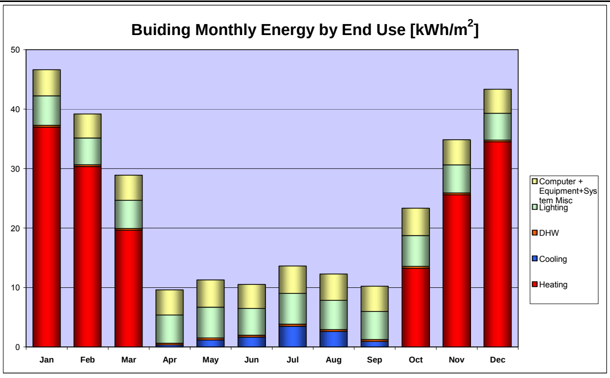
Table 3 DesignBuilder Building Fabric Inputs

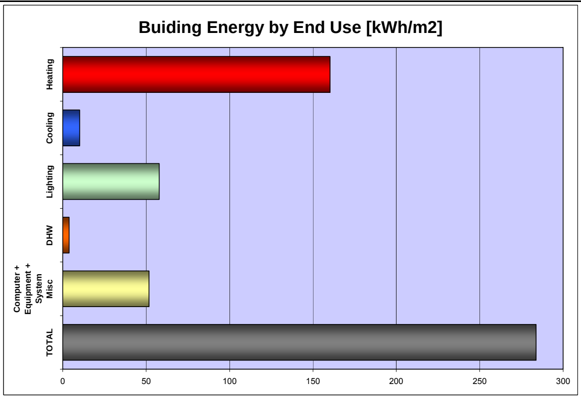
PROJECT DATABASE		
Name	**Description**	**U-value [W/m^{2}K]**
External walls		
Southgate N/S	• Cast concrete − 200 mm	2.824
Southgate W/E	• Cast concrete − 30 mm • MW stone wool − 30 mm • Air gap − 10 mm • Gypsum plasterboard − 15 mm	0.831
Roof		
Flat roof	• Asphalt − 20 mm • Cast concrete − 200 mm	2.757
Floors		
Ground floor slab	• Concrete slab − 130 mm	3.058
Internal floor slab	• Concrete slab − 200 mm	2.652
Internal partitions		
Southgate − internal_ground	• Aerated concrete block − 200 mm	0.937
Internal partitions 1st ÷ 4th floor	• Light weight 2 x 25 mm gypsum plasterboard with 100 mm cavity	1.712
Glazing		
Single clear − 6 mm	• Total solar transmition (SHGC) − 0.81	6.121

Comparing the values in Tables 2 and 3 it can be seen that DesignBuilder is more conservative on building fabrics quality than SBEM.

The results obtained from DesignBuilder are given in Figure 7.

Figure 7 DesignBuilder results





The Asset Rating provided by DesignBuilder is presented in Table 4.

Table 4 Southgate House Asset Rating according to DesignBuilder

Summary	
Name	Southgate House
Date	30/01/2008
Building type	OFFICE
Treated Floor area	1279.34
Assessment type	4-EPBD Asset rating
Dimension	Inner
Calculation method	1-EnergyPlus
Climate base location	GBR_Finningley_IWEC
Heating degree-days	3116
Cooling degree-days	689
Output	
Actual building carbon intensity	79.95kg CO2/m2
Regulations compliant variant carbon intensity	59.31kg CO2/m2
Asset energy performance rating	1.3480
Class	**C**

Discussion

This paper investigates the issues surrounding the application of Asset rating on existing buildings and its compatibility with Operational Rating, but also with detailed simulation software as part of UK Carbon reduction in buildings, CaRB, research project. The case study is a typical narrow plan office building hosting University estate built in early 1970 with treated floor area of 1280m^2 on 4 flours. The methodology used for the Asset rating is UK national calculation methodology SBEM, while the detailed simulation program used is DesignBuilder. In absence of a UK national methodology for Operation rating, EPLabel software has been applied, although the building energy consumption has been compared with UK design guide for office buildings.

The Southgate House scored D Operational Rating using EPLabel web tool which can be considered a good result for at least 35 years old building with original boilers and retorfitted VRF air-conditiong system in the later stage of building life. Also that result is brodely speaking similar to buidling energy performance comparison with ECON 19 Guides, see Table 1.

Since SBEM gives Asset rating in percentages and not in letter scale it is difficult to compare the results for the Southgate House directly with the C Asset Rating obtained by detailed simulation software. It is possible however to compare the predicted annual carbon emission. Detailed simulation software predicted annual CO_2 emission of 80kgCO_2/m^2, Table 4. This result is similar when compared with the SBEM results of 83.38kgCO_2/m^2 and/or 66.79kgCO_2/m^2, Figures 5 and 6 respectively, suggesting overall annual CO_2 emission somewhere around 95kgCO_2/m^2. If the Asset Rating is interpret as building theoretical potential and Operational Rating as operational reality, the result would indicated that there is a room for improvement, but also that the gap should be relatively easy to close.

However, the significant differences in results can be compared when comparing energy end use breakdown, rather than it's comparison with notional building or benchmarks. The difference between detailed simulation software and SBEM prediction in Southgate House end energy use is given in Figure 7.

Figure 7 Building Energy End Use breakdown as predicted by SBEM (Figure 7a) and DesignBuilder (Figure 7b)

Figure 7a SBEM results

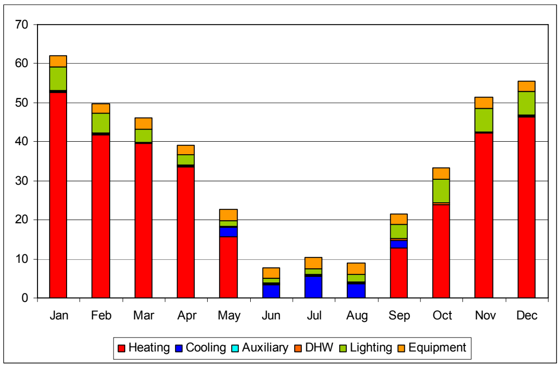
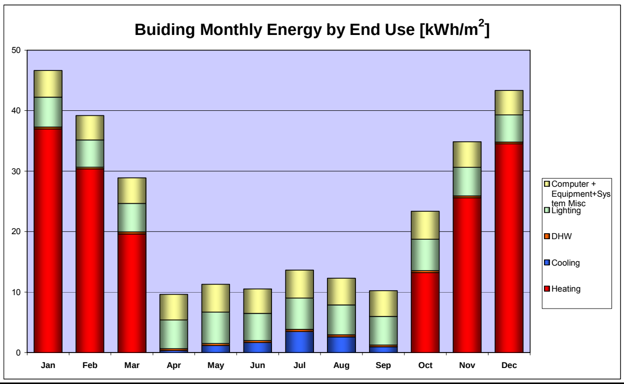


Figure 7b DesignBuilder results



Since the certificates should be accompanied with the reports and suggestions on how to improve the building performance, if the breakdown of energy end-use is not predicted or benchmarked reliably it is difficult to see how could report than point to real problems in building energy use. The modelling predictions were rather different for the annual fuel consumption too as presented in Table 5.

Table 5. Building annual energy consumption and CO_2 emission

	Metered energy consumption	**SBEM results**	**DesignBuilder results**
Gas	247.72kWh/m^2	312.2 kWh/m^2	164.06 kWh/m^2
Electricity	111.69kWh/m^2	100.1 kWh/m^2	119.72 kWh/m^2
CO_2 emission	114kgCO_2/m^2	≈ 95kgCO_2/m^2	80kgCO_2/m^2

When comparing different software tools it is usually of interest to comment on time intensities involved in their implementation. iSBEM, being a very basic user interface, requires a large amount of data about the building geometry to be calculated and entered manually. The calculation itself is fast. DesignBuilder is above all detailed simulation software which primary purpose is to be a design tool, whilst Asset rating is one extra feature it offers. As any established building design tool, it has user friendly interface allowing easy data input, but the execution time for Asset rating is naturally much longer than SBEM.

Conclusion

This paper investigates the issues surrounding the application of Asset rating on existing buildings and its compatibility with Operational Rating, but also with detailed simulation software as part of UK Carbon reduction in buildings, CaRB, research project. The case study is a typical narrow plan office building hosting University estate built in early 1970 with treated floor area of 1280m^2 on 4 flours. The methodology used for the Asset rating is UK national calculation methodology SBEM, while the detailed simulation program used is DesignBuilder. In absence of a UK national methodology for Operation rating, EPLabel software has been applied, although the building energy consumption has been compared with UK design guide for office buildings.

The results for the Operational Rating, D, and Asset Ratings, C, are rather consistent with the building reality and are also largely compatible between different tools used. However the values for absolute prediction between tools for both fuel break down and end energy use break down differ significantly. These significant differences suggest that great care and understanding must in employed while producing and interpreting building energy certification.

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IEECB'08

Energy Performance of Buildings Directive (EPBD)

Implementation of EPBD Article 7.3 in Germany and the UK: Comparison of Methodologies and Procedures

R. Cohen, Energy for Sustainable Development
I Therburg, Energiereferat
W. Bordass, William Bordass Associates
J. Field, Power Efficiency

Abstract

EPBD Article 7.3 states that "Member States shall take measures to ensure that for buildings with a total useful floor area over 1,000 m^2 occupied by public authorities and by institutions providing public services to a large number of persons and therefore frequently visited by these persons an energy certificate, not older than 10 years, is placed in a prominent place clearly visible to the public.". Both Germany and the UK have published their legislation to implement this requirement. This paper compares and contrasts the approaches in each country. It covers:

- the methodology;
- the content of the energy certificates to be displayed by public buildings;
- the Advisory Report (giving the recommended energy improvement measures);
- the training and accreditation requirements for assessors.

Except in Scotland, the UK is using two complementary procedures for quantifying the energy efficiency of a non-residential building:

1. Energy performance certificates (EPCs) which reflect the intrinsic efficiency of a building assuming standard use (the Asset Rating). EPCs are the responsibility of the owner, are based on calculation for heating, hot water, cooling, ventilation and lighting only, and will be required when a building is constructed, sold or let, i.e. as a part of a property transaction.
2. Display Energy Certificates (DECs) which are based on the actual total amount of energy used by a building over a year (the Measured or 'Operational' Rating), and compared with an appropriate benchmark. DECs are required to fulfil EPBD Article 7.3 and must be displayed prominently by all 'Public Buildings' over 1,000m^2 from 1st October 2008.

Germany is using the same principles for energy certification of non-residential buildings. However, in contrast to the UK, the building owner is allowed to choose whether the certificate on public display is based on the asset rating or the operational rating.

Background

The provenance of operational ratings can be traced back in many respects to UK government-funded studies in which the UK authors participated at the end of the 1980s. One of these studies involved helping nine sets of industry-leading design teams and their clients to produce exemplar low energy non-residential building designs. Another collated the results of examining the energy performance in use of about 100 office buildings in some detail, 15 of which were published as energy efficiency case studies. These data, together with a much larger set of background statistics, formed the backbone for the UK's seminal document on operational ratings, Energy Consumption Guide 19, Econ 19 (latest edition Action Energy (2003)).

The design studies employed the latest dynamic simulation models to predict annual energy use. Their conclusions exposed in stark relief a huge gulf between the predictions of building energy use by computer software and the observed outcomes in terms of measured energy use. As a consequence the UK government and a respected industry Journal eventually funded a seven year (1995 – 2002) series of post occupancy studies called Probe (BR&I 2001) which investigated and published in some detail the actual performance-in-use of twenty buildings that had been featured in the Journal at the time of their completion (often for their innovative design and low energy aspirations). Probe was lauded by the industry for drawing its attention to the massive credibility gaps which could occur between design intent and achieved performance, even for these leading buildings.

At this time, the UK authors also helped to produce and test TM22 (CIBSE, 1999), another key element of operational rating methodology. It is based on a 'tree-diagram' approach to energy assessment and reporting which both creates an end use breakdown of actual energy use and allows benchmarking at many levels, from the installed capacity of equipment, through systems energy use up to the whole building. The tree diagram methodology underpinned Econ 19, from which TM22 was a natural progression.

In April 2001 the EC published its draft proposals for the Energy Performance of Buildings Directive (EPBD). At that time, most policy makers and practitioners assumed that energy certificates would be based on so-called asset ratings, a calculated energy performance assuming a standard use, familiar to the designers of new buildings and employed for Building Regulation compliance. The authors saw things differently and launched independently two EC-funded projects to demonstrate the overwhelming benefits of allowing energy certificates to be based also on operational ratings. One of these projects was Europrosper (Cohen, 2004) which aimed to roll out the Econ 19/TM 22 and Probe methodologies for building operational performance assessment to practitioners at a European level. The other was GreenEffect (Therburg, 2005) which aimed to develop robust methodologies for operational ratings in buildings which employ renewable energy sources and high efficiency energy conversion technologies such as heat pumps, CHP and absorption chillers.

Europrosper paved the way for the implementation of building energy certificates based on operational ratings, illustrating a tailored benchmark approach for office buildings based on a tree-diagram model of energy end use but backwardly compatible with the fixed benchmarks in Econ 19. After informal collaboration between Europrosper and GreenEffect, the UK and German authors joined forces in EPLabel (Cohen, 2007), another EC funded project, with the aim of extending methodologies developed for office buildings to six major public building sectors (public administration offices, schools, higher education, sports centres, health and hotels). Both Europrosper and EPLabel informed the development of the EPBD CEN Standards relating to Operational Ratings through detailed contributions to CEN TC89 WG4 which authored the applicable Standards (CEN, 2007).

From this background, the authors have been deeply involved in influencing the legislation for implementing EPBD Article 7.3 in their respective countries. The UK authors were commissioned in July 2006 to suggest a strategy for implementing Operational Ratings in England and Wales. This encompassed the approach developed by EPLabel for mixed-use buildings and a procedure known as a Landlord Energy Statement (LES) for dealing with multi-tenanted buildings, and which is being taken forward for offices by the British Property Federation which represents major UK landlords and their managing agents (BPF, 2007); and is now spreading to other sectors. These methods can be combined to deal with multi-building campuses where some (or all) buildings are not sub-metered. The strategy was completed in September 2006 and informed the UK government's implementation plans for EPBD Article 7.3. The details were developed by technical experts, taking into account the views of government lawyers on how the legislation should be interpreted for the UK context and of the public authorities whose buildings have to display DECs, and became law on 29th March 2007 (Statutory Instrument No. 991, 2007). At the time of completing this paper (February 2008) a few critical aspects remain to be finalised in government guidelines. The reader should be aware that the content of the paper is the authors' present understanding of what will transpire by 1st October 2008, when all public buildings in England and Wales will be required to display a DEC.

In Germany, a discussion about operational and asset ratings started soon after the EPBD was ratified. It initially focused on housing, with a debate between the industry, environmental NGOs and professional engineers. Operational ratings were seen by the industry as an easy, inexpensive and quick solution if with limited insight due to the vagaries created by occupants. Asset ratings were criticised as too time consuming and expensive, an "income generation" programme for engineers and architects. Eventually, at the end of 2005, the legislative process turned to non-domestic buildings. Realising that they had to create thousands of certificates for public display, the Public Authorities put pressure on the government to offer a simple certification method for non-domestic buildings based on an operational rating. A steering group was set up by the Ministry of Building to develop a draft operational rating methodology, and a draft law was published on 16 November 2006. The law was finally passed on 24 July 2007 as an amendment of the German "Energieeinsparverordnung" (EnEV).

The methodology for operational ratings in the UK (ex Scotland)

Defining the building needing a DEC

The 'building' boundary and the requirement for a DEC are determined by the space let or owned by the occupier and whether the occupier is a public authority or an institution providing a public service (see Figure 1). A building with multiple occupiers may need several DECs: each is considered separately. The space of each occupier may be defined as a single building type or a mix of several building types: if mixed-use, the area of each building type must be measured separately in order to calculate an area weighted composite benchmark for the total space.

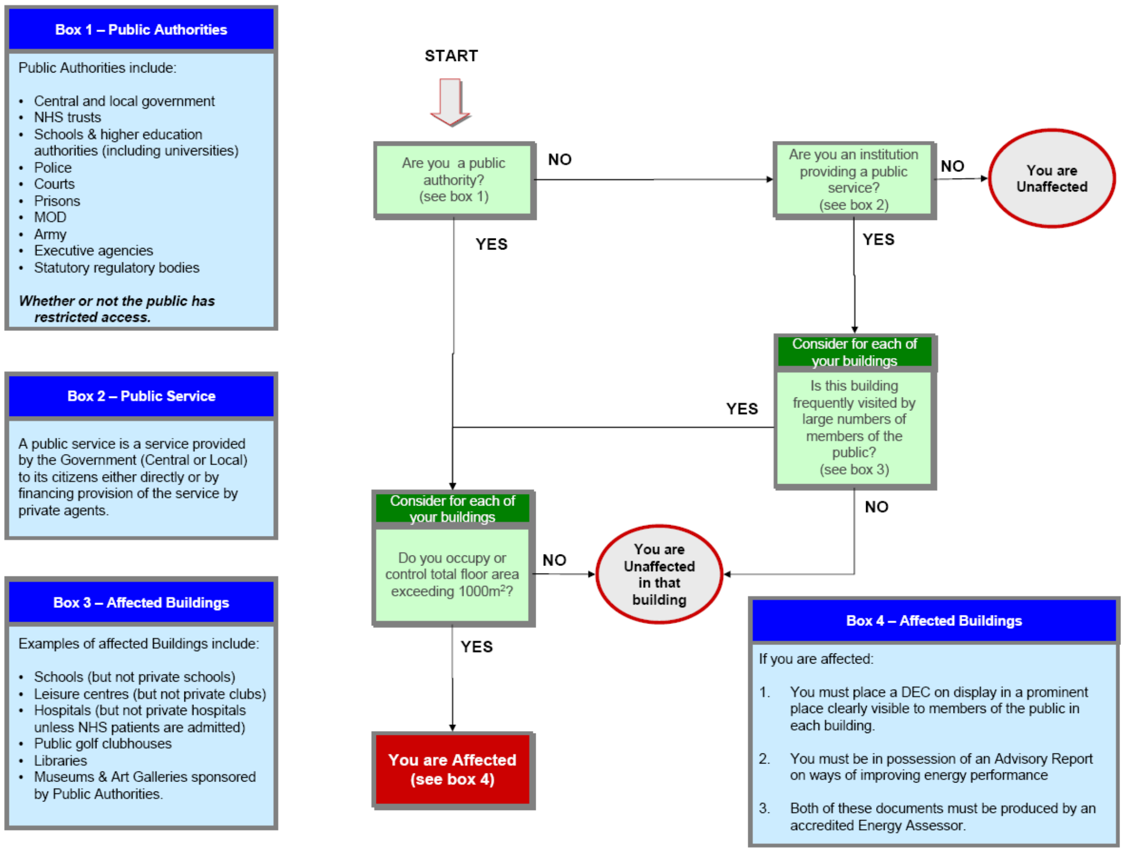


Figure 1 Flow chart defining the buildings requiring DECs in England and Wales

For multi-building sites, the requirement is for any building over 1,000m^2 to display a DEC. Individual buildings with dedicated sub-metering and an applicable benchmark category are given a specific DEC. The total residual energy and total residual composite benchmark are allocated to all the other buildings on the site pro rata each building's area, taking into account data from sub-meters where available. In the absence of any sub-meters, these other buildings will display a DEC calculated on a pro rata basis i.e. they will all receive the same rating, but the total carbon footprint will be different.

Certificate content and layout

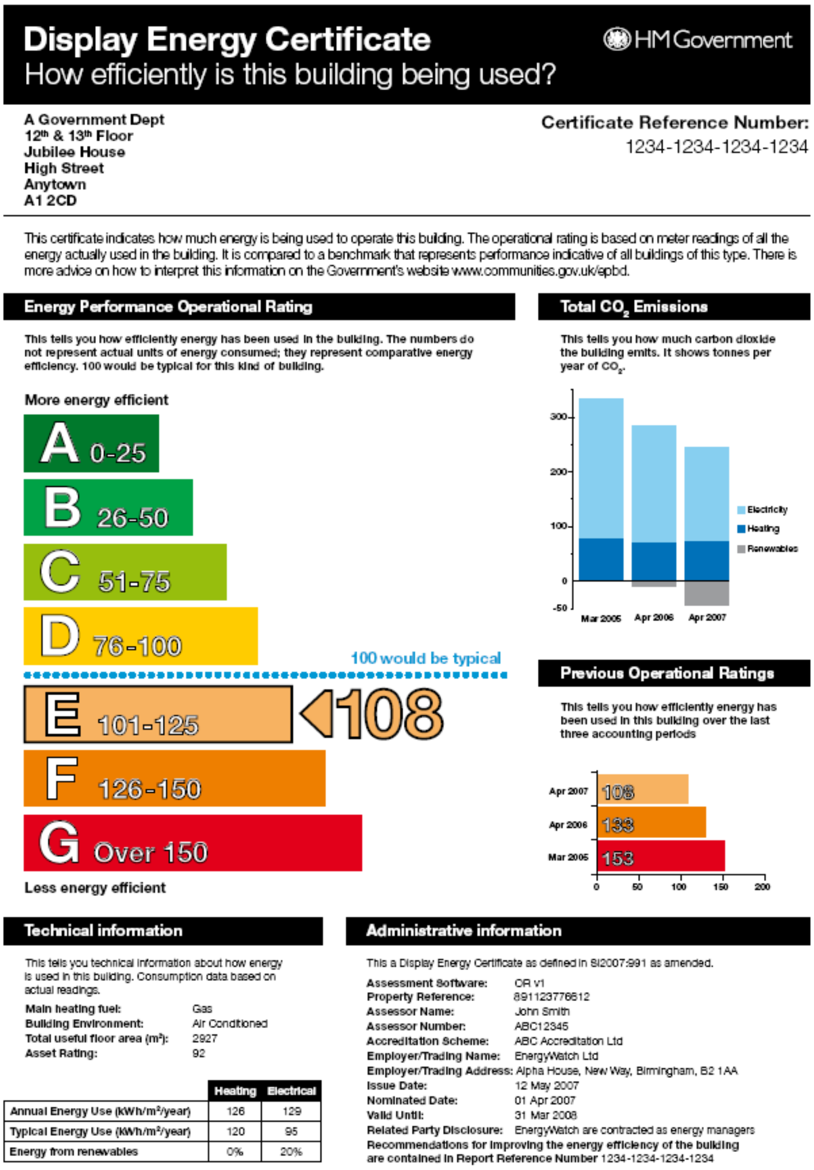
An example of a DEC is shown in Figure 2. It provides four main results:

1. The headline energy performance indicators which comprise a class, i.e. a letter from A to G, as commonly used for other energy labels, and an index, to provide greater resolution, defined as the percentage of the actual CO_2 emissions resulting from energy supplied to the building compared with the benchmark emissions typical for the building type being assessed (per m^2 per year). The A to G scale is simple and linear, so that a typical building, with an index of 100, lies at the D/E boundary. The index is called the operational rating, even though CEN Standard prEN 15603 ascribes this term to the absolute total emissions per year which are the subject of the next point.
2. The total carbon footprint of the building in tonnes of CO_2 per year, for the last three years, showing separately the contributions from electricity (green tariffs are ignored), and fuel and heat. The CO_2 saved by the use of renewable energy sources (RES), either on site e.g. PV or

through delivered energy e.g. biomass, is shown below the axis. In accordance with CEN Standard prEN 15603, the CO_2 saved by RES is calculated by working out the emissions from the extra conventional energy that would have been required were the RES not present.

3. The index or (as defined for the UK) the “operational rating” for the last three years.
4. Technical information which allows technically aware people to understand the energy story behind the rating based on CO_2 emissions. It includes the kWh/m^2/year of electricity and fuel and heat and the energy supplied by RES.

A DEC is valid for a period of 12 months from its nominated date, which is a date expiring not later than three months after the period over which the rating displayed on the certificate has been calculated. This allows a short period for the data for the chosen 12 month period to be collected and analysed, submitted to the accrediting body and the certificate issued.



Display Energy Certificate
How efficiently is this building being used?

HM Government

A Government Dept
12th & 13th Floor
Jubilee House
High Street
Anytown
A1 2CD

Certificate Reference Number:
1234-1234-1234-1234

This certificate indicates how much energy is being used to operate this building. The operational rating is based on meter readings of all the energy actually used in the building. It is compared to a benchmark that represents performance indicative of all buildings of this type. There is more advice on how to interpret this information on the Government's website www.communities.gov.uk/epbd.

Energy Performance Operational Rating

This tells you how efficiently energy has been used in the building. The numbers do not represent actual units of energy consumed; they represent comparative energy efficiency. 100 would be typical for this kind of building.

Total CO_2 Emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO_2.

Previous Operational Ratings

This tells you how efficiently energy has been used in this building over the last three accounting periods

Technical information

This tells you technical information about how energy is used in this building. Consumption data based on actual readings.

Main heating fuel: Gas
Building Environment: Air Conditioned
Total useful floor area (m^2): 2927
Asset Rating: 92

	Heating	Electrical
Annual Energy Use (kWh/m^2/year)	126	129
Typical Energy Use (kWh/m^2/year)	120	95
Energy from renewables	0%	20%

Administrative information

This a Display Energy Certificate as defined in SI2007:991 as amended.

Assessment Software: OR v1
Property Reference: 891123776612
Assessor Name: John Smith
Assessor Number: ABC12345
Accreditation Scheme: ABC Accreditation Ltd
Employer/Trading Name: EnergyWatch Ltd
Employer/Trading Address: Alpha House, New Way, Birmingham, B2 1AA
Issue Date: 12 May 2007
Nominated Date: 01 Apr 2007
Valid Until: 31 Mar 2008
Related Party Disclosure: EnergyWatch are contracted as energy managers
Recommendations for improving the energy efficiency of the building are contained in Report Reference Number 1234-1234-1234-1234

Figure 2 Building energy certificate to be displayed by public buildings in England and Wales

Defining the floor area used for the DEC assessment

The 1,000m^2 threshold determining whether a DEC is required is based on gross internal area, as defined by RICS. This is also called the Total Useful Floor Area (TUFA). The total area for the DEC Assessment (TADA) is defined as the TUFA less the area of any special energy uses. The total accessible unconditioned area, e.g. unheated attics or basements, must also be measured but is not deducted from TUFA in the calculation of energy performance; the benchmarks allow for a default amount of unconditioned area.

Defining the energy used by the "site"
It is required to identify all energy supplies used by the site e.g. electricity, gas, oil, PV, etc. and have metered values for their use over a 365 day assessment period which must start or end with a date for which there is a meter reading for the main heating fuel. At present it is rare to have meter readings 365 days apart for all energy supplies, so the measurement period for each supply can be 365 ± 31 days and the calculation methodology extrapolates or interpolates to 365 days, using degree days for the main heating fuel and on a linear basis for all other energy supplies. A synchronicity requirement means that the start and the end dates of the measurement period for each energy supply must be within ± 31 days of the start and the end dates of the assessment period (see Figure 3).

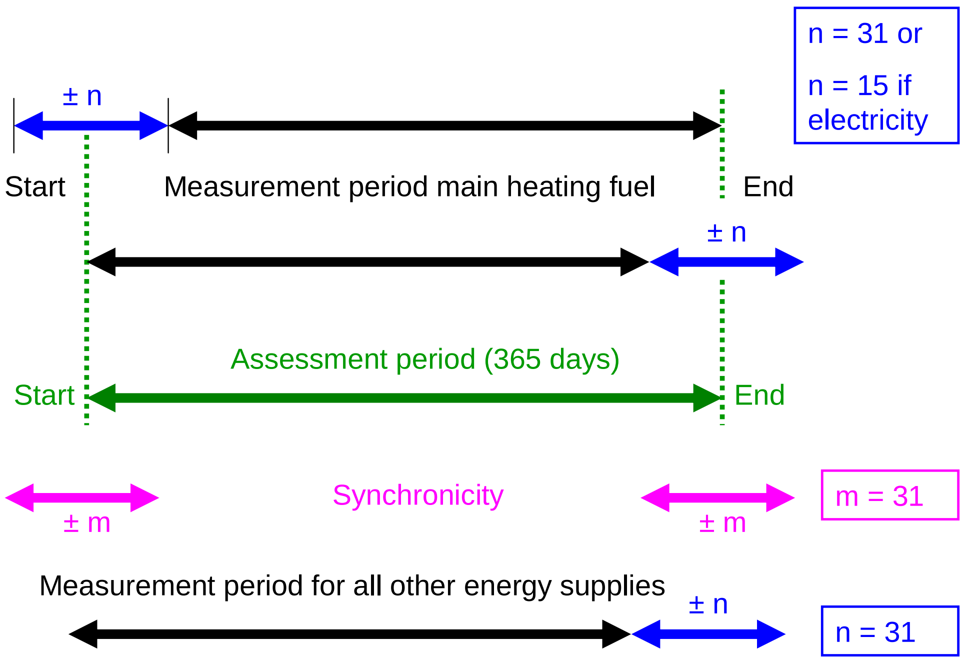


Figure 3 Tolerances for the start and end dates of energy supply measurement periods

Energy supplies are categorised as

- metered electricity
- metered fuel or heat e.g. mains gas or district heating
- bulk deliveries e.g. oil, lpg, coal

For metered energy supplies, it is desirable (but not mandatory) to calculate use over the measurement period from meter readings at the start and the end of the period. For bulk deliveries, use over the measurement period is found from stock levels at the start and the end combined with the sum of all deliveries in-between. The CO_2 intensities of energy supplies are taken as national default values, except for district heating (see below).

Landlord's energy statement (LES)
In a multi-tenanted building, there is a statutory duty on the landlord to collaborate in providing information to each occupier requiring a DEC. The LES is an industry-standard method of doing this, reporting to each tenant their share of the energy used and CO_2 produced by the landlord's services. The method of allocation will vary with the building concerned: some use a simple pro rata basis by area; others also adjust this in relation to each tenant's hours of occupancy (either actual or as in their tenancy agreement); while others make use of metering. In order to prepare its DEC, a tenant will need to combine the energy reported in the LES with any energy it procures directly.

Energy statement from district heating supplier
Where a building uses district heating, an occupier will normally have meter readings from the supplier. However, to meet the DEC requirement, the district heating supplier will also need to state the associated emissions (e.g. in kg CO_2/kWh of the heat supplied).

Benchmarks
The benchmarks for "typical" annual energy use have been defined as separate kWh/m^2/year values for electricity and heating fuel for a list of about 240 different building types in the UK. Following a review of existing data, many of these building types have been given the same benchmark values, giving currently a total of only 29 separate benchmark 'categories', into one of which each building type is allocated. Thus, for example, a crown court, a conference centre and a public sector or commercial office have all been placed in the general office benchmark category.

The benchmarks include an allowance for space heating based on a year with 2,021 degree days to base 15.5/15.5ºC - the average of the eighteen degree-day regions in England, Wales and Northern Ireland, and it is specified what proportion of each benchmark value is climate related. Usually the adjustment is applied to the fossil fuel/heat benchmark, unless the building is an all-electric category. The benchmark for a specific building will be corrected for the degree days over the assessment period in the region where the building is located (determined by its post code), taking account of the climate dependency of each benchmark.

Each benchmark value is associated with a standard hours of occupancy per year (e.g. 2,040 hours for offices). Optionally, the benchmarks can be adjusted to take account of the actual hours of occupancy, but only where suitable valid evidence is available, e.g. the published opening hours of a library. The increased benchmark is obtained by entering the actual occupancy hours per year, separately for each building type forming part of the site being assessed, and with a requirement that extended occupancy is only applicable for times when the occupancy level is at least 25% of the nominal maximum occupancy. Each building type has a maximum extended occupancy (e.g. 8,760 hours for offices, 5,355 hours for a sports centre). The percentage increase in the benchmark allowance between the standard hours and the maximum occupancy hours is defined separately for each benchmark category and differs for the heating and the electricity benchmarks.

The standard values for annual electricity and fossil fuel use for each benchmark category are shown in Figure 4, here converted to common units of $kgCO_2/m^2$/year. The values take into account existing statistics but are also informed by a tree diagram energy end use model (see Figure 5) for an iconic example of each building category. As described in a later section, the data for each certificate will be lodged in a central database the analysis of which should in due course allow better benchmarks to be produced for a wider set of building types.

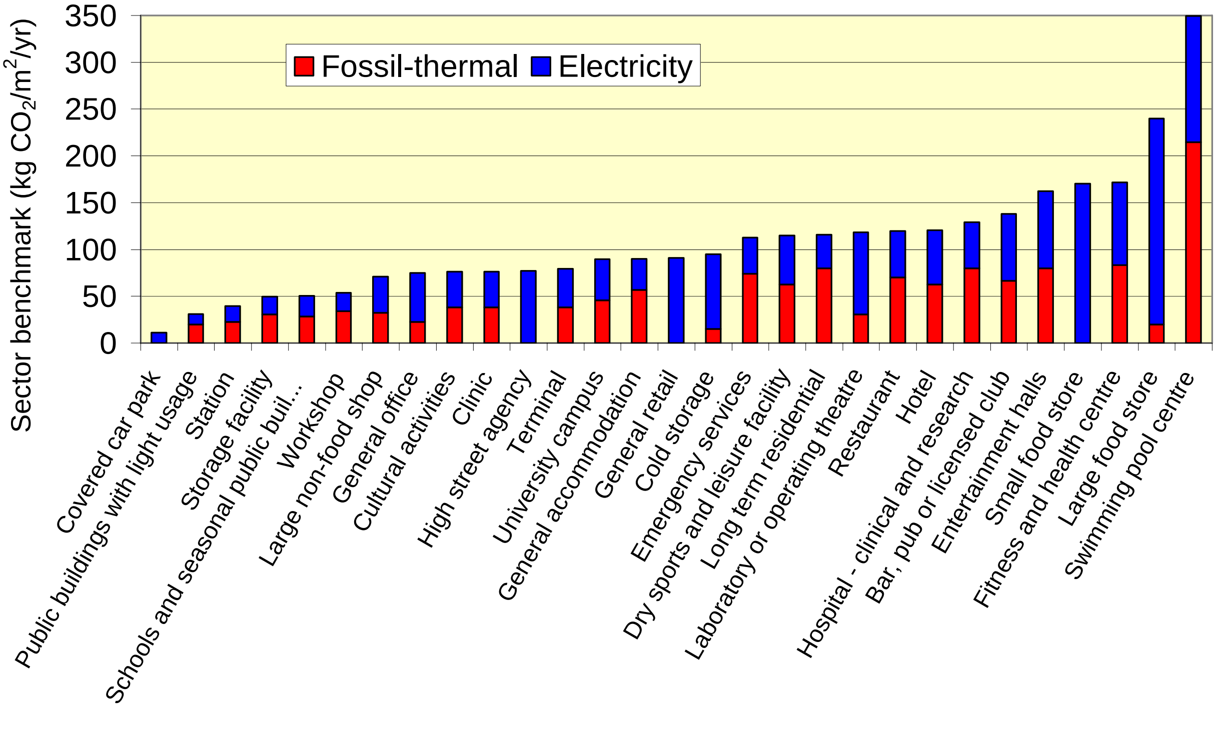


Figure 4 Standard values for each benchmark category, converted to $kgCO_2/m^2$/year

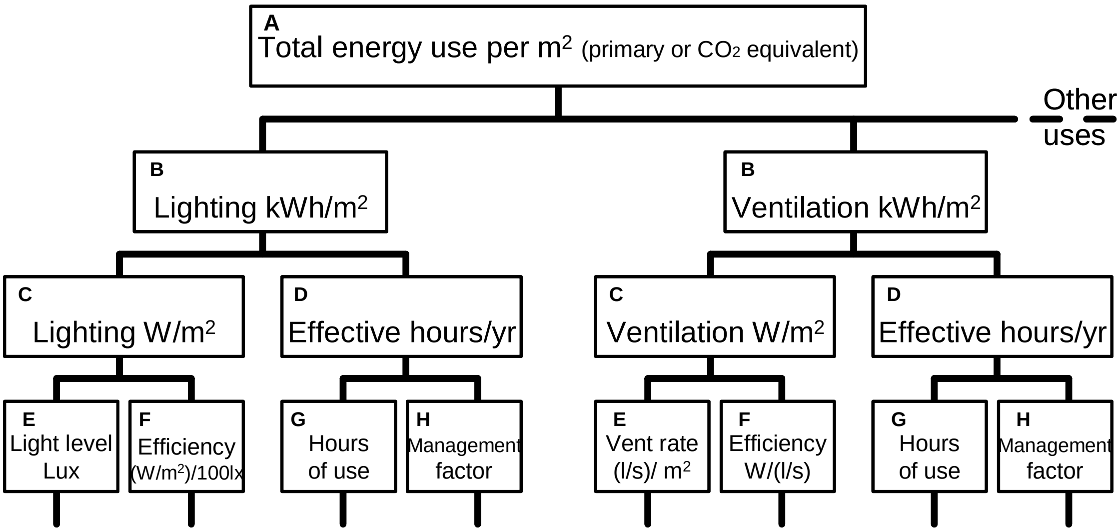


Figure 5 Tree diagram model of building energy use

A building or site comprising a mix of building types is given an area weighted composite benchmark. An example for a dry sports centre with a swimming pool and a restaurant is shown in Figure 6.

		Energy benchmarks		CO2 benchmarks (calculated from energy benchmarks)		
		Electricity Typical benchmark kWh/m2	Fossil-thermal Typical benchmark kWh/m2	Electricity Typical benchmark kgCO2/m2	Fossil-thermal Typical benchmark kgCO2/m2	Total Typical benchmark kgCO2/m2
Dry sports and leisure facility		95	330	52.3	62.7	115.0
Swimming pool centre		245	1130	134.8	214.7	349.5
Restaurant		90	370	49.5	70.3	119.8

Total for each building type

Zone category	Area (m2)	Electricity kWh	Fossil-thermal kWh	Electricity kgCO2	Fossil-thermal kgCO2	Total kgCO2
Dry sports and leisure facility	800	76,000	264,000	41,800	50,160	91,960
Swimming pool centre	500	122,500	565,000	67,375	107,350	174,725
Restaurant	200	18,000	74,000	9,900	14,060	23,960
Total	**1500**	**216,500**	**903,000**	**119,075**	**171,570**	**290,645**

Totals per m2 of whole building		Electricity kWh/m2	Fossil-thermal kWh/m2	Electricity kgCO2/m2	Fossil-thermal kgCO2/m2	Total kgCO2/m2
Dry sports and leisure facility		51	176	28	33	**61.3**
Swimming pool centre		82	377	45	72	**116.5**
Restaurant		12	49	7	9	**16.0**
Total	**1500**	**144**	**602**	**79.4**	**114.4**	**193.8**

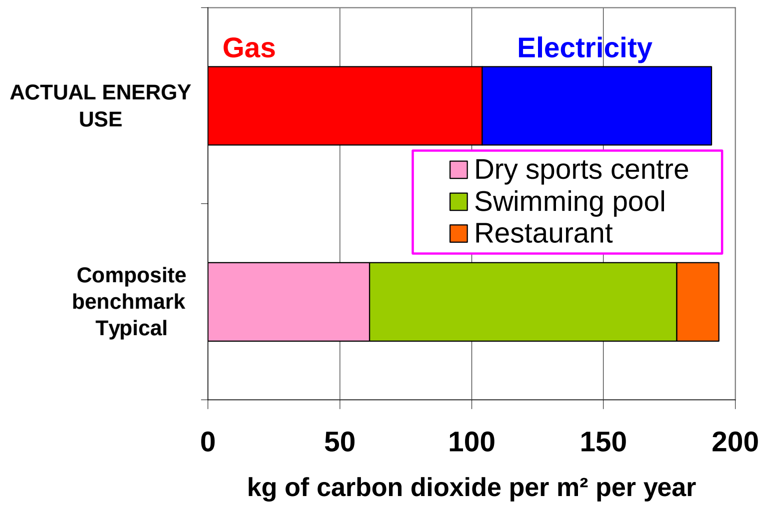


Figure 6 Illustration of a composite benchmark for a site or building with three building types

Special energy uses

Some buildings contain 'special' energy uses which are not allowed for in their benchmark – because they are either unusual or highly variable. If a special use is sub-metered over the assessment period, then its energy use and emissions can be deducted from the measured totals in the calculation of the operational rating. However, the total carbon footprint for the building still includes any special energy uses.

Technical information summary

To supplement the results shown on the DEC itself, the table below will also be produced. This provides a detailed explanation of how the calculation treats special energy uses, details of renewable energy sources as well as additional performance indicators, separately for fuel/heat and electricity.

Annual energy use, CO_2 emissions, and performance indicators (building floor area = 1,000 m^2)	Fuel and heat[1]	Electricity[2]	Units for energy data	CO2 emissions	Units for CO2 data
Total energy use in the year concerned	100,000	230,000	kWh	146.5	tonnes CO2
Special energy use deducted 1: data centre	5,000	150,000	kWh	83.5	tonnes CO2
Special energy use deducted 2	0	0	kWh	0	tonnes CO2
Calculated performance indicators	95	80	kWh/m2 pa	63	kg CO2/m2 pa
Reference performance benchmarks corrected	160	100	kWh/m2 pa	87	kg CO2/m2 pa
Benchmark ratios and Operational Rating (lower is better)	59	80	Typical = 100	72	Typical = 100
Operational Rating grade (A is best)	C	D	A to G	C	A to G
Renewables type 1: imported biomass	5,000		kWh	5%	% of total avoided
Renewables type 2: on-site PV		16,000	kWh	7%	% of total avoided

[1]Fuel and heat includes imported combustion fuels and heating and cooling from community systems, nett of exports.
[1]Delivered heat is factored by 1.25 to allow for conversion and distribution losses.
[2]Electricity includes electricity used for all purposes, including heating, cooling, small power, etc., nett of exports

Advisory reports

A simple questionnaire has been devised to identify the potential energy saving measures in each building receiving a DEC. The recommended improvement measures are then listed in an advisory report, which the law requires the building occupier to have but not to display. The measures are categorised as short, medium or long payback and high, medium or low carbon impact. Additional recommendations can be added by the assessor, and can incorporate results from a previous detailed energy survey. Ideally, the Advisory Report will also include recommendations for improving the energy efficiency of any special energy uses, or for an assessment by an expert in this area (e.g. in data processing equipment and not just air conditioning in a data centre).

Unlike a DEC which must be renewed each year, an advisory report remains valid for up to 7 years.

The Process for obtaining a DEC in England and Wales

Data collection, verification and registration

A building occupier must appoint an accredited DEC energy assessor (EA) to produce an official DEC. It is permissible for the EA to be an employee or contractor of the occupier. However, all EAs must operate in an independent manner. The DEC must show any association between the EA and an occupier as a "related party disclosure". The EA is responsible for approving all the data used to produce the DEC and must obtain and retain suitable evidence to substantiate the data, sufficient to satisfy any quality control checks by the Accreditation Scheme to which they belong. The end-to-end process for producing a DEC is illustrated in Figure 7. The EA enters the data collected for a building into approved software to obtain a provisional DEC, which they submit to their Accreditation Scheme for checking. The Accreditation Scheme then lodges the DEC and advisory report on a web-based central register operated by the government. An approved DEC will then be made available to the EA, for issue to the occupier for physical display in the building.

To help to prevent an unapproved DEC being put on display, each DEC has a unique report reference number (RRN). Anyone who notes down the RRN on a DEC, can log into the Central Register and verify that the DEC is bona fide.

Accreditation schemes

The government has approved ten organisations to operate Accreditation Schemes for DECs in England & Wales. Each scheme is responsible for the accreditation of and the quality of work done by its EAs, which means, inter alia, demonstrating that their EAs are:

- Qualified and achieve appropriate levels of consistency and accuracy. It is expected that 90% of Operational Ratings will be within ± 2% of the "correct" answer (i.e. one produced by a very experienced assessor) and that 100% will be within ± 5% of the right value.
- "Fit and proper persons" who comply with an appropriate code of conduct and complaints procedure and are covered by suitable indemnity arrangements.

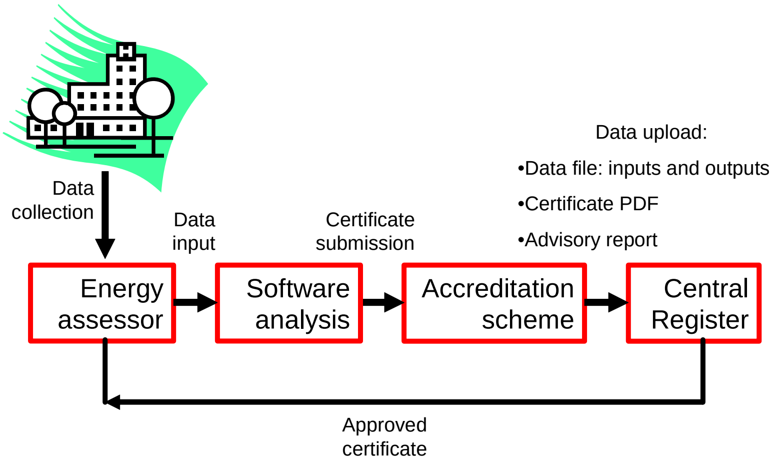


Figure 7 Process for collecting and processing the data for a DEC

The methodology for operational ratings in Germany

Operational and asset rating in Germany
In Germany, unlike in most EU countries, non-residential building owners have a free choice between asset and operational ratings (see Figure 8). Public buildings are always considered as non-residential, so a certificate on display may be based on either an operational or an asset rating.

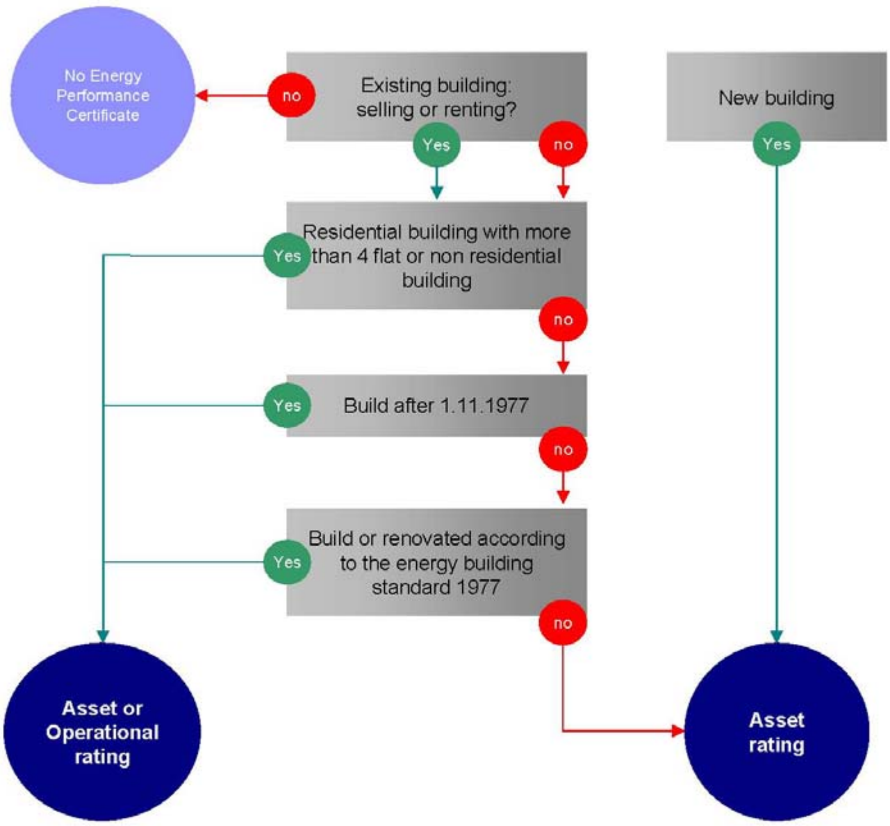


Figure 8 German decision process for whether an operational rating is allowable or not

Definition of a public building

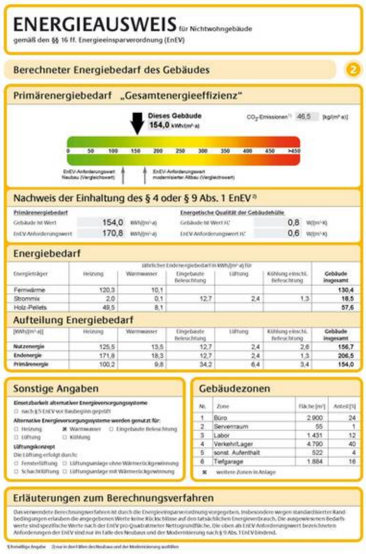
A Public building is defined in the German legislation as follows:
"If public authorities or other organisations deliver public services for a large number of persons and the building has an area which is larger than 1000 m², this building is considered as a public building/facility and needs a DEC on public display." There may be cases where the interpretation of this aspect of the law has still to be defined.

EPC and DEC in Germany

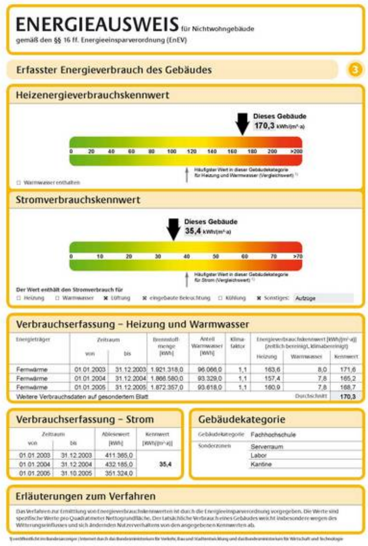
A public building will always have both an EPC, a 5 page document (see Figure 9), and a DEC, a 1 page summary displayed to the public, shown in Figure 10. The DEC is a supplement to each EPC for non-residential buildings.

EPC page 1:Cover

EPC page 2: Asset rating



EPC page 3: Operational rating



EPC page 4: Explanations

EPC page 5: Optimisation measures

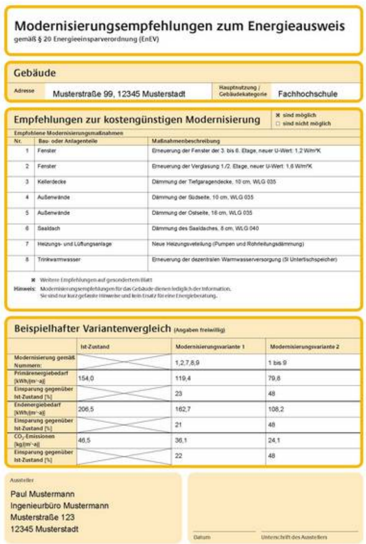
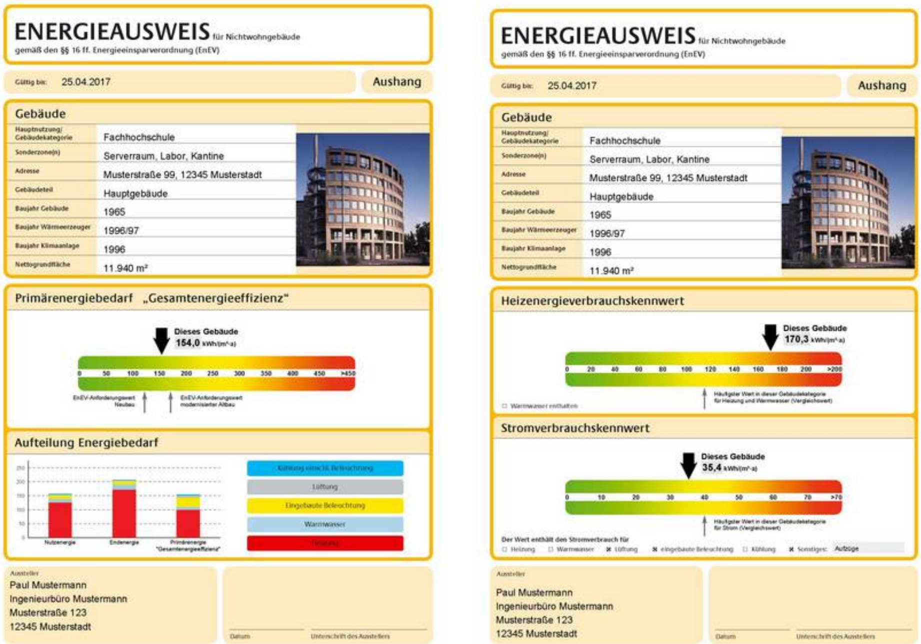


Figure 9 German Energy Performance Certificate EPC

EPC page 1: Cover sheet with general information about the building and the issuer. Additionally it shows whether the certificate is based on operational and/or asset rating and whether the data was provided by the building owner or the issuer

EPC page 2: Building performance based on an asset rating. The rating metric is primary energy. Additional information shows the predicted energy use for heating, lighting, ventilation, cooling and hot water. Further information is provided on the ventilation system, the use of renewables and the building zones.

EPC page 3:	Building performance based on an operational rating. The rating metric is the delivered heating energy and the delivered electricity. The energy source, the energy/fuel metering and the climate correction factor are shown. Special uses may be indicated on the certificate, but are not taken into account in the performance.
EPC page 4:	Explanations, mainly to assist in understanding the different energy types (primary, end and delivered energy).
EPC page 5	Advisory report



DEC asset rating	DEC operational rating
Shows information on the building, the issuer, the energy performance indicator and a breakdown into the different energy end uses.	Shows information on the building, the issuer and the energy performance indicators for fuel/heat and electricity.

Figure 10 German Energy Performance Certificate for public display (DEC)

Building definition

Unlike the UK, the German legislation always requires the energy performance certificate to be for the whole building, independent of the structure of ownership or occupiers. This can lead to a situation where one user of the building needs a certificate when the others do not. The one who needs it has to produce the certificate for the whole building - and obtain all the necessary information from the other owners or occupiers. Several practical problems can be expected from this in implementation.

Building area: definition

The building area is defined as the "net gross" floor (NGF) area. All areas which are treated thermally must be included. Non-certification of parts of buildings is possible. The following default conversion factors can be used when the net gross floor area is not available (ARGE, 2007):

				Conversion factor to		
Building categories		**Sample size**	**NGF**	**BGF**	**NF**	**HNF**
7.1	Hospitals more than 250 beds	8	1	0,865	1,70	2,41
8.5	Airport terminal	5	1	0,90	1,86	N.A
9.1	Office building heated	55	1	0,80	1,44	1,82
9.2	Office building, ventilated	60	1	0,81	1,32	1,57
9.3	Office building air conditioned	9	1	0,80	1,36	1,69

Gross Floor Area (BGF in German): this area includes external walls and unheated areas like car parking, cellars, etc.
Net Floor Area (NGF in German): this area is the BGF, less the area of external and internal walls including chimneys, etc.
"Use" area (NF in German): NGF minus corridors and functional areas (technical area)
Main use area (HNF in German): NF minus kitchens, toilets etc.

Multi-building site
In general the German legislation demands an energy certificate for each building. However, an exception is allowed if different buildings on a site are metered together and a certificate based on an operational rating is being used; then one certificate can be issued for all buildings.

Landlord's energy statement (LES)
Unlike UK, Germany doesn't have a LES. The German government regards the building as a physical and not a commercial construction. However, landlords of a multi-tenanted building may find it very difficult to produce the operational rating, because they would need to acquire the energy bills of every single one of their tenants over the past three years. In a large building complex, this might be a huge undertaking. A discussion of this issue is still ongoing and it is not yet clear if a solution will be found.

Defining the reference values (benchmarks)
The German government developed reference values for public buildings on the basis of a large database of energy use. After the first revision of this database, it became clear that further data were needed and a consortium named ARGE Benchmark was commissioned to develop reference values for privately owned buildings. Consequently, the German legislation contains two tables of reference values: one for public and one for non-public buildings (see Figure 11).

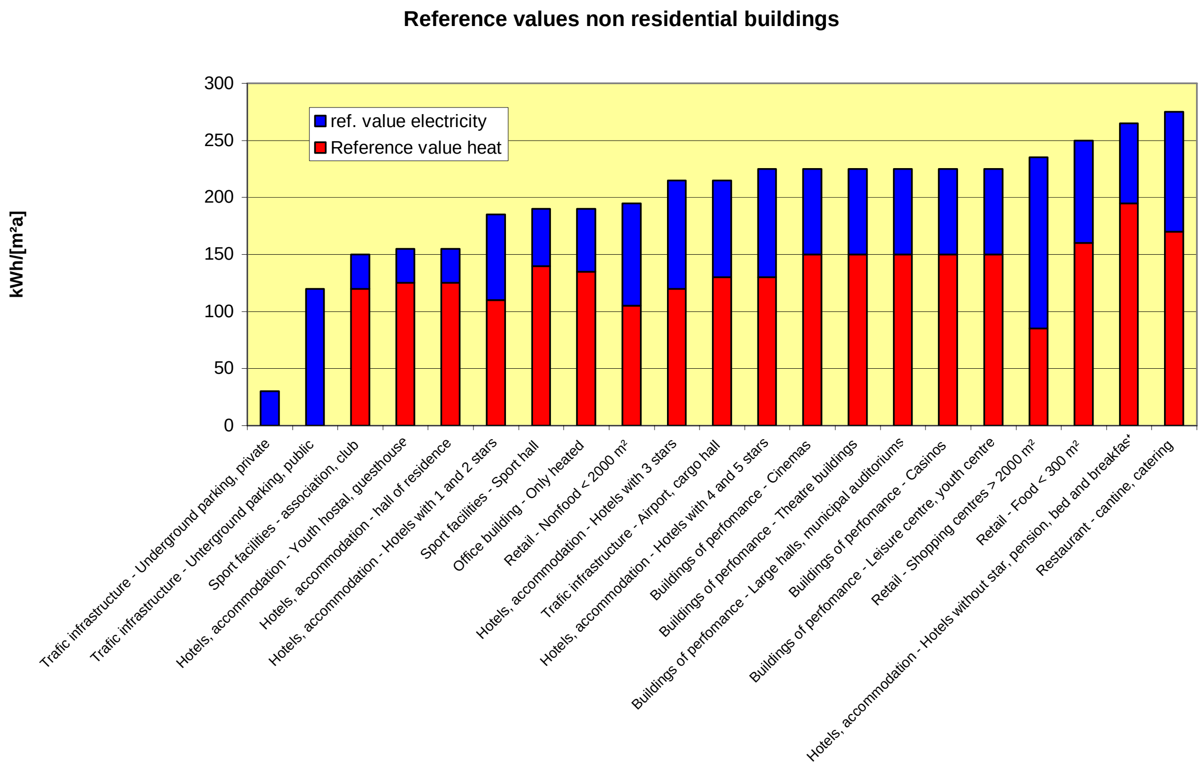


Figure 11 German reference values for non-public buildings (based on delivered kWh)

The reference values are calculated on a statistical basis. So far, no further empirical development of the reference values has been allowed, although a change in this procedure is being discussed.

Special energy use
Special energy uses can be indicated on the certificate, but not deducted from the total energy consumption.

Mixed use
If a building has more than one usage, a composite reference value is calculated, according to the area ratio of the different usages.

Adaptation to the hours of use
An adaptation to different usage times is not allowed.

Climate correction
The metered energy consumption is adjusted according to correction factors relating to the period and the region (defined by the post code). A new correction method is under development and is expected to be published in May 2008. The new climate correcting model is based on a refined set of climate data. The correcting factor can be calculated for each metering period and each location, allowing differences of altitude within one climate zone to be taken into account.

The Process for obtaining a DEC/EPC in Germany

Data collection, verification and registration
In the German legislation (ENEV) the requirements for an assessor are defined. Depending on the type of EPC, different levels of education and professional experiences are required. The building owner is allowed to collect the data and submit this to the assessor. The assessor has to verify the data, to issue the certificate and to sign it. Apart from spotting what should be obvious mistakes in the basic data, the assessor is not responsible for the quality of the data. The German legislation includes an annex where a training course is described. But this annex is voluntary.

Based on the provision of data by the owner, web based services for energy certificates are established in Germany for both asset and operational ratings of residential buildings and for operational ratings of non-residential buildings. These cost between 25 and 50 Euros. In contrast, an energy certificate for non-residential buildings based on an asset rating will take 5 to 15 days and will cost orders of magnitude more.

There is no central registration of assessors nor any central collection of the results of certificates.

Accreditation schemes
Beside the requirements on educational and professional experience, no further accreditation credentials are needed. Each assessor has to decide by self-regulation whether they are suitably qualified to issue a certificate for a specific building or not.

Conclusions

Implementation in England and Wales
The energy certificates for public buildings (DECs) are aimed both at the organisations occupying a building and at the general public. For the first time ever, the energy performance of buildings and the resultant CO_2 emissions will become visible. The DECs will identify poor buildings to be prioritised for improvement and there will be a high profile reputational pressure to implement energy saving measures - reinforced by the fact that a DEC highlights year-on-year performance.

The government policy for DECs has many synergies with forthcoming new legislation such as the EU's Energy Services Directive, a UK government initiative called the Carbon Reduction Commitment (a cap-and-trade emissions trading scheme for large non-industrial organisations) and, of course, the EC's anticipated enhancements and tightening of the EPBD.

Implementation in Germany
Energy performance certification of public buildings in Germany lives in two worlds: the operational and the asset rating. The operational rating is a simple basic certification scheme, whilst the asset rating for non domestic buildings is very complex and time consuming. Further development must be done, to simplify the asset rating on the one hand and to enhance the operational rating on the other hand. A solution for multi-tenanted rented buildings must be found too.

Key differences between the UK and German methodologies
1. Weather adjustments are made to the benchmarks in the UK whilst in Germany they are made to the actual energy use. The UK approach has the merit of reporting actual (unadulterated)

results on the certificate and is technically more rigorous because the proportion of the benchmark which is weather dependent can be specified, but it means that the benchmark for each building type will be different in different regions and will vary from year to year. The German approach has the benefits of fixed benchmarks for each building type, but suffers the vagaries of using a model to correct the metered energy for the effects of weather.

2. Special energy uses can be deducted in the UK but not in Germany.
3. The UK certificate headlines an overall rating for the building, whilst the German certificate shows only the use of electricity and fossil fuel or heat compared with benchmarks, on separate graphics.
4. For a multi-tenanted building, separate certificates are required for different tenants in the UK, whilst the landlord must produce a single certificate for the whole building in Germany.
5. The UK has a more formalised approach to the training and accreditation of the assessors permitted to produce building energy certificates.
6. The German approach does not include the central collection of energy performance data which means that, for the moment, the German government is missing the opportunity to collect the data which can support the development of benchmarks and strategic policy measures.

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Towards an Optimal Approach to Effectively Incorporate Feasibility Studies of Alternative Energy Systems (Art. 5 EPBD) in the Common Building Process

Suzanne Joosen, Ecofys Netherlands B.V., the Netherlands
Åsa Wahlström, SP Technical Research Institute of Sweden, Sweden
Marjana Sijanec Zavrl, Building and Civil Engineering Institute ZRMK, Slovenia

Abstract

The Energy Performance of Buildings Directive (EPBD) has imposed obligatory feasibility studies of alternative energy systems (AES) for large new buildings. Most countries have transposed the requirements into their national legislation. However, operational legislation, technical guidelines and support tools are usually not yet in place. Within EIE SENTRO project (http://www.sentro.eu/) an approach is being developed to effectively incorporate the introduction of feasibility studies of AES in the common building process. The approach consists of a checklist to filter out most promising AES at an early stage and a handbook with a protocol to carry out feasibility studies. Technical, economic, environmental and organizational aspects are covered by the approach to assure that a complete package of barriers is dealt with. The paper describes the approach, including the tools. Furthermore, the first two experiences with testing the approach in practice on school building design are reported. These first results show that the checklist is a helpful tool in filtering out the most interesting AES. In addition, the proposed approach turned out to be very useful for communication within a project/design team, which consists of key actors with all different kind of backgrounds. For the foundation of these conclusions more results are needed. It is aimed at 35 cases in total divided over 7 EU-countries. It is expected that the final results of the field trial will be published in the autumn of 2008 on the project website (www.sentro.eu).

Introduction

CO_2 emission potential

In general implementation of renewable energy and energy savings are regarded as essential to keep the effects of climate change within acceptable limits and to guarantee the certainty of the energy supply.

Energy efficiency measures in new and existing buildings could considerably reduce CO_2 emissions with net economic benefit. By 2030 about 8% of the worldwide emission reduction potential (30% of the potential in the building sector) can be avoided with net economic benefit. The reason that this potential is still available is related to multiple barriers. These barriers include financing, poverty, higher cost of reliable information, and lack of an appropriate portfolio of policies and programs (IPPC, 2007).

EPBD – feasibility study requirement

The buildings sector accounts for 40% of the EU's energy requirements. An estimated potential of one-fifth of the present energy consumption could be saved by 2010. To translate this potential into reduced energy consumption, the Energy Performance of Buildings Directive (EPBD) 2002/91/EC is set to promote the improvement of energy performance of buildings.

As of 4th January 2006, the EPBD enforces all EU-countries to create within legal and administrative framework of the their building codes, minimum energy performance requirements, energy certification, calculation procedures, feasibility studies requirements, inspection of boilers and air conditioning systems. It is estimated that through these requirements a cost-effective savings potential is realizable by 2010 of around 22% within the building sector. If this potential is realized, around 20% of the EU Kyoto commitment can be met (Buildingsplatform, 2006). This is about 35-45 Mtonne CO_2 emission reduction in the EU-15 member states by 2010 (ECCP, 2003).

Till now the focus has been on the calculation and certification methods for the energy use of new and existing buildings. Less attention has been paid to the requirements for feasibility studies of alternative energy systems (AES) for new large buildings (part of article 5 of the EPBD).

This part of article 5 of the EPBD states:
For new buildings with a total useful floor area over 1000 m^2 Member States shall ensure that the technical, environmental and economic feasibility of alternative systems such as:
- decentralized energy supply systems based on renewable energy
- CHP
- District or block heating or cooling, if available
- Heat pumps, under certain conditions,

is considered and is taken into account before construction starts.

Measures which reduce the energy demand (e.g. insulation) of a building are for a large extent stimulated by other articles in the EPBD. The mentioned part of article 5 focuses on the promotion of energy savings which can be achieved by energy efficient supply systems and renewable energy systems. Usually a combination of barriers hinders the use of AES. For example: higher investment costs, lack of knowledge and additional required permits. Core of the barriers is the estimation of risk on the part of the decision makers towards often unfamiliar AES.

Article 5 of the EPBD offers a unique framework to contribute towards diminishing the above-mentioned bottlenecks, since through performing feasibility studies more actors will become aware of alternative solutions for their energy systems.

SENTRO-project

These were the underlying reasons to start a European project called “Sustainable Energy systems in New buildings-market inTROduction of feasibility studies under the Directive on Energy Performance of Buildings” (SENTRO). In this project, which is scheduled to run from 1 November 2006 till March 2009, it is expected to gain insight into solutions to overcome barriers in the realization of AES in new buildings. The main aim is to develop and promote an optimal approach in order to effectively incorporate the feasibility studies of alternative energy systems (art. 5 EPBD) in the common building practice.

The project started by making an inventory on how European member states comply with the requirements of conducting a feasibility study of alternative energy systems for new buildings. The inventory also encompasses which policies they pursue to actively introduce this requirement. The results are presented in the next section. Subsequently, in the seven SENTRO countries (Denmark, France, Lithuania, Poland, Slovenia, Sweden and the Netherlands), another inventory is made of the building practices as possible barriers of the implementation of alternative energy systems. Several main conclusions are given in the next section.

Based on the outcomes of the inventory phase, an approach is being developed to ensure that assessment of alternative energy systems will become an integral part in the common planning process of new buildings. The outline of the approach is discussed in a separate section. To support the approach two tools are made. It concerns a universal checklist and a handbook, which cover technical, financial, organizational as well as environmental aspects. Some explanation of these tools is reported.

Core of the project is the test of these tools in a field trial in the participating countries. As the field trial is carried out in the period November 2007 till July 2008, only preliminary results are discussed in this paper. Till now 8 test cases have been carried out.
Towards the end of the project the experience is disseminated through workshops and conferences to policy makers and key actors in the building process.

Expected results (deliverables) from the SENTRO-project are:
- Up-to-date information concerning the status of the feasibility study part of the EPBD in all EU-27 MS (Sijanec Zavrl, M. (2007)).
- Insight in the barriers which are hindering the use of alternative systems and insight in possible solutions to overcome these barriers (Hansen, K. (2007)).
- Supporting methods and checklist for imbedding feasibility studies in the common building practice.
- Lessons learned from the field trial of these tools and the evaluation of this element of the EPBD.

Status March 2007 - Feasibility study requirement EPBD

An overview of EPBD art. 5 transposition status in EU-27 countries and Norway (status 3/2007) is presented in Table 1.

The results show that in March 2007 most countries completed the process of transposition on the legal level. However, to a much lesser extent operational regulations are in place. Technical guidelines and supporting tools are in many countries still under development or not yet started.

Two main approaches to EPBD art. 5 transposition are identified:

1) Direct approach - i.e. transposition of art.5 at a legal level and subsidiary legislation based on either
   a) A definition of the protocol for feasibility studies (e.g.: Slovenia, Finland, France) or
   b) A list of selected alternative energy systems (e.g.: Spain, Portugal).
2) Implicit transposition – i.e. based on already existing regulation or through an EPBD calculation methodology, i.e.:
   a) Art. 5 is integrated in EPBD calculation procedure and tools (e.g.: The Netherlands, Bulgaria, Luxemburg)
   b) Other legislation concerning heat supply and/or planning predefine the use of renewable energy systems corresponding to the scope of art.5 (e.g.: Denmark, Lithuania).

Furthermore, most researched countries (17) have the feasibility study requirement included in the building permit procedure. However, the decision upon energy systems is usually made before the building permit is considered. This implies that for article 5 to function properly, attention has to be paid to the content and enforcement of the specific requirements.

It is possible that the current status is somewhat different from the presented status in Table 1. However, it is expected the two overall conclusions are still valid: (1) almost all countries have taken care of national transposition of feasibility study requirements, (2) technical guidelines and supporting tool are still needed in a number of countries. Inquiry about the status of the seven participating SENTRO-project countries teaches us that (status March 2008):

- For Lithuania, Poland, The Netherlands and Sweden the status is as presented in Table 1.
- For France art. 5 is transposed into national legislation. Support measures are also available.
- For Slovenia the technical regulation has been drafted and has passed the public consultation procedure. The process for promulgation is expected to be completed in April 2008. The regulation defined obligatory elements of feasibility study in order to enable evaluation of the energy, environmental, financial and other (technical, technological and spatial) aspects of an AES. At least two AES have to be analyzed; the evaluation must be based on a set of predefined energy, CO_2 and financial (including LCC) indicators. The existing VEM tool covers environmental and financial aspect for selected AES. Various energy simulation tools can cover technical (energy) aspects. By the end of 2008 also the official Slovenian tool for EPBD energy calculation will be ready. The enforcement framework is developing, though more demonstration projects would facilitate the increased implementation of AES.

Table 1 Status of art. 5 transposition in EU-27 and Norway, (March 2007)

GENERAL APPROACH A) Detailed regulation planned for feasibility studies from Art. 5 / B) Feasibility study integrated in regulation about EPBD calculation methodology and min.requirements / C) Feasibility studies integrated in other existing regulation / D) technology list prepared	SUMMARY Art. 5 implementation level (country status: March 2007)	Art. 5 implemented at legal level			Art. 5 technical regulation and/or other adequate support for implementation of alternative systems (i.e. technology list) ready			Support measures for enforcement of Art.5 regulation (tools, checklists, information, promotion…)		
		Not yet / action just started	Draft law ready	Law adopted / finished	Not yet / action just started	Draft ready	Adopted / finished	Only some technology promoted, not systematically	Promotion programmes, incentives available	Tools available, good promotion, advisory programmes, demonstration projects
B	**Austria**									
A	**Belgium**									
B	**Bulgaria**									
decision in progress	**Cyprus**									
B	**Czech Republic**									
C	**Denmark**									
decision in progress	**Estonia**									
A	**Finland**									
A	**France**									
B	**Germany**									
decision in progress	**Greece**									
B	**Hungary**									
A	**Ireland**									
B	**Italy**									
decision in progress	**Latvia**									
C	**Lithuania**									
B	**Luxembourg**									
B	**Malta**									
B	**The Netherlands**									
decision in progress	**Poland**									
D	**Portugal**									
B	**Romania**									
A	**Slovakia**									
A	**Slovenia**									
D	**Spain**									
B	**Sweden**									
B	**United Kingdom**									
C, no detailed information	**Norway**									

The inventories carried out within the SENTRO-project make clear that at least two points deserve particular attention. These are the starting points for the development of an optimal approach to embed the feasibility study aspect of the EPBD in the common building practice:
1) Early timing of a feasibility study of AES in the building process is crucial.
2) The approach has to tackle a combination of barriers to gain the confidence of decision makers in AES conclusively.

To generate a level playing field of AES, it is important that good objective insight in the technical and economic opportunities for the various AES – including their environmental benefits – becomes available before the final design of the building.

Outline of an optimal approach to integrate the feasibility study of AES into the building process

Based on the inventories, it has become clear how the feasibility study of AES ideally should be integrated in the building process. The approach is illustrated by two figures (1 and 2).

Figure 1 shows the building stages, the involved main actors and the related actions to consider the feasibility of AES before constructions starts. Of course the building process differs in the various EU-countries. However, in general it is possible to distinguish six different stages as defined in the figure.

During the planning and programming phase awareness of the AES has to be created first of all. This can be done by putting the topic on the agenda of project meetings. As a support to raise awareness, descriptions of the basics of AES as well as good national practice examples in the handbook can be used. Also answers to frequently expressed objections towards AES are listed.

Depending on how the feasibility requirement of article 5 of the EPBD is transposed there are several paths to proceed.
1) When there is a direct obligation, the key actors have to fulfill the legislation.
2) When the transposition is implicit, key actors have to be made aware that AES are valued in the energy performance calculations.
3) When there is no obligation (yet) the next step is to achieve commitment that the feasibility of AES has to be studied.

In all cases, it is recommended that key players ask for a feasibility study at an early stage of the process.

The proposed approach of a possible implementation of AES feasibility studies consists of a checklist for a brief pre-feasibility study and of a method for a more detailed feasibility study of the interesting AES. The feasibility study starts with filtering out unrealistic AES options. The checklist (detailed description in next paragraph) can be used for this selection. The aim is to identify at least two interesting AES options at the beginning of the proposal stage.

Thereafter, a more detailed feasibility will be performed for these interesting AES. The results have to be available when the final decision is made (often at project stage) on the building’s energy system. To support the evaluation of AES, a handbook is being developed. Besides technical aspects, a protocol for financial, organizational and environmental issues is included. All the collected and calculated insights have to contribute towards an optimal consideration of AES in the decision making of the final energy system.

As the approach is being developed to support impact of art 5 of the EPBD, the focus is on AES. It has to be stressed that an optimal energy concept can never be achieved without taking into account building related energy measures such as insulation, ventilation and use of day light. The importance of integral energy design is included in the handbook.

Three situations can be distinguished in realizing AES in buildings: 1) new individual building 2) new housing area 3) renovation of existing building(s). As the focus is article 5 of the EPBD is on new buildings, the approach is concentrated on the first two situations. The third situation is beyond our scope, unless the building is totally stripped. In this case it can be regarded as a new building.

The approach is more or less the same for the first two situations. In this paper the approach, including the tools, is explained for a new individual building. The development of a new housing area differs from a new single building with respect to more opportunities for collective energy systems and more freedom in the choice of energy infrastructure. As a consequence, in this case the study of the feasibility of AES is more complex and has to take place at the very beginning of the building process. For instance, decisions about the energy infrastructure usually are made at the planning stage.

Figure 2 is added to stress the importance of taking energy concepts into account right from the beginning of the building process. The space to find suitable solutions to realize an optimal energy concept in the building is funnel-shaped (marked blue). This illustrates that when for example AES is only considered from the project stage there are fewer opportunities to realize a good AES concept compared to a consideration on AES which was initiated in the planning stage. Of course the available solution space to realize a high quality building, including its energy concept, is also closely related to the required cost. Little solution space indicates higher cost and much solution space indicates lower costs. (Prins, 2006; WBCSD, 2007)

Main actors	***Building stage***	***Content***	***Action related to the feasibility study***
Municipality Energy suppliers Developers	Planning stage	Urban planning incl. energy infrastructure, heat plans, and constrains on number, size and use of buildings in the area.	The planning stage should include feasibility studies on the potential for inclusion of alternative energy systems on district level or on building level... This means also start to identify most feasible options by using the checklist.
	↓		
Client or Developer Consultants	Programming stage	Defines the occupants' needs and requirements in the building program.	Start of the feasibility study. 1. Identification of the most feasible energy systems. Use checklist to find at least two options of alternative energy systems. 2. Make efforts to arise awareness of alternative energy systems. (good practice examples and answers to frequently asked questions are included in the handbook) 3. Planning of the coming stages in the feasibility study.
	↓		
Client or developer Architect, Consultants	Proposal stage	Defines the basis on which the client makes his decisions on the specific performances of the project in question. The proposal stage may include consideration of a number of alternative energy concepts for the building	1. Optimization of the energy demand and production. Identify building concepts for inclusion of chosen energy systems. 2. Evaluation of at least two energy systems based on handbook and by using suitable simulation tools. 3. Include choice of building concepts and energy systems.
	↓		
Client or developer Architect, Engineers and Consultants	Project stage	Describes the project in unique terms to allow it to form a basis for final approval by the authorities and for tendering, contracting and construction	Decision of the energy system. 1. Complete the feasibility study and hand in along with the building permit application. 2. Decide on needs for further feasibility studies.
Local authorities	↓	Decision building permit (yes/no)	
Contractors Installers	Construction stage	The building is constructed incl. energy systems, so that a use permit can be given	
	↓		
Owners Occupants Installers	Operation stage	The building is in use	

Figure 1 Building stages and actions towards an optimal consideration of the technical, economic, environmental feasibility of AES before construction starts

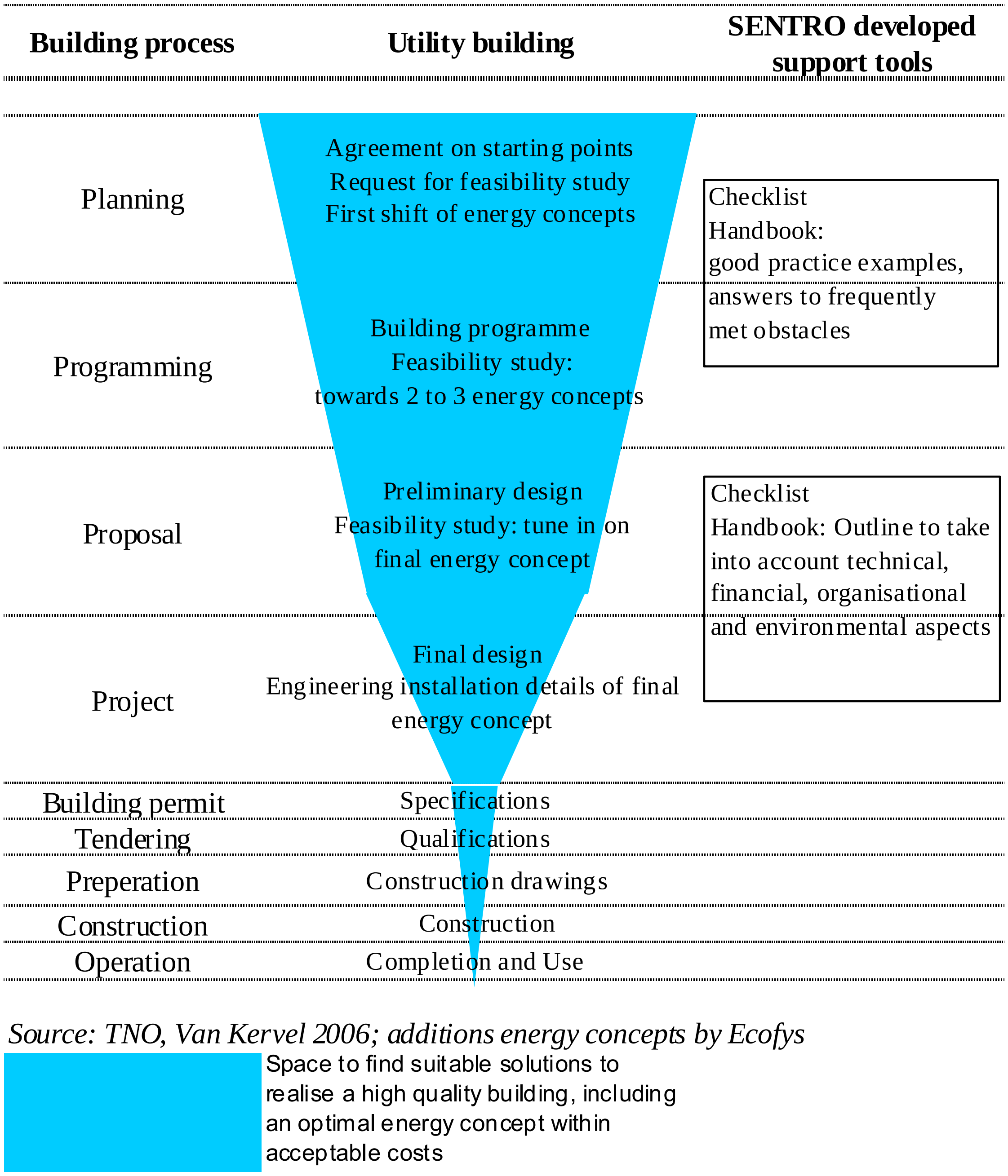

Figure 2 Solution space to realise a high quality building, including optimal energy concept and the developed support tools taking AES into consideration

Developed support tools Checklist and Handbook

Checklist, explained by first experiences of testing it in field trials in Slovenia and in The Netherlands

The objective of the SENTRO pre-evaluation checklist (Wahlström, 2007), intended to be used early in the building process, is to make a fast identification of promising AES for further investigations. By using the checklist it should be possible to choose a few alternative energy systems for further investigations together with the conventional system. It is recommended that at least two promising energy systems are chosen for further investigations.

The checklist is explained by two test cases. In the first case, carried out in Slovenia, the originally universal developed checklist is tested. In the second case, carried out in the Netherlands, it turned out that the originally checklist needed some improvements.

AES checklist field trial in rebuilding of schools complex in Kamnik

The municipality of Kamnik, Slovenia, is planning a rebuilding of a school area, with two old existing elementary schools. The municipality is highly interested in sustainable solution, since it has the role of both investor and owner and it is also paying the operational and maintenance costs. As part of the planning stage a call for architectural competition for 9.616 m^2 of new and/or partly rebuilt school area was prepared. As the terms for evaluation of architectural solutions should consider also the economy of the proposed design in a whole life-cycle and environmental acceptability of the renovated schools the checklist was used to pre-select the AES with considerable prospects for realization. The results are presented in Figures 3 and 4. They indicate the micro CHP and the heat pumps using geothermal energy the most promising systems and therefore worth of utmost consideration in further elaboration in design proposals.

For each alternative energy system four evaluation parameters are considered. Each evaluation parameter is weighted with weighting parameters, which are set on the first page in the Excel spread sheet tool (Figure 3), default weighting value is 0.3 for technical, 0.2 for financial, 0.1 for organizational and 0.4 for environmental aspect, as the most important one. Once the weighting parameter is set, the same weighting will be used for all alternative energy systems. If the weighting parameters are set to 0.25 for all parameters it means that they all are equally important. The evaluation parameters are in their turn weighted between numbers of aspects that are relevant to consider in order to tackle the barriers for each specific alternative energy solution. Each aspect is evaluated with scores from 1 to 3; 1 means that it needs a high effort to realize success while 3 means that it only need a low effort.

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WP4- CHECK LIST FOR FEASIBILITY STUDIES

		Score Technical parameters	Score Financial parameters	Score Organisational parameters	Score Environmental parameters	Probability for sucess in comparison of efforts
	Weighting to fill in, (0 - 1)	0,3	0,2	0,1	0,4	
	Decentralised energy supply					
A1	Solar thermal systems (hot water and/or heating)	56%	50%	83%	67%	62%
A2	Solar electricity systems (photovoltaics, PV)	100%	60%	75%	67%	76%
A3	Biomass energy systems (hot water and/or heating)	67%	78%	40%	50%	60%
	CHP and District or block heating or cooling					
A4	CHP (micro) at building level	89%	78%	50%	100%	87%
A5/A6	District or block heating	50%	44%	33%	33%	41%
A7	District or block cooling	33%	33%	33%	33%	33%
	Heat pumps					
A10	Geothermal energy systems (heat pumps for heating and/or cooling)	72%	67%	67%	100%	82%
A11	Heat pumps other than geothermal	0%	33%	75%	100%	0%

Figure 3 A summary page of the checklist with predefined weighting of technical, financial, organisational and environmental parameters (Walström, 2007); results refer to a pre-selection of AES in case of a checklist field trial in Kamnik schools, Slovenia.

A3	Biomass energy systems (hot water and/or heating)	Low effort demand to realise sucess = 3 points	Medium effort demand to realise sucess = 2 points	High effort demand to realise sucess = 1 point	SCORE to fill in, 1 to 3	SUBScore (%)
Technical parameters	sufficient space for fuel storage	available room for storage that are protected towards moisture	possible ta arrange for a two week storage that are protected towards moisture	no space for storage	1	
	accessibility of fuel storage	easy to access with a truck that can load fuel directly in the automatic feeder	need for manual move from truck to storage or from storage to the automatic feeder	difficult to access, need several manual loadings	3	
	efficiency (availability of technology on the market, with an good design)	yearly mean efficiencies over 75%	yearly mean efficiencies over 65%	yearly mean efficiencies less than 65%	3	
	fuel logistic system	fuel supply system available and well functionally	fuel supply system available	no fuel supply system in the neighbourhood	1	67%

Figure 4 Fragment of a checklist showing evaluation of biomass technical parameters by rules of thumb in a 1 to 3 points system (results for Kamnik field trial), (Walström, 2007).

The scores are based on rules of thumb. It may be necessary to change some of the parameters in order to adapt to local conditions. It is meant that the design team should only need to use one or two hours of discussion by filling the checklist in and thus get a relatively good overview of AES for further investigation in a detailed feasibility study (Figure 3). Therefore the design team should only set the scores based on previous experiences and no background investigations or calculations should be needed. In the worst case this may lead to constant abandoning of some systems, which the design team has a previous bad experience with. On the other hand, it is only compulsory to do the feasibility study, and not to actually use the suggested alternative energy system. In order to get real actions it might be more successful to concentrate on systems that the design team feels comfortable with.

Each evaluation parameter is followed by a number of aspects that should be assessed with scores from 1 to 3. For technical aspects the lowest score should describe the most difficult to realize the aspect. If it is impossible to realize a technical aspect the whole alternative system solution fails and further assessments should be done for other systems. In the same way technical aspects that will not cause any problem in implementation are not considered. The following example illustrates the criteria for evaluation of one of financial aspects, i.e. availability of subsidy schemes for PV systems: low effort demand to realize AES successfully, evaluated with 3 points, is chosen when subsidy of over 60% of investment is available; medium effort demand and corresponding 2 points are chosen if subsidy of over 30% is easy to get; while high effort demand to realize PV system and corresponding 1 point are selected when minor or no subsidy is available.

In the summary sheet (Figure 3) the scores for different aspects are presented, so that the design team can choose one or two AES that have high scores (preferably above 75%) and thereby promising qualities. Note that some of the systems are independent of each other and may therefore need separate assessments. For example, it is possible to use a solar thermal system together with district cooling.

AES checklist field trial in multifunctional building in Breda

The municipality Breda, the Netherlands, is developing a multifunctional building with a gross floor area of 4316 m^2 in a residential area. The building encloses: two schools: Laurentius and Dr. Visser, a day care-centre: Kobergroep, and a sport facility. In 2007 the building process was in the pre-design phase, it is planned that the building will be finished in 2010. The municipality of Breda is also the owner of the building. The users of the schools and day care centre will pay for the energy costs; other third parties will rent the sport accommodation in the evening (rent includes energy costs).

Within the field trial three meetings are arranged. The aim is to have a serious consideration of AES at the beginning of the building process, ultimately towards decisions upon AES. During the first meeting as much as possible information is collected to make a first shift towards performable energy systems. At that point some problems were encountered by using the original checklist. First of all, several options appear to be not realistic under local circumstances. This means it is not useful to enter all the data in the checklist for these options. Secondly, some questions on financial data (LCC costs etc) are hard to answer: In addition, people that are able to answer these questions do not need a checklist to decide which AES are most feasible. Finally, the choice between the three categories can be made easier if we give examples as well as "numbers". Based on these findings it was decided to adapt the checklist towards the Dutch national contact. It is expected that some of the changes are adopted by other countries as well, especially the fast filtering of unrealistic options.

The structure of the checklist is explained in figure 5. It is a two step process. In the first step unrealistic options are filtered by questioning the main features of the project and its' surroundings per AES. Only yes, no or unknown are possible answers. The second step is to select the two to three most promising options. This is done by valuing the key factors that influence the opportunity for successful realization per AES. Score runs from 3 to 1, respectively positive and negative influence. Beside the fact that financial valuation based on LCC is not considered, the content of this second filtering is strongly based on the originally checklist.

In the second meeting the checklist developed within the SENTRO project is tested and evaluated. The selection of AES is further tuned towards three favorable options. During the field trial in Breda it turned out that a heat pump in combination with heat and cold storage, solar thermal systems and wood fired boiler are the most interesting AES options. The requirements for a detailed feasibility study of these favorable AES, including solution paths for possible financial and organizational obstacles will be discussed during the third meeting. Furthermore in the last meeting appointments for the upcoming period will be made. The selection scheme, including the results for the multifunctional building in Breda, is presented in Figure 5.

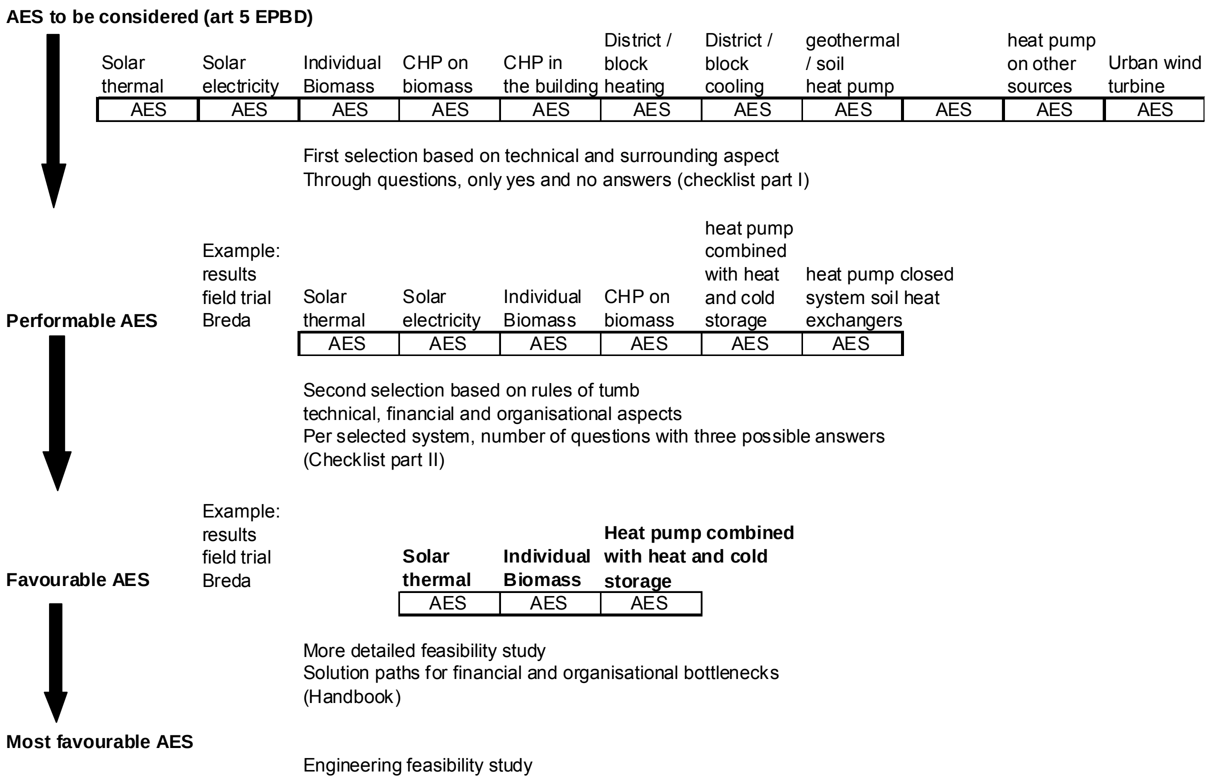

Figure 5. AES selection scheme in multifunctional building in Breda, The Netherlands.

The field trial demonstrated the score of 75% in case of geothermal heat pumps (closed and open systems), 72% for wood biomass boiler, 58% for solar thermal systems (hot water and/or heating), 49% for PV system and 42% for biomass combined heat production (CHP). Other AES like geothermal energy systems district or block heating and/or cooling and micro CHP at building level were found to have negligible potential for success.

Handbook

Since the article 5 of EPBD requires an evaluation of a technical, environmental and economic feasibility of AES, the main feasibility study has been developed from these aspects. Besides these aspects also organizational aspects need to be considered and so in the suggested method the feasibility study is divided into four parts: technical, economical, organizational and environmental. First a technical evaluation is performed to see if it is possible to technically install the energy system. Here the right size of the alternative energy system is decided for and thereby space, construction and installation requirements. The energy system's performance parameters are used in order to calculate the expected yearly energy use in the building's operation phase. The results from the technical evaluation are used in order to make an economical and environmental evaluation. In the economical evaluation different scenarios of the development of energy prices and interests are calculated. The environmental evaluation is made for different mixes of electricity sources and for different scenarios of future energy sources, for example in a district heating system. The feasibility study also consists of an organizational evaluation of experts' knowledge both during the performance of the feasibility study (design team) as well as in the operation of alternative energy systems (employees or users). All the results from the economical, organizational and environmental evaluation are thereafter summarized in one common score.

This means the background of the checklist is thoroughly explained in the handbook. Also included are good practice examples of feasibility studies for AES per country, how to respond to frequently put forward objections against the use of AES and an overview of relevant tools for feasibility studies.

Conclusions so far

Most EU-countries have transposed the feasibility study requirement of the EPBD into their national legislation. However to a much lesser extent countries have operational regulation, technical guidelines and support tool in place.

To effectively incorporate feasibility studies of AES into the common building process early timing is crucial. The first experiences in the field trial show that the checklist for the implementation of feasibility studies is helpful for identifying the most promising AES. Furthermore, the proposed approach turns out to be very useful in communication with a project/design team, which includes key actors with all kind of different backgrounds.
For the foundation of these conclusions of course more results are needed. For instance, the preliminary case for a new housing area in the Netherlands shows that this situation is more complex because of the opportunities for collective AES systems.
It is aimed at 35 cases in total divided over 7 EU-countries. It is expected that the final results of the field trial will be published in the autumn of 2008 on the project website (www.sentro.eu).

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A Review of Non-Domestic Energy Benchmarks and Benchmarking Methodologies

Rob Liddiard, and Andrew Wright
Institute of Energy and Sustainable Development, De Montfort University, Leicester, UK

Ljiljana Marjanovic-Halburd:
Department of the Built Environment, Anglia Ruskin University, Chelmsford, UK

Abstract

This paper, as part of the research remit of the UK Carbon Reduction in Buildings (CaRB) project, gives a review of a number of existing non-domestic building energy consumption benchmarks from both the UK and elsewhere. Although a range of benchmarking methodologies exists, including comparisons to statistical regressions or statistical distributions and comparison to a prototypical/model building, there are no clear guidelines on when and how to use them.

The paper presents reviews of the classification of building/occupant activity types, sources of data and its collection and analytical/quantification methodologies for a number of benchmarks. Through a discussion of the above, buildings practitioners should be enabled to make more informed and better quality choices in which benchmarking system to apply.

Introduction

The research presented in this paper is part of the major four-year research project Carbon Reduction in Buildings (CaRB), involving a consortium of five UK universities, investigating the associated carbon dioxide emissions from the UK domestic and non-domestic building stock. A key element of the project is the development of the CaRB Community non-domestic model. The aim of this is to allow yearly energy end-use modelling of the non-domestic building stock, at a Community level, where a Community can be anything from part of a city up to national level. The model thus must be capable of handling large numbers of non-domestic buildings, their diversity in both built form and activity and different levels of, in general, limited input data. In the worst case scenario, the only input data available would be building floor area, main activity and age. In general, the data initially available for buildings will be insufficient to allow energy calculations, therefore inference will be needed to generate the missing data; for example, the inference of construction properties based upon age and building type. A further stage is to infer likely HVAC plant configurations. The inference method is thus, if not more important than, then at least as important as, the first principle model used to predict the buildings' energy consumption. Existing benchmarks for non-domestic buildings represent a natural and logical source of information and data for developing the CaRB non-domestic community model inference engine.

Over the last couple of years, energy benchmarking in buildings has gained prominence with the adoption of the Energy Performance of Buildings Directive (EPBD) in 2002, more specifically implementation of the Directive through requirements for Operational Rating Certificates and Display Energy Certificates. However, long before EPBD, benchmarks were recognised as being important for comparing the operational energy efficiency of buildings and for influencing energy policy within building management. This paper gives a short review of a number of these benchmarking systems.

Review of benchmarks

The energy performance of a non-domestic building is frequently quantified by judging its performance against that of a sample of other similar buildings, usually through the application of a benchmark calculated from the sample. Alternatively, a prototypical building may be used as the benchmark. There are several basic types of benchmarking methods, of which the most common have been identified as:

1) Ranking systems [1]

2) Distribution models, using medians and percentiles [2]
3) Regression models [3]
4) Regression models using standard errors of a regression [4], or mean EUI (Energy Use Intensity), of the sample [5]
5) Prototypical models [6] [7]

These models usually take the form of an Energy Use Intensity (EUI), commonly kWh/m^2/year (kWh/sqft/year), MJ/m^2/year (Btu/sqft/year), or similar. The use of these units makes benchmarks easily understood by energy management professionals. Alternatively, a unit of kg CO_2/m^2/year may be used. Some benchmarks also give guidance on the percentage of energy which should be attributable to a particular end use.

This part of the paper presents the review of a number of benchmarking systems. Limitations of space have restricted the level of detailed description, but those aspects relevant to later discussion are presented.

UK Energy Efficiency Office Guides

At the end of the 1980s, the UK Energy Efficiency Office (EEO) produced a number of guides relating to the benchmarking of energy use in a range of non-domestic buildings [8]. Table 1 gives a summary of the end use percentages for a number of building use classifications, according to these guides. Essentially, these benchmarks use prototypical buildings, with adjustments made for the target building. The source of the data, upon which the benchmarks are based, is not given in the guides, but the level of disaggregation of the energy end uses, is quite detailed. The number of building uses covered is also quite broad. The assessment can be made for overall energy consumption or for the disaggregated end uses, making the benchmark suitable for identifying where a single end use consumes a disproportionately large amount of energy.

Table 1 is a simplification of the original documents, as there should be 28 notes attached to its content, indicating that there are a number of assumptions and restrictions affecting these building classifications and the energy end uses.

EEO benchmarks also include corrections for position of the building (sheltered, average, exposed), occupancy hours and degree day adjustment.

Table 1: End energy consumption, by percentage, according to EEO guides

Building classification	Space heating	Lighting	HWS	Other	Catering / Cooking	Ventilation	Manager's Accom'	Beer Cooling	Refrigeration	Date
Agency (high street)	67	19	4	10						1989
Bank (high street)	67	19	4	10						1989
Bingo Hall / Social Club	66	13	5		7	5		5		1990
Church	88	7		5						1990
Cinema	77	2	3	3		15				1990
Cold Store	8	10		***** [3]					82	1989
Court	84	8	5	2	1					1989
Factory	72	15	3	10						1989
Fast Food Outlet	3.5	1.5	24	1	70					1990
Health Centre	67	12	21							1991
Hospital (300 bed)	54 [4]	4.1	26.6	6.2	9.1	***** [4]				1991
Hotel (large)	50	9	11	12	18					1990
Libraries, Museums, Art Galleries	60	18		11		11				1990
Motorway Service Area	22	9	32		30	7				1990
Nursing Home (with pool)	46	7	20	27						1991
Office (natural ventilation)	60	20	8	12						1990
Office(with A/C)	48	16	6	1		29				1990
Prison	45	10	25	10	10					1989
Public House	38	12	18	5	11		6	10		1990
Restaurant	25	15	15		40	5				1990
Sports Centre (without pool)	75	11	3			11				1990
Supermarket	***** [1]	11	2	3	11	23 [1]			50	1990
Swimming Pool	***** [2]	9	3	33		55				1990
Transport Depot	80	6	4	8	2					1989
Warehouse	80	8	2	10						1989

Notes: [1] Heating and ventilation combined. [2] If not sub-metered. [3] See lighting. [4] Space heating and AC

UK Energy Consumption Guides

The Carbon Trust makes a number of benchmarking tools and publications available to the non-domestic sector. Among these are the Energy Consumption Guides (ECON Guides or ECGs) which provide benchmarks for a wide range of building occupancy types, or industrial activities. As well as paper documents, there are also online benchmarking tools [9].

As an example of the Guides, ECON19, for the assessment of the energy performance of office buildings, classifies office buildings into the following descriptive types:

1. Naturally ventilated cellular: A simple building, often (but not always) relatively small and sometimes in converted residential accommodation.
2. Naturally ventilated open-plan: Largely open-plan, but with some cellular offices and special areas. Typical size ranges from 500 m^2 to 4000 m^2.
3. Standard air-conditioned: Largely purpose-built and often speculatively developed. Typical size ranges from 2000 m^2 to 8000 m^2.
4. Air-conditioned, prestige: A national or regional head office, or technical or administrative centre. Typical size ranges from 4000 m^2 to 20 000 m^2. [10]

ECON19 may be used to benchmark energy consumption for nine or ten end uses, depending upon the above building classifications. These end uses are:

Heating and hot water	Cooling
Fans, pumps and controls	Humidification
Lighting	Office equipment
Catering, gas	Catering, electricity
Other electricity	Computer and communications rooms

Each of these end uses and the overall energy consumption are gauged as energy use indices (EUI). A factor may also be applied to each of the fossil fuel and electricity consumptions to give carbon dioxide emissions indices (CEI).

ECON19 divides the benchmarks into two categories:

1. **Typical.** Energy consumption patterns, which are consistent with median values of data collected in the mid-1990s for the Department of the Environment, Transport and the Regions (DETR) from a broad range of occupied office buildings.
2. **Good Practice.** Examples in which significantly lower energy consumption has been achieved using widely available and well-proven energy-efficient features and management practices. These examples fall within the lower quartile of the data collected.

The data upon which the benchmarks are based come from surveys of a range of office buildings in the 1990s, but that is the only information readily available on the source data. The method of application is a distributional model. However, there is evidence that the ‘good practice’ benchmarks have been derived from buildings in which a particular energy end use is significantly lower than the norm [10]. This means that the ‘good practice’ lighting may come from a building with extremely low lighting energy use, but that the ‘good practice’ space heating system may have been taken from a different building. As energy flows within buildings are intricately interconnected, reaching the level of energy consumption equating to ‘good practice’ for a whole building is difficult.

Due to its diverse building use classifications, another informative Guide is ECON75, for UK Ministry of Defence Estates [11]. For each of its eleven building use categories (see Table 2), there are varying levels of disaggregation of energy end uses, with the data provided in simple ‘typical’ energy use percentage tables. Of particular interest is the normalisation of space heating by degree days and the inclusion of a simple factor for exposure of the building to the weather. Twelve energy end uses are given as part of the benchmarking system (see Table 3), but not all of these apply to each building use category. For “specialist site facilities”, no energy end use percentages are given.

Table 2: ECON75 building use categories

Offices	Workshops	Hangars	Training & education facilities
Sports & recreation	Motor transport facilities	Catering Facilities	Specialist site facilities
Multi-occupancy accommodation	Sores/warehouses	Messes with integral accommodation	

Table 3: ECON75 energy end uses

Space heating	Water heating	Heating / hot water	Hot water / catering
Food storage, preparation and cooking	Cooling	Fans, pumps, controls	Lighting
Office equipment	Catering	General power	Other electricity use

Additionally, for some building use classes in ECON75, a factor is used to modify the energy consumption according to shift patterns; e.g. for workshops, the factor ranges from 1.00, for a 10 hour shift on five days per week, to 0.72 for continuous working. Temperature set points and degree days also form part of the ECON75 benchmarking process, thus increasing its accuracy and applicability.

CIBSE TM22 Energy Assessment and Reporting Method

TM22 is the Chartered Institute of Building Services Engineers’ (CIBSE) energy consumption assessment method for non-domestic buildings [8]. This method assesses on the basis of kWh / m^2 and other performance criteria, then compares the target building against established benchmarks from ECON19, for both kWh / m^2 and for $kgCO_2$ / m^2, using UK conversion factors for CO_2 emissions. The TM22 methodology covers the building use classifications shown in Table 4.

Table 4: CIBSE TM22 building types. [14]

Building general type	Building sub-type
Office	Naturally ventilated cellular Naturally ventilated open plan Air conditioned standard Air conditioned prestige
Hotel	Luxury, no AC or pool Luxury, with AC, no pool Luxury, with pool no AC Luxury, with AC and pool Business, no AC or pool Business, with AC, no pool Business, with pool, no AC Business, with AC and pool Smaller, no AC or pool Smaller, with AC, no pool Smaller, with pool, no AC Smaller, with AC and pool
Bank or Agency	Bank, gas heating, no cooling Bank, all electric, no cooling Agency, gas heating, no cooling Agency, all electric, no cooling Bank, gas heating, with cooling

	Bank, all electric, with cooling Agency, gas heating, with cooling Agency, all electric, with cooling
Mixed use industrial	Distribution and storage Light manufacturing Factory office General manufacturing Naturally ventilated cellular office Naturally ventilated open plan office Air conditioned standard office Air conditioned prestige office

One of three levels of appraisal methodology may be used, depending upon the available data.

1. *Option A*: Simple building assessment of a building of a single type with one or two energy supplies.
2. *Option B*: General building assessment of a building or site which can have zones of different types and non-standard occupancy and energy uses.
3. *Option C*: Systems assessment against benchmarks for the building systems.

Within the Option B assessment of TM22 the energy end use categories are:

Heating & hot water	Lighting	Office equipment
Ventilation & pumps	Cooling	Lifts & vertical transport
Controls	Humidification	Controls & telecoms
Local kitchens & vending		

"Special energy uses" are:

Dedicated computer room or suite	Catering kitchen and restaurant
Dealing rooms	Sports & leisure facilities
Covered car park	

Where a building is mixed use, the smaller, secondary use is entered as a separate area to the main area. Occupancy can be adjusted in Option B, as well. For each Option assessment type, the data is given a quality assurance (QA) rating to ensure that those reading the data are aware of its source. However, no methodology is specified for the survey process itself, though the procedure spreadsheets indicate the data required for a full plant survey.

When compared to the Energy Efficiency Office Guides' building classifications, the number of subclasses within TM22 has increased, thus making the benchmark more closely tailored to a specific building use/type.

Asia-Pacific Economic Cooperation (APEC) Energy Benchmark System

The Asia-Pacific Economic Cooperation (APEC) provides an example of a basic non-domestic building energy benchmarking system [15]. The building classification system is limited to offices, hotels, hospitals, paper mills, metals production and cement manufacture. Offices, hotels and hospitals are benchmarked in GJ/m^2/yr.

For hotels, the required data are:

1. A building number (previously assigned by the APEC member economy)
2. Location

3. Gross floor area
4. Number of workers (main shift only)
5. District steam or hot water (yes or no)
6. Energy source for space heating
7. Number of lodging rooms (optional)

Offices and hospitals are required to provide the same data as hotels, except for the numbers of workers and rooms. There is no disaggregation of energy end uses. Data may be submitted online, into a public access database, making the source data readily visible. However, there does not appear to be a validation procedure for the data submitted. As well as electricity consumption, figures may be entered for up to three other energy sources. The benchmarking process is achieved by comparing the test building's $GJ/m^2/yr$ value against those of other similar buildings in the database, using a number of charts, presented online.

US Energy Star®

Energy Star® is the assessment and benchmarking system made available by the U.S. Environmental Protection Agency and the U.S. Department of Energy [16]. Energy Star® covers many aspects of reducing energy consumption, but has a benchmarking tool which is specifically aimed at allowing the operators of non-domestic buildings to assess energy consumption.

Energy Star® uses data from the Commercial Buildings Energy Consumption Survey (CBECS) [17], which is carried out every 4 years, with the latest data being from 2003 and the next survey due to be carried out in 2008 [18]. The surveys are conducted, on behalf of the United States Energy Information Administration, to determine the end-uses of energy consumption in non-domestic buildings in nine major Census regions of the US. The survey data is publicly available to download from the CBECS website.

Overall, the sample sizes are large – in excess of 4,000 buildings in 2003 – with some (more complicated) buildings being subjected to an on-site survey. The basic survey is carried out over the telephone, but may include access to data on metered utilities. Note that the samples are cleaned before inclusion in the survey data. There is also data for degree days.

CBECS uses the following main building use classifications [18]:

Education	Food Sales	Food Service	Health Care
Lodging	Mercantile	Office Public	Assembly
Public Order & Safety	Religious Worship	Service	Other
Warehouse & Storage	Vacant		

These classes are subdivided into between two and twelve further sub-divisions, giving a total of 81 classifications. This is a workable number of classifications, even though it may aggregate some building uses into wider classifications than would be ideal. Surveys prior to 1999 did not use sub-divisions.

The survey collects sixty-five pieces of data in the following basic divisions:

1. Gross floor area
2. Use classes (14 main types)
3. Building age (8 bands)
4. Census regions, with subdivisions
5. Number of floors (5 categories)
6. Existence of internal transport systems (e.g. elevators)
7. Occupancy numbers (7 bands + vacant)
8. Occupancy hours (6 bands)
9. Number of establishments (subdivision of buildings)
10. Building envelope type – walls
11. Building envelope type – roofs

12. Modifications to building (yes / no)
13. Energy sources
14. Energy uses
15. Energy-using equipment
16. Treated floor areas

This data is put through a weighted least squares regression analysis, together with data filters, to produce an index of Source [Primary] Energy Use Intensity (EUI). The index of performance is from 1 to 100. To achieve Energy Star® status, a building must have a score of between 75 and 100. A score of 50 would indicate average performance for the building and its operational characteristics. Corrections are made for hours of occupancy, size of building etc.

Not all of the collected variables are included in the regression model, only those which explain *how* a building operates are included. In other words, factors which describe the physical operation, such as: floor area, hours per week, number of occupants, number of computers, cash registers, or number of refrigeration units, etc, [17]. Variables which explain *why* a building performs the way it does are not included because they do not describe a building's physical characteristics. These factors can be broken into two categories:

1. "Technology Factors – Factors that describe technologies that may contribute to overall performance are excluded because they are not physical constraints on the building operation. The type of lighting present (e.g. T-12 vs. T-8) is excluded from the analysis, because it is within control of the building owner/operator and does not define the building activity. Correct management and operation of a more efficient technology (e.g. T-8 lights) will result in lower energy consumption and a higher rating. By excluding technologies from the regression, buildings that install and properly manage efficient technologies should and will receive higher scores.
2. Market Conditions – Factors that may influence why a building performs the way it does such as energy prices. These factors do not define activity within a building and are external to a thermodynamic assessment." [17]

The most interesting aspect of Energy Star® is that it is based on the CBECS, for which the source data is readily available. The level of transparency about data gathering appears rare amongst non-domestic benchmarking methodologies – especially at this level of detail – and gives greater confidence in the validity of the benchmark's classifications and assessments. Additionally, the methodology of how the data are collected, by telephone, is also available [18].

Modelled Benchmarks

In order to avoid the problems of data collection and sample sizes associated with empirical benchmarks, it is possible to use an alternative model-based benchmark. Such benchmarks are usually associated with specific building activities and an example for laboratories is described in [6]. This method calculates the minimum energy consumption capable of allowing the building to perform its function. This is then compared to metered energy consumption for the target building. The process was tested on a number of laboratory buildings with some success, but the authors of [6] suggest that it could also be used for any building type. However, they also point out that some buildings with heavy consumers of energy may be adversely penalised. The example they give is for a laboratory with stringent air filtration requirements being compared to a less stringent standard building design.

The benchmark methodology has nine 'required inputs', such as plan areas of lab and non-lab spaces, location, electrical and fuel consumptions and time duration, which have no default values. Another twelve 'inputs with defaults', mainly concerning design parameters such as air-change rates and relative humidity, which may be overwritten with values that are known for the target building. From these inputs, the building's energy requirement can be calculated from first principles. The sources of the default values are given in [6], making these transparent.

The output metrics are the effectiveness of the electrical and fuel consumptions. These are given by the calculated energy consumption divided by the actual energy consumed for a given period. The efficiencies may then be compared to those of other buildings. However, the efficiency is for the specific building, so it is almost a self-contained benchmark and may be used to compare dissimilar buildings, but [6] indicates that accuracy of the model decreases in these circumstances and more research is needed.

Discussion

Some of the potential problems with energy benchmarks can be identified as:

1. Benchmark may be based upon small and unrepresentative samples
2. Normalisation may not be consistent across different methods
3. Source data is frequently not visible
4. Difficulties in establishing the assumptions used
5. Reliant on 'snapshot' data at time of surveys – both for the building and for the base dataset
6. Some models appear to ignore occupancy factors
7. Survey methodologies may lead to measurement of different characteristics
8. Inaccuracies in data collection

Jones et al [2] point out that the validity of statistical benchmarks, which use medians and percentiles, depends upon the use of samples which are sufficiently large, i.e. more than 100. Problems of accuracy may arise with inadequate amounts of accurate/detailed data on sufficient numbers of a wide range of non-domestic building types, or within the samples for classifications of buildings. The heterogeneity of non-domestic buildings indicates that these problems are likely to continue. It seems logical to assume that a reduction in building classifications would help increase the sample size for a given classification, without increasing the number of data and the time taken to collect them. This is relevant to the CaRB Community model as the availability of data is more important than extreme levels of detail.

An exception to the problem posed by small sample sizes is the prototypical, or model, building approach. One of the strengths of this method is that it does not require a dataset of existing buildings at the instigation of the benchmark model. However, the process is one of modelling, with an associated level of specific application to one building type and a need for accurate data inputs. The data upon which the prototypical building is based are primarily defined by local building regulations and design codes, so this could make the benchmark more useful to organisations which have a number of similar buildings in differing regulatory or climatic regions. Also, the design regulations and codes are in the public domain, thus making this aspect of the benchmarking process transparent.

To the questions above, we may add the role of assumptions and how they, too, may not be fully explained. One assumption may be that all building surveys and their data, upon which a benchmark is based, are of equal accuracy/value. TM22 partially avoids this assumption by including an element of quality assurance (QA), but this only applies to the source of the data gathered by the surveyor. Another consideration is that even where survey methodologies are identical, there is still considerable room for differences in the recorded data and/or survey output, as described for domestic energy surveys, by Chapman [19]. This variability of data quality could affect both the benchmarking process of a target building and the initial sample data collection, on which the benchmark is based.

It seems likely that some surveys will not represent a random sample of the building stock, thus affecting the distribution of energy performances within the sample. When data collection is not purely for the information of a benchmarking system, it is possible that there are other factors to be considered. Where surveys have been initiated by building managers who operate their buildings well, the energy consumption will probably be lower than average. In the Probe series of surveys [20] of a number of UK buildings, the buildings were mostly recently constructed, "…selected on the basis of their technical interest…" and "…only potentially well-performing buildings were long listed" [21]. If benchmarks were based upon these surveys there is a probability that the distribution of energy consumption would be skewed, compared to the full population of the building stock. Surveys, such as CBECS, upon which

Energy Star® is based, should avoid this problem as their sole purpose is to collect random samples, unlike the APEC system which relies on building operators contributing data themselves.

CBECS also has the advantage of having a scheduled update of its content (approximately) every four years. This schedule allows building operators to reassess their energy performance on a regular basis and for government to evaluate the overall performance of the building stock at state/regional and national levels. Because the base data for benchmarks, such as ECON19 are not accessible, this type of data suffers from being a 'snapshot' of similar buildings at the time of the design of the benchmark. Thus, updating the dataset – and hence the benchmark – becomes important. It may be that samples are updated, but this is not always obvious. This may also be the case with alterations to methodologies. Occupancy factors also suffer from this 'snapshot' problem, due to the possibility that occupancy factors change over time, even for the same building or premises. This may be significant, as some literature indicates that occupancy can be a variable of prime importance [4]. However, in [22], Bordass et al feel that occupancy is not a sound variable upon which to benchmark energy consumption.

Before data have been collected there is the question of the classification of building types and data analysis to be considered. The number of classification subdivisions appears to have increased over the years – e.g. EEO compared to TM22, or the development of CBECS/Energy Star® [18]. It seems that most benchmarks use dissimilar building classification systems and that there are many different methods of analysing and presenting the benchmark data. It may be that much of this diversity of methods is due to differences in the number of variables recorded and the volume of data collected. For these reasons, alone, it might be said that no two benchmarks can be directly comparable.

The range of sophistication of data inputs for benchmarks appears to vary, with the simplicity of the APEC system at one end of the spectrum, and the complication of the model described in [6], at the other. Because the data inputs/outputs, for APEC, are so limited, it is difficult to see how useful this benchmark tool would be to building operators. As a national level comparison tool, however, it may be of more value. Alternatively, it could be said that data can be submitted continuously, thus giving the APEC benchmark the potential to be permanently up-to-date. The problems of verifying the data are still present, though, together with extremely limited building use classifications.

The model building benchmark system presented in [6] could be adapted for other building types, but this would still require choices of new data inputs, which is likely to make it less user-friendly than other benchmarks. Although the benchmark can tell the building operator how efficiently energy is being used in their building, it does not compare it to other similar buildings directly, except where a sample of similar buildings have been assessed using the same methodology. This latter problem could make the benchmark of less value to building operators. Also, increasing complexity allows a greater probability of incorrect data input, or manipulation, as described in [19] [23].

Benchmarks, such as ECON75, are somewhere between the two extremes of data requirements. The benchmark includes sophistications such as occupancy factors and degree days. However, there are some un-stated assumptions which are apparently based upon hidden empirical data, for example, built form and heating plant, the details of which are not required (except for fuel type). Energy Star® provides a fair compromise of data transparency, usability and value to building operators. Although the CBECS data gathering has great strengths, it is only fully relevant to the United States, but CBECS does represent a workable methodology for others to consider when gathering non-domestic building stock data upon which to base benchmarks.

Conclusions

This paper has reviewed some existing benchmarks, datasets and methodologies for non-domestic buildings in both Europe and elsewhere. The benchmarks reviewed have varying degrees of complexity and comprehensiveness. The benchmarks with limited data inputs give outputs which are limited in their level of detail and applicability to specific building uses, whilst those with more comprehensive inputs may be so tailored to individual building types that they are also of limited value at the national scale.

Additionally, with increased data collection and inputting comes the danger of an increase in the number of errors.

It also seems that, whichever methodology is used, the quantity, quality and auditable source of a benchmark's base data are of importance. There appears to be a general lack of data transparency in a number of empirical benchmarks. The combination of these two situations makes a comparison of one building, using one benchmark, to a second building, using a different benchmark, problematic and of questionable value. A possible exception to this situation is a model-based benchmark, which can be applied to an individual building according to local design restrictions.

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Preparing the Implementation of the EuP Directive for Fans in Non-Residential Building Ventilation

Julia Oberschmidt, Peter Radgen
Fraunhofer Institute Systems and Innovation Research

Abstract

Fans for ventilation in non-residential buildings have been subject to a preparatory study for the European Commission analyzing eco-impact and in particular energy efficiency of these products with regard to measures for the implementation of the European Energy-using Products Directive (EuP Directive 2005/32/EC). The EuP Directive establishes *"a framework for the setting of Community ecodesign requirements for energy-using products with the aim of ensuring the free movement of those products within the internal market"* and to provide *"for the setting of requirements which the energy-using products covered by implementing measures must fulfill in order for them to be placed on the market and/or put into service. It contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply"* [1].

Even if all energy using products are covered by the EuP Framework Directive only those products for which implementing measures will be introduced are directly affected. Products that do not comply with requirements defined in implementing measures can not receive the CE mark and can ultimately be prohibited from being traded within the EC. The decision for product-specific implementing measures will probably be based on the results of the EuP preparatory studies.

Lot 11 of these preparatory studies considers electric motors 0.75-200 kW, water pumps for commercial buildings, drinking water, food and agriculture, circulators in buildings and ventilation fans for non-residential buildings. The paper presents results from this study concerning fans for non-residential building ventilation. This includes market analysis and technical analysis of specific product categories defined with the aim to represent typical applications in non-residential building ventilation. The product analysis comprises an environmental impact assessment of the whole life-cycle. Particular attention is paid to energy efficiency issues during the use phase of the product which determines most of the environmental impact of ventilation fans.

Even though the EuP Directive focuses on the product, system characteristics are also taken into account. Potentials for improving the environmental performance are identified. Based on a model estimating the number of products in use, the market analysis additionally serves to quantify the European-wide environmental impact and the overall potential for improvement in the future, if minimum efficiencies are defined for the different product categories.

1 The European Energy-using Products Directive and its Implementation

The production, distribution, usage and disposal of energy-using products cause environmental impacts by consuming energy, materials and resources, generating waste and releasing hazardous substances to the environment. Hereby more than 80% of all product-related impacts are determined at the design stage of the product. Eco-design aims at improving the environmental performance of products throughout the life-cycle. Against this background the Energy-using Products (EuP) Directive (2005/32/EC) aims at promoting the integration of environmental aspects of products in enterprise policies by setting a common framework for eco-design requirements. In this way it shall contribute to sustainable development by increasing energy efficiency of products and the level of environmental protection, while at the same time increasing the security of energy supply [1].

All products that depend on energy input to work as intended fall under the EuP directive, but only those for which product-specific implementing measures are introduced will be directly affected. The directive describes the principal approach to be followed when analyzing energy-using products to prepare the decision making, if implementing measures for a class of products should be established.

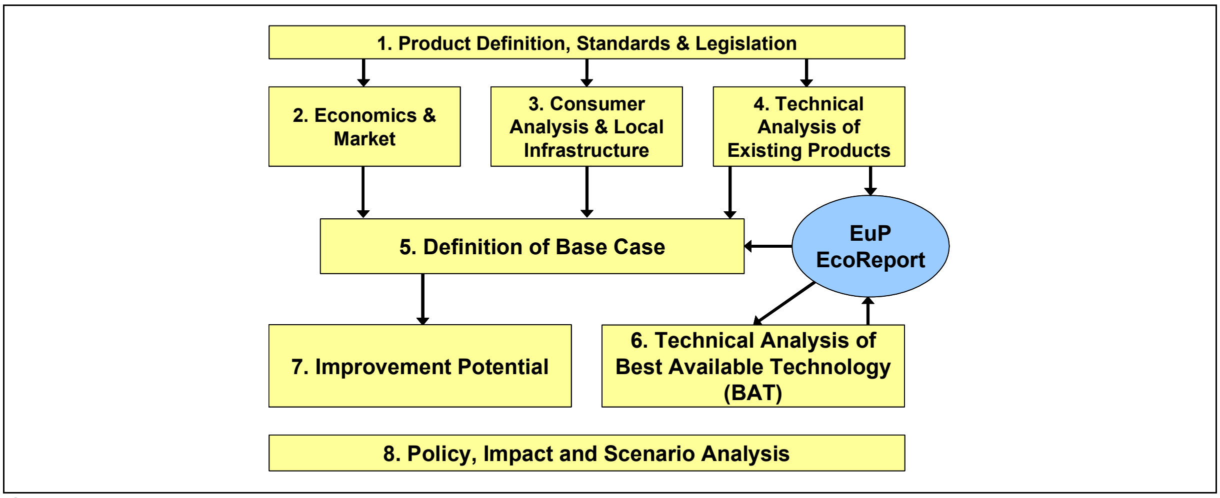
Products that will comply with these implementing measures could have the CE mark attached, those which do not can ultimately be prohibited from being traded within the EC. To prepare implementing measures the European Commission has launched preparatory studies for different product groups (lots) as a means to deliver the necessary technical information on state-of-the-art products, best available technologies, their environmental impact and improvement potential. The products dealt with in the preparatory studies range from office equipment through household appliances to industrial goods such as electric motors, pumps, circulators, fans and residential room air conditioners.

Lot 11 of the EuP preparatory studies is concerned with electric motors (0.75-200 kW), water pumps, circulators and fans for non-residential building ventilation. The final draft report of this study has been published recently. This article provides an insight into main findings of the sub-study on fans for non-residential building ventilation. First the general methodology for analyzing EuPs is shortly explained. Then the scope of the study and the products to be analyzed for non-residential building ventilation are described. In the following results of the environmental impact assessment for average products is shown. Finally the improvement potential by introducing minimum performance standards is illustrated.

2 The methodology for Analyzing Energy-Using Products

The methodology for the environmental impact assessment in the context of the EuP directive was designed in an earlier study for the Commission undertaken by VHK (Van Holsteijn en Kemna BV, Netherlands) [2]. The structure of the EuP methodology is outlined in Figure 1. It is applied to evaluate all products examined in EuP preparatory studies. It starts with the definition of the product and an analysis of existing standards and legislation (step 1). The following steps are all based on the product definition and categorization as determined in this first step. However, adjustments can be made if knowledge gained at a later point of the analysis allows a more suitable product categorization. In step 2 the (European) market for the products under consideration is analyzed, followed by an analysis of consumer behavior and local infrastructure (step 3).

Figure 1: The EuP methodology for product analysis



Source: Kemna, van Elburg and van Holsteijn, 2005: MEEUP Methodology Report [2]

Products, which are already available on the market, are analyzed in step 4, while the analysis of the average product per category (base case) is subject to step 5. In step 6 those products are analyzed which will presumably be available on the market in 2 to 3 years time (best available technology). The improvement potential for the different product categories is analyzed in step 7. Finally, in step 8, a scenario and impact analysis is conducted. This article focuses on steps 1, 2, 5 and 8 of the preparatory study on non-residential building ventilation.

In addition to the outlined methodology, an Excel spreadsheet model was developed, which links the amount of materials used in the production phase, the energy consumption in the use phase as well as recycling and disposal factors to the overall ecological impact of the product. From there ecological impact categories are calculated differentiated by the different life-cycle phases of the product. Impacts considered include energy and water consumption, material use, waste generation, emissions to air and emissions to water. It is the task of the preparatory studies to collect and analyze the necessary input data to the model in a structured way, including economic, material and energy use data. Thus, the EuP spreadsheet model builds the common basis for product analysis within all the EuP preparatory studies [2;3].

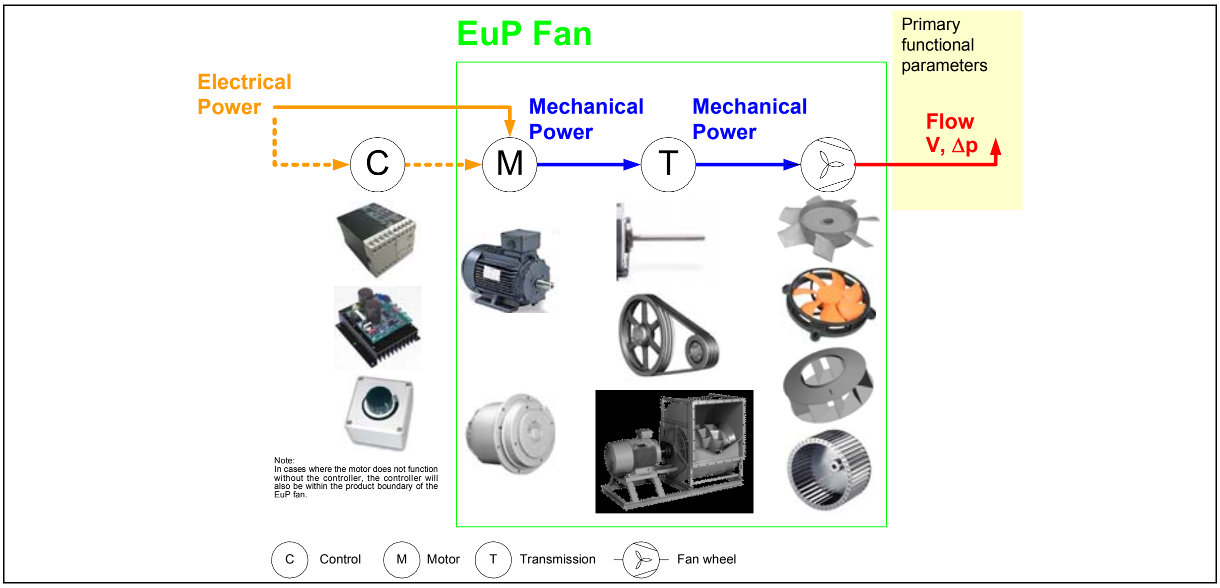
3 Defining the Energy-Using-Product for Non-Residential Building Ventilation

The EuP directive is a product-related approach, focusing on products and their functions rather than systems. According to Directive 2005/32/EC [1] an Energy-using Product is defined as

> *"a product which, once placed on the market and/or put into service, is dependent on energy input (…) to work as intended, or a product for the generation, transfer and measurement of such energy, including parts dependent on energy input and intended to be incorporated into an EuP covered by this Directive which are placed on the market and/or put into service as individual parts for end-users and of which the environmental performance can be assessed independently"*.

For fans, the product placed on the market can be either fans that are connected to the motor by e.g. belt or shaft, or it can be integrated products, where fan and motor cannot function independently as they share components (for example fans with an inside-out motor where the rotor of the motor is also the impeller of the fan wheel). Regarding the EuP Directive both types (integrated and non-integrated) need to be compared since they compete on the market to be used in the same applications.

Figure 2: Definition of the product boundaries for ventilation fans



Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]

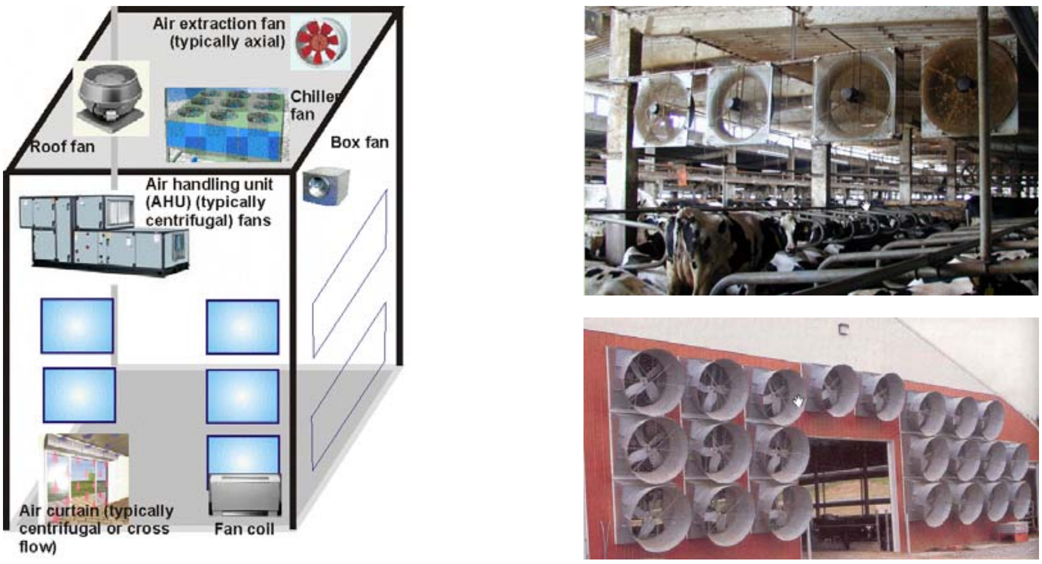
From a life cycle perspective integrated and non-integrated ventilation fans can only be compared with each other if the product boundaries are set in a consistent way, i.e. to include or not to include the motor for the analysis. For integrated products it does not seem practical to analyze only the fan wheel without the motor. Furthermore, it was confirmed by several European fan manufactures that in most cases also the non-integrated fans are sold together with the motor or fan manufacturers even produce the motor themselves. Thus, it was perceived that the product placed on the market typically is the complete fan plus motor unit. Furthermore the EuP spreadsheet model for analyzing the use phase of the product requires the electricity used as an input. Therefore the boundaries for fans as an energy-using product were defined as shown in Figure 2.

3.1 Fans for non-residential building ventilation

Non residential buildings cover a broad range of commercial, industrial and agricultural buildings. Some building types may have similarities in the technologies used for ventilation but could differ significantly in the way the building is used. Applications range from concert halls in which fans are used only in the evening for some hours, to school buildings which might be used only in the morning, over to office buildings where the ventilation is mainly required during work times. There are also workshops in which there is a three shift production, making it necessary to operate the ventilation system round the clock. Furthermore, as the ventilation is used to exchange the air and to remove heat, humidity and other contaminants, the required air flow varies typically over the year with higher ventilation rates during summer time [4].

Figure 3 shows different fan types and applications of non-residential building ventilation. The most well known products for commercial and industrial buildings are the roof fans (Figure 3, left). These are located on the roof of the building and are connected to a ducting system to extract air from the building. In the case of factory buildings it is also possible that they are not attached to a ducting system. The function of the air extraction fans is similar to the roof fans but they eject the air through the walls. Their location is inside the building whereas the roof fans are located outside. This has implications regarding the materials used and the weather protection required.

Figure 3: Fans for non-residential building ventilation



ventilation in commercial and industrial buildings | ventilation in agricultural buildings

Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]; Heidenreich, n.d.: Stallklimatisierung für steigende Leistungen [5].

If in addition to mechanical ventilation heating and air conditioning is also required, air handling units are applied (AHUs). They are connected to the air distribution system of the building and include heat exchanger, filter, water evaporator, air intake as well as air extraction fan in one casing. As they are also used for ventilation, heating and air conditioning they are outside the scope of the EuP preparatory study lot 11, which is restricted to ventilation fans only. However, there are some fan products for the OEM market to be incorporated in AHUs that are within the scope of lot 11 and could consequently be subject to implementing measures. The same applies to fans incorporated in fan coils, which are another option for central based air conditioning. In this case each room is equipped with a fan coil in combination with the central pre-treatment of air.

Air curtains separate the air inside and outside the building to reduce heating and cooling losses. They are widely used in public buildings and shopping centers, where doors remain open during the day because people are entering and leaving frequently. To extract air from single rooms, sometimes small window fans with a power below 125 W are used. These are however typically used in private buildings and are therefore not within the scope of lot 11.

Apart from commercial and industrial buildings, agricultural ventilation is also within the scope of the EuP preparatory study lot 11 (Figure 3, right). Main agricultural applications are temperature and humidity control in livestock buildings, circulation of air in greenhouses and crop drying in storage buildings and silos [6;7;8]. In most agricultural applications axial flow fans are used, e.g. for re-circulating air in barns (Figure 3, right top) or for air extraction/supply (Figure 3, right bottom). The system to be used depends on the needs of the user and building layout.

3.2 Selection of product categories for the EuP Analysis

After setting the boundaries for the energy-using product and examining the scope of the study, the product categories to be analyzed in detail are defined. According to Article 15 of the EuP Directive the eligibility criteria for product categories to be analyzed are as follows [1]:

1. Significant volume of sales and trade, indicatively more than 200,000 units a year within the Community according to most recently available figures;
2. Significant environmental impact within the Community;
3. Significant potential for improvement in terms of environmental impact without entailing excessive costs.

Table 1: Ventilation products analyzed for the EuP preparatory study lot 11

Product Category	Direction of Flow	Type	Sizes [a] [mm]	Example	
1	Axial	≤ 300 Pa (static pressure)	200-1400		Source: Helios
2		> 300 Pa (static pressure)	200-1400		
3	Centrifugal	forward curved blades (with casing)	120-1600		Source: Nicotra
4		backward curved blades (no casing)	120-1600		Source: ebmpapst
5		backward curved blades (with scroll housing)	120-1600		Source: Ziehl-Abegg
6	Other	box fans	100-1000		Source: Fläktwoods
7		roof fans [b]	250-1000		Source: Gebhardt
8		cross-flow fans	60-120		Source: ebmpapst

Notes: (a) Size refers to impeller diameter except in box fans where it refers to spigot size. (b) Roof fans can be either centrifugal or axial.
Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]

Based on this indicative list as well as on market analysis and discussion with stakeholders a product categorization for non-residential building ventilation was elaborated (Table 1). This categorization has been discussed extensively with stakeholders and changed significantly during the project. It is finally supposed to reflect the main applications of fans in non-residential building ventilation. The fan categories shown can be found in all applications, even if there might be some preference. For example, most agricultural fans are of axial type (categories 1 and 2). Centrifugal free wheels (category 4) are mainly used for air handling units. Boxed fans (category 6) are mainly used in commercial buildings. The main application of cross-flow fans (category 8) are air curtains. However, the main aim of all ventilation products is to move air at a specified volume flow and pressure increase, independent from the type of building; therefore the different products can not be allocated to particular building types.

It was also discussed whether to include smoke extract units as an additional category. Howver, although these are used in large numbers, their electricity consumption during the use phase is negligible because they are only switched on in emergencies. Therefore their overall environmental impact is not significant, because the main impact regarding the life-cycle of fans results from the electricity consumed during use. For this reason smoke extract units were excluded from the EuP analysis.

4 The European Market for Non-Residential Building Ventilation

To approximate the overall environmental impact of non-residential building ventilation in the European Union, the number of products in use was estimated for each of the product categories defined above (Table 1). Starting point for the analysis was Eurostat's Prodcom Annual[1], where for specific product categories yearly production, import and export data for European countries is available since 1995 (in number of units and Euros). For analysis of the non-residential building ventilation market, data on three Prodcom categories relevant to non-residential building ventilation was examined [9]:

- 29.23.20.30 Axial fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output ≤ 125 W)
- 29.23.20.50 Centrifugal fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output ≤ 125 W)
- 29.23.20.70 Fans (excluding table, floor, wall, ceiling or roof fans with a self-contained electric motor of an output ≤ 125 W, axial fans, centrifugal fans)

Less aggregated data to reflect the product categories as defined in Table 1 are not available. Furthermore it is difficult to interpret the Eurostat data in the context of the non residential building ventilation market for the following reasons [4]:

1. The product categories available for fans are highly aggregated in terms of technology (e.g. only differentiated between axial, centrifugal and other fans).
2. The definition of product categories is not always clear; for example, even though the definition of axial (29.23.20.30), centrifugal (29.23.20.50) and other fans (29.23.20.70) does exclude "table, floor, wall, ceiling or roof fans with a self-contained electric motor of an output ≤125 W", it can still include other fan types below 125 W, e.g. those fans used in vehicles.
3. There may be significant double counting of some products, for example if a product is exported to one country, modified and then re-exported to another country.
4. The categories do not differentiate applications, i.e. fan products for vehicles, for industrial processes, for ventilation of buildings, etc. are all recorded under the same categories. This makes it especially difficult to identify the share of fans used in the ventilation of non residential buildings.

In addition to these disadvantages, the data that is available is often incomplete for many countries and/or years (mostly due to confidentiality reasons) and often seems unreliable. Notwithstanding these drawbacks, the data retrieved from Eurostat was analyzed and amended using "best estimates" to fill in the gaps in data. The analysis of the production data revealed that the main manufacturers of axial and centrifugal fans (in terms of number of units produced) are in Germany, France, the Netherlands, Italy, UK, Denmark and Spain.

[1] "Prodcom [PRODuction COMmunautaire] is a system for the collection and dissemination of statistics on the production of manufactured goods. […] It is based on a product classification called the Prodcom List which consists of about 4500 headings relating to manufactured products. Products are detailed on an 8-digit level; 1 to 4 digits refer to the NACE classification in which producing enterprise is normally classified" [http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2594,58778937&_dad=portal&_schema=PORTAL#PROD].

Based on the Eurostat data on production, import and export amended with own estimates, apparent consumption per year for axial, centrifugal and others fans (Prodcom categories 29.23.20.30, 29.23.20.50 and 29.23.20.70) was calculated. As the Eurostat numbers for these categories do not only include fans for ventilation in non-residential buildings but also fans for industrial process ventilation, fans for transportation vehicles, fans for residential ventilation etc., a model was developed to break down the number of units to the eight EuP product categories used for non-residential building ventilation. This model is based on the available data, discussion with fan experts and manufactures, own market research and on assumptions, for example regarding the share of applications per Prodcom category, the share of high and low pressure axial fans in the different applications etc. [4].

In this way the number of units going into the market for non-residential building ventilation from 1995 to 2005 (for these years Eurostat data was available) was obtained. Based on the estimated data for the years 1995 to 2005, apparent consumption for past and future years was approximated with different growth rates (logarithmic and linear growth based on regression of 1995 to 2005 as well as constant growth rate of 2% and 10%). Then, based on an average product lifetime of 15 years the number of products in use in past and future years was estimated. Because the obtained numbers are based on a large number of assumptions they should not be over-interpreted. Nevertheless the data seems to be consistent with the results of an earlier study [Radgen, 2001], where the total fans energy consumption in the tertiary sector was calculated.

Some results of the calculations are summarized in Table 2. The number of products in use in 2025 varies widely due to the different assumptions about the growth rate of apparent consumption. The largest number is not likely as it is based on a constant growth rate of 10%. However, even when assuming lowest growth rates the number of products in use is very high for all of the product categories, ranging from 3.6 Million for cross-flow fans to 52.5 Million for roof fans in 2025.

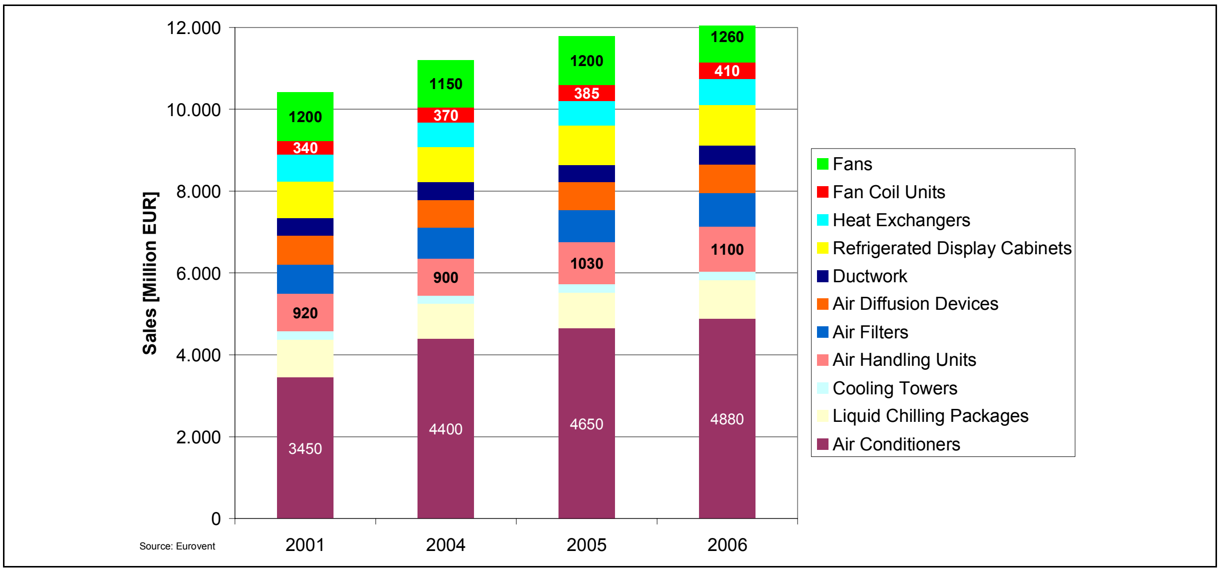
Table 2: Number of fans for non-residential building ventilation placed on the market in EU27 in 2005 and estimated Number of Products in EU27 in use in 2005 and 2025

Product Category	Direction of Flow	Type	Apparent Consumption	Number of products in use (Mio.)	
			2005	2005	2025
1	Axial	≤ 300 Pa (static pressure)	718,075	6.1-7.3	14.0-40.4
2		> 300 Pa (static pressure)	1,994,653	16.8-20.2	38.8-112.3
3	Centrifugal	forward curved blades (with casing)	1,091,680	9.2-10.3	16.8-61.4
4		backward curved blades (no casing)	337,563	2.8-3.2	5.2-19.0
5		backward curved blades (with scroll housing)	376,180	3.2-3.5	5.8-21.2
6	Other	box fans	1,532,397	20.6-23.0	29.8-86.3
7		roof fans	2,694,325	36.2-40.4	52.5-151.7
8		cross-flow fans	182,428	2.4-2.7	3.6-10.3

Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]

Apart from Eurostat hardly any other market data on non-residential building ventilation in the European Union is available. For a number of years the European Committee of Air Handling and Refrigeration Equipment Manufacturers (Eurovent-Cecomaf) has published data on sales of refrigeration and air handling equipment (Figure 4). This data shows, that the total sales volume for fans is about 1.2 Billion Euro and for fan coil units 410 Million Euros. However, the data does not include all manufacturers and might only cover 60 to 70 % of the market. Nevertheless the numbers are showing an increasing trend for fans and fan coil units between 2001 and 2006.

Figure 4: Sales of fans and air handling products



Source: Eurovent, 2005 and 2006: Market Evolution and Sale Statistics. [10;11]

Due to an increasing demand for air conditioning within the European Union, the demand for ventilation fans will also increase. In addition to the fans themselves, most products listed in the Eurovent statistics are containing fans. Even though it can be observed that the prices of most air conditioning and ventilation products are decreasing due to the high competition on the international markets, the total sales volume is still increasing. Consequently, the increase in number of units will be even higher than the increase in sales volume.

5 Life-cycle analysis of ventilation fans

As in all EuP preparatory studies the EuP spreadsheet model was used for life-cycle analysis of the products under consideration to identify their ecological impact. To examine the environmental impacts of one product the model requires input on the production phase (Bill of Materials (BOM) of the product), distribution phase (volume of packaged product), use phase (energy consumption and consumables) and end-of-life (recycling and disposal rates). Based on this data input the model calculates ecological impact categories differentiated by life-cycle phase. Impacts considered include energy and water consumption, material use, waste generation, emissions to air and emissions to water. Regarding emissions to air, greenhouse gases, acidifying agents, volatile organic compounds, ozone depleting substances, persistent organic pollutants, heavy metals, fine particulate matter and suspended particulate matter are analyzed. The examined emissions to water include heavy metals, substances affecting oxygen balance and persistent organic pollutants [2; 3].

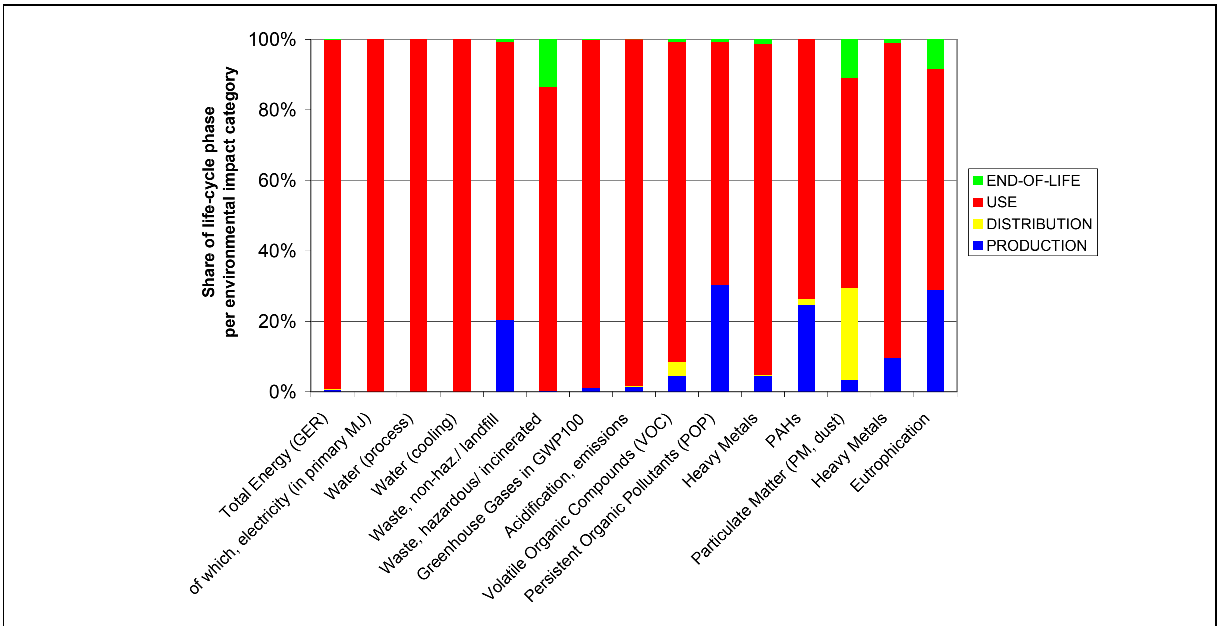
For several individual fan products manufactures provided detailed BOMs. To derive generalized BOMs independent of individual manufacturers additionally information available on materials, total weight and motor power from catalogues was used. Efficiency data for calculation of the energy usage during the use phase of the product was derived mainly from fan performance charts based on several manufacturers catalogues from various European countries. For the distribution phase standard assumptions e.g. on packaging were made. For the end-of-life phase standard recycling and disposal rates were chosen.
Based on the information on individual products the specifications for the „base case reference model" were derived for each product category. The base case shall represent the „typical" product for each of the selected product categories (Table 1) that is expected to be sold in three years time. This projection is necessary so that any implementing measures relate to products available at the anticipated time of introduction. Table 3 summarizes the data on average electricity input and average weight for the base case of each product category.

Table 3: Base case electrical power input and weight for each product category

Product Category	Direction of Flow	Type	BASE CASE Electrical Power Input [kW]	BASE CASE Weight [kg]
1	Axial	≤ 300 Pa (static pressure)	0.8	47
2		> 300 Pa (static pressure)	1.3	55
3	Centrifugal	forward curved blades (with casing)	0.44	10.7
4		backward curved blades (no casing)	3.76	38.6
5		backward curved blades (with scroll housing)	3.82	77.4
6	Other	box fans	0.37	9.9
7		roof fans	1.2	60.4
8		cross-flow fans	0.42	7.8

Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]

Figure 5: Environmental impacts of the base case for axial fans (≤ 300 Pa) per life cyle phase



Source: [3; own calculations]

Figure 5 shows the results for analysis of the base case model for axial fans with a static pressure increase ≤ 300 Pa (EuP category 1, Table 1). As can be seen, the ecological impact is clearly dominated by the use phase of the product for all environmental impact categories. Thereby, most of the emissions (e.g. heavy metals) are not caused by the fan itself, but are indirect emissions resulting from energy consumption during fan operation, i.e. the main part of the emissions can be assigned to the underlying power generation mix. For all products and all categories it can be shown, that the impact of the use phase is highly dominant. On the other side, a change in the amount of materials used or a change of material type, e.g. aluminum for copper, has only a negligible effect on the overall environmental impact. Therefore, the main focus for the analysis was on the use phase and not on the production, distribution or end-of-life.
For analysis of the product's use phase the EuP spreadsheet model mainly requires the energy consumption of the EuP as an input. According to the model the energy consumption of an EuP is calculated as follows [3]:

$$Total\,electricity\,consumption = P_{On-mode} \cdot t_{On-mode} + P_{Stand-by-mode} \cdot t_{Stand-by-mode} + P_{Off-mode} \cdot t_{Off-mode}$$

Where: P = power consumption (kW)
t = operating hours (h)

Off-mode consumption is usually not applicable to fans and the focus here is on on-mode consumption. However, stand-by consumption is considered for EC (Electronically Commutated) and VFD (Variable Frequency Drive) fans. Because fans typically operate at varying loads part load operation might also be relevant and. Furthermore, the operating point of the fan depends not only on the fan but the overall system, which is very often not able to be influenced by the fan itself (e.g. pressure drop in the system).

In general the required input power of a product can be calculated dividing the useful work obtained by the efficiency of the respective product. The work done by a fan is the product of the flow rate (m³/s) and the pressure rise (N/m² or Pa). The product is then obtained in W (watts). The actual power consumption of the fan, which is the necessary input for analysis of the use phase in the EuP spreadsheet model, can then be calculated by dividing the product of flow rate and pressure rise by the total efficiency of the product:

$$P = \frac{Q \cdot p}{\eta_{fan} \cdot \eta_{trans} \cdot \eta_{motor} \cdot \eta_{control}}$$

Where: P = Electrical Input Power (kW)
Q = air flow rate (m³/s)
p = fan pressure (kPa)
η_{fan} = fan efficiency
η_{trans} = transmission efficiency
η_{motor} = motor efficiency
$\eta_{control}$ = efficiency of fan control system

As the overall efficiency of a fan product depends on all parts in the chain from motor drive to the fan, the final energy use of the fan is dependent on how well its components are matched, not just the fans peak efficiency. The overall efficiency is a multiplication of all involved parts efficiencies, which means that the result always will be lower than the least efficient part of the chain, and that all parts are important.

However, it was shown that energy efficiency of the fan product is the main factor affecting the environmental impact of the product. Therefore the main focus of the EuP preparatory study was on collecting efficiency data of fans. Numerous performance charts and data from various manufacturers where examined to derive the efficiency of each base case product as defined in Table 1 and Table 3. Based on the base case and market analysis for each product category the overall environmental impact of non-residential building ventilation was then estimated. Table 4 shows the results of the environmental impact assessment for each product category and the resulting overall environmental impact of non-residential building ventilation in EU27.

Table 4: Overall Environmental Impact of Non-Residential Building Ventilation in EU27 (2005)

Product Category	1	2	3	4	5	6	7	8	

Life Cyle Indicator	unit	Axial ≤ 300Pa	Axial > 200Pa	Centrif. forw. w. housing	Centrif. backw. w/o housing	Centrif. w. housing	Box fans	Roof Fans	Cross-flow	Overall
Total Energy (GER)	PJ	122	558	152	401	454	104	868	15	**2,674**
of which, electricity	*TWh*	*11.5*	*52.7*	*14.4*	*38.1*	*43.1*	*9.7*	*81.6*	*1.4*	***252.5***
Water (process)*	mln.m3	8	37	10	27	30	7	57	1	**177**
Waste, non-haz./ landfill*	kton	197	839	211	494	577	167	1,33 7	22	**3,844**
Waste, hazardous/ incinerated*	kton	3	15	4	10	11	3	21	0	**67**
Emissions (Air):										
Greenhouse Gases in GWP100	mt CO2eq.	5	24	7	18	20	5	38	1	**118**
Acidifying agents (AP)	kt SO2eq.	32	145	39	103	117	27	224	4	**691**
Volatile Org. Compounds (VOC)	kt	0	0	0	0	0	0	0	0	**0**
Persistent Org. Pollutants (POP)	g i-Teq.	1	5	1	3	3	1	10	0	**24**
Heavy Metals (HM)	ton Ni eq.	2	10	3	7	8	2	16	0	**48**
PAHs	ton Ni eq.	0	2	0	1	1	0	2	0	**6**
Particulate Matter (PM, dust)	kt	2	6	1	3	4	2	14	0	**32**
Emissions (Water):										
Heavy Metals (HM)	ton Hg/20	1	4	1	3	3	1	6	0	**19**
Eutrophication (EP)	kt PO4	0	0	0	0	0	0	0	0	**0**

Note: *=caution: low accuracy for production phase
Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]

6 Environmental Improvement Potential

As the environmental analysis of existing products has shown, significant improvements can only be achieved by improving efficiencies of the product. The potential to improve fan efficiencies becomes obvious when looking at the wide spread of efficiencies of state of the art products. Table 5 summarizes the results obtained form the efficiency analysis of individual products. By assuming that the average product might have an efficiency between the minimum and maximum values, an average product could be improved by 5 to 10 % points. For the different products this implies that higher efficient products have a lower improvement potential than very inefficient products.

The environmental improvement potential by increasing the efficiency of average fan products (base case) can be calculated using the EuP spreadsheet model by reducing the electrical power input to the model. For example, the average power of the base case category 1 product is 0.8 kW (Table 3). Assuming an improvement potential of 33.3 % (Table 5), the environmental impact of the improved product is calculated with a power of 0.8°kW*(1-0.333) = 0.533°kW. As the use phase dominates the impact, an increase in efficiency will also lead to a reduction of the life-cycle impact by approximately the same rate, i.e. one third for category 1 products. For example, if all category 1 products were replaced by the improved products, the greenhouse gas emissions would therefore also be reduced by one third from 3 to 2 Mt CO2eq.

Even though theoretically there is a large improvement potential regarding efficiency of fan products covered by this study, the market is moving only slowly towards higher efficient products. This is due to a high competition regarding first cost, even though life cycle cost of products with a higher efficiency are reduced based on energy savings during the use phase. Therefore it seems to be appropriate to set minimum efficiency levels for products to be sold in Europe with the aim to remove the products with the worst efficiency from the market and significantly improving the average efficiency of the products on the market.

Table 5: Summary of average efficiency differences of state of the art products by category

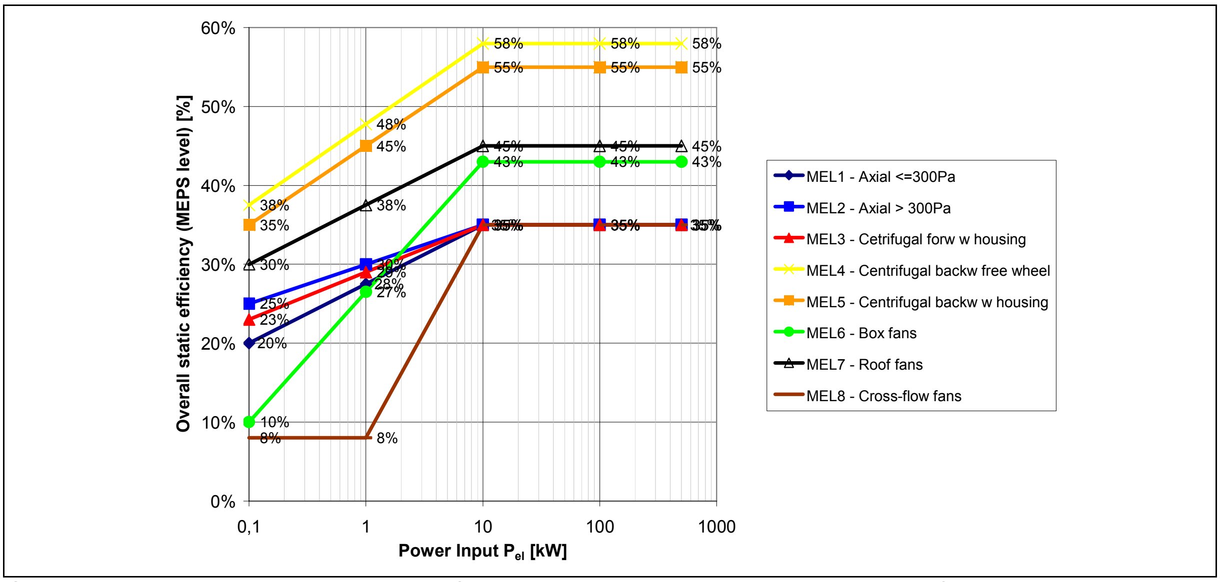
Product Category	Direction of flow	Type	Typical efficiency of the product [%]	Achievable improvement of the product [%]	$\Delta\eta_{(max;min)}$ of existing product*) [%-points]
1	Axial	<= 300 Pa (static pressure)	30,0%	33,3%	20,0%
2		> 300 Pa (static pressure)	38,0%	19,7%	15,0%
3	Centrifugal	forward curved (with housing)	30,0%	25,0%	15,0%
4		backward curved (free-wheel)	50,0%	13,0%	13,0%
5		backward curved (with scroll housing)	60,0%	8,3%	10,0%
6	Other	Box fans	30,0%	33,3%	20,0%
7		Roof fans	40,0%	31,3%	25,0%
8		Cross-flow fans	8,0%	62,5%	10,0%

Note: *) $\Delta\eta_{(max;min)}$ is the approximate efficiency difference between the best and the worst efficiencies of the products based on the collected data

Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]

As efficiency levels of fans not only depend on the product design but also on power range, different values should be set not only for different categories but also for different sizes (referring to power input). Figure 6 shows a possible set for minimum efficiency performance standards (MEPS) for each of the EuP fan categories. The graph indicates overall static efficiency over electrical power input. The proposed MEPS lines are a compromise between the accurateness of addressing each product and product size on a very detailed level and the easiness of the MEPS approach.

Figure 6: Proposed Minimum Efficiency Performance Standards

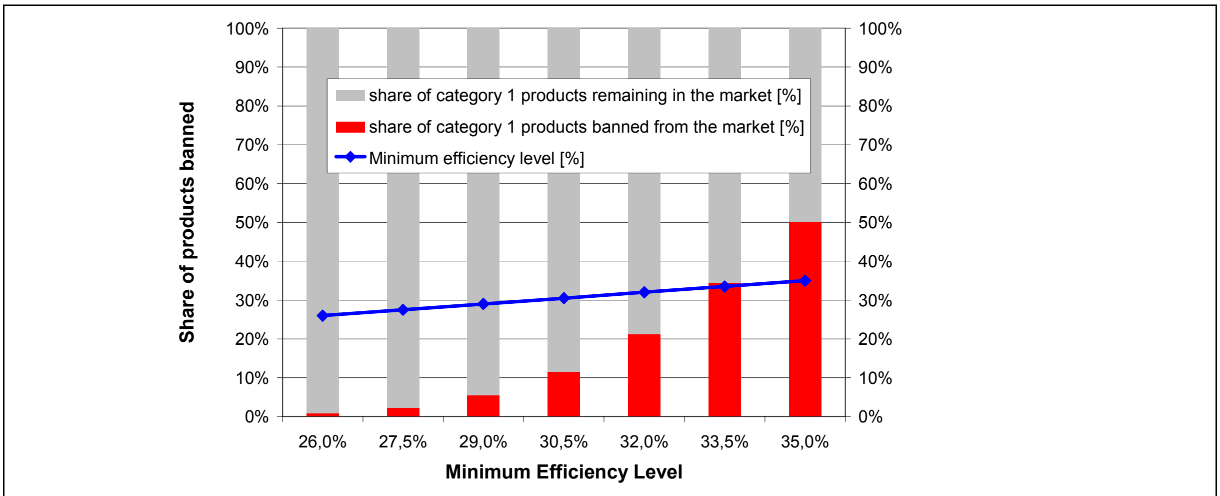


Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]

Category 4 (centrifugal free wheel) and Category 5 (centrifugal backward curved) products have in general the highest efficiency with the free wheel some efficiency points above due to the more complete conversion of the energy into static pressure. Above a power of 100 kW only a limited number of data was available. Because for larger products the perception of energy consumption is usually higher anyways, the MEPS are proposed to remain constant from 10 kW and above, which would have in any case no negative impact on the market. From an electrical power input of 10 kW and above the same arguments apply for all other product categories. This approach is supported by other results of the EuP preparatory study showing that about 40 % of the overall electricity consumption in product categories 1 to 5 (axial and centrifugal fans) are related to fan products with a power of less than 10 kW, for product categories 6 to 8 (roof fans, box fans, cross-flow fans) products under 10 kW are even responsible for about 90 % of the total electricity consumption. Thus, most attention should be paid to the products with a power below 10 kW. On the longer run it could be recommended, that some lines might be merged, such as the MEPS for products category 1 and 2 (axial fans).

If MEPS where introduced, for category 1 the share of products shown in Figure 7 might be banned from the market, depending on the minimum efficiency level. Figure 7 is based on the fact that the efficiency of category 1 products (axial ≤ 300 Pa) of 1 kW deviates between 20 and 50 % with a mean value of 30 % (see also Table 5). Furthermore, Figure 7 shows, that if at least the worst 10 % of the fans on the market should be eliminated, this would require to set a minimum efficiency level for category 1 products of 1 kW to around 30% overall static efficiency. For each category of product such an analysis can be performed. The lower the total variance in efficiencies, the smaller would be the difference in efficiencies between the mean value and the minimum efficiency level to be fixed.

Figure 7: Share of products eliminated from the market depending on minimum efficiency level defined for a 1.0 kW category 1 (axial fan < 300 Pa)



Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]

As a general guideline it could be said, that for product categories with small differences in efficiencies (<20°%) on the market the minimum level should be set about 3°%-point below the average efficiency and for products with a large difference in efficiency for the same size (> 20°%) the minimum level could be set 6°%-point below the average efficiency of the product of this size. It should however be noted that the results are rather sensitive in terms of shares and efficiencies. So in the above case, for example if the MEPS would be raised from 29°% to 32°% overall static efficiency, the number of products banned from the market would be doubled. The adoption of MEPS should therefore be introduced carefully, because they will force manufacturers with low efficient products to improve their products to comply with the obligatory minimum levels. Therefore sufficient time should be given before the MEPS come into force.

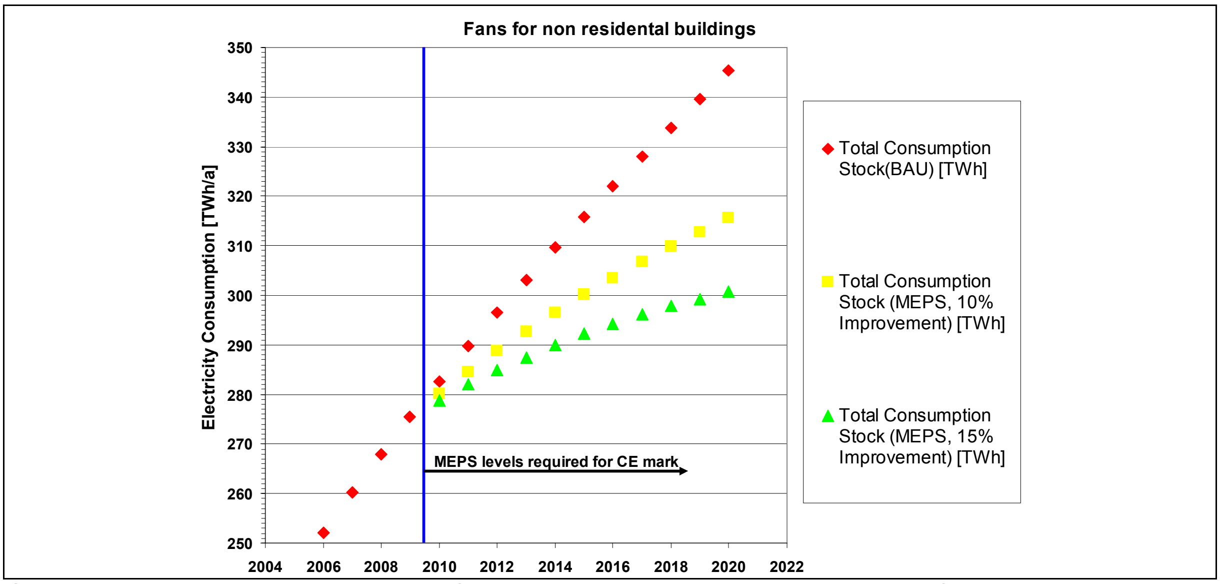
To estimate the possible savings related to the introduction of MEPS, two cases have been considered compared to a business as usual scenario:

1. **BAU (Business as Usual)**: No further improvement of fan efficiencies
2. **MEPS+10:** Cutting of the worst fans with corresponding efficiency levels for each of the 8 fan categories from 1.10.2010 and therefore improving the average efficiency of the products entering the market by 10 %.
3. **MEPS+15:** Cutting of the worst fans with corresponding efficiency levels for each of the 8 fan categories from 1.10.2010 and therefore improving the average efficiency of the products entering

the market by 15 %.

In the business as usual case it was assumed that no efficiency improvement of the newly installed fans takes place in the future, due to the high price pressure in the market and the existing split-incentives problem often found in the building ventilation market. The introduction of MEPS will however cut off the poorest products from the market and will thus lead to an increase of the average efficiency of the products on the market. Assuming that about 10°% of the products with the lowest efficiency on the market would be eliminated, the average efficiency of the products sold would increase by 10 or 15°%. Figure 8 shows the development of the electricity consumption in the BAU scenario compared to the MEPS+10 and MEPS+15 scenarios. As can be seen, for the improved efficiency scenarios, the overall electricity consumption will also continue to rise, due to a much faster growth of number of units which can not be fully compensated by improved average product efficiencies. However, compared to the BAU scenario, the cumulated energy savings from 2010 to 2020 for MEPS+10 would be 29,629 TWh and for MEPS+15 even 44,444 TWh.

Figure 8: Development of electricity consumption for the BAU and MEPS cases.



Source: Radgen, 2007: EuP Lot 11: Fans for ventilation in non residential buildings, Draft Final Report [4]

7 Concluding Remarks

The EuP Directive sets a framework for eco-design of energy-using products. Products with significant trade volume within the European Union, significant environmental impact and improvement potential will be covered by implementing measures. Which products exactly will be covered by implementing measures will be decided by the Commission together with a group of experts (the Consultation Forum) and assisted by a Committee.[2] The EuP preparatory studies provide the Commission with the necessary technical information and data for subsequent political decisions to implement the EuP Directive.

This article presents results of the EuP preparatory study on fans for non-residential building ventilation. The product and market analysis of non-residential building ventilation showed that there is a large variety of technical designs and different applications of ventilation fans. The environmental analysis of the fan products using the EuP spreadsheet model showed that the use phase by far dominates the ecological impact compared to other life-cycle phases (production, distribution and end-of-life). The key for improving the environmental performance of ventilation fans is therefore improving their energy efficiency. Technical analysis of the products under considerations and scenario analysis showed that theoretically a large improvement potential and high energy efficiency

[2] or a more detailed description of the political EuP implementation process see:
ttp://ec.europa.eu/enterprise/eco_design/index_en.htm

savings could be achieved within the European Union. However, due to market barriers, e.g. a high international competition regarding first cost of fan products, political measures will be needed to realize those energy savings.

Acknowledgments

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Renewable Energies Perspective to the Energy Performance of Buildings

J.J. Bloem,
European Commission, DG JRC Institute for Energy

Abstract

Introduction of renewable energy technologies in the built environment gives opportunities to improve the energy performance of buildings. In particular the use of solar energy applications offers a variety of possibilities. The Energy Efficiency and Energy Service Directive [1] and the Energy Performance of Buildings Directive [2] require all Member States to implement national regulations within the near future. Other European Directives are stimulating further improvements in energy performance and energy efficiency in the building sector. Integration of renewable energy sources for heating and electricity in the built environment is also stimulated through national regulations in a few Member States. This paper presents renewable energy technologies and related CEN energy standards dealing with the built environment taking into account the overall energy demand of the building and placed in the overall energy context.
Keywords: Renewable Energies, Energy Performance, standards

Approach

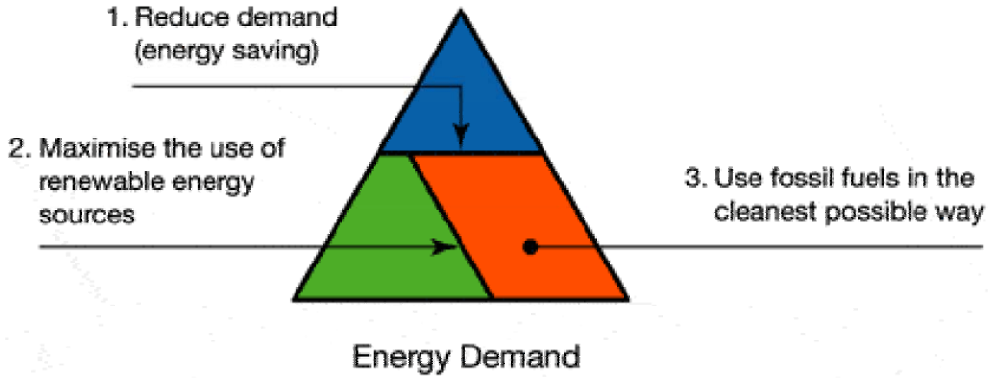
The philosophy underlying this study starts from the integral energy performance concept. The building can be considered as one entity that consumes energy to provide the required comfort to work and live in it. Most of the present national and regional regulations deal with components of the building, such as the maximum of thermal heat loss through the building envelope. All options for energy demand and supply must be considered together if society is to attain significant levels of energy efficiency and renewable energy deployment.

The Trias Energetica should be considered as a philosophy for energy use (Novem 1996, [3]) and was further developed as a strategy applied for sustained energy (TU Delft). Its main aspects are:

1. Minimisation of Energy Demand (energy saving and energy efficiency)
2. Maximum use of Renewable Energies (
3. Highest efficiency of other forms of energy

These aspects are placed in order of priority. Integration of these elements is sometimes possible but should be studied in the context of economic feasibility. The philosophy of the Trias Energetica is applicable to the full range of energy sizes, e.g. from domestic to large office buildings. The philosophy is nicely illustrated in figure 1.

Figure 1. Source: Sintef 1996 (NO)



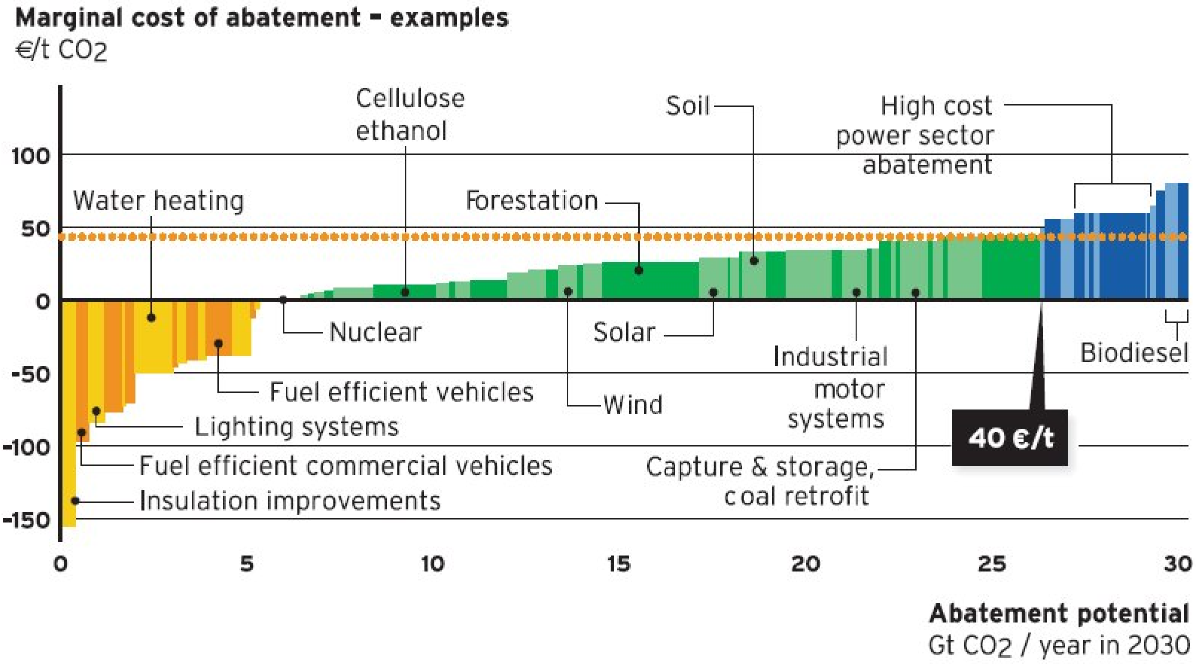
The application however might be different for Member States considering national conditions and the mix of energy resources. The range of energy sizes can be: a residential building (solar energy), a building block, urban area (district heating), city, region (investment in energy saving lamps), country (power plant).

In relation to this philosophy, priority areas may be recognized as defined by the European Parliament (Greens Party); Stimulating a Democratic Debate on FP7 for Energy and Nuclear Nov 5, 2005.

1. Energy Efficiency and Saving
2. RE – Fuel Production
3. RE – Electricity
4. RE – Heat and Cool
5. Smart Energy Networks
6. Knowledge for Energy Policy Making
7. Hydrogen and Fuel Cells
8. Carbon Capture and Storage
9. Clean Coal Technologies

Conclusion from the Trias Energetica philosophy should be that renewable energy technologies become interesting after measures have been taken under item 1, such as insulating the building envelop (walls and windows; Construction Product Directive (1989), [17]) and applying energy efficient technologies for lighting. It might be clear that for building renovation from economic point of view it makes more sense to reduce building energy consumption for lighting and hot water production than to invest in photovoltaic technologies. There is still a lot to gain in the area on energy saving and efficiency, which is nicely illustrated in figure 2. [4]

Figure 2. Source: McKinsey-Vattenfall report.



The McKinsey-Vattenfall 2030 climate map report presents CO_2 abatement potentials in relation to investment. When it concerns buildings, insulation is by far the highest (1.7 Gt CO_{2e}) contribution to reducing energy consumption and therewith CO_2 emissions; Water heating, air conditioning (0.5 Gt CO_{2e}) Lighting (0.2 Gt CO_{2e}) White good applications (0.2 Gt CO_{2e}) and stand-by losses (0.2 Gt CO_{2e}). Solar energy as a form of renewable energy applied for water heating would be supported by this report.

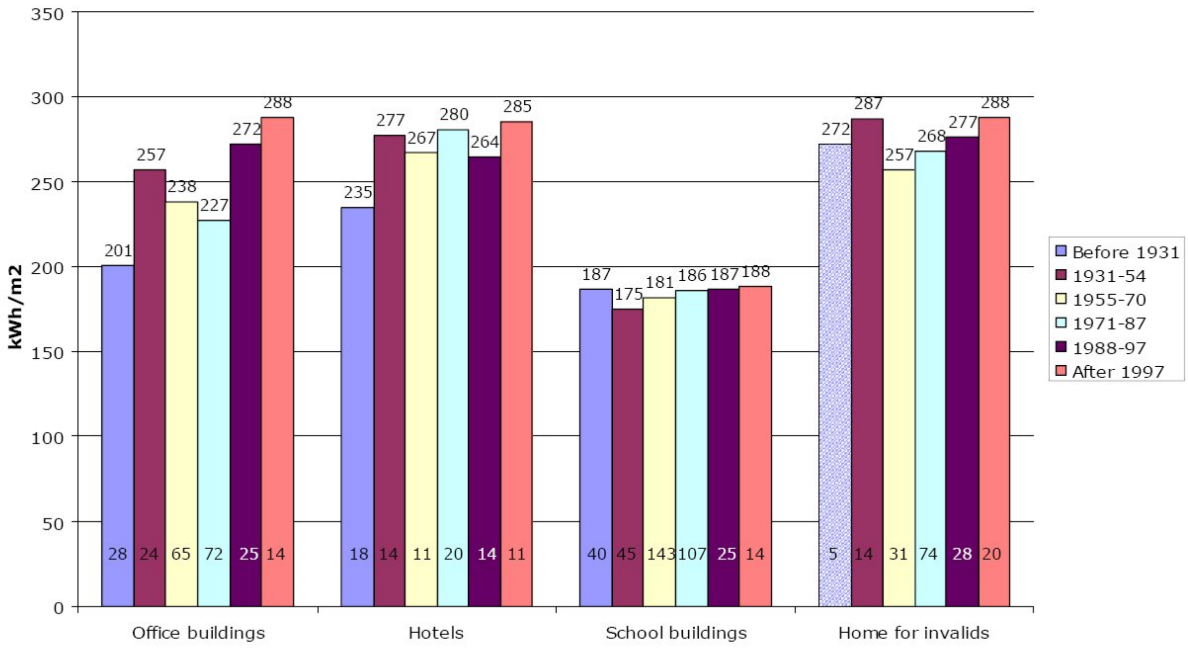
The Directive on the Energy Performance for Buildings [2] is an important Directive for reducing energy consumption in buildings. A given building has typical energy consumption expressed in kWh/m^2/year. Any change in the energy consuming components of the building for the improvement of the building comfort should not increase but lower this typical energy consumption and improve the energy performance of the building. Building simulation and energy calculation tools can help the building designer to assess the energy demand for renovated or new buildings.

The integration of renewable energy technologies in the building requires not only the assessment of the individual system performance but in respect to the overall building performance instead. In this context it is noted that much interest is lately given to double skin facades. For example, during the winter period, warm air from a double skin PV system might be applied for pre-heating of ventilated air into the building. A proper analysis of building overall energy performance is therefore required and should integrate the calculation rules for thermal insulation, shading and other energy flows.

Introduction

The building stock and energy consumption.
Energy consumption in buildings is rising over the last decades (481 Mtoe or 41% of the final energy consumption in 2005 according to Eurostat data, [5]) due to rising income, resulting in higher standards of living. In particular the demand for electric appliances for increased comfort levels, communication and information technology has increased the demand for electricity in this sector. Hunderd years ago energy was consumed for space heating only, while nowadays, on average in Europe, 2/3 is required for space heating and 1/3 (electricity) for other use in buildings. Although space heating and cooling are the most energy demanding the integrated energy consumption in buildings does not decrease as illustrated in figure 3 (exception to this might be Denmark).

Figure 3. Source: ENOVA J.P. Burud (Tokyo 2005).

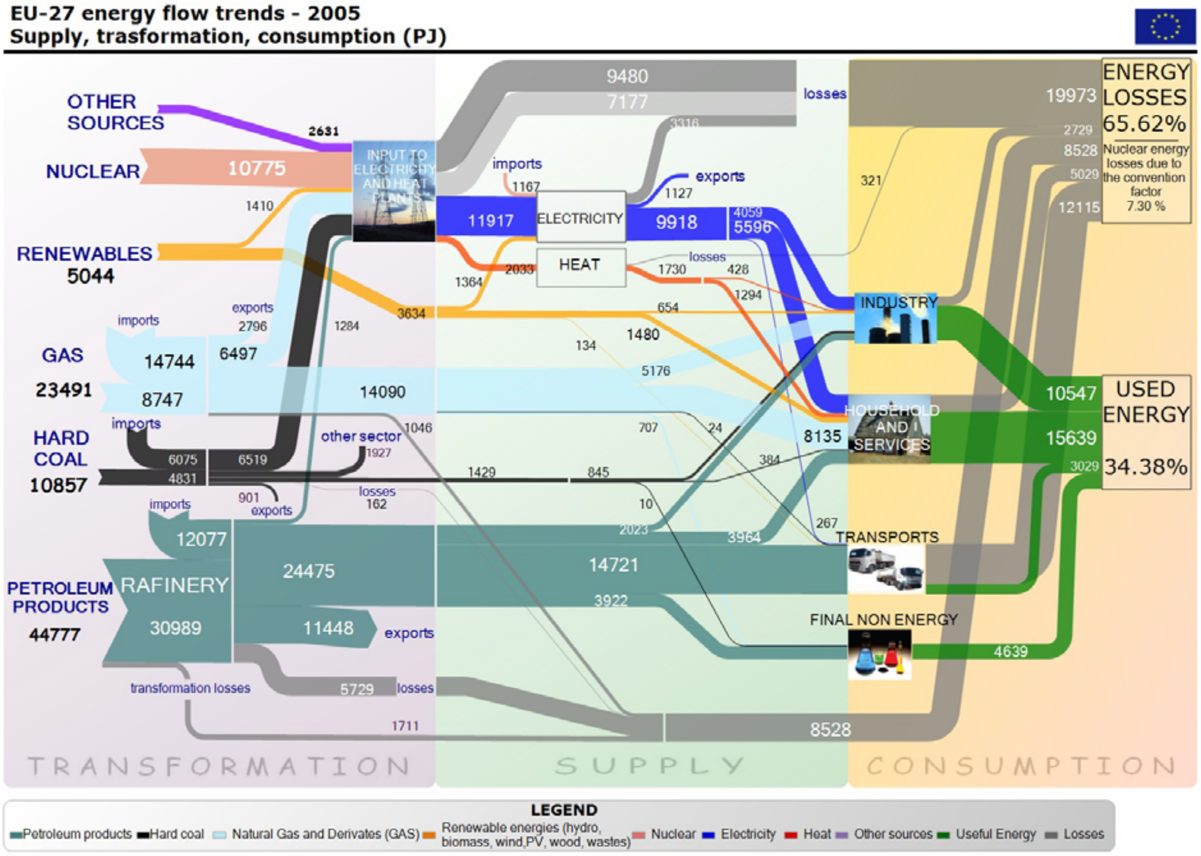


In figure 3 are given data for buildings in Norway. The average over all buildings <1930 is 257 kWh/m^2; the average >1987 is 277 kWh/m^2. Similar data are reported by other national organisations. Efforts to reduce energy consumption by improving insulation are compensated by a higher electricity demand leading in some case to black-out due to electricity intensive air-conditioning.
Continuous survey [20] of end-use electricity consumption in residential and tertiary sectors shows that the total electricity consumption for the residential sector for the EU-25 has grown by 10.8% in the period 1999-2004, from 690 TWh in year 1999 to 765 TWh in year 2004 and by 1.8% in the period 2003-2004.
The gas consumption of the residential sector has continued to grow in the period 1999 to 2004 in the EU-25 from 4721 PJ to 5399 PJ with an increase of 14%, while the yearly growth rate in the period 2003-2004 has been 2.2%.

Renewable energy technologies in the built environment.
As renewable energy technologies in the built environment are in general considered: solar energy, biomass and geothermal energy. The use of heat-pumps to convert heat from underground (shallow geothermal energy) and ambient (heat from air or surface water) to optimise energy use for heating is a growing application.
The advantage of introducing solar energy, electrical and thermal systems in the built environment is often presented as an option to reduce primary energy resources and therewith the harmful emissions for our climate. However the impact of these systems on the overall energy performance of a building is a difficult measurable phenomena. Electrical output of a PV system can be measured but the impact of building integrated PV systems on the thermal behaviour of a building is more complicated and depends on a lot of parameters. Moreover, in the case of less efficient technologies in the building, for example incandescent bulbs, the impact of PV (and the investment as well) might be fully worthless.
Solar energy can be consumed where or close to where it is produced. Geothermal (and the use of heat pumps) and the primary resource to end-use consumption. Biomass (indicate forest areas and cost for transport) and carbon neutral.

The energy context
Important is to place energy consumption in the context of the whole process of energy flow. The transformation, distribution and end-use of energy should be considered in order to get clear insight in the energy saving potential and the impact of renewable energy technologies and energy efficiency measures on the reduction of primary energy resources and CO_2 abatement.

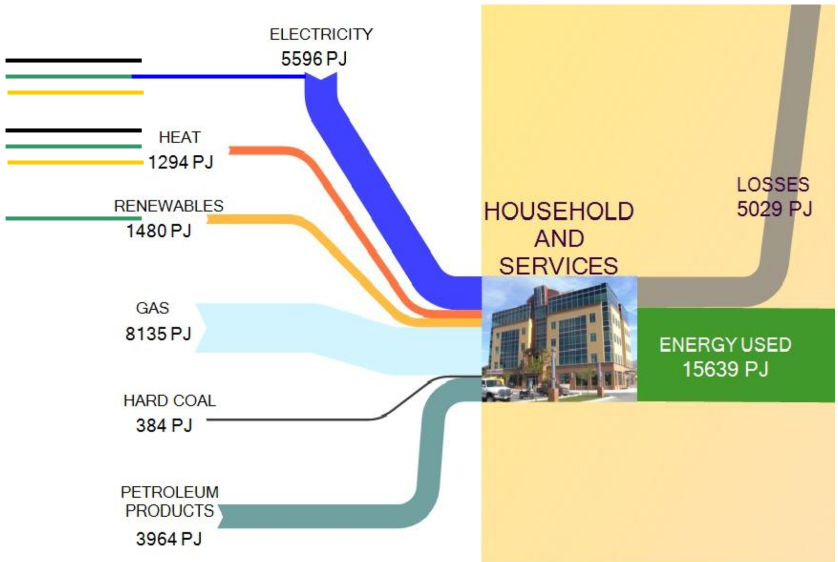
Figure 4. From Primary energy resource to useful energy delivered (including distribution). Source JRC; based on Eurostat data (2005).



Fossil fuels account for 79.1 % and nuclear energy for electricity for about 14.2 %. Renewable energy sources account for 6.7% (2005 Eurostat data, [5]) of the total primary energy consumption in EU-27. Biomass takes the biggest portion with 4.4%. Solar energy accounts for about 0.7%. Environmental heat, using heat-pump conversion is not considered and therefore not traceable.

With the policy targets of 2020 in mind, a contribution of 20% renewable energy to the energy end-use, it is worthwhile to colorize building delivered electricity, heat and fuel. Energy then becomes traceable for its origin and ‘green-washing’ of fossil produced energy will be avoided. Fossil (black), nuclear (yellow) and renewable (green) produced electricity and heat becomes for the end-user a different product and can be calculated in correct way in statistical analysis.

Figure 5. The energy delivery side of buildings. From building energy demand to energy end-use. This picture might be very different for fuel type and Member States energy mix.



EPB directive

At present Members States should have implemented the EPBD. When it concerns renewable energies the EPBD give:

- explicit attention to the positive contribution of renewable energies in the context of energy performance regulations
- A global view on the energy flows, whereby a correct integration of
  - energy saving,
  - renewable energies and
  - efficient energy production technologies

The present energy standards related to the EPB Directive dealing with renewable energy technologies are given below. These standards provide methods for calculating the energy contribution from installations.

prEN15316. Provides methods for system efficiencies and/or losses and auxiliary energy.
prEN15316-4-2 Part 2.2.2. Heat pump systems
prEN15316-4-3 Part 2.2.3. Thermal Solar systems (including DHW)
prEN15316-4-6 Part 2.2.6. The performance of other renewable heat and electricity.
prEN15316-4-7 Part 2.2.7. Biomass combustion systems
prEN15316-3-3 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 3. Domestic hot water systems:

Several Member States have put in place more drastic regulations in particular when it concerns new buildings, like Portugal and Spain where solar thermal energy for domestic hot water installations has given a high priority and are obligatory.

Solar Energy in the Built Environment

Solar energy technologies may be distinguished in:

- Passive technology, e.g. building design, urban planning.
- Active technologies e.g. solar thermal and photovoltaics.

Passive solar energy technology by definition do not need auxiliary energy to perform and is related to careful design taking into consideration the location, climate and level of solar radiation. Already centuries ago buildings were constructed in such a way that thermal mass and solar radiation were matching the need for a comfortable environment to live and work in. It is during the last half century that an energy careful design has received less attention due to the availability of appliances that provide and control a comfortable indoor environment. However, note that with electricity consumption for air conditioning units and hot water systems is increasing rapidly despite rising energy costs.

Although a very important aspect of energy saving using solar radiation as primary energy resource, the passive solar technology is in general not considered as a renewable energy technology. Solar chimneys that recently gets more attention in Spain, might change that point of view.

Concerning solar thermal systems the market is doing very well. Solar thermal systems in the built environment are used for:

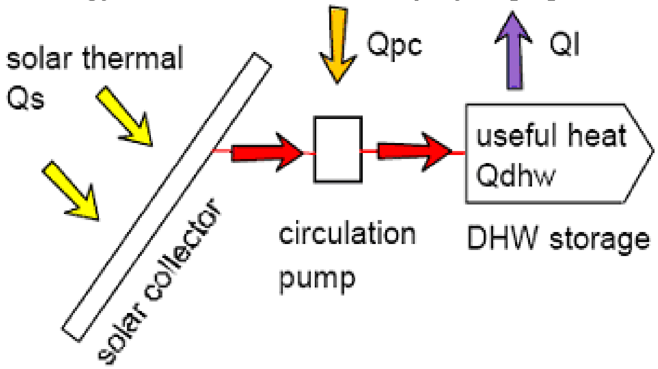
- Domestic Hot Water systems (DHW), being the major application.
- Space Heating, mainly in Northern Europe
- Space Cooling by solar assisted cooling, in the Mediterranean area

The applied solar thermal technology can be distinguished in:

- Flat glazed thermo-siphon systems of about 2-3 m^2 can be found mostly in Southern Europe.
- Flat glazed forced circulation systems of about 2-6 m^2 is installed in Mid- and Northern Europe.
- Evacuated Tube Collectors which have about 15% higher efficiency in south Europe and about 30% in northern Europe than the flat plate collector.
- Unglazed collectors.

Evacuated Tube Collectors (ETC) take about 10% of the total collector sales in 2005 and are expected to become more popular. By far, most of the systems are used for Domestic Hot Water (90%). Other applications are space heating (in almost all cases these are combination systems) and pool water heating (mostly by unglazed collectors). See also the IEA report[1] [6].

Figure 6. Solar Thermal energy flow. Source K4RES-H project [16].



In general small systems (<10 m^2) are found in the residential and tertiary sector. Bigger systems (>10 m^2) are found in the tertiary and industrial sector.
Renewable Energies from solar thermal (Qs) is produced if:

$$(Qdhw-Ql) > (Qpc)$$

[1] www.iea-shc.org/publications/downloads/IEA-SHC_Solar_Heat_Worldwide-2007.pdf

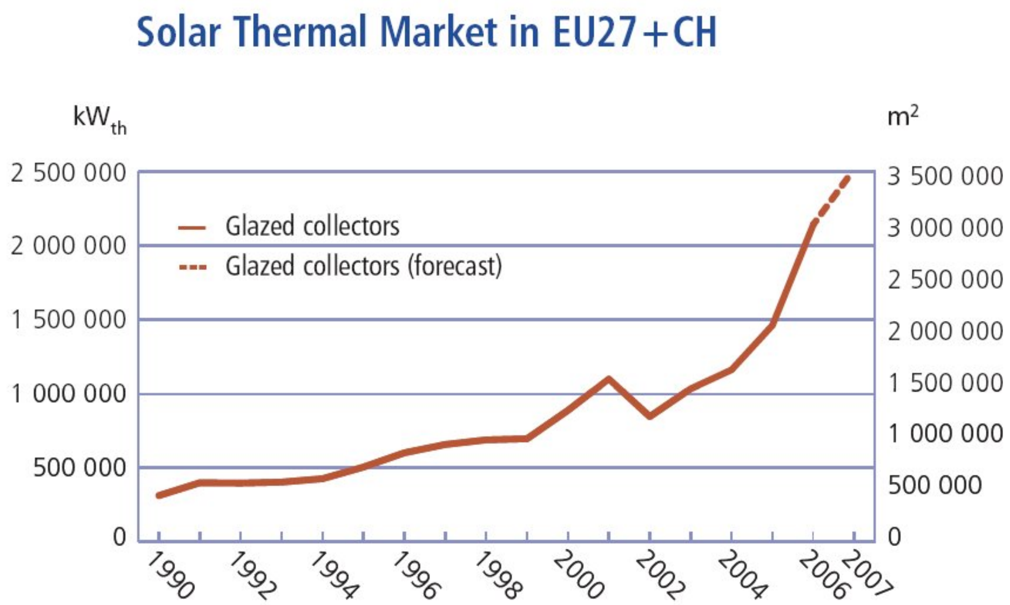
where (Qpc) is primary energy input (for electric power).

Market and resources

Industrial associations and IEA statistics provide enormous amount of information [7, 8, 9,10 and 14] and report the potential for growth. This paper will concentrate on solar and geothermal energies. For information on biomass reference is made to the biomass association [9].

Solar thermal data (Figures 7 and 8) are available from the European Solar Thermal Industry Federation[2] (ESTIF, [7]) and are usually expressed in square meters (m^2) sold or installed area. The International Energy Agency's Solar Heating & Cooling Programme, together with ESTIF and other major solar thermal trade associations have decided to publish future statistics in MW_{th} (Megawatt thermal) and have agreed to use a factor of 0.7 kW_{th}/m^2 to convert square meters of collector area into MW_{th}

Figure 7. Solar thermal capacity in 2006. Source ESTIF.



In 2006, almost 2200 MW_{th} of solar thermal capacity (3.1 million m^2 of collector area) was newly installed in Europe – 26% more than in the previous year. The traditional lead markets Germany, Austria and Greece, are responsible for about ¾ of the operational capacity in Europe and have all performed well in 2005. Some very good developments in several of the high-potential markets like France and Spain can be noted. At the end of 2005, the total capacity in operation in the EU and Switzerland was 11,175 MWth ($15.9 \cdot 10^6$ m^2 of collector area).

To calculate the produced heat energy from solar thermal collectors, one needs to know its location and the annual solar radiation and that site. Since the amount of solar radiation is not equally distributed over Europe the calculation is a complex task. In figure 10 is given an impression of how much thermal energy could be produced by a 1 m^2 solar collector area in Europe. Roughly twice more collector surface area is required in Scandinavian countries than for Mediterranean countries.

The Spanish implementation of the EC Directive on the Energy Performance of Buildings, with the new technical building code (CTE) includes an obligation to cover 30-70%, depending on climate zone, of the Domestic Hot Water (DHW) demand with solar thermal energy. It is expected that the CTE will support the boom in the solar collector market in Europe. In addition the European certification scheme, the Solar Keymark for solar thermal collectors (EN 12975) and factory made systems (EN 12976) is more and more accepted, both by the industry and by public authorities.

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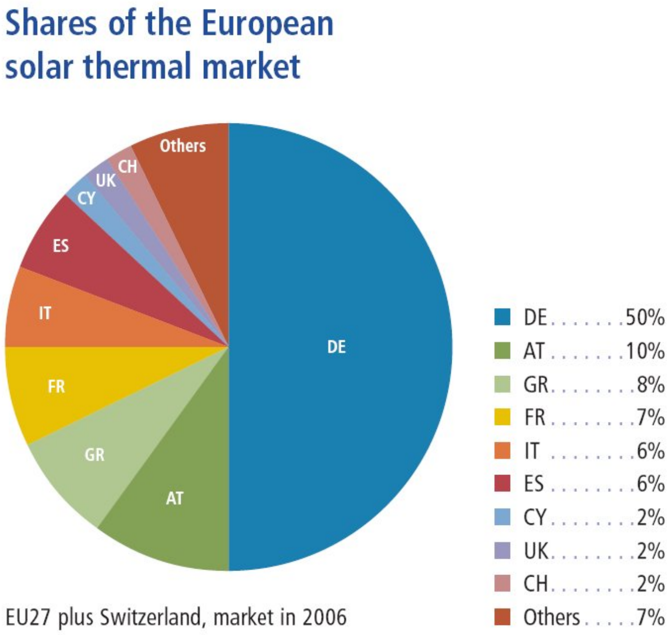
[2] www.estif.org

Figure 8. Share of solar thermal market in 2006. Source ESTIF.



A more recent picture (2006 data, figure 9) shows the solar thermal capacity and energy in relation to other Renewable Energy resources. For clarity reasons, biomass and hydropower are left out.

Figure 9. Renewable Energy technologies Capacity and Produced Energy. Source IEA-SHC [6].

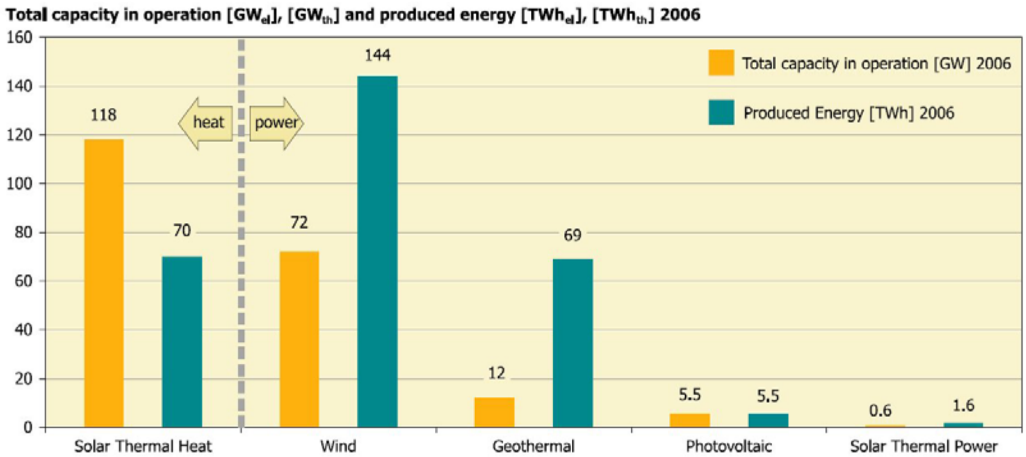
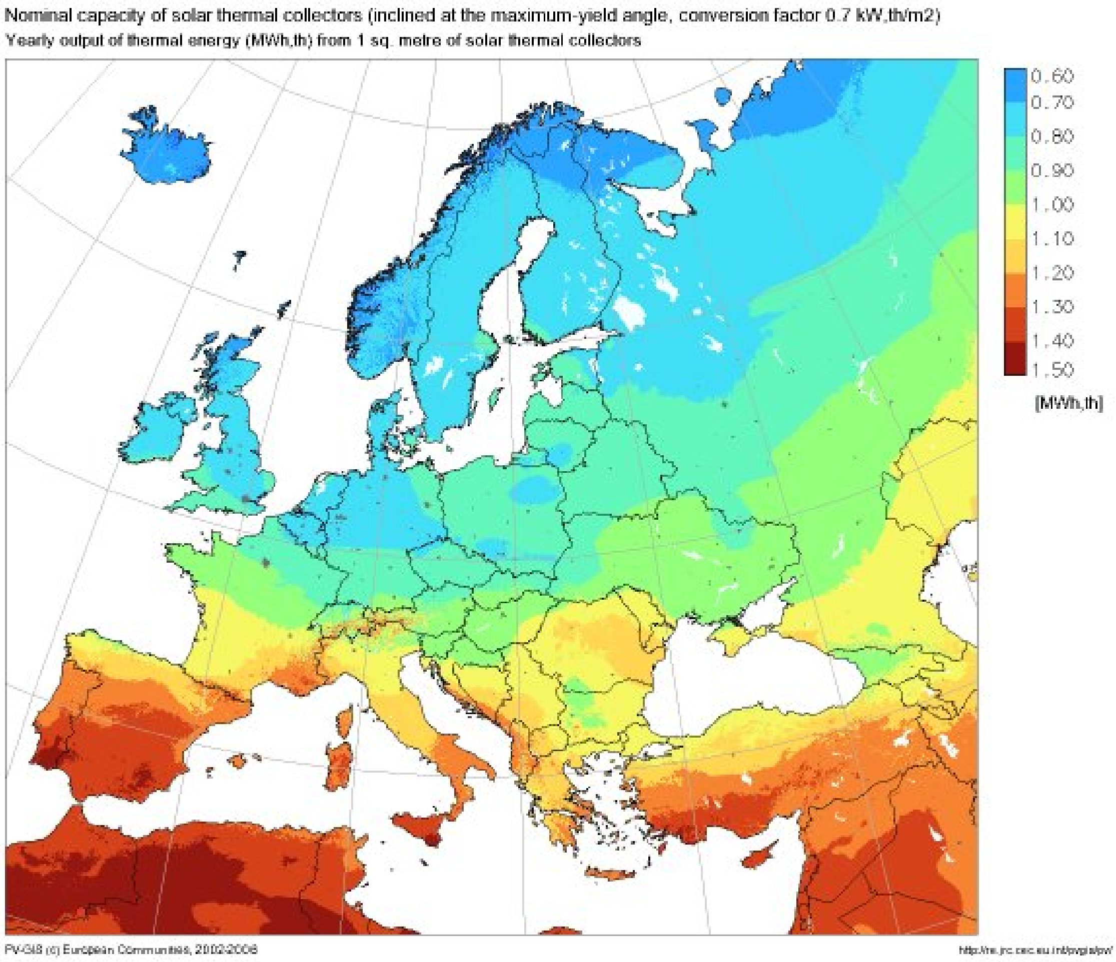


Figure 10. Solar map produced by EC – JRC – IES – Renewable Energies Unit[3].



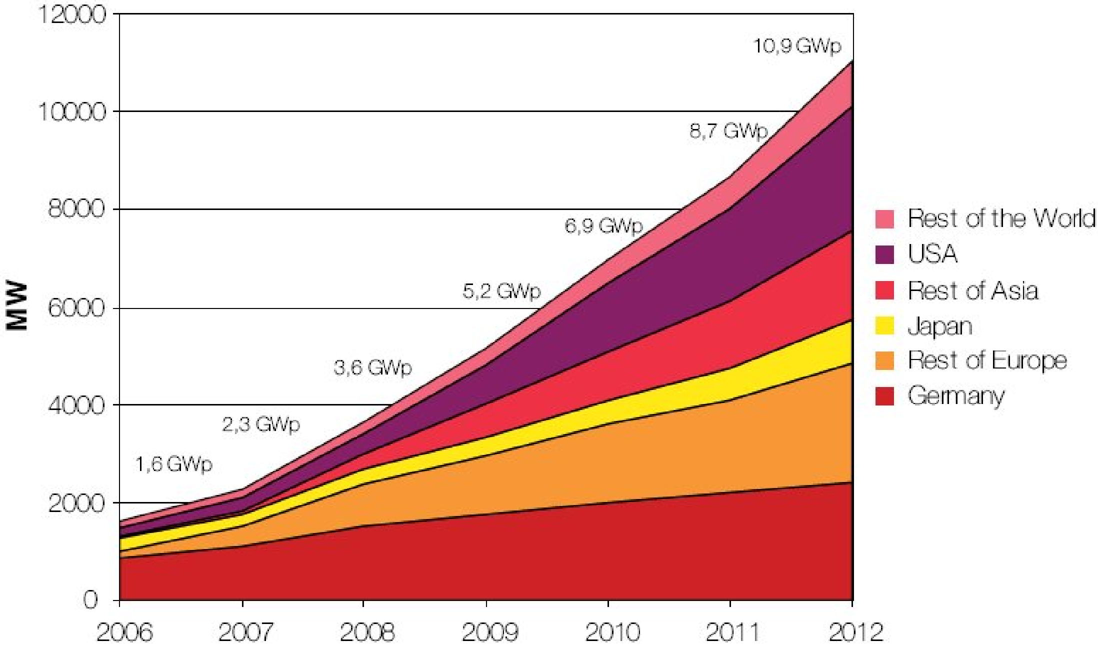
Building Integrated PV

The integration of PV in the building envelope requires not only the assessment of the electrical performance. PV awning applications will avoid overheating of the building while at the same time it reduces peak electricity demand. In the winter period the warm air in a double skin PV system might be applied for pre-heating of ventilated air into the building.
Including a building integrated PV (BIPV) calculation module into the ESP-r simulation tool [15] will allow to make a proper analysis of building overall energy performance since it integrates the calculation rules for thermal insulation, shading and other energy flows. Simulation of such systems under different climate and boundary conditions would help a lot to understand the integration in the build environment.

Some considerations about the introduction of PV technology in the build environment in relation to the calculation method have to be made. In terms of energy performance one is interested in the annual power production from the PV system. However the produced energy is depending on daily and seasonal climate conditions. During hot summer days the produced electricity from PV systems can support the reduction of peak power demand while at the same time shading parts of the building. During the winter period the warm air behind a PV façade can preheat the air for ventilation. Thus the overall impact on the building energy performance should be considered and not only the produced power. Several ways have been studied to present an integrated energy performance for buildings. Interesting reading can be found [11, 12 and 13].

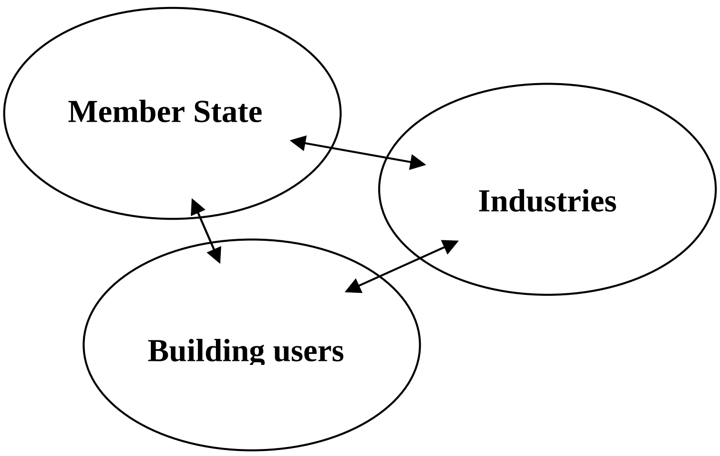
[3] http://re.jrc.cec.eu.int/pvgis/pv/.

Figure 11. Source EPIA 2007 Global PV markets (policy driven scenario).



According to EPIA[4] market expectations [18] the market for thin-film PV modules will grow significantly. In addition to the established c-Si capacity, approximately 4 GW of thin-film capacity is expected to be available by the end of 2010. This would represent 20 % of the overall module production capacity. Although all technologies face high expansion rates, thin-film capacities are currently expanding at a faster rate than capacities for other technologies.

Figure 12. Three groups of interest



In general there are three parts (figure 12) involved when evaluating energy savings in buildings.

1 - The EU Commission and Member State governments, where its strategy is to reduce energy consumption and to abate CO_2 emissions. Targets are 20% in 2020 while at the same time the integration of renewable energy resources is stimulated, 10% in the electricity production. Three important building energy related EC Directives are supporting that strategy: EPBD, EESD and the forthcoming RES.

[4] www.epia.org

The Member States will have to implement regulations to support that strategy but will have to consider also their energy-mix which in the context of the EU energy-mix might lead to different strategies and national regulations and incentives.

2 - At the bottom end are the building user or owner (in case of rented offices, residential buildings, etc) who may have a more economic evaluation. The energy bill is often the major concern for residential and tertiary buildings owners and users. Energy prices and capital investment might lead to different solutions. A proper approach for existing buildings would be to follow the Trias Energetica; invest in energy saving measures before introducing new renewable energy installations. The driving factor here is an economic evaluation.

3 - In between the industry is positioned. They want to sell their products, being buildings, heat or cool installations, domestic appliances, air-conditioners, etc. Some of these products on the European market are of high energy efficiency and quality but would not necessarily much contribute to the goals of the European strategy if the Member State energy mix is not taken into account. Industries play an important role for introducing renewable energy and innovative technologies into the market. Products have to be reliable, efficient, a high quality and well priced.

In the calculation method the primary energy demand should be the final result, starting from building energy consumption. With the above in mind, the solar hot water (but also heat-pump) installations should be considered. This will lead to different situations for different Member States.

The restriction to evaluate only fossil-fuel hot water installations will give a distorted view on the matter. Electricity for hot water in general should be included too. Hot water in buildings (residential and tertiary) is produced in different ways and it should not be neglected the impact of white good appliances, such as dish-washers and washing machines that use electricity to heat water.
The calculation method will lead to improved results when these appliances will have 20 or 30 degree input water temperature which might be produced by existing fossil fuel boilers. These means that the potential is higher but also might be an option for building owners and users. Industry is able to produce dishwashers and washing machines for this purpose.

Returning to the primary energy demand, it is clear that electricity produced by fossil fueled power plants give a complete different result than in cases of electricity produced from wind or hydro-power plants. Also in cases of gas-boilers the energy and economic evaluation will be different. Therefore the energy saving potential should address three points of view and consider the potential of all cases where electricity is used for water heating in relation to the national (or sometimes regional) energy-mix and the related energy prices.

Example: Scandinavian countries like Sweden and Norway will promote the use of electricity for domestic hot water and heat-pumps because of their huge electricity produced from renewable resources in the energy mix. It is clear in their implementation of EU Directives that a different regulation is the result than it would be for the UK, Spain or Italy.

Heatpump applications

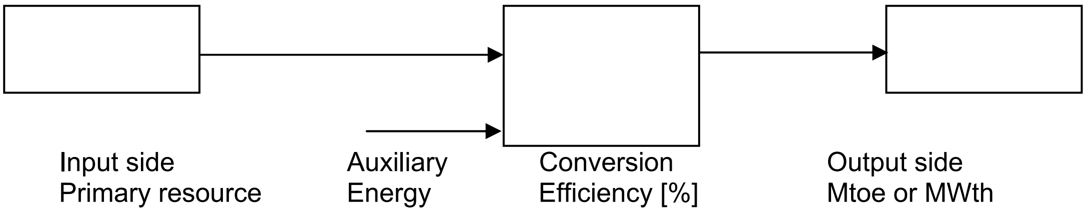
A heat pump is by definition any device that accepts heat at one or more temperatures and rejects heat at a higher temperature. A heat-pump is a thermal conversion technology that consumes electricity. It is mostly used in geothermal and environmental thermal applications. The heat produced might be considered as renewable heat. Heat pumps are nowadays becoming popular choices for space heating as well as for cooling, especially in areas with less severe winters. Further information is provided by EGEC [8].

In general heat pumps are more effective for heating than for cooling if the temperature difference is held equal. Ground-source heat pumps typically have higher COP's than air-coupled heat pumps, because they draw heat from ground or groundwater, and this is at a relatively constant temperature all year-round below a depth of about 2.5 m. The trade-off for this improved performance is that a ground-coupled heat pump is usually more complicated due to the need for wells or buried coils, and thus is also usually much more expensive to install than an air-coupled heat pump.

The performance of such a system should be considered in a proper way. Being an energy system in a building it should contribute in a positive way to the overall energy performance of that building. However, important as well is its performance in the whole energy chain, cq. from primary energy resource to energy end-use.

The term "renewable heat" covers all heat that is the result of a conversion process of renewable resources or that contain renewable resources (waste or hybrid power plants). It is important to describe the conversion processes or systems, including the conversion efficiency and the renewable energy input resource.

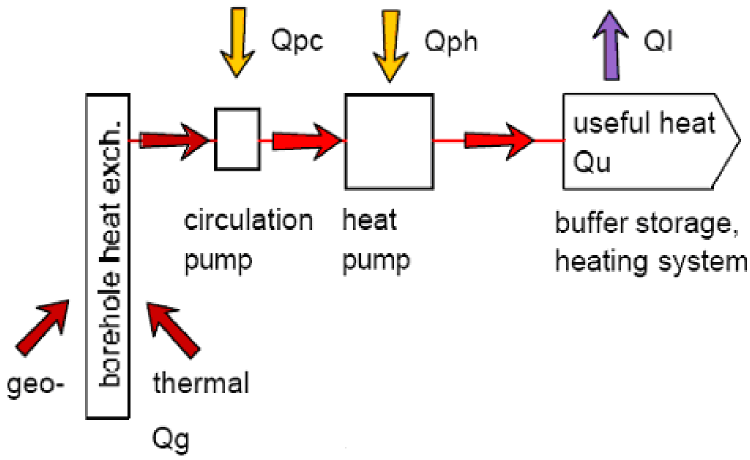
Figure 13. Schematic energy conversion chain.



Since the information and data comes from different origin a lot of attention has to be given to accuracy of the data, conversion of parameter values and efficiencies of the heat conversion installations. In particular the amount of operation hours should be treated carefully for all applications and calculation methodologies.
Coefficient of performance (COP) is the ratio of the output heat to the power input. The greater this value, the greater the efficiency of the unit and the quicker the initial costs can be recuperated. to describe the ratio of useful heat movement to work input. When comparing the performance of heat pumps, it is best to avoid the word "efficiency" which has a very specific thermodynamic definition. An important consideration is the application of heat pumps in buildings. The high COP can be achieved at certain temperature levels which make the heat-pump system good for floor-heating (space-heating). Most commonly, heat pumps draw heat from the air or from the ground. Air-source heat pumps do not work well when temperatures fall below around −5°C.

In all ground source heat pump systems (GSHP), there is a basic difference between the heat output to the heating system, and the geothermal heat input into the system (Qg in the figure 12 below).

Figure 14. Geothermal energy flow; source K4RES-H project [16].



Renewable Energies from geothermal heat (Qg) is produced if:

$$(Qu-Ql) > (Qpc + Qph)$$

where (Qpc + Qph) is primary energy input (for electric power)

The auxiliary energy (mainly Qph in the figure 14) is always higher than 5 % and is typically in the order of 20-30 % of the final energy output. Thus it cannot be neglected.

Electricity supply from fossil power plants with an efficiency of 40% requires a heat-pump with at least a COP of 2.5 (the heat-pump technology is advancing a lot and a COP of 3 to 4 can be reached). In Scandinavian countries with a major supply of electricity from hydro-power plants and more and more wind, the situation is much different and would favour the use of air-to-water heat-pump systems. In this context it is important to consider the energy mix of the Member State and sometimes also the regional availability of energy.

Heat pumps extract the heat stored in the ground, air or water in order to warm homes and could provide sanitary hot water. In areas where natural gas is not available, heat pumps are a popular alternative, but using only a heat pump for all heating needs wouldn't be economical, or even possible. Most heat pumps use electricity as a power source, and most of them do not operate at highest efficiency in very cold weather. Supplementary energy for heat such as gas, oil, electric and wood is used when the temperature falls below about −5°C.
When used for heating a building on a mild day, a typical heat pump has a COP of three to four, whereas a typical electric resistance heater has a COP of 1.0. The work does not make heat, but instead moves existing heat "upstream". When there is a wide temperature differential, e.g., when heating a house on a very cold winter day, it takes more work to move the same amount of heat indoors as on a mild day. Note that the system must periodically melt the ice on the outdoor heat exchanger.

Conclusions on heat pump application.
Under certain conditions (climate, energy costs, resource and national energy mix) the use of heat pumps contributes to a positive impact on reducing final energy end-use.

Conclusion

Challenges exist for renewable energy technologies in the built environment, in particular for domestic water heating (solar energy) and space heating (pellet burners). Geothermal energies might be interesting when the conditions are an advantage for energy and economical reasons. The use of heat-pumps should be considered in the context of the national energy-mix in order to support the reduction of CO_2 emissions. National regulations and incentive schemes should take away barriers for private investment while industries should provide products and appliances that offer to end-user and government all aspects to reduce primary energy and emissions.

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The Seal of Quality for the Energy Performance Certificate:

A Motor for Energy Modernisation!

Thomas Kwapich, German Energy Agency (dena)

Abstract

On 4th January 2003, the EU issued a directive on the "Total efficiency of buildings" to improve the energy efficiency of buildings. It calls for the EU member countries to implement comprehensive measures for significant reductions in the energy consumption of buildings. The main element of this directive is the introduction of energy performance certificates. This aims to provide more transparency in the real estate market and encourage property owners to carry out investment in their buildings. The energy performance certificate provides reliable information on the energy quality of a building, shows sensible energy saving potential, and offers concrete modernisation recommendations. According to the EU guideline, energy performance certificates are to be issued by independent, qualified professionals.

Germany has implemented this EU guideline with the Energy Savings Act (EnEV 2007), which came into force on 1st October 2007. This means that a compulsory energy performance certificate for existing buildings in Germany will be introduced in stages from 1st July 2008 for the renting out, selling and leasing of properties.

According to the EnEV 2007, craftsmen are also permitted to issue energy performance certificates in addition to engineers and architects. For the craftsman sector at least, the required qualifications are not based on a specifically-named training or further education but are based on a curriculum of the required technical knowledge specified in an appendix to the EnEV. However, practical experience has shown that, in many cases, simple possession of a formal qualification is not automatically a sufficient and adequate qualification for issuing energy performance certificates. To guarantee high-quality energy performance certificates, particular "quality requirements" must additionally be maintained in the process. This especially applies to existing building stock because here, in contrast to new buildings, energy performance certificates cannot be based on existing planning data. For reasons of deregulation, no legally prescribed quality assurance for the energy performance certificate are planned by the government. For this reason, dena is planning the introduction of a voluntary seal of quality for energy performance certificates, to be carried by market partners.

The main aim of this is to win consumer trust in the energy performance certificate for buildings and to maintain this trust. The preconditions for this are:

Establishment of a uniform qualification standard for issuers of energy performance certificates

Technical professionals who wish to issue energy performance certificates with a seal of quality must possess qualifications that exceed the minimum requirements of the EnEV. Within the scope of quality assurance, there will be a registration procedure for issuers. Existing further education qualifications will be recognised during a transition period. The second step will be to introduce a unified sample national examination that provides comparable quality control qualifications for certified issuers in the long term. In addition to this, to maintain and extend the existing level of knowledge, all registered issuers will be obliged to take part in regular measures for further education.

Establishment of uniform quality standards for procedures when issuing energy performance certificates

The EnEV allows a wide spectrum of methods to be used when issuing the energy performance certificate. Requirement-based energy performance certificates based on engineering calculations are permitted as well as consumption-based energy performance certificates based on the individual consumption data of the users. The required data for the certificate can either be gathered by the issuer or alternatively by the homeowner himself. The quality, content and results of the energy performance certificate can therefore vary greatly, depending on the calculation basis and the quality of the applied data.

Within the scope of the seal of quality, uniform standards are defined for the procedures to be used when issuing the certificate and also the type of certificate.
Only certificates based on the calculated energy requirements are permissible. The EnEV 2007 already allows simplified data acquisition methods to be used. These simplifications according to the EnEV 2007 are also to be permitted for use within the scope of an energy performance certificate with a seal of quality.

Conformance with the following binding standards is required for the issuing of an energy performance certificate with a seal of quality:

Examination of the building by the issuer
The acquisition of building data on-site is the decisive first step for ensuring the quality of energy performance certificates. All elements of a building can only be technically assessed correctly when the certified issuer personally examines the building on site. Acquisition of data using only construction plans, by a vicarious agent or by the building owner is not permitted for energy performance certificates with a seal of quality. For this reason, within the quality assurance system, the issuer who is responsible for issuing the energy performance certificate, and who signs it, must also personally inspect the building on site.

Qualified customer advice
To allow the building owner to better understand and assess the energy performance certificate, a certificate with a seal of quality requires a personal explanation or explanation by telephone of the results by the issuer. This allows the building owner to ask relevant questions. This will allow him/her to trust the suggested modernisation recommendations.

Additional documentation of the data used for the assessment
An energy performance certificate with a seal of quality requires three additional forms containing information on the acquisition of building data and the modernisation recommendations to be appended, which should present the owner with additional information in a way that is understandable to the consumer.

- The first form must contain information on the acquisition of the building data used as the basis for the energy performance certificate. The building owner receives information on the energy quality of the major building components (ceilings, exterior walls, windows and system technology). Easily-understood coloured assessment fields (red, yellow, green) are used to make the energy quality of the individual components readily understandable.
- The two other forms contain information on the planned modernisation recommendations. Similar to the building data acquisition form, these forms must show which building components are suggested for refurbishment and what effect this will have on the energy quality. The changes to the energy quality will also be clearly displayed for each area using coloured fields (red, yellow, green).

Ensuring the specified standards through the creation of quality assurance facilities
The following positions will ensure that the required standards are maintained when implementing the quality assurance system:

Clearing centre
The building owner can consult a regional arbitrator if he has doubts about the correctness of the energy performance certificate or the methods used. There are advisory positions already available in consumer advice centres and in regional energy agencies, which can extend their services to include advice on the seal of quality. In cases of conflict, the respective positions can

work in an advisory capacity and function as arbitrators between the parties if necessary. The costs will be borne by the building owner.

Random samples

The quality of energy performance certificates with a seal of quality will be checked using random samples. On the one hand, samples will be taken when this is justified and on the other, samples will be taken on a random basis so that, theoretically, any issuer can be checked. To reduce costs, the samples will be taken in a two-step process. After an initial analysis of the calculation documents, an examination of the building can be done on site if this is justified.

The random samples will be taken nationally by independent, technical professionals who are not in competition with the issuer to be checked. The costs of the samples will be borne by the revenue from the system. To ensure adequate financing, the maximum number of samples per year will be limited.

Measures against issuers

If an issuer violates quality control standards then dena can impose the following sanctions:

- Obligation to correct an energy performance certificate
- Obligation to undertake training in a particular area
- Announcement that additional samples are to be taken
- Exclusion from the quality control system
- The issuer has the right to contest the dena decision
  - In this case a neutral arbitrator will be named by dena
  - dena and the issuer are bound by the results of arbitration
  - The issuer must contribute to the arbitration costs

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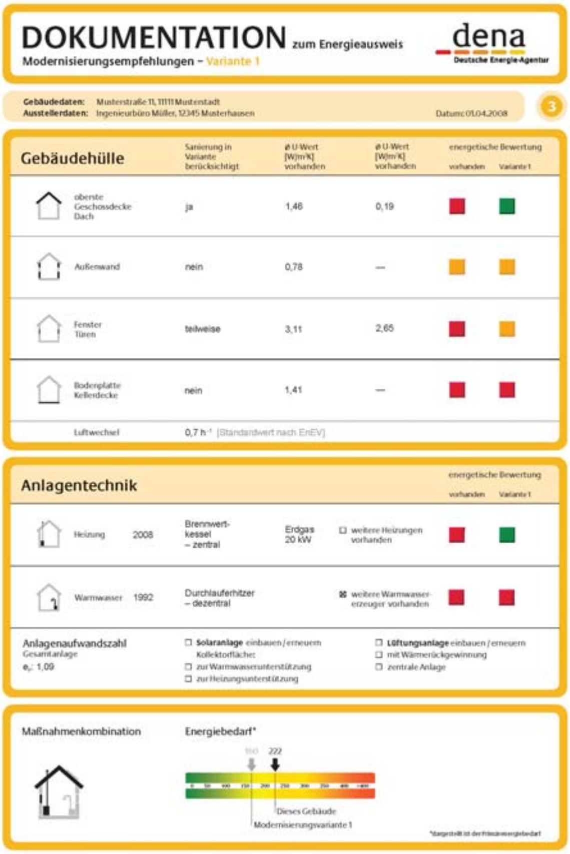
<tr><th>Figure</th><th>Caption</th></tr>
<tr><td>
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<td>FIG. 1: ADDITIONAL DATA ACQUISITION DOCUMENTATION WITH EASY-TO-UNDERSTAND ASSESSMENTS OF THE MAIN BUILDING ELEMENTS</td></tr>
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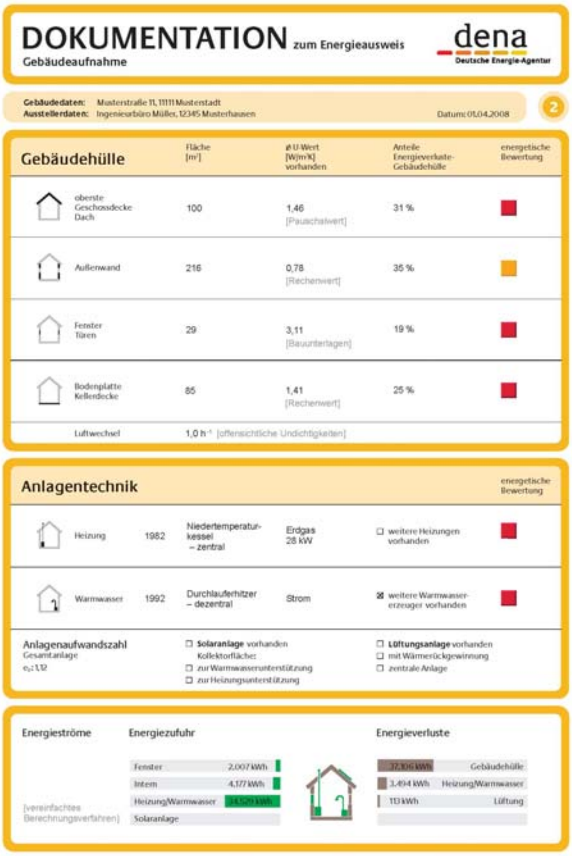

DOKUMENTATION zum Energieausweis
Gebäudeaufnahme

dena
Deutsche Energie-Agentur

Gebäudedaten: Musterstraße 11, 11111 Musterstadt
Ausstellerdaten: Ingenieurbüro Müller, 12345 Musterhausen
Datum: 01.04.2008
2

Gebäudehülle	Fläche [m²]	ø U-Wert [W/m²K] vorhanden	Anteile Energieverluste-Gebäudehülle	energetische Bewertung
oberste Geschossdecke Dach	100	1,46 [Pauschalwert]	31 %	
Außenwand	216	0,78 [Rechenwert]	35 %	
Fenster Türen	29	3,11 [Bauunterlagen]	19 %	
Bodenplatte Kellerdecke	85	1,41 [Rechenwert]	25 %	
Luftwechsel	1,0 h⁻¹ [offensichtliche Undichtigkeiten]			

Anlagentechnik					energetische Bewertung
Heizung	1982	Niedertemperatur-kessel – zentral	Erdgas 28 kW	☐ weitere Heizungen vorhanden	
Warmwasser	1992	Durchlauferhitzer – dezentral	Strom	☒ weitere Warmwasser-erzeuger vorhanden	

Anlagenaufwandszahl
Gesamtanlage
e_p: 1,12

☐ **Solaranlage** vorhanden
Kollektorfläche:
☐ zur Warmwasserunterstützung
☐ zur Heizungsunterstützung

☐ **Lüftungsanlage** vorhanden
☐ mit Wärmerückgewinnung
☐ zentrale Anlage

Energieströme
[vereinfachtes Berechnungsverfahren]

Energiezufuhr
Fenster 2.007 kWh
Intern 4.177 kWh
Heizung/Warmwasser 34.529 kWh
Solaranlage

Energieverluste
37.106 kWh Gebäudehülle
3.494 kWh Heizung/Warmwasser
113 kWh Lüftung

FIG. 2: ADDITIONAL DOCUMENTATION SHOWING THE MODERNISATION RECOMMENDATIONS

Figure source

1. German Energy Agency
2. German Energy Agency

IEECB'08

Behaviour & Investor Motivation

Analysis of the Building Owners' Motivations for Investing in Energy Efficiency: Results from the GreenBuilding Programme

Michaela Valentova and Paolo Bertoldi
European Commission DG JRC Institute for Enerhy

Abstract

In 2005 the European Commission launched the GreenBuilding Programme, which aims at improving the energy efficiency of existing as well as newly constructed non-residential buildings in Europe on a voluntary basis. Building owners from different sectors are participating in the programme e.g. public authorities with schools, hospitals or swimming halls, companies from the services and industry sectors with office buildings, sport centres and hotels. To become GreenBuilding Partner, building owners perform an energy audit at their premises and formulate an action plan. By applying they agree to reduce their primary energy demand of the building by 25% (if economically viable) and to report the results of the renovation measures. Since January 2005, thirteen organisations from ten European countries have been implementing a two-year pilot phase; these organisations are called National Contact Point (NCP). The NCP assists building owners in this process by providing guidelines for energy saving renovation, and a website in national language with an inventory of best-practices. Other private and public organisations may help potential Partners join the programme as Endorsers. Besides reducing energy as well as operational costs, other reasons for building owners to join GreenBuilding are:

- Public recognition for the participating organisations;
- Practical help by the NCP
- Public commitment for environmentally friendly behaviour
- Reduction of CO2-emissions

As of April 2008, 71 GreenBuilding Partner statuses have been awarded leading to a reduction of primary energy of about 120 000 MWh per year. Furthermore, about 29 000 tons of CO2 emission savings will be achieved each year.

This paper will present the results of the first three years of operation, in terms of saved energy, type of buildings, and type of organization. In addition, following interviews with the participants, the paper will also describe their motivations in investing in energy efficiency, as well as their views on the GreenBuilding Programme.

Introduction

In its Green Paper on Energy Efficiency, the European Commission (EC) identified the building sector as an area where important improvements in energy efficiency can be realised. According to the Green Paper, the building sector accounts for more than 40% of the final energy demand in Europe. At the same time, improved heating and cooling of buildings constitutes one of the largest potentials for energy savings. Such savings would also improve the energy supply security and the EU's competitiveness, while creating jobs and raising the quality of life in buildings.

In 2005, the European Commission initiated the GreenBuilding Programme. This programme aims at improving the energy efficiency and expanding the integration of renewable energies in non-residential buildings in Europe on a voluntary basis. The programme encourages owners of non-residential buildings to realise cost-effective measures which enhance the energy efficiency of their buildings in one or more equipment systems.

In a pilot phase in the years 2005-2006, the GreenBuilding infrastructure has been set up in ten European countries. In each participating country, a so called National Contact Point has been established for aiding organisations, which consider participation in GreenBuilding. The GreenBuilding pilot phase has been a project supported by the European Commission's Intelligent Energy Europe Programme.

The GreenBuilding Programme

The GreenBuilding Programme (GBP) is a voluntary programme that started in 2005. It aims to enhance the realisation of cost-effective energy efficiency potentials by creating awareness and providing information support and public recognition to companies whose top management is ready to show actual commitment to adopt energy efficient measures in non-residential buildings.

Participation in the GBP starts with the submittal of an action plan defining the scope and nature of the company's commitment. Based on an initial energy audit, the action plan must define the buildings in which energy efficiency actions will be undertaken as well as the energy services (heating, lighting, water heating, ventilation, air-conditioning, office equipment, etc.) and the specific measures, to which the commitment applies. If the action plan is accepted by GreenBuilding, the company is granted Partner status. Three years after the completion of the last GreenBuilding project (e.g. in case a company is participating with more than one building), the Partner status will expire.

GBP provides documents ("Modules") defining the technical nature of an appropriate commitment for each energy service covered in the programme. The modules are complemented by Guidelines on horizontal issues, such as "Financing", "Energy Audit" and "Energy Management". The GBP encourages its Partners to tap a large reservoir of profitable investments without the need for specific incentives from the Commission. GBP investments use proven technology, products and services for which efficiency has been demonstrated. It is thereby considered to make good business sense for companies to join the GBP.

GBP Partners have direct benefits resulting from the growing attention of consumers and investors. Their ability to deal successfully with environmental issues may indeed be considered as a credible measure of management quality. GBP Partners also benefit by saving money and in most cases by improving working conditions. They realise technically and economically feasible energy savings, thereby increasing their competitiveness and the value of their buildings.

GreenBuilding provides support to the Partners in the form of information resources and public recognition, such as press coverings in newspapers and magazines, presentation at fairs and conferences across Europe, a regular newsletter, and a brochure and a catalogue of success stories. The GBP plaque allows Partners to show their responsible entrepreneurship to their clients.

The GBP is complementary to the EU Energy Performance of Buildings Directive (EPBD) as it will stimulate additional savings in the non-residential building sector.
Information about the GreenBuilding Programme can be found at
http://re.jrc.ec.europa.eu/energyefficiency/greenbuilding/index.htm

GreenBuilding Partners

The so-called GreenBuilding Partners are building owners or long-term tenants of non-residential buildings. An organisation may qualify to become a GreenBuilding Partner in three different ways:

- Refurbishment of one or more existing non-residential buildings, which will result in a 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.
- New non-residential buildings, which consume 25% less total primary energy (if economically viable) than prescribed in the building standard in force at the time, or below the consumption levels of "conventional" buildings currently constructed.
- 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.

Fulfilling one of the criteria listed above, a four-step process is necessary in order to become a GreenBuilding Partner:

1. Energy Audit of the organisation's building(s), which are selected to participate in the GreenBuilding programme.
2. Formulation of an Action Plan, defining the scope and nature of the organisation's commitment.
3. Approval of the Action Plan by the Commission in consultation with the National Contact Point; Commission grants Partner status to Organisation.
4. Execution of the Action Plan, report to the Commission and to the relevant National Contact Point.

GreenBuilding Endorsers

The GreenBuilding Endorser Programme has been established to help the European Commission and the GreenBuilding National Contact Points to promote GreenBuilding to potential participants and to support already registered GreenBuilding Partners in their efforts to reduce the energy consumption. The GreenBuilding Endorser Programme is open to almost all interested parties from the building sector and in particular,

- 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
- Facility management

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 (e.g. lay out a specific plan of how to promote the GreenBuilding or have assisted at least one building owner in becoming a GreenBuilding Partner). In return, the Endorser will get public acknowledgement for their efforts. Though not entailing legally binding obligations, joining the Endorser Programme requires a commitment to the objectives of GreenBuilding. Joining proceeds through a registration whereby the company in question commits itself to fulfil the GreenBuilding Endorser Programme requirements. Endorsers may use the GreenBuilding logo, and their relevant activities and products may be included in the promotional and technical support material.

Selected Examples of renovation projects – Winners of the GreenBuilding Programme Award 2007 – 2008

Among the 71 GreenBuilding Partners, the following organizations have been selected as winners of the first GreenBuilding Programme Award 2007-2008. In this section, a short description of their projects, as well as achieved savings is provided.

The Athens International Airport (AIA) became a GreenBuilding Partner in September 2006. The candidature of AIA was based on refurbishment of six buildings within the airport complex. Total area of 74 880 m2 has been upgraded, resulting in savings of 3 760MWh per year. The total investment amounted to 49 600 EUR, but also 225 440 EUR/year of energy savings were achieved. The energy efficient actions included:

- Ventilation time schedule, chillers time schedule and routines re-engineering – BMS optimization (re-engineering of all the time schedules for the auto-run program, to modify night operation, weekend operation, holidays operation as per the actual needs of the buildings and possible shifts of personnel)

- Heating and Cooling set points revision (Complete revision of set points as per buildings and specific areas needs)

Figure 1 Athens International Airport

The Italian GreenBuilding Partner, City of Faenza, joined the GreenBuilding Programme in November 2006. The building in question, Tolosano Primary school was constructed in 1950 and includes also a number of specialized spaces, such as laboratories, language studies or a sport hall. The main modernization of the school building took place in 2003 and 2006. In 2003, a digital controller for boiler plant by COSTER was installed. An insulating fiberglass layer (80mm depth) was applied to the roof. In 2006, thermal plant equipments were refurbished, the old boiler has been substituted with 4 condensing boilers lined together in cascade system. Thermostatic control valves were installed on radiators. Thanks to the renovation, 42.8% of the primary energy used for heating has been saved. The annual primary heating energy consumption decreased by 160 542 kWh.

Figure 2 Tolosano Primary School

In November 2006, the Portuguese mass public transport company, Companhia Carris de Ferro de Lisboa, received a GreenBuilding Partnership status for refurbishment of a building, used as garage and maintenance services for buses. The building, constructed in 1979, with total area of 2 038m2, was modernised in 2005. The general concept aimed to reduce energy losses through glazing elements, roof, floor and walls (exterior and interior), as well to optimise solar gains. The height of windows was reduced and double glazing and shading devices introduced. An air handling unit was installed in the roof to ensure interior air renovation and quality. Lighting system has been upgraded and also several changing to the general energy management system have been made. Thanks to the refurbishment:

- The primary energy demand for heating decreased by 50% (from 43.6 kWh/m2.y to 26.8 kWh/m2.y).
- The primary energy demand for cooling decreased by 60.8% (from 90.9 kWh/m2.y to 35.6 kWh/m2.y).
- In the time of refurbishment, the annual primary energy demand of the building was 75% below the Portuguese building regulations in force.

Figure 3 Companhia Carris de Ferro de Lisboa

FEZ Berlin – Kinder-, Jugend- und Familienzentrum has become the GreenBuilding Partner in January 2007. The sports and leisure complex, built in 1979, is the largest non-profit children, youth and family centre in Europe. It includes among others a swimming pool, a sports centre, and theatre or concert halls. Total area of 19 380m2 of this leisure and recreation centre has been refurbished. An energy service company (ESCo) was hired to carry out the project. The buildings of the centre as well as its swimming pool have been modernised. The following measures have been implemented:

- Heating and hot water production (Installation of modern central control system with single room temperature control; Optimisation of warm water production)
- Air conditioning and ventilation (Installation of frequency converters; Refurbishment of selected ventilation equipment; Modernisation of the control equipment)
- Lighting (Installation of state-of-the-art (T5 and electronic ballast)
- Swimming pool water treatment (Installation of sewage treatment to reduce fresh water demand)
- Central Building Control System **(** Energy Control System ensures monitoring and thus successful and sustained implementation of the savings targets; Facility automation ensures the efficient operation required by demand

The measures carried out in the centre resulted in that the heating energy demand of the buildings decreased by 26% (2 173.4 MWh) per year. The annual electric energy demand of the buildings was reduced by 30% (1 071.4 MWh). The overall energy savings reached 29%.

Figure 4 FEZ Berlin – Kinder-, Jugend- und Familienzentrum

GEK SA, one of the four major construction groups in Greece, became the GreenBuilding Partner in January 2007. In its newly built central office building, the company has applied energy efficiency measures, which have led to significant reduction of energy consumption in comparison to conventional buildings. The energy savings, compared to the conventional buildings, amount to 325 MWh/year. On the area of 10 000 m2, the following measures have been carried out:

- Heat recovery from conditioned air stream mechanically exhausted from the building. Additionally heat recovers from one of the Heat Pumps of the building (heat riser). The system recovers hot water (while producing cold water) that is used for heating up the building during mid-seasons between winder and summer.
- Installation of frequency inverters to all the motors (fans, pumps, etc.) concerning the building air-conditioning, thus all the equipment is consuming power proportional to the process demand of the building at any time.
- Regulated Venetian blinds in the internal space.
- Installation of BEMS. Monitoring the indoor temperature, humidity, people presence and controlling relevant subsystems (heating-cooling, lighting) Power factor correction Add capacitor systems at the main electricity board.

Figure 5 Office building of GEK SA

The first GreenBuilding Partner from Sweden is HUSÖ Fastighets AB. HUSÖ is a private property owner with both residential and non-residential buildings in Söderhamn, Hudiksvall and Bollnäs. HUSÖ joined the GBP with a police station situated in Söderhamn and a Swedish district courthouse in Hudiksvall. The district courthouse was built in 1909 and renovated in 2005. It has a total area of 2 006 m2 and is heated by district heating, based on almost 100 % renewable fuels. Before the renovation, the building was heated with oil. In the process, energy efficiency measures were implemented, resulting in energy savings of 131 950 kWh per year. Styr och ställer AB has carried out the energy audits for the two buildings and is currently helping HUSÖ to implement the energy efficiency measures in the police station. The expected energy savings in this building are 25 %. Styr och ställer AB is the first accepted GreenBuilding Endorser from Sweden.

The energy savings of the renovation of the courthouse resulted in that:

- The heating energy demand was reduced by 30 % (105 000 kWh) per year
- Total energy savings of 131 950 kWh per year
- The electricity demand for ventilation was reduced by 68 % (13 000 kWh) per year

Figure 6 The district courthouse in Hudiksvall

KfW Bankengruppe became a GreenBuilding Partner in October 2006. The main office building of the banking group has been renovated. Being constructed in 1968, the building was refurbished in 2006. It consists of four towers with total area of 26 000m2. The main actions to increase the energy efficiency of the building complex were:

- Ventilation (central exhaust-air-plant, also used for night cooling)
- Heating/Cooling: existing co-generation (with absorption refrigeration machine) will also be used after refurbishment due to its already high energy efficiency, active cooling via cooling ceiling of at least 35% of the ceiling surface; adiabatic supply air cooling)
- Use of energy efficient lamps
- Building envelope (external solar radiation protection, glazing with g-value below 0.40, insulation with 14 cm thermal (conductivity 0.04 W/mK)

Thanks to the above mentioned measures, the annual primary energy consumption for heating decreased from 245 kWh/m2a to 130 kWh/m2a, which means reduction by 46% compared to the state before the renovation.

Figure 7 KfW Bankengruppe

As a first Spanish partner, the company La Vola joined the GreenBuilding Programme in July 2006. The Ecoedifici (Ecobuilding), headquarters of the environmental service company La Vola, is an office building situated in Manlleu, in the province of Barcelona. The Ecoedifici is a new building, in service since March 2006. It integrates passive energy efficiency measures with an optimised building envelope, as well as highly efficient energy production systems including renewable energy sources. Additionally, an automated building management system contributes to increase the energy efficiency of the whole building. Compared to the reference building, thanks to the energy efficiency measures, 30.7% of primary energy demand is saved.

Figure 8 Ecoedifici of La Vola

The Vienna city council has been accepted among the GreenBuilding Partners in January 2006 with the indoor swimming hall Floridsdorf. The indoor swimming hall, located in Vienna, in the district Floridsdorf, was renovated using 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 heat energy consumption was reduced by about 64%, the water consumption by about 40%. The pay back time of this investment is about 8.5 years.

Figure 9 Indoor swimming hall Floridsdorf

Slovenian participant, Menerga, d.o.o., became part of the GreenBuilding Programme in November 2006. The office building with circa 3 000 m2 of indoor area was constructed within 2002 and 2004. Menerga commercial building is a building, where optimum working and living conditions along with very low energy consumption are achieved, at comparable investment costs, which appear in classical buildings. The basis of an energy efficient building is firstly very efficient heat isolation. Also, high efficient air-conditioning devices (regeneration over 90%) and a heat pump have been installed. Energy efficient lighting has been installed and uniform digital control system is being used. As a result, the energy demand has been reduced by 62%, i.e. 224MWh/year have been saved (the CO_2 emissions decreased by 47%, i.e. 46.4t/year).

Figure 9 Menerga building

Last, but not least, Pfizer AB, the marketing and sales organization of Pfizer in Sweden, joined the GreenBuilding Programme in April 2007. The new office building is localised in an "eco-park" in Silverdal, in the Sollentuna municipality, located north of Stockholm. The criteria for all (both commercial and residential) buildings were to be at least 35% more energy efficient that "standard buildings". Biomass and combined heat and power have been chosen for heating and domestic hot water. Cooling is based on waste cooling from heat pumps and on free cooling from the Baltic Sea. The HVAC system in the office floors is based on water distributed cooling by chilled beams. Occupancy linking has been used for making the lighting system more energy efficient.
As a result of all the measures, 98.6 kWh/m2 energy consumption has been achieved, which is about 30% lower compared to other office buildings built in that period (energy consumption of ca 147 kWh/m2).

Figure 10 Pfizer – eco-park in SIlverdal, Sollentuna municipality

Results of the GreenBuilding Programme

The GreenBuilding has now been in operation for more than three years. Until April 2008, the total of 87 buildings has been promoted by the GreenBuilding project. Furthermore **71** GreenBuilding Partner statuses have been awarded since 2005. An overview of the type of buildings, measures carried out, primary energy savings as well CO_2 emission savings achieved between 2005 and 2008 is provided. Analysis of the results until April 2007 was made by Dr. Lorenzo Pagliano (*Pillen et al.* 2007) and updated until April 2008 by the authors.

The buildings participating in the GBP cover a broad variety of different types of non-residential buildings. Almost half of the buildings are office and administration buildings (49%). The second largest group of buildings are education facilities such as universities, schools or day-care-centres (21%). 8% are commercial facilities and hotels and by the same percentage **-** 6% **-** hospitals and sport facilities are represented. The remaining 10 % include industrial buildings, municipal buildings (a city hall and a community centre), an airport, a church, a prison, and a police station. The majority of the buildings belong to private organizations (66%), the other 34% are owned by public bodies.

Most of the 87 GreenBuildings (69%) are existing buildings which have been refurbished, whereas 31% of the GBP buildings are newly constructed.

A variety of end use services have been addressed by the GreenBuilding Partners. The following lists the most frequently applied measures:

- 70 % heating
- 55 % lighting
- 51% air conditioning / ventilation
- 50% control systems
- 42% building envelope
- 26% renewable energies
- 18% heat pumps
- 13% summer heat protection
- 15% cooling
- 4% ground exchange
- 4% co-generation
- 4% electric appliances

The measures mentioned above have led to primary energy savings of almost 120 000 MWh per year. Thanks to the 71 GreenBuilding Partners, 29 000 tons of CO_2 emissions will be saved each year. Assuming a lifetime of 20 years, these savings will accumulate to 2.4 TWh of primary energy and 580 000 tons of CO_2.

So far, as of April 2008, there have been 32 Endorsers from 9 European countries joining the GBP. The number of Endorsers is lower than in other similar projects, such as the GreenLight or Motor Challenge Programmes. This seems to be due to the requirement that Endorser status was only awarded in case the applicant provided at least one GreenBuilding Partner to the project. This process was invented in order to reduce the Endorser applications to experts which are really interested in the topic. Furthermore it proved that the Endorsers listed in the project have a minimum of experience in modernising or designing energy efficient non-residential buildings. Nevertheless agreeing to this application process also meant that becoming GreenBuilding Endorser involved at least two people interested in the project (the Endorser and the Partner) (Pillen *et al.* 2007).

Major drivers for implementing energy efficiency measures and joining the GreenBuilding Programme

Apart from the energy saving results of operation of the GreenBuilding Programme, the major motivations of the GreenBuilding Partners to participate in the Programme have been examined. A questionnaire (see Annex 1) has been distributed to all the current GreenBuilding Partners (as of January 2008), i.e. the total of 67 Partners has been addressed; out of this number, 30 Partners actually replied. The GreenBuilding Partners recruit from all different areas, from private, as well as public sector. In our sample, the variety has been preserved. We have received answers from all kind of businesses, as well as from public authorities and public owned facilities. Two thirds (66%) of the companies from our sample are from private sector. There were 4 construction and 4 real estate companies, 3 insurance companies, but also an accommodation facility, publishing company or an Energy Service Company (ESCo). Other more than a third (34%) of the participating Partners is coming from public sector (mostly municipalities, but also a hospital or a detention centre).
GreenBuilding Partners from nine countries were interviewed. We have not managed to receive answers from GBP Partners from the EU new member states.

For the majority of partners, the main motivation to join the GreenBuilding Programme was environmental considerations and reduction of energy consumption and costs. In 63% of the organizations (19 out of 30) both these factors were seen as the major reason for implementing the energy efficiency projects. In other 6 organizations, it was either the environmental consciousness or energy reduction alone that were the most important factor. Apart from that, one Partner stressed the importance of having a good practice example to "show it is possible to live or work in an old building with low energy consumption". Similarly, another Partner emphasized the possibility to renovate a historical building at an energy standard of a new one.
Partners coming from public sector also pointed out their role as front runners in the climate change policy and climate protection; i.e. the need to represent the exemplary role of public sector. By the same token, respondents coming from business sector highlighted the comparative advantage they can profit from if they become more energy efficient.
Two of the respondents mentioned that energy efficiency measures in their building and becoming the GreenBuilding Partner would make them more attractive to their tenants. Another reason, reported by two Partners, was the increase in value of the building. Two respondents also emphasized it was important that the thermal conditions improved (especially as it concerned a school building); and in one case, the national and international acknowledgment through the GBP played one of the decisive roles to undertake the project.

In most cases, the Partners agreed that there were not many obstacles in persuading the company board to implement the energy efficiency solutions. Only 3 out of 27 organizations, which answered this question, faced difficulties in trying to convince their management body. In these cases, the financial aspect represented the crucial point. In several cases, when Partners are recruited from public organizations or municipalities, the budgetary constraints given by the public budget were reported to play an important role.
In any case, the organizations agreed that the economics of the action represented an important

issue in making the decision; however other factors, such as the business opportunity (e.g. for construction or real estate companies), strategic standpoint or environmental consciousness of the organization played significant role in the decision making. Most of the organizations, in which the environmental issues are at high stake (e.g. existence of a long term energy management plan or compliance with environmental standards EMAS/ISO 14001), the interviewees did not report to have faced major opposition. Similarly, tight building standards in the area were another reason for rather smooth approval by the management. Additionally, in two cases, the hiring of a "competent service company" made the decision easier to obtain.

When assessing the energy efficiency measures and their feasibility, different criteria were taken into consideration. In most cases (17 replies, 56%), the respondents reported that the energy reduction was the main criterion in evaluating the feasibility of the project. Several organizations actually set a target, how much energy reduction should be achieved (e.g. reaching the passive house standards or reaching certain level of CO2 emissions). In 12 cases, the interviewees followed the pay-back period criterion, although the actual reported time needed for the pay back differed rather significantly. At one (public) organization, the pay back time not to be surpassed has been set to 40 years. Low maintenance costs played a significant role, too. Appreciation of the value of the building and marketing impact were also reported as important criteria. Two interviewees used the more holistic, life-cycle cost analysis and focused on materials with long service life avoiding non-recyclable, short lifetime ones.

As to the financing of the projects, in most of the cases it was based on the future cash flow resulting from reduced energy costs; i.e. the money saved by the energy efficiency measure serve to pay back the initial cost of the investment. From our sample, 11 organizations used this approach to energy efficiency financing when implementing their projects. Three respondents stated to have used the value of the purchased asset as a collateral for the financing. Other methods for financing of the project were contributions of the members of the organization, own reserve funds or sales of assets.
From the 30 respondents, one third has used services of an Energy Service Company (ESCO) to accomplish the project. The rest of the organizations said they did not hire an external party, but rather used internal specialists (e.g. own R&D department) or a consultancy company.

All the respondents verified or plan to verify in the near future the savings that they reported when applying for the GreenBuilding Partnership. In cases, when the project was not yet complete or too short period passed since the accomplishment of the measures in the time of carrying out the interview, the organizations stated to be willing to do the verification in the near future. In cases the savings have been already verified, the companies reported to achieve the expected amount savings or even more.
Similarly all organizations but two stated they have indeed implemented a monitoring system and are regularly monitoring the energy consumption in their facility or office as part of the building energy management system. The monitoring is done either on a continuous basis or periodically. One of the two companies without an automated monitoring system reasoned that it was too expensive for them and therefore they had to do the monitoring manually.

Unanimously, the participating organizations agreed they are willing or planning to implement other energy efficiency projects. In particular, the companies mentioned further projects would be part of a broader energy or environmental management plan. By the same token, other energy efficiency projects will be part of the energy and CO2 emissions reduction targets adopted by the respondents. For two interviewees, building and modernizing buildings is a business priority. Two organizations claimed they are willing to apply for further GreenBuilding Partnerships with their other buildings. One Partner tries to be granted the status of GreenBuilding Endorser.

In broader terms, the companies expressed their general satisfaction with GreenBuilding Programme and its concept. The companies appreciate using the GreenBuilding Partnership in their marketing and public relations activities. Also, the European dimension of the GreenBuilding Programme was found to be an "an important motivation to go on this way". As to other Partner, "the exemplary projects presented by the GB partners serve as a challenge for others". However, as mentioned by several others, it would be welcome to have the GBP "more widely promoted around Europe", as of now, it does not really receive "the attention it deserves". Larger promotion would indeed "motivate more of the larger companies to implement such measures". Conversely to other opinions, two Partners claimed not to have received enough help and attention from the Programme coordinators.

Conclusions

The GreenBuilding Programme has been successfully developing since its launch in 2005. Over the first three years of its operation, more than 70 GreenBuilding Partner statuses have been awarded. Thanks to the implemented energy efficiency projects, primary energy savings of almost 120 000 MWh per year have been achieved. This means about 29 000 tons of CO_2 emissions will be saved each year. Assuming a lifetime of 20 years, these savings will accumulate to 2.4 TWh of primary energy and 580 000 tons of CO_2.
A survey among the Partners showed the main motivation for energy efficiency measures is both environmental considerations and energy reduction. The organizations that join the GBP usually do not face any problems in getting support from the management body. A facilitating factor is an existence of broader environmental or energy management plan in the company. Majority of the companies used payback period and energy reduction target as the major criteria. One third employed an Energy Service Company for the project. All the companies are willing to continue with other energy efficiency actions.
The GreenBuilding Programme initiative is very much appreciated among the companies; however, focus on wider promotion is still needed in order to disseminate the best practice examples among other interested parties and attract new, potential Partners.

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Annexes

Annex 1 Questionnaire

1. What was the main reason to undertake an energy efficiency project in your building (environmental considerations, energy cost reduction, to increase the value of your property, different criteria)?

2. Was it difficult to persuade your company board to implement energy efficiency solutions? What was the crucial point in the decision making? (e.g.financial aspect - pay back time, return on investments, etc.)?

3. Did you use any specific criteria (criteria on the pay back period, on life cycle costing, on total cost of ownership, on a target for the reduction of energy consumption, etc.)? Please comment.

4. Did you verify the savings after the project was completed (only if you reported calculated savings)?

5. Did you use an Energy Saving Companies (ESCO) in implementing the project?

6. What was the financing of the project based on? (E.g. future cash flow (reduced energy costs) or on the value of the asset (collaterals))

7. Do you have a regular monitoring of the energy consumption?

8. Would your company implement other energy efficiency projects? Please comment.

9. Are you happy with the European GreenBuilding Programme and with the way it is promoting your project?

10. Any other comments/suggestions you would like to add.

Energy Efficiency and Performance of Commercial Real Estate

Anil Kashyap, Jim Berry and Stanley McGreal, University of Ulster, UK

Abstract

Buildings have a profound impact on the quality of our lives and the world around us. All types of buildings are a major source of greenhouse-gas emissions and account for over 40% of the European Union (EU) final energy demand. This makes energy efficiency as a key element of the European climate change strategy where buildings have a key role to play in driving environmental sustainability outcomes. The commercial buildings sector is one of the fastest growing energy consuming sectors. Green office buildings are good for the environment; provide healthier places to live and more productive places to work. Energy and emissions management helps buildings to manage their energy usage, improve their efficiency, drive down costs and reduce carbon emissions. Investors have been increasingly demanding in the disclosures that businesses are required to make concerning their greenhouse gas emissions. This paper examines the sustainability in commercial building from users' and investors' motivation perspective. Furthermore this paper identifies key barriers in achieving low carbon commercial buildings.

Introduction

Global climate change is most important environmental challenge faced by our communities. The global energy industry is under pressure to find alternatives to the consumption of fossil fuels in order to reduce the amount of greenhouse gas (GHG) released. Rising energy prices have dominated the media over the past years, thereby increasing the public awareness of energy use and costs throughout the domestic, commercial and transport sectors. The International Panel on Climate Change (IPCC) suggests that buildings and the activities that occur within residential and commercial buildings produce more carbon than the transport or agricultural industries. Hence, reducing demand within existing commercial property assets have potential opportunities to drive the sustainability agenda forward.

Commercial buildings include a wide variety of building types—offices, hospitals, schools, police stations, warehouses, hotels, libraries, shopping malls etc. of which office buildings have significantly higher energy use. According to the DOE's Commercial Buildings Energy Consumption Survey (2003), commercial office buildings are the largest single consumer of energy among all buildings. For instance in the UK, commercial buildings are responsible for around 13% of total carbon emissions. Australian commercial property industry produces 8.8% of the national greenhouse emissions each year and forecasted to almost double its emissions between 1990 and 2010 (DEH, 2001). Given that buildings are responsible for carbon emissions, property sector will clearly have to take the lead to meet this objective. The UK government's intentions were made clear in the Energy White Paper (2007) and the Green Paper (2007), setting the target to cut carbon emissions in buildings. The European Energy Performance for Buildings Directive (EPBD) 2006 and other policies and legislation brings sustainability as a major issue for all those across the industry, affecting planners, developers, occupiers and investors. This paper examines the sustainability in commercial building from users' and investors' motivation perspective and identifies key barriers in achieving low carbon commercial buildings.

Sustainability in Commercial Buildings

There has been considerable debate throughout in property industry about the likely future impact of sustainability issues on the commercial property sector. Sustainability is now being considered much more than the design, construction and material choices in a property. It is also becoming recognised as a vital concern for those who are financial stakeholders in the whole building lifecycle, including the front-end financing and the long-term management and operation of buildings. Increasing the energy efficiency of commercial buildings constitutes a significant step towards improving the environmental efficiency of property. However, energy efficiency is simply part of a much wider issue of achieving sustainability.

Buildings account for almost 45 to 50 per cent of all energy consumed in the UK. In the United States also, buildings account for an estimated 39 percent of the country's energy consumption and 43 percent of its carbon dioxide emissions. Seventy-six percent of all electricity generated by US power plants goes to supply the Building Sector. Electricity and natural gas are the most common energy sources used in commercial buildings. Along with domestic buildings, sustainability is becoming an increasingly important issue for the commercial property industry. McKinsey Quarterly Report (2007) indicates that four of the five most cost effective methods of greenhouse gas abatement (being building insulation, lighting systems, air conditioning and water heating) are related to the commercial and residential buildings. With the soaring oil prices, the need to significantly reduce level of consumption and dependency on non-renewable energy is at the heart of drive towards sustainability. Therefore it is vital to make commercial buildings more energy efficient and acceptable. Recent advances in green design and technology create an opportunity as well as a responsibility to reduce its environmental impacts in the building sector.

A sustainable commercial building can be defined as a building with planning, design, construction, operation and management practices that reduce the impact of development on the environment. A sustainable commercial building is also economically viable, and potentially enhances the social amenity of its occupants and the community. Ministry of Environment, New Zealand defines Sustainable buildings as buildings that are designed, built and operated with low environmental, social and economic impacts while enhancing the health, welfare and quality of life of the people that live and work in them.

Green building also makes efficient use of resources, minimizes pollution and waste, and reduces overall environmental impact. Green buildings require less maintenance cost reduce short and long-term costs. They have better indoor air quality thus promoting good health among occupants and improve worker satisfaction. Green building demonstrates commitment to sustainability, gives a competitive advantage in the market, greater workforce productivity and even more significant effect on company profits. In addition to the satisfaction of contributing toward a better environment, a healthier workplace and an improved community, green commercial buildings often bring financial rewards in the form of cash reward from utility companies and tax incentive from Federal government (Green Building Initiative, 2008).

Commercial buildings also use district energy system which is usually not common in residential buildings. In the case of buildings located closely like on a college campus or in a neighbourhood, it is sometimes more efficient to have a integrated central heating and cooling plant that distributes steam, hot water, or chilled water to all of the different buildings. This system can reduce equipment and maintenance costs, as well as save energy.

The number of policies and legislation now emerging are designed to enhance the environmental performance of the sector. Arguably, the most crucial of these, once fully implemented, is the Energy Performance of Buildings European Directive (EPBD), in force from 2006. The European Energy Performance for Buildings Directive (EPBD) aims to reduce emissions through increased energy efficiency of the European Union (EU's) 160 million buildings which generate more than 40% of total EU carbon emissions. By implementing the Directive, the EU could potentially reduce its carbon outputs by 45 million tonnes by 2010. Indeed, it is so important that the EC's climate change and energy strategies are heavily dependent on its achievement.

Users' motivations and demand

Sustainable commercial buildings are designed to use fewer resources such as energy and water, to operate them; thereby lowering operating costs. Hence it is important for occupiers of buildings to consider these issues with regards to the property they occupy. According to RICS Report (2007) and

National Real Estate Investor Research (2007), there has been a steady increase in level of demand for environmentally efficient commercial property over the last decade. Such demand is increasingly coming from all major stakeholders including government, institutional investors in property stocks, tenants and direct inventors in property. Leading corporate occupiers are also requesting energy efficient space although much of the impetus is still generated by occupiers themselves. This assertion is backed up by the results of the IPD UK Occupier Satisfaction Survey 2007 which indicates that environmental sustainability has become a critical issue for many occupiers.

The occupation of property that is sensitive to the concept of sustainable development provides an ideal and tangible vehicle through which a company can exhibit its support of corporate social responsibility (CSR). Corporate Social Responsibility which normally embraces a commitment to 'sustainable' business practice is another key driver of current demand for 'green' offices. Companies, particularly those working in the financial and business services sector, are increasingly aware of the benefits of using a green space. These benefits include improved reputation and staff productivity as well as brand loyalty and recognition; all leading ultimately to greater profitability.

Beyond simple enhancement of corporate image, there are other clear benefits associated with the occupation of green buildings. Arguably, the most tangible benefits are the financial savings associated with increased energy efficiency. According to JLLM estimates (2007), buildings with sustainable element can save up to 20% in total electricity cost thereby enhancing long-term building value and returns. Yu and Chow (2001) have identified as inverse relationship between building energy cost and size. In other words, the bigger the building, the smaller would be the energy cost per unit floor area.

Many sustainable design features also have a positive impact on employee satisfaction, translating into increased productivity. Features such as natural lighting, air quality, worker-controlled temperature and ventilation can have many positive effects, leading to reduced illness, absenteeism and increased productivity of the workforce. Rocky Mountain Institute study (2005) identified productivity gains of 6-16% through energy efficient design, with decreased absenteeism and improved quality of work from employees. A detailed survey of 11,000 people in the USA found a 1 to 1.5% increase in productivity within a 'green' building. For a 4,000 sqm tenancy, on salaries alone - that equates to more than $200 000 a year, or $50 per square metre.

The property industry has been presented with numerous arguments to support the case for implementing 'green' initiatives, such as cost savings through energy management and potential value differential driven by occupier demand. It has also been established that green buildings are not only good for the environment, but also offer direct benefits to occupiers. To accelerate the creation of sustainable buildings and to transform markets, there is a need to determine, demonstrate and calibrate how sustainable buildings actually add value, to ensure that value is captured within the development process, and to ensure that fiscal incentives are provided where needed. Evidence on the economic advantages of sustainable property investments is needed to persuade business practices, to inform the public debate and to transform the markets for sustainable buildings. However, these benefits are undervalued under the current system, and the industry needs to incorporate them within property valuation.

According to National Real Estate Investor Survey (NREI) 2007, corporations and developers are rising to meet the new demand for energy efficiency in US market. The focus on sustainable real estate is clearly on the rise with 84% of corporate users and 77% of developers expecting to own, manage or lease at least some green properties five years from now. This survey results support the premise that corporations and developers are embracing green building practices. Respondents expect that green building ownership and management will increase dramatically in just a few short years. Energy efficiency likely generates the most attention because it also produces the biggest payback on green design. The desire to cut energy costs is the main force pushing green building into the mainstream. Four in five respondents indicate energy efficiency is important to their company when selecting, acquiring or developing a green building.

Colliers International's Canadian Office Tenant Survey, conducted in July 2007 demonstrates a high market demand for green leased space. 91 percent of tenants prefer green buildings, 90 percent of respondents agree on the importance of landlords and developers greening their portfolios, 65 percent of tenants would pay a premium for greener leased space, and 62 percent would be prepared to pay net rent premiums given their utility consumption was lowered by 30 percent. Drivers that tenants ranked as most important for staff attraction and retention include proximity to public transportation, excellent indoor environmental air quality and thermal comfort and high level of natural light.

Investors' motivations and responses

Rising public awareness will cause stakeholders of all types – tenants, employees, shareholders, investment analysts, and insurers to look closely at climate change practices within real estate industry as the public comes to understand the significant impact that the built environment has on energy consumption and consequently, green house gas emissions. The value of a building has essentially has two components – the rental income, and the investment yield. Both of these components have impact on competitive landscape of developers and investors.

In a survey of large companies conducted by the British Council for Offices, 67% respondents stated that sustainability would be 'very important' in the future conduct of their organisation. Companies are recognising that a 'green profile' can enhance their corporate reputation among consumers and thereby bring commercial advantages, and systems are in place to encourage this. GVA Grimley Survey (2005) of office occupiers, carried out for Maple Grove Developments, states that only 24% of respondents stated that occupation of a green building would be unimportant to company image. Moreover, 17% and 25% respectively stated that it would be very important and fairly important to the corporate image of the company.

Interest and enthusiasm for green building has never been higher in the building industry until building professionals have realised the commercial benefits of green buildings. Use of the Integrated Design Process to achieve the higher performance of green buildings keeps down construction costs. Moreover, green-building professionals in early in the design stage before key decisions are made could help maximizing the benefits of green design while minimizing costs. Global survey of corporate occupiers by Jones Lang LaSalle and the CoreNet Summits observed that many tenants would be willing to pay higher rental costs to occupy a 'green' building with a higher level of energy efficiency. This is highly favourable indicator for sustainable property going forward and encourages developers to accommodate any potential additional costs resulting from energy efficient design initiatives. Grubb & Ellis (April 2007) research highlights that commercial real estate investors and managers will be challenged to address new requirements for underwriting investments and operating their portfolios.

There has been a widespread perception in the real-estate industry that green buildings are significantly more expensive than traditional methods of development. A 2003 study conducted for the California Sustainable Building Task Force shows that an initial increase in upfront costs of approximately 2% for green design will yield lifecycle savings of more than ten times the initial investment. A green building may cost more up front, but saves through lower operating costs over the life of the building. The green building approach applies a project life cycle cost analysis for determining the appropriate up-front expenditure. This analytical method calculates costs over the useful life of the asset. These and other cost savings can only be fully realized when they are incorporated at the project's conceptual design phase with the assistance of an integrated team of professionals. The integrated systems approach ensures that the building is designed as one system rather than a collection of stand-alone systems. Some benefits, such as improving occupant health, comfort, productivity, reducing pollution and landfill waste are not easily quantified. Consequently, they are not adequately considered in cost analysis. For this reason, consider setting aside a small portion of the building budget to cover differential costs associated with less tangible green building benefits or to cover the cost of researching and analyzing green building options.

Harvard Business Review (March 2007) states that climate changes affects company's competitive landscape and companies which manage and mitigate their exposure to climate change risks while seeking new opportunities for profit will generate a competitive advantage over rivals in carbon-constrained future. Jones Lang LaSalle (JLL) Research (2007) shows that sustainability issues drive change in investment choices. 28% of Australian commercial property investors are now prepared to pay more for an investment with sustainability potential. An additional 58% of respondents agree that if all other things are equal, sustainability can sway their choice between alternative investments.

The GVA Grimley survey (2006) reveal that efficient energy use was rated as the most important with 87% of respondents rating this as important or very important. The results are perhaps unsurprising, given that they bring the most tangible benefits to occupiers – in the form of cost savings through more efficient consumption. Accordingly, the fact that rather less importance was attributed to other sustainable features, such the use of sustainable materials in the construction process or locating on brown field land, is probably because they are not perceived to deliver tangible, day-to-day benefits.

At the heart of the debate over the linkage between green buildings and asset value itself are the different notions of what constitutes ‘value’. According to RICS Green Value Report (2005), there are a number of alternative approaches to valuation, namely Triple Bottom Line, Full-Cost Accounting and Multiple Accounts Evaluation. All seek to model value more holistically by integrating environmental, societal, and community as well as strictly ‘financial’ concepts, and all have yet to achieve universal acceptance. Lifecycle cost analysis is needed to make the link between green building and asset value because much of a green building’s asset value may lie in its long-term lifecycle benefits. Better and more formalised life-cycle valuation will help to demonstrate the advantages of green buildings.

The installation of environmental technologies in buildings is becoming more and more common with the increased market awareness, popularity, and client interest in green buildings and design. Organisational approach to sustainability can have significant influence over the perceived and real value of its intangible assets, and therefore can affect its market value. From an investor's perspective, sustainability in the commercial building sector is important as it is significant in determining the intangible and future value of the business and impacts on material risks and opportunities of the business.

Major property developers are already incorporating more and more eco-friendly features in commercial buildings such as turbines to generate power for offices, solar thermal hot water heating, grass roofs to insulate buildings, laminated timber as an alternative to steel and using high efficiency lighting and enhanced skylights that increase natural light and reduce consumption of electrical power. Occupiers should be prepared to pay a higher rent for a more environmentally friendly building. Thus, a more sustainable building should have a higher rate of rental growth. An increase in costs related to low carbon construction is likely to affect either levels of rent, developer profitability or the price paid for land in the first instance.

Research by Sarah Sayce, Louise Ellison (Kingston University, UK) and Philip Parnell (Drivers Jonas Chartered Surveyors, UK) surveying a cross-section of property investors, developers, consultants and bankers indicates that a notable shift is beginning to occur among property investors in the UK from a simple concern for environmental protection to a wider remit, encapsulating well-being and triple bottom line sustainability. The increasing emphasis on corporate social responsibility is becoming a driver in the property investment community.

Rational behaviour by investors, developers and occupiers is linked to requirements for optimisation of return combined with risk containment. For current progress to be sustained and accelerated there is a need for both continued industry response informed by easily applied metrics and a need for government intervention in the form of fiscal incentives. Federal, state and local governments have been working to encourage sustainable development with programs ranging from tax rebates and grants to preferential zoning and fast-track development schedules.

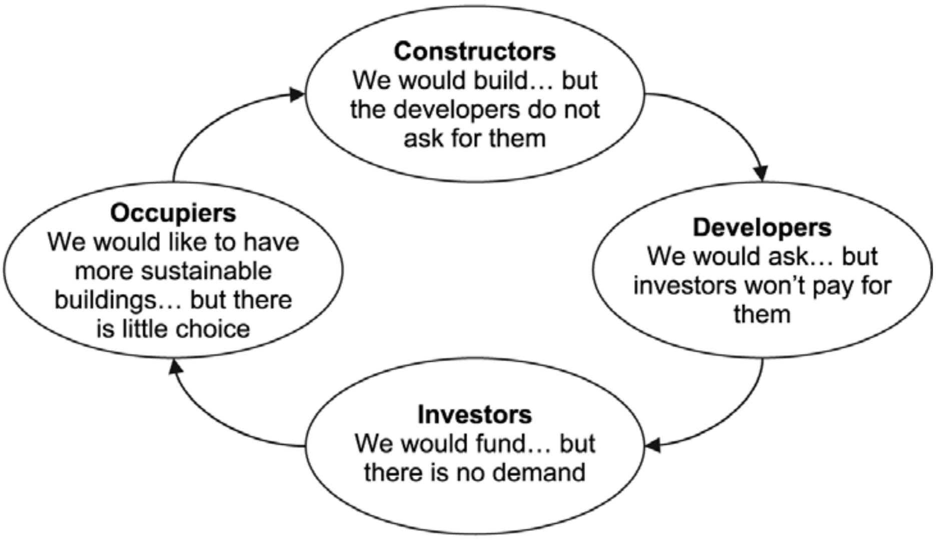
According to NREI Survey (2007), number of legislation, resolutions, ordinances, policies, and incentives can be found across the United States and Canada. The majority of corporate and developer respondents - 74% and 71% respectively - have noticed an increase in green building initiatives from local, state and federal government. Yet nearly three-fourths of respondents - 77% of corporate users and 72% of developers - have not taken advantage of government incentives for green building developments. Among respondents who have taken advantage of incentives, the most commonly used are tax breaks, fee waivers and a “fast-track” permitting process.

Despite the fact that an increasing number of corporate occupiers already have in place environmental and / or sustainability policies that express their commitment to such development, there is a considerable degree of inertia in the property industry about the costs and benefits associated with the construction, operation and use of sustainable buildings. Traditional property valuation and appraisal methods are not currently suitable to meet environmental or social requirements of sustainability. The GVA Grimley survey/CBI Survey asked occupiers their opinion on what factors were most likely to drive environmental change within the industry. Occupiers believe that both cost issues and legislation (both UK and European) will be of key importance in driving change. Conversely, respondents viewed pressure from employees and share holders as the least significant potential driver.

Barriers

Previous studies have identified a ‘circle of blame’ in Figure 1 shows that developers and investors are waiting for occupiers to declare their demand for green property, and thus creating a defined market segment. Simultaneously, developers believe that there is no evidence that corporate occupiers are willing to pay increased rents or premium rent to compensate developers for extra cost incurred in the construction of sustainable buildings. The key to breaking the circle of blame is for the industry and valuation professionals to recognise the virtues of sustainable buildings and therefore include sustainable issues in market valuations and calculations of worth.

Figure 1: The Circle of Blame



Source: SCFG (2000)

The main barrier to the construction of sustainable commercial buildings directly relates to the different incentives that drive developers, investors and tenants. Developers want to build a commercial facility that will attract tenants and quickly sell to the investment market at a good profit. Meanwhile, investors want to own a building that will attract and keep tenants, while tenants want low-cost leasing arrangements. Therefore, a developer may have little interest in design and construction initiatives that can't be immediately valued by tenants and investors. Likewise, investors may resist paying for sustainability initiatives that tenants cannot immediately identify and value as part of their decision to lease.

In the context of commercial development cycles, requirements for enhanced sustainability which result in higher construction costs could delay a recovery. Secondly, developers strive to maximise the floor area of buildings by minimising the thickness of external wall construction. The adoption of a heavily-insulated wall construction could also impact on capital values and loss of net lettable floor area (and hence capital value) by 5 per cent (UK GBC, 2007). The investment yield reflects a whole host of factors such as risk, rental growth, obsolescence, investor perception of a particular market or sector, and more general investor demand. Therefore, investor demand for sustainable buildings is likely to rise relative to the market as a whole, which will have a positive impact on values for such buildings.

Decision to invest in commercial offices is typically associated with the prospect of improved capital and rental growth. In addition, it is hoped that the investment asset will experience a low vulnerability to depreciation and obsolescence. The same principles hold true with investments in sustainable property, with the additional hope that any such asset may prove to be either cheaper, or at best cost neutral, compared to its non-green alternative, or at least provides an increase in value sufficient to offset any additional costs, such as higher plant costs. As green buildings typically incorporate the latest design principles, depreciation and obsolescence should have less of an impact than might be the case with a standard building. Given the urgency of greening buildings due to their greenhouse gas emissions and other environmental, social and economic impacts, removing barriers to rapid market transformation is necessary.

Conclusion

The property industry is beginning to take the issue of environmental efficiency and sustainability very seriously. The discussion and survey undertaken by major property consultants and researchers indicates that 'green issues' will be a much more important consideration to occupiers in accommodation strategies in the coming years, as companies become increasingly committed the notions of corporate social responsibility. Sustainability is also an important issue from a property investment perspective, as it has impact on a building value. Legislation will drive change towards more sustainable property. The introduction of energy performance certificates will be crucial in raising awareness and thus promoting a market for more environmentally friendly buildings among occupiers and investors.

Occupiers are receptive to greener buildings and that they may even be prepared to pay a higher rent in order to reap the benefits, in terms of corporate image, energy savings and productivity gains. The factors driving the interest and awareness of the various stakeholder groups are closely linked to the perception of demand. Investors and developers see the need to create energy-efficient buildings as driven by tenant-occupiers, coupled with developers' perception that creating such buildings offers the potential to increase the liquidity of their property portfolio. For tenant-occupiers, the main incentives are the opportunity to reduce running costs and improve their brand image as good corporate citizens.

Much of the occupier market is currently in infancy regarding use of sustainable buildings, although in the medium terms it is predicted that occupiers will increasingly want to occupy such buildings and that sustainability will move up the location in decision matrix. The challenge for valuers is to be able to take account and quantify any changes in stakeholder attitude. In other words, it is likely to become increasingly important to find effective ways to incorporate sustainability issues into their both valuation and appraisal processes.

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Overcoming the Commodity View

Catherine Cooremans, HEC University of Geneva, Switzerland

Abstract

According to decision-making and organisational finance research, an investment decision must be analysed as a stage in a process influenced by individual, organisational and contextual factors, and by the characteristics of the investment itself. Of all investment characteristics, strategic importance is the first decision driver, before profitability. In this context, strategic importance can be defined as the investment contribution to a company's competitive advantage in performing its core business activities; and competitive advantage can be defined as a balance between costs (for the company), value (for its customers) and risk.

Energy-efficiency investments can improve a business's competitive advantage in all three dimensions by reducing costs, increasing value and decreasing several kinds of risk (legal, price, energy security). Unfortunately most business decision-makers have a commodity view of energy: they only consider its cost. And if energy cost is low or is perceived as necessary to a firm's core business, the cost reduction induced by the energy-efficiency investment is not going to be a powerful decision factor. Energy auditors share the same commodity view of energy: they only point to cost reduction entailed by technical equipment and systems improvements, without highlighting the other benefits of energy-efficiency investments to core business.

Using organisation studies' concepts and decision-making research findings, the aim of this paper is to analyse businesses' and energy auditors' commodity view of energy and to explore possible ways to switch from a commodity view to a strategic view of energy. The conclusion summarizes the main findings, which point to three important investment decision drivers: strategy (non-strategic issues lose the competition); power (powerful managers get what they want) and culture (powerful managers' choices are influenced by several spheres of culture).

Introduction

The question of why certain energy-efficiency investments are not decided by economic actors has been a point of debate for twenty-five years. A review of mainstream literature presents contradictory conclusions: according to the economic perspective, energy-efficiency investments are profitable but various market and organisational failures, mainly linked to information problems, prevent them being decided upon; according to the financial perspective, these investments are profitable only in appearance, as several hidden and transaction costs, as well as a high level of risk, lower their profitability below a firm's cost of capital. A review of "alternative" energy literature points to many factors influencing organisational decisions on energy-efficiency investments: organisational factors such as companies' size, location, financial performance (DeCanio & Watkins, 1998; De Groot et al., 2001), structure (Cebon, 1992; Stern & Aronson, 1984) or culture (Kulakowski, 1999; Hennicke *et al*., 1998; Togeby *et al*., 1997); individual factors such as energy awareness or energy managers' skills (Kulakowski, 1999; Rigby, 2002); external factors such as energy prices. The influence of these numerous factors, individual, organisational and external, is reducing *ipso facto* the decisional weight of investment profitability: profitability is only one decision factor, among others.

However, beyond contradictory views and the complex interaction of numerous factors, a certain image of energy in organisations is emerging from a review of the different streams of energy literature: energy consumption is generally not taken into consideration by organisations when making equipment or appliance decisions (Weber, 2000); energy-efficiency retrofit projects are often treated as an expense and not as a financial investment, therefore are not on the same field as other capital improvement projects (Kulakowski, 1999); energy managers, when they exist, lack power due to the secondary nature of their task (Cebon, 1992); moreover, they often lack the necessary skills to champion energy efficiency within their organisation (Rigby, 1991); there is no time for energy issues (Sorrel *& al*., 2000) and energy or energy efficiency seem to be subjects of insignificant organisational importance. On the whole, many organisations consider energy as a secondary or peripheral subject (Sorrel, 2000; Weber, 2000; Kulakowski, 1999; Robinson, 1991; Cebon, 1992).

Two factors responsible for this situation are mentioned by several authors: the first factor is the frequently poor organisational energy culture, or "energy awareness", notable even in energy-intensive industries (Tunnessen, 2004), which is problematic in view of the fact that energy culture indeed does influence energy-efficiency decisions (Sorrel, 2000; Kulakowski, 1999; Togeby, 1997; Cebon, 1992; Stern & Aronson, 1984; Hennicke *et al.*, 1998). The second factor often cited as a barrier to energy-efficiency investments is the missing or loose link between energy-efficiency investments and a firm's core business (Sandberg et Söderström, 2003; De Groot & al., 2000; Harris et al., 2000; Sorrel, 2000; Weber, 1997, Weber, 2000).

Yet important questions related to these findings are not discussed in the energy-efficiency literature: how can such a vital resource be treated so casually? Why is energy a peripheral subject in many companies? Why is the relationship between investments and core business important enough to sometimes block profitable investments, or conversely, to boost non-profitable investments (two practices clearly in contradiction to the investments choice theory)? What is the role played by organisational culture(s)?

The primary goal of this paper is to answer these questions. With this in mind, I shall analyse the prevailing view of energy, which can be labelled a "commodity view" (Stern & Aronson, 1984) and its consequences when pertaining to energy-efficiency investment decision-making. In doing so, I will use several organisation studies’ concepts or findings, such as the resource dependence perspective or strategic decision-making in organisations. This will enable us to understand the link between energy and core business and its influence on energy-efficiency investment decisions. This analysis will form the first part of the paper. The second goal of this paper is to explore possible ways to switch from a commodity view to a strategic view of energy. This will form the second part of the paper. The conclusion will summarize the main findings useful in successfully promoting energy-efficiency in business firms.

The commodity view of energy

Many business firms have a commodity view of energy, as defined by Stern & Aronson in their 1984 typology:

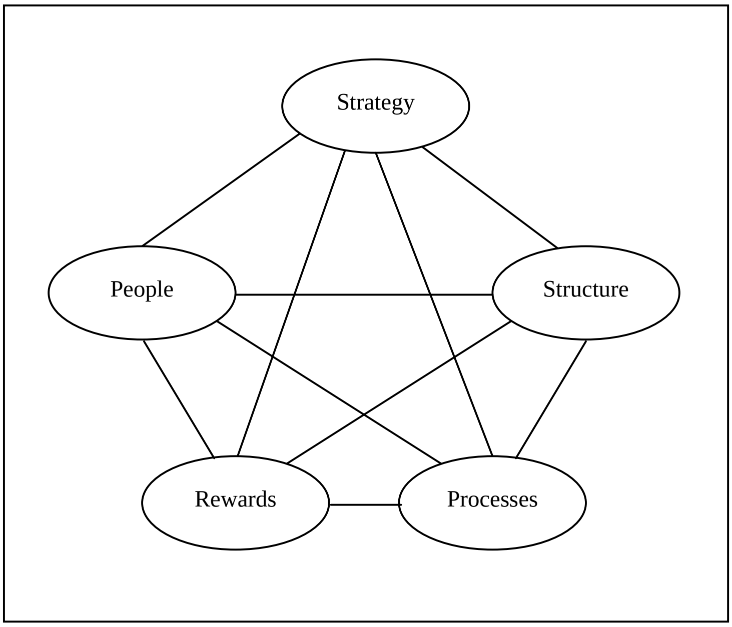
> *"…energy is often seen as a commodity or, more accurately, a collection of commodities. Energy means electricity, coal, oil, and natural gas … Commodity energy consists of energy forms or energy sources that can be developed and sold to consumers. The commodity view emphasizes the value of choice for present-day consumers and producers. It assumes that such choice will allocate energy (and other commodities) effectively and efficiently. … It focuses analysis on the transaction between buyer and seller and away from other aspects of energy use that are external to the transaction" (1984, p. 15).*

The commodity view of energy refers to the neo-classical economic concept of efficient markets driven by prices: energy is a commodity which rational buyers will try to buy at the lowest price. "Commodity view organisations" will focus on energy supply and procurement, disregarding energy management. Tunnessen (2004, p. 50) points to "a large knowledge gap between those organisations that effectively manage energy use and those that simply use energy", a gap which results in huge differences in energy performances.

"Commodity View Organisations"

An organisation is a system in which variables interact internally and externally with the environment. One fine representation of this system is the Star Model of Jay R. Galbraith (1995):

Figure 1 – Galbraith (1995), The Star Model



In Commodity View Organisations, energy is at a disadvantage in all respects:

Structure: This determines the *locus* of decision-making power. Having studied 150 decisions in 30 industrial and services British companies, the Bradford research team has shown that highest power is always within a "core triad of heavyweight functions" (Miller et al. 1997, p. 301), the functions of production (or its equivalent in services companies), sales & marketing and finance. Actually these functions are those more closely associated with core business. Therefore, the person responsible for energy (who is normally also responsible for building facilities or production) is not a powerful actor in the organisation, with the possible exception of production managers in industrial companies. Energy is part of the physical infrastructure (which is least valued by management according to Hammer, 2003 and Teece *et al*.1997); still it is generally invisible in physical terms (because hidden in pipes, furnaces, bulbs or computers). As there is no energy management, energy is also invisible in managerial terms. And we know that an invisible element is easily forgotten (Stern 1992). Sometimes energy is included in the environmental management system, a very restrictive and indirect way to grasp energy issues.

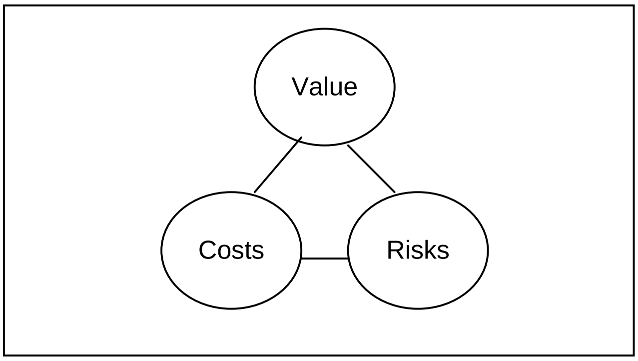
Processes: They determine the flow of information and the answers to technological innovation. Although a vital resource, energy is diluted within information considered more important by the organisation. In accounting terms, energy is a resource of indirect use ("just" enabling equipment and appliances to work); it is included in general expenses (as a cost) and not in the cost of goods sold (as a source of profit).

People: This term refers to staff mind-sets and skills. With the exception of production staff in industrial companies, people in dominant functions usually don't have engineering skills or energy awareness.

Reward system: This aims to influence people's motivation and behaviour to address an organisation's goal. In Commodity View Organisations, there are no rewards for energy savings achievements.

Strategy: "Strategy is the company's formula for winning" (Galbraith, idem, p. 12); "strategy is about winning" (Grant, 2004, p. 4). Beyond these vibrant definitions, most authors in the field agree on the following basic elements: strategy sets out the *basic direction of the organisation*, by specifying the organisation's *long-term activities and goals,* according to its *internal resources* and to *external factors, in order to build a durable competitive advantage* (Johnson & Scholes, 2000, p. 27). Thus, long-term activities - the core business activities - are the source of this vital competitive advantage, which allows firms to differentiate themselves from the competition, to create financial value and to survive. Competitive advantage is obtained by doing better and/or being less expensive than the competition. In other words, it is the relationship between the perceived value – meaning the value attached to a company's products by its clients (the higher the value, the higher the selling price) - and the production costs. We can add risk as the third dimension of the competitive advantage: for example, a firm should not choose a new, less expensive, supplier if the source is not reliable. The figure below illustrates the three dimensions of competitive advantage:

Figure 2 – The three dimensions of competitive advantage



As shown by my empirical research on the drivers of corporate energy-efficiency investments (Cooremans, 2006), Commodity View Organisations do not consider energy as a strategic resource, because they consider energy's contribution to their competitive advantage to be negligible. They don't see the potential risks or value associated with energy: they only consider its cost. But when cost is low, or when it is considered as necessary to core business activities, it doesn't carry much weight. This can be illustrated by one extreme example: in a Geneva five-star hotel, maids leave the room with lights switched on after cleaning, so that the room will be more warmly welcoming to its guests. Another example is the fact that more and more shops leave their doors open to encourage customers to come in, thereby heating or cooling the street. Switching off room lights or closing shop doors would save money, but would be perceived by Commodity View Organisations as a detriment to core business.

Stern & Aronson's energy views typology[1] (1984, pp. 15-20) is referring to energy as a "socially defined entity" (1984, p. 15). Therefore, when describing the strategic view, Stern & Aronson refer to the State level, the American security of energy supply. Pfeffer & Salancik (1984) have developed a similar concept at the firm's level, to explain organisational behaviour: the resource dependence theory. According to this theory, resource dependence exists not only if a resource is vital to organisation's functioning but also if there is a threat on its supply. When such a risk exists – or is perceived as existing - the resource is considered strategic. Thus Pfeffer & Salancik theory answers our first question: it is because there is no – perceived – risk on energy delivery that a resource so vital as to paralyse most firms in case of a black-out is considered so casually.

[1] The four views are: energy as a commodity, an ecological resource, a social necessity and a strategic material.

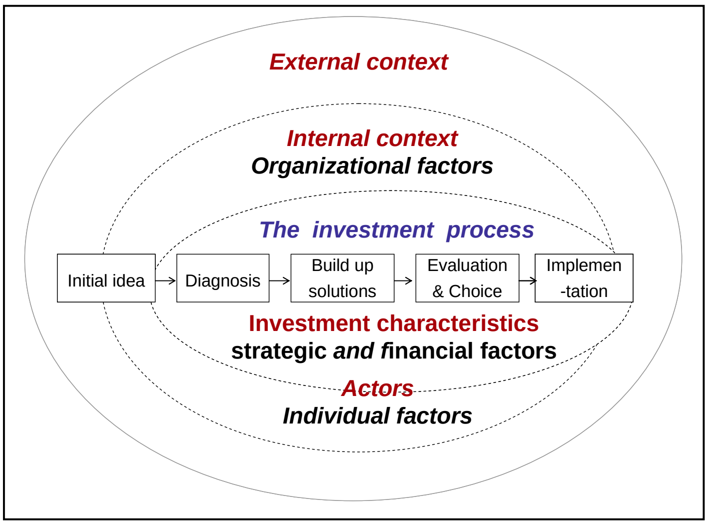
If cost and risk dimensions of energy are not considered as strategic factors by Commodity View Organisations, the situation is even worse for the third strategic dimension: Commodity View Organisations cannot see any contribution of energy to their products' value, because they only consider energy commodities and not energy services.

An issue - perceived as - not related to core business will be undervalued and disregarded. This answers our second question as to why energy is a peripheral subject in many companies. Strategic importance is the first decision driver, before profitability, as it was shown by organisational finance research (De Bodt & Bouquin 2001; Cooremans, 2007). As noted by the energy literature and contrary to mainstream investment choice theory, investments considered as not related to core business or, in other words, as non-strategic, will probably lose the competition against other investments, sometimes less profitable, and will not be decided upon. Decision-making research is proposing explanations as to why and how this happens.

Non-Strategic Decision-Making

Organisational decision-making research has a long and rich history of sixty years. It has shown that an investment decision must be analysed in a process, which is influenced by the actors involved, the organisational and external contexts and by the characteristics of the investment itself. I have constructed the figure below to illustrate decision-making process and the factors influencing it.

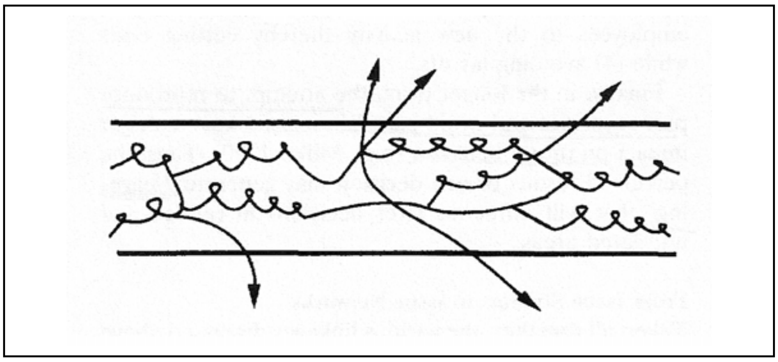
Figure 3 – Decision-Making Drivers



The decision process can be defined as a dynamic chain of actions and events. Contrary to what is shown, for clarity reasons, in the above diagram, a decision process is rarely smooth and linear: Mintzberg, Raisinghani & Theoret (1976) have found it to be "groping and cyclical" in the case of strategic decisions; the Bradford team studies have shown that decision processes can be "sporadic, fluid or constricted", depending on the complexity and the politicality of what is under decision (Cray & al., 1988).

A decision process starts with the "identification of a stimulus for action and ends with the specific commitment to action" (Mintzberg, Raisinghani et Theoret, 1976, p. 246). According to this view, the decision process is clearly identifiable - as well as the decision taking place at the end of it as a clear "commitment to act". Later on, Mintzberg questioned the usefulness of this analysis: commitment can be "vague and confusing", difficult to identify without a clear place and time in the organisation (Mintzberg & Waters, 1990). Therefore, decision-making must be understood and studied not as an episode unit (Pettigrew, 1990) or a discrete and concrete phenomenon (Langley et al., 1995) but as a continuous process inserted in the history and context of the organisation and of the external world. But even this process can be difficult to isolate, because decisions are intertwined with other decisions, or interact with one another. Because of these interactions, decisions processes must be considered as "issue streams", or even as "issue networks" of interconnected decisions, as illustrated in the figure below.

Figure 4. Langley, Mintzberg, Pitcher, Posada, Macary, Organizational Decision Making as Interwoven, Driven by Linkages, 1995, p.275.



Langley et al. (1995) propose a typology of linkages between decisions issue streams: decisions may be linked *sequentially*, in the case of different decisions concerning the same issue at different points in time; *precursively*, when a decision on one issue can critically affect the premises for subsequent decisions on a variety of other issues; and *laterally* across different issue streams. Among lateral linkages, pooled linkages exist when different issues compete for resources: financial resources, managerial time and energy and political support. According to Langley et al., decision-making is thus a function of the type of organisation in which it is embedded and of the linkages (or coupling) between decisions. Within this context**,** issues do or do not generate organisational decisions (idem, p. 276).

Applying Langley *et al.*'s typology to energy-efficiency investments issues, we better understand why they do not generate organisational decisions (remaining outstanding in some managers' desks as many audit reports do), or why they generate negative decisions: as non-strategic issues, these investments are championed by non powerful managers, and they cannot win the competition for financial resources, for the time and energy of powerful heavy-weight functions managers, or for political support and direction of upper management. This answers our third question by explaining the influence of the link between investments and core business on investment decision-making.

Energy-efficiency investments issues face another problem: although non-strategic, they are often "unstructured". Herbert Simon (1960) first drew the distinction between structured decisions – familiar, repetitive, programmed - and unstructured decisions – complex, new, unprogrammed. Unstructuration requires the design of a new solution instead of the use of a ready-made one. Therefore unstructuration means a high level of uncertainty and, in turn, a longer and more political and cycling decision-making process. Energy-efficiency investments may be unstructured when they involve important changes in buildings or production systems, or because energy savings are not clear-cut, or because energy prices are unstable.

Make it Strategic!

Strategic Benefits of Energy-Efficiency Investments: the Case of Commercial and Office Buildings

As stated in Johnson & Sholes's definition of strategy (see p. 4), competitive advantage results from a good fit between a firm's internal resources and external threats and opportunities. There are six broad types of resources: organisational, human, physical, technological, branding & reputation and financial resources. Energy-efficiency investments in office and commercial buildings positively impact on every strategic resource:

Organisational resource: Global thinking about its offices' energy consumption involves global thinking about the organisation's structure and how it can be improved: for instance, how people and departments are located in the buildings, and how internal and external communication is flowing. An integrated approach to energy entails questioning and rationalizing operations which offer a huge potential for improvements and profits within most companies (Hammer, 2004).

Human resource: Energy-efficient buildings typically consume 25-40% less energy than conventional buildings, but energy expenditure represents only about 1% of total building expenditures; on the contrary, employee expenditures represent about 80% of total building expenditures and even a small improvement in employees' performance has an important impact on a company's profitability.

Health benefits and productivity gains associated with better indoor comfort are demonstrated by a very large body of technically sound American and European studies. According to Greg Kats, principal author of the Report to California's Sustainable Building Task Force on the Costs and Benefits of Green Buildings, who made a major synthesis of these studies, productivity and health value is about seven to ten times higher than energy savings value: *"there is a growing recognition of the large health and productivity costs imposed by poor indoor environmental quality (IEQ) in commercial buildings – estimated variously at up to hundreds of billions of dollars per year. The costs of poor indoor environmental and air quality – including higher absenteeism and increased respiratory ailments, allergies and asthma – are hard to measure and have generally been "hidden" in sick days, lower productivity, unemployment insurance and medical costs" (Kats & al., 2003, p. 55-56.)*. More comfortable buildings not only generate higher employees' productivity and reduced absenteeism costs: they also result in higher sales in their more comfortable and better lighted sales area.

Physical resource: Energy-efficiency involves optimizing existing equipment and installations or investing in more efficient ones, often smaller. This reduces O&M costs and may extend equipment lifespan. Improving energy-efficiency also results in a diminution of the outage risk, due to increase because of the lack of European investments in generation and transmission and because of extreme climatic events (storms, floods, heat waves). The growing importance of data processing and telecommunications for any company results in considerable costs in the event of electricity outage (IEA, 2002, p. 49). Therefore, corporate requirements regarding security and reliability of energy supply are very high: the current standard is that of the "6 nine" of safety (99.9999%), which is equivalent to 30 seconds of power cut per annum. To prevent any power cut, companies heavily invest in expensive data processing back-up systems: a more energy-efficient IT system entails lower back-up costs. An energy-efficiency investment also results in an increase of a building's value (reduced annual operating and retrofitting costs will raise the Net Operating Income and therefore the Net Present Value).

Branding and Reputation: If properly communicated outside, efficient energy management may increase a company's value as perceived by customers and therefore help a company differentiate itself positively from its competitors This will enable such a company to keep or increase its customers' base and/or to sell more products, possibly at a higher price. An energy-efficient building will improve a company's image and will result in higher staff and customer loyalty, lower employee turnover, higher demand for company products, and higher trust by the financial markets.

Technological resource: Finding new ways to operate stimulates change and creativity in new products, new processes or new technologies; this in turn results in lower expenses and more efficient and profitable operations.

Financial resource: Any resource improvement will ultimately result in an improvement of the financial resource, thanks to the numerous direct and indirect financial benefits of energy-efficiency investments, more or less easy to evaluate and quantify.

Energy-Efficiency Contribution to Core Business

The most important point to remember is that, in order to promote energy-efficiency investments as strategic opportunities, it is necessary to find out and emphasise how they can improve core business activity. Here are a few examples of this reasoning, for commercial or industrial activities, which implies thinking in terms of energy *services*:

- Car parks must offer to their customers security (no physical aggressions) and air quality. Energy can contribute to this through excellent lighting and good ventilation. Therefore, energy specialists have to "sell" these services in their energy-efficiency projects, even before discussing energy consumption and costs reduction.
- A primary function of a bank nowadays is to store, manage and supply information in a highly secure way. Energy specialists have to select energy-efficient solutions capable of improving communication reliability and security.
- Pharmaceutical laboratories need a stable temperature to test new drugs, whatever the conditions outside the room or the building. Energy specialists have to find out how energy-efficient solutions can stabilize indoor temperature as well as reduce energy consumption.
- The watch industry needs stable hygrometry and a low level of dust. Energy specialists have to find out and demonstrate how energy-efficient solutions can achieve that.

In summary, the important point is helping business companies to better perform their activities. This approach should be adopted by energy specialists; unfortunately they generally share the same commodity view of energy as their client organisations: they only point to cost reduction entailed by technical equipment and systems improvements, without looking for and highlighting the benefits of energy-efficiency investments to core business. As proof, this introduction to an audit report made in Geneva stating that: "the primary goal of this study is to help you reduce your energy consumption"[2].

Actors, cognition, culture(s)

Commodity View Organisations, as any other organisations, are not monolithic entities: they are comprised of people with partially competing preferences. Strategic decision-making is political in the sense that powerful people get what they want and, therefore, organisational strategic choices reflect the preferences of powerful people. These central ideas of the political perspective on organisational decision-making are now solidly established by research findings, as shown by Eisenhardt & Zbaracki (1992) in their extensive review of the literature.

"Executives' experiences, values and personalities greatly influence their interpretations of the situation they face and, in turn, affect their choices" (Hambrick, 2007, p. 334). The cognitive perspective describes how decisions are influenced by the cognitive frames of decision-makers. The "soft" stream of cognitive perspective is personified by the famous concept of bounded

[2] "L’objectif de cette expertise est principalement de vous faire diminuer vos consommations d’énergie".

rationality: because of their limited cognitive capacities, decision makers filter information and use several heuristics which bias their decision-making. Or, to put it differently, the external world is distorted by decision makers' perceptions. However, says the "soft" cognitive perspective, with additional information and the help of adequate decision tools, true reality can be unveiled, limitations to decision maker capacities can be overcome and decision-making can be unbiased. A more radical cognitive perspective states that there is no objective reality: reality exists only in our minds. Henry Mintzberg (2005, p. 160) summarizes, with his usual sense of humour, the ultimate conclusion of the "constructivist" cognitive perspective: "I see it when I believe it". In other words, the external world is re-created in decision-makers' minds by their own interpretations, which are then revealed in their strategic choices. Several studies (Schwenk, 1988; Dutton & Jackson, 1987; Hambricks & Mason, 1984) have shown how decision makers' cognitive frames influence not only their decisions, but also their selection of strategic issues; issues are not intrinsically or objectively strategic: they are interpreted as such by decision makers.

This is an important finding with regard to investment decisions: decision-making research (see above, p. 6) has shown that organisational issues compete for resources. Therefore, non-strategic investments generate no decisions, or negative ones. But what the cognitive perspective on strategic decisions is telling us is that issues are perceived as non-strategic not for some "good objective" reasons (for example, the low cost of energy for a company) but for subjective reasons, which are related to decision makers' cognitive frames. The same can be said about investment parameters: risk is a subjective notion depending on decision maker perception and personality; assessment of future energy prices (or oil reserves) also depends on decision makers' cognitive frames[3]. Therefore, investments don't have an absolute profitability, which can be "discovered" using finance evaluation tools. This explains why neo-classical finance can only be a normative theory, as advocated by organisational finance (Charreaux, 2001), and why the debate on energy-efficiency investments profitability is a dead-end debate.

The concept of mental frames also explains why information alone is not enough to change behaviour: it has been proven that people retain only the information supporting the views, beliefs or hypotheses they have long cherished (Mintzberg, Ahlstrand, Lampel, 2005; Giordan, 1998). This means that information alone on strategic aspects of energy use, or on energy-efficiency investment benefits will not enable the switch from "Commodity View" to "Strategic View Decision Makers". Change management techniques must be used as well.

Improving knowledge of decision makers' cognitive frames regarding energy will help understand how they perceive energy issues and, accordingly, make decisions on energy-efficiency investments. This is difficult to achieve at the individual level. But the process of reality creation described by the cognitive perspective has also a collective dimension, because it is "by interacting with others that individuals create their mental world"[4] (Mintzberg, idem, p. 174). Culture is part of this collective dimension. It consists of "a pattern of shared basic assumptions", taken-for-granted perceptions, thoughts, and feelings, which are unconscious and therefore non-confrontable (Schein, 2004). Culture is not monolithic; six interrelated spheres of culture have been identified as influencing individuals and organisational choices behaviour: the national, regional, company, industry, professional and functional spheres of culture (Schneider & Barsoux 1999, p. 47).

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[3] As illustrated by the following quote: "*The Reference Scenario assumes an average IEA real crude-oil import price between 2000 and 2010 of $16,50 per barrel in 1990 dollars, equivalent to $21 per barrel in today's money. This price equals the average from 1987 to 1999. Between 2010 and 2020, the price increases steadily to $22,50 per barrel in 1990 dollars or $28 per barrel in today's money*" (IEA, 2000, p. 39).

[4] "…ce processus [de construction] a une dimension collective: c'est dans l'interaction que les individus créent leur univers mental".

Building on Hambrick and Mason's upper echelons theory stating that "the demographic characteristics of executives can be used as valid, albeit incomplete and imprecise proxies of executives cognitive frames" (Hambrick, 2007), we can hypothesize that organisational cultures can be acceptable proxies to evaluate executives' cognitive frames regarding energy. Among those, professional and functional cultures are probably highly influential regarding energy issues perceptions: it is likely that people assuming technical functions in an organisation (i.e. technical support department, facility management, production) and/or people with a "technical" education (like engineers) will be more energy-aware than, say, finance or commercial people; their professional culture induces them to have technical systems working efficiently. Corporate culture is also important in two respects: it determines which professional culture is most powerful inside a company; it determines the importance assigned to energy issues. These insights partially answer our fourth question regarding what is the role played by culture on investment decisions. However, more research is needed on the cultural dimension of energy-efficiency investment decision-making.

Conclusion

In analysing the prevailing commodity view of energy and the possible ways to switch to a strategic view of energy, organisational studies' concepts and decision-making research findings have proven useful in answering the four questions stated in the introduction to this paper: energy is often treated in a casual way because there is no perceived risk on its security of supply; energy is a peripheral subject in many companies because an issue perceived as not related to core business - or in other words as non-strategic - is disregarded; non-strategic investment projects do not generate positive decisions because they lose the competition for financial resources and for the time and energy of powerful managers, competition which does exist in organisations between issue streams; issues are not intrinsically strategic but are perceived as such by decision-makers, and several spheres of culture influence decision-makers' cognitive frames and, in turn, energy-efficiency investment decision-making.

These findings explain why profitability is not the most important decision factor, and point to the need for broadening the conventional mainstream approach to investment decisions. To successfully sell energy-efficiency investments, it is necessary to take into account all three paramount decision drivers discussed in this paper: strategy (non-strategic issues lose the competition); power (key managers impose their choices) and culture (powerful managers' choices are influenced by several spheres of culture). To address these complex issues when communicating with business firms, multidisciplinary teams combining strategic, financial, change management, technical and marketing & communication skills are needed.

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Green Leases: an Opportunity to Develop a Sustainable Approach for Tenanted Commercial Buildings in the UK

Angela Langley, Lara Hopkinson, Vicki Stevenson
Centre for Research in the Built Environment - Welsh School of Architecture

Abstract

Approximately 98% of the building stock in Europe comprises existing buildings. Landlords of commercial existing buildings are facing increased legislation, notably the Energy Performance of Buildings Directive. This is driving them to reduce their energy consumption whilst striving to remain in a competitive market. In its widest sense energy also applies to other resources. Office tenants and landlords are finding their energy performance is increasingly being scrutinised by customers. Both parties see benefits in reducing their energy consumption. However, the relative benefits of improved practice for tenants and landlords do not always match the responsibilities apportioned in the current commercial lease agreement.

An investigation incorporating thirty five commercial tenants operating from five buildings in two South Wales cities identified that the commercial lease was a major systemic barrier to energy efficiency in commercial buildings. This may be due to behavioural practice within a building, lack of defined obligations and responsibilities, ineffective communication and payment structures that inhibit tenants from carrying out actions to reduce their impact. Landlords also have difficulty in justifying investments in equipment or operational changes that would lead to environmental improvements.

The potential of altering the commercial lease agreement to become a tool to aid environmental improvements (rather than a barrier) was investigated. To this end clauses which could be incorporated in the commercial lease agreement were developed. These clauses provide non-technical solutions to tackle the identified barrier and lead all parties to reduce energy consumption. As a result of this investigation, the thirty five participating tenants implemented thirty three energy minimisation initiatives, plus twenty eight relating to general waste and three relating to water. This indicates the progress which can be achieved when the barriers are addressed.

Introduction

A total of 77% of the existing commercial building stock was constructed before Building Regulations covered energy conservation [1]. Given that buildings constructed in 2006 are typically 40% more energy efficient than those built in 2002 [2], it can be assumed that the majority of the building stock performs significantly under current energy efficiency standards. At the end of 2003 the existing commercial offices were valued at approximately £159bn [3]; this is a significant investment, from which the owners wish to maximise their return. Since existing building stock represents 98-99% of buildings in the UK at any one time [2], it must be accepted that these buildings will remain as energy consumers for some time to come.

The realisation that 18% of UK's carbon emissions are from non-domestic buildings [4] is leading to increased legislation aimed to reduce carbon emissions from this sector.

The European Energy Performance of Buildings Directive (EPBD) [5] has been implemented in the UK through the revised Building Regulations [6] and the Energy Performance of Buildings (Certificates and Inspections) (England and Wales) Regulations 2007 [7]. The Building Regulations require any refurbishment of large buildings to also incorporate energy efficiency improvements. However, commercial buildings can go decades before major refurbishment is considered by their owners. Building certificates [7] highlight the energy efficiency of the building to prospective tenants and buyers, thereby encouraging owners to improve their building's performance.

The property sector can expect further legislation to help drive improvements. The Carbon Reduction Commitment [8] has already undergone consultation, and is expected to come into effect this year. This will apply mandatory emissions trading to large commercial and public sector organisations. Further developments of the EPBD have also been proposed – these include extending the requirement for improved energy efficiency to all buildings being refurbished [9, 10]. Similarly, the requirement for display energy certificates could be extended to all public and private sector buildings [4]. In addition, further amendments to the building regulations are expected.

Non legislative drivers are also affecting landlords and tenants in the commercial sector. The values of customers and clients are driving companies to prove their corporate social responsibility [11] and improve their environmental performance. This is generally manifested in adoption of environmental policies and management systems, but in the future could also result in companies refusing to take up contracts in buildings with poor energy performance ratings. Already the demand from tenants for more energy-efficient buildings has been described as 'palpable' [1].

It is also possible to identify a change in investor attitudes. Investors have to look to the future, and some are identifying green buildings as a better bet for the future [12]. This is compounded by fears of 'price chipping' [13, 14] which could be associated with poor energy performance. Add to this concerns over increasing energy costs [14], and it is evident why companies like British Land PLC have already pledged to be carbon neutral by 2008/9 [15].

There has been a general trend in the reduction of lease lengths since 1998, with shorter leases of 5 years or less being favoured more than the longer leases of 15 years or more [16-19]. Differing sectors of the market have differing lease lengths, with new and higher value properties attracting longer length leases than second hand and lower value properties [19]. In the UK, the leasing process is governed by a voluntary Code of Practice, which sets out a series of recommendations to help better inform tenants. The process also benefits from a Code for Leasing Business Premises in England and Wales. Both Codes of Practice makes reference to open channels of communication between landlords and tenants at all stages of the leasing process [20, 21].

Within the leasing process, the use of a service charge is popular in recovering costs for common services, especially in multi-let buildings. Within the Service Charge Code, it states that services are to be procured "on a value for money basis", ensuring that "written quotations are obtained for the supply of services" [22]. On occasions, these services will be administered by a facilities manager, who could be external to the building for which they are procured. Typical examples of services considered within the service charge are electricity supply, waste management and maintenance costs [23].

Whilst the Service Charge Code does make reference to transparency in service charge costs, it makes no reference to consideration of aspects of sustainability. Given the changes in legislation, such issues will need to be considered when procuring services such as energy and waste management. Previous research has indicated that changes in practice by those who manage and operate buildings will be facilitated by changes in policies [24]. However, there is criticism relating to why consumers do not take advantage of the energy efficient opportunities available to them. There are a number of market barriers to the uptake of energy efficient opportunities, including technical (options may not yet be available), economic (insufficient capital investment for such opportunities) and institutional (no well-defined structure to decide upon and carry out investments) [25]. The landlord – tenant barrier relates to the fact that the organisation carrying out the improvements (e.g. the owner or manager of the building), may not be the organisation(s) who gain the benefit from the outcomes of the improvements (e.g. the tenant(s) of the building) [25].

Initial studies [26] explored opportunities to improve environmental performance in 40 commercial based small to medium sized enterprises (SMEs) in South Wales. For the purpose of participant selection, the European definition was used whereby the organisation employs 250 or less people, has a turnover of less than €40 million and is less than 25% owned by one or more companies not falling within this definition.

The study identified that over 60% of the SMEs were renting office space in multi-tenanted buildings. Furthermore, whilst many cost-effective opportunities for improving environmental performance had been identified, the implementation of these were somewhat hampered by uncertainties in responsibilities between landlord and tenant together with lack of financial incentives for either party.

Studies undertaken by Jayne [27, 28] suggested that landlords are exposed to a considerable amount of environmental risk and the associated liabilities . Scope exists to reduce this through improved letting practices. Changes are needed in the way leases are negotiated to respond to the introduction of environmental legislation but lawyers generally do not consider environmental issues during transactions relating to sales, acquisitions or leases in the UK [29].

When a building is occupied, maintaining the environmental performance is very much dependant on the efficiency of operation and implementation of best practice. In a tenanted building, particularly a multi-tenanted building, responsibilities for maintaining performance becomes distributed between landlord, tenants, facilities management and property agents. This paper explores further:

- the opportunities to implement environmental best practice with landlords and tenants,
- the barriers to implementation
- and the methods to overcome the barriers identified.

The Study

The investigation led by the Centre for Research in the Built Environment [30] commenced with the development of a working partnership with representatives from King Sturge, the Royal Institute of Chartered Surveyors Foundation (RICS Foundation), the Environment Agency Wales and Envirowise.

Development of Cluster Groups
To encompass a broad range of tenant and building scenarios common within the UK, 5 buildings were identified within south Wales for inclusion in the study. These became the cluster groups for the investigation (refer to Table 1).

The buildings varied in terms of age, number of tenants and type of office according to BRE benchmark guides [31]. Office types can be summarised into 4 categories as follows:

Type 1: A naturally ventilated building with cellular offices. A simple building often relatively small between $100m^2$ to $3000m^2$ and is often formed from a converted residential property. The building typically has limited common facilities comprising one or two small domestic areas and toilet facilities.

Type 2: A naturally ventilated building ranging in size between $500m^2$ to $4000m^2$ 'with some open plan offices and some cellular offices. This building is typically formed from converted industrial buildings. There are often more common areas equipped with a variety of shared facilities including office type equipment.

Type 3: Typically an air-conditioned standard office ranging between $2000m^2$ and $8000m^2$. This type of building is largely purpose built with the internal design being similar to Type 2 buildings but often with a deeper floor plan with tinted windows.

Type 4: An air-conditioned prestigious office ranging from $4000m^2$ to $20,000m^2$. This tends to be purpose built for national or regional head office businesses. The building is constructed to high specifications often with their own catering departments, extensive storage areas, car parks and air-conditioned rooms for IT equipment.

The 35 tenant organisations participating in the study were based within one of the 5 commercial categories listed below and ranged in size, (according to the EU definition of an SME) from a micro SME (fewer than 10 employees) through to a medium- sized SME (fewer than 250 employees).

- 10% tenants from financial services (medium sized SMEs)
- 10% tenants from property sector services (medium sized SMEs)
- 10% tenants from legal services (medium sized SMEs)
- 37% tenants from community and training services (ranging from small to medium sized SMEs)
- 33% tenants from scientific services sector (ranging from micro SME to small SMEs)

Table 1 – The Five Cluster Groups Developed For The Study

	Building A	Building B	Building C	Building D	Building E
Landlord Company	Associated British Ports / Norwich Union	Danmerc Property Management (agent)	Welsh Development Agency		Aberdeen Asset Management
Property manager	Caxton Facilities Management				King Sturge
Age of Building	6 years	6 years	12 years	8 and 2 years (2 phases)	33 years
Number of Tenant Companies	3	1	5	8	18
Type of Building [31]	4	3	2	1	3

Building D was located on a scientific industrial park and as such, 7 of the tenants in this building were based within the scientific services sector. The offices rented by these tenants were also equipped with small laboratory facilities. All other tenants participating were office-based undertaking administrative duties only.

During Phase 1, preliminary meetings were held with the landlord (or property agent) and the facilities manager for each cluster group to obtain organisational details, general concerns regarding the building, leasing arrangements and refurbishment work undertaken or planned. The meetings were also used to agree an approach for recruiting tenant organisations to the project. This involved providing free environmental reviews for each tenant, with the additional purpose of identifying opportunities for environmental improvement.

Identification of Opportunities – Environmental Audits and Lease Reviews

During Phase 2, each of the participating tenant organisations was provided with an environmental review of their rented area. The review served to identify concerns, priorities and responsibilities relating to energy, water and waste within the building. Opportunities to reduce resource consumption and cost were discussed with the tenant during a meeting following the review. For Buildings A, C, D and E, the environmental review also extended into common areas within the building.

Due to the complex nature of the issues identified during the reviews and to extend the support available to the cluster groups, the partnership welcomed a representative from a law firm, Eversheds, during Phase 2. Exemplar leases for each of the buildings were reviewed with support from Eversheds. This review established the extent to which environmental issues and efficiency of operation were incorporated in the lease. From this a generic summary of opportunities relating to the lease contract for landlords was developed to cover a range of scenarios and findings encompassed in the project.

A written summary report was provided to the landlord organisation following the reviews. The report documented the findings and observations from both the environmental and lease reviews. It also provided a series of recommendations for improving environmental performance within the building divided into those which tenants could implement themselves and those that required the landlord to implement and manage.

Cluster Group Meetings and Training

During Phase 2, a series of cluster group meetings were organised for tenants within each of the buildings. The first was attended by the landlord organisation or property agent to demonstrate further support to the programme. Subsequent meetings focused on the provision of training to the tenants and the facility manager. The training sessions focused on some of the key issues identified during the environmental reviews. Responsibilities relating to energy efficiency and waste management were the key concerns of the tenants so training focused around methods that could be employed by each organisation to improve their own management within their rented area.

Questionnaires & Consultation
For the purpose of data collation, a questionnaire was developed in Phase 3. This was circulated to the 35 tenant organisations during cluster group meetings. Respondents were asked to state their reasons for participation in the project, their leasing arrangements and provide feedback on their implementation programmes together with any progress made. They were also required to rank their opinions on environmental management and the issues raised within the environmental and lease reviews. A small number of questionnaires were not completed due to tenant relocation during the study period.

Results

Tenant Reasons For Participating In The Study
Feedback from tenants during the reviews and questionnaires indicated that 25% ranked improving their own energy management as a high priority, while 19% were deterred from improvements since costs were largely under landlord control and therefore considered it as medium priority. A further 13% identified that the study offered opportunities to improve their overall environmental performance, with similar figures for development of waste management programmes and environmental policies / accreditation schemes (although this was considered a lower priority). Interestingly, 6% of the tenants viewed the study as an opportunity to improve their communication with the landlord, and considered this a high priority. A further 6% identified that it would encourage increased communication with other tenants within the same building, and rated this as a medium priority. These results are summarised in Figure 1.

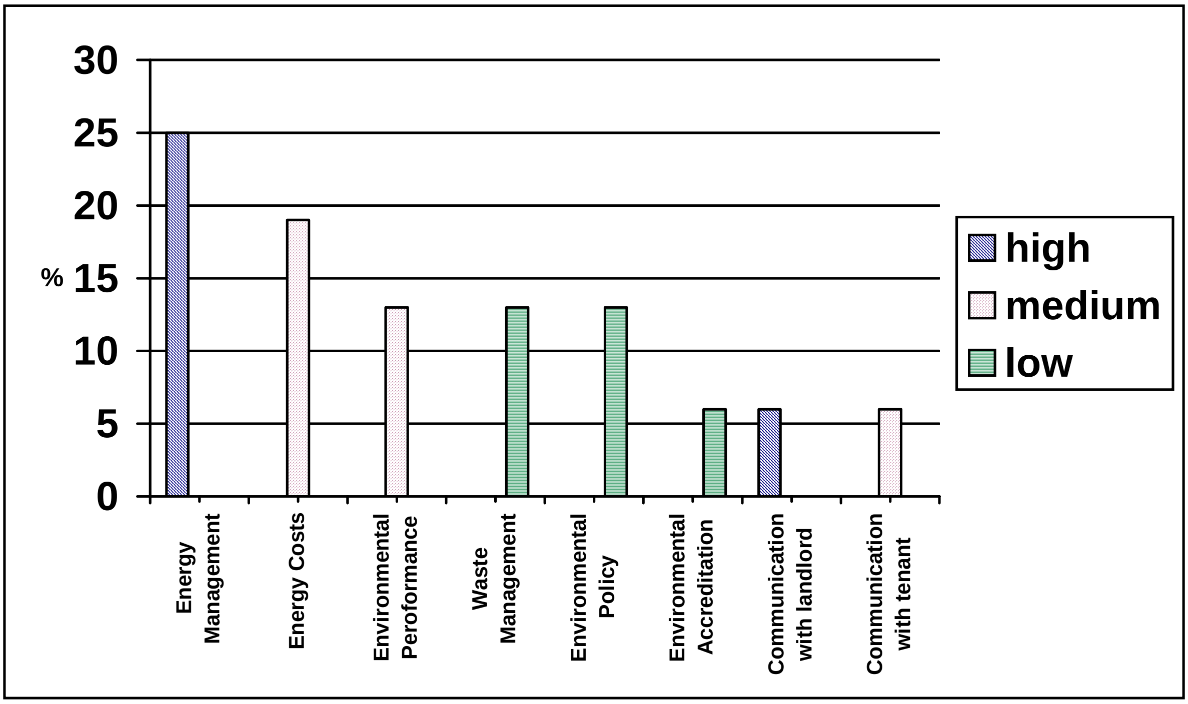

Figure 1 – Tenant Reasons for Participating In The Study

When questioned about energy, 70% of the tenants identified energy consumption as the most costly resource against waste management and water consumption . Despite this, 52% of respondents considered their energy consumption to be poor, due to a lack of formal monitoring. Interestingly, 33% considered their energy consumption to be good, but considered provision of more accurate information from the landlord to be of high priority. Only 15% had no opinion on consumption as it was considered beyond their control.

The Cluster Group Approach

Whilst most tenants at the start of the study considered they had good relationships with their landlord, the establishment of cluster groups proved to be an effective method for improving communication not only with the landlord. More importantly, the cluster groups improved communication with other tenants in the same building. Often best practice is not noticed by other tenants of the same building, thus initiatives implemented by individual tenants in a multi-tenanted building are perceived as having minimal impact.

As a result of the development of cluster groups during the survey, Buildings C, D and E initiated regular discussion groups for the tenants that continued after the study period. The property agent of Building E also established a web-site to inform existing and future tenants on building related issues, including the availability of metered information for tenants within the building.

Implementation of Opportunities Identified

In total, the 35 participating tenants implemented 33 energy minimisation initiatives, plus 28 relating to general waste and 3 relating to water. Initially only 6% had viewed their participation in the project as an opportunity to improve communication between the landlord and other tenants. However, by the end of the study, 46% had improved communication with the landlord and other tenants. This was demonstrated through the establishment of energy reduction targets, initiation of formal energy monitoring programmes and discussions of shared opportunities with other tenants through meetings. A further 18% had commenced weekly monitoring programmes and had discussed opportunities to improve efficiency within their area and the building.

During the course of the study, tenants noted an increased awareness of environmental issues and impacts of their activities. All 5 buildings had commenced awareness campaigns including the development and use of posters and bulletins. Within Buildings A, B and E, the tenants had collectively commenced switch off campaigns ensuring that a total of 1,510 computers and monitors, 100 printers, 30 photocopiers, 16 vending machines and 1 microwave were switched off every night. Collectively, this provided an estimated power save of 187.3kW for every hour the equipment was switched off.

In Buildings A, B, C and D monitoring of overnight energy consumption was undertaken. Furthermore, suppliers were contacted and half hourly readings were made available for tenants to view and record. Buildings C, D and E established collective waste monitoring schemes between the tenants and as a result commenced recycling schemes of common wastes (e.g. paper).

The tenant in Building B had installed a Building Management System to improve energy efficiency and considered it a high priority to identify further opportunities to improve their environmental performance. Through initiation of staff training programmes, implementation of good practice, switch off campaigns and monitoring programmes within the first 6 months, the tenant recorded a reduction in their energy consumption by 20.47kWh/m^2 .(4.2%) within their first year. Having raised staff awareness the company were actively developing further initiatives aimed at reducing consumption within the second year. They also set a target for reducing consumption by 10% within a 2 year period. Under a full maintenance and repair lease, prioritisation for implementing opportunities remained in the control of the tenant with only consent required from the landlord. Improving communication with the landlord was therefore considered low priority. Increased staff awareness through staff training programmes helped to ensure the implementation programme remained on schedule.

Key Issues Identified Through Lease Reviews

Evidence gathered during the study indicated that tenants within multi-tenanted buildings had not generally investigated opportunities to improve their environmental performance or resource consumption through opportunities within lease contracts. Feedback suggests that this is largely due to the fact that energy supply, base load consumption and control are beyond the control of their rented areas.

Of the 5 exemplar leases reviewed, reference to environmental issues and management of the building were minimal and only served to deflect liabilities from landlords rather than provide information or systems to help tenants. Existing commercial lease contracts do not reflect the use of energy efficient technologies or management within the building. Furthermore, there is no requirement for tenants to employ the use of energy efficient management or technology within their own rented areas. Feedback from tenants revealed that 24% would like lease contracts to include information regarding energy efficient facilities within the building. A further 24% could see the benefit for including information from the landlord regarding energy efficient initiatives, and other environmental initiatives, planned or implemented within the building.

Interestingly, 17% indicated that results of regular environmental and energy audits should be made available within the lease contract for viewing at lease negotiation stages but only 8% thought that their own rented area should be included. The reason for this was that benefits to the tenant would be minimal unless financial support was available either through shared capital outlay with the landlord or reflected in reductions in the service charge within the leases.

Procedures for undertaking refurbishments within rented areas are generally covered within lease contracts and require consent from landlords. However, the study identified that one of the most common problems associated with refurbishment of rented areas related to energy efficiency. Installation of partitioning walls in open plan office areas demonstrated detrimental effects in relation to heating facilities, air conditioning systems and lighting configurations. Control of efficiency therefore migrates to the tenant rather than the landlord. The study identified that 2 of the landlord companies could see the benefit for the inclusion of covenants within future lease contracts preventing alterations which adversely affect the environmental performance, of the rented area and of the entire building. To this regard, sufficient information would need to be supplied under tenant covenants for the landlord to make an informed judgement, preferably with the support of a qualified consultant.

Feedback also indicated that financial credentials of prospective tenant companies were investigated but that environmental credentials were disregarded. It could be argued that tenants who have already adopted an accredited Environmental Management System present less liability and risk to the landlord. This could be extended to encouraging landlords to develop environmental policies for the building. Prospective tenants, and indeed sub-assignees, could be made aware of the policy and through the lease agreement, be required to adhere to the policy.

Through discussions with the landlord companies, the study identified that longer leases in excess of 15 years with no break clauses were costly to amend and as such presented a major systemic barrier to environmental improvement and energy efficiency. However, through introduction of tenant handbooks and information packs that encourage adoption of best practice, the barrier could be somewhat overcome. Government measures in the UK to reduce lease lengths substantially increase opportunities to incorporate best practice into lease agreements. However, discussions further revealed that little guidance was available for landlords and tenants at lease negotiation stages to adopt good practice. A flexible, voluntary approach would be required that provides guidance at lease negotiation stages for landlord and tenants to discuss.

Discussion

The study identified a number of key issues preventing the improvement of energy and environmental performance of tenants in multi-let buildings. This included issues such as how costs of improvements were controlled (generally, these were under the control of the landlord, and therefore not seen as applicable to the tenant), lack of formal monitoring or provision of monitoring data, lack of communication with the landlord as well as other tenants within the building, and the lack of inclusion of such information within the lease contract (other than to provide protection of landlord liabilities).

To ensure that responsibilities, liabilities, capital outlay and benefits are divided proportionally, change is required within leasing structures. Opportunities to introduce change have been identified during the study, but landlords have indicated that the approach be flexible to encourage open dialogue and must allow for voluntary adoption. Furthermore guidance was required for implementing such change. To this end, a key output from the working partnership of the study was the development of a series of model lease clauses and recommendations [32, 33] that address the key issues identified.

Development of model lease clauses and recommendations
To encourage adoption of model lease clauses by both landlord and tenant at lease negotiation stages, benefits need to be clearly highlighted and stated in guidance documents. If the lease incorporates clauses that assist with compliance of new legislation [5, 6, 7], clear benefits are achievable for the landlord. The model lease clauses developed from the study refer to the specific articles within relevant legislation for landlords to consider. As more stringent legislation is introduced, tenants are becoming increasingly aware of their environmental credentials and environmental management programmes. As such, the model lease clauses acknowledge environmental credentials of a tenant and not just financial credentials.

The study has identified that communication and flow of information needs to be three way. Landlords and tenants need to exchange information on a regular basis but tenant to tenant communication in a multi-let building is also important. A variety of model lease clauses have been designed to ensure communication is maintained and that information is readily available. These clauses include a requirement for landlords to establish an information pack or tenant handbook. Such information could include availability of metered information, planned improvement programmes, maintenance schedules and performance rating of the building. To encourage both tenant and landlord to maintain good practice, clauses require the adherence to an environmental policy for the building, which includes any sub-assignees contracted into offices areas within the building. Regular audits are recommended with reports and information being available to both new and existing tenants.

The introduction of resource reduction targets (particularly for energy) provides a common goal for both landlord and tenant. Model lease clauses have been designed to encourage setting of targets through consultations with external qualified environmental consultants, who can establish capital expenditure and pay-back periods. Regular support from an environmental consultant would also help to identify new opportunities and help maintain compliance with new legislation.

The study has revealed that financial incentives are needed to encourage adoption of good practice, particularly where installation of efficient technologies require capital outlay. Model lease and recommendations have been made to ensure that good practice by a tenant is acknowledged through the service charge.

Often tenants implement changes within the building, such as installation or removal of partitioning walls or domestic facilities. Feedback indicates that currently, neither landlord nor tenant give due regard to the environmental implications of planned changes or consult with a qualified environmental expert. Recommendations and model lease clauses have been presented to abate this problem.

The partnership has developed a series of feasible draft model lease clauses based on findings of the study which has encompassed a range of tenant scenarios common to the UK. However, since the guidance document provides a voluntary and flexible approach for landlords, model lease clauses can be selected or rejected as appropriate at lease negotiation stages. As such, the model lease clauses can be adopted and applied to tenants and landlords of both new and existing buildings.

Conclusions

The research findings and evidence suggest that challenges in the UK commercial stock exist in multi-tenanted buildings, where responsibilities to improve efficiency become shared between a number of tenants, the landlord and the facility manager / property agent. This work has highlighted that energy efficiency can be achieved when tenants and building managers work together. It also highlighted that the major systemic barrier to achieving such environmental and energy efficiency improvements was the commercial lease agreement and its lack of clauses relating to efficiency issues.

The Good Practice Guide [32, 33] provides opportunities to adopt sustainable best practice through the lease agreement. It also presents a voluntary method which empathises with differing building stock conditions and improvement programmes. Landlords and tenants are able to discuss and adopt as many or as few of the model leases clauses as are appropriate. Current investigations being conducted by CRIBE are trialling the uptake and efficacy of the Good Practice Guide.

The model lease clauses developed as a result of this study can be adopted by commercial landlords and tenants for single-let occupancy or multi let buildings thus providing a sustainable and yet common approach for the UK. This methodology could also be applied to other countries worldwide.

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Is the Client Willing to Pay to Occupy a Greener Building?

Sandra Gómez, CB Richard Ellis Ltd

Abstract

There is no question that the intention to be green, or being seen to be greener than a competitor is becoming more prevalent amongst some investors and developers, but how to measure the 'greenness' of a building and how to assess the valued added, if any, are still the object of speculation and uncertainty. Once the developer has committed to a greener building the practical questions is, will the occupier pay for any extra costs?

The paper covers briefly two of the most widely methodologies to measure environmental sustainability, BREEAM - Building Research Establishment Environmental Assessment Method, and LEED - Leadership in Energy and Environmental Design, and summarises the scarce evidence available on the costs of greener buildings.

These methodologies are discussed because they are increasingly being adopted by corporate clients with a global portfolio.

To try to evaluate green development costs, the paper also presents research carried out by CB Richard Ellis. We have compared the standard costs of construction in England for a 12-storey, 50 unit development totalling around 80,000 sq ft with a theoretical zero-carbon development of the same size. Research shows that consumers are willing to pay some portion of the cost increase for green developments but not all.

The research carried out by CB Richard Ellis illustrates that a combination of legislation and consumer philanthropy is currently insufficient to meet the goal of zero- or near zero-carbon developments.

The convergence of public sentiment, legislative pressure and technological advances is driving the Green Agenda forward. Individual consumers are making real contributions through goodwill and premiums paid in green tariffs and investing in green features expecting returns in energy costs savings. However, there is no evidence that this behaviour has been transferred to decisions in the commercial world and at least in the United Kingdom (UK), we still have not reached the point where climate change goals can be achieved by market forces alone.

How "Green" are our Buildings?

Various techniques and methodologies exist to assess how 'green' a building is. Some only consider certain individual aspects like energy (such as Energy Star), materials used or waste generated during construction or operation, whilst others try to take a broader view through a set of design and operational criteria.

In the latter category, the two more commonly used at the design stage are BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design). Both have sprung 'families' of tools for assessing environmental impact, each with variations on a similar theme. The variations are either specific to different building types or to different stages in the construction and occupation of a building. For instance, there are BREEAM schemes for office buildings, schools, leisure buildings, etc. and LEED variations for commercial interiors, existing buildings, schools and retail buildings.

Within this paper, we will be giving a brief overview of the key differences between the two assessment methods:

BREEAM - Building Research Establishment Environmental Assessment Method

BREEAM is the world's longest established and most widely used environmental assessment method for buildings. It sets the standards for best practice in sustainable development and provides a recognised level of achievement.

BREEAM is an assessment tool developed in the UK that rates the performance of buildings based on their environmental impact or measures taken to avoid such impacts. A building is rated on management, energy use, health and well-being, pollution (air and water), transport, land use, ecology, water consumption and efficiency, and materials. Buildings are certified as pass, good, very good, or excellent.

In the UK 65,000 buildings have been certified to date and a further 270,000 are currently registered for assessment[1].

LEED - Leadership in Energy and Environmental Design

The LEED green building rating system was originally developed by the US Green Building Council (USGBC). Largely based on BREEAM, it provides a recognised standard for the construction industry to assess the environmental sustainability of building designs. LEED promotes integrated whole-building design, with the overall aim of reducing a building's environmental impact. LEED provides a framework for assessing building performance and meeting sustainability goals and like BREEAM, it produces a point-based rating system.

The USGBC has attracted over 6,500 paying members bringing in over $24 million a year. Despite this, since it was formed in 1995, just over 1,000 buildings have obtained LEED accreditation with about 9,000 projects registered for assessment.

Comparison

There is a great deal of similarity between both systems. The following table summarises the criteria and scoring for each one.

Table 1. BREEAM vs. LEED

System	Criteria	Scoring
BREEAM	1. Management (policy, commissioning site management, procedures). 2. Energy (operational use, CO2). 3. Health and well-being (indoor and external issues). 4. Pollution (air, water). 5. Transport (CO2, location factors). 6. Land use (green fields, brown fields). 7. Ecological value of site. 8. Materials (including life-cycle impacts). 9. Water (consumption and efficiency).	Credits awarded for each criterion. Weightings applied to produce overall score. Score translated into rating and a certificate awarded: 25-39 Pass 40-54 Good 55-69 Very good 70 or more Excellent Updated regularly[2].

[1] This figure includes data for EcoHomes, the BREEAM scheme applicable to residential developments

[2] In England and Wales, Building Regulations dictate the baseline and changes and updates in the regulations trigger an update in the BREEAM criteria

LEED	1. Site 2. Energy 3. Water 4. Materials 5. Indoor environmental quality	Credits specified for each criterion (7-12 in each area). 29 out of 69 is the minimum required to obtain a certificate. User selects criteria for scoring. Prerequisites must be met. Rating based on total number of points scored. The building is given a special designation if more than 50% of the credits are achieved: 50-60% Bronze 61-70% Silver 71-80% Gold 81% or more Platinum Updated every three years.

To be meaningful, the rating should take into account the local conditions. A pass score in BREEAM assumes compliance with Building Regulations and seeks to award extra credits only for features above those already required. When the methodology has been used outside the UK is has been adapted to the requirements of each country.

The last point is particularly important because the baseline between countries is different as building regulations (or building codes) are more demanding in some countries than others. One cannot assume that a building certified as LEED Silver in one location is 'equally green' to another LEED Silver building in a different country.

Both schemes have been used outside the UK and the USA either formally to certify specific buildings or informally as a proxy for qualifying the greenness of a project. They were chosen to be discussed in this paper not because they are universally accepted as truly measuring the greenness of a building but because they are increasingly being adopted by corporate clients with a global portfolio.
BREEAM has been used to certify buildings in the UK, Ireland, Hong Kong and Canada.
LEED has been used to certify buildings in USA, Canada, India, China, Brazil, UAE, Mexico, Argentina, Italy and Spain.

LEED differs from BREEAM in that the latter also takes into account the operational use of the building. LEED is more complex than BREEAM in some respects. For example, it requires building materials to be recyclable, while BREEAM will award credits for using recycled materials but does not make it compulsory. In addition, BREEAM tackles carbon emissions, while LEED focuses more on the building design (although with companies and cities like New York adopting carbon neutral targets, it is almost certain that emissions will become part of LEED's accreditation process in the next few years).

State and city governments are the main driving force behind the greening of America's buildings. Cities including New York, San Francisco and Seattle have adopted green building programmes and New York became the first state to grant a tax break for sustainable buildings. Universities and environmental organizations make up the rest of the green building vanguard and their names dominate the list of LEED-certified buildings.

Similarly, in the UK, local authorities and central government specify that a minimum BREEAM rating be achieved for the buildings they occupy. The UK Office of Government Procurement (OGC) requires all government departments when undertaking new build or refurbishment construction projects to carry out environmental assessments using BREEAM. From March 2003, all new buildings have had to achieve a BREEAM "Excellent" rating and refurbishment projects "Very Good".

At the same time, more and more corporate clients are seeking to occupy buildings acknowledged to be greener but mainly for their headquarters and not necessarily throughout their whole property portfolio. However, on both sides of the Atlantic a 'green' HQ is becoming the new corporate status symbol and therefore the importance of achieving a high rating in either scheme is significantly more important.

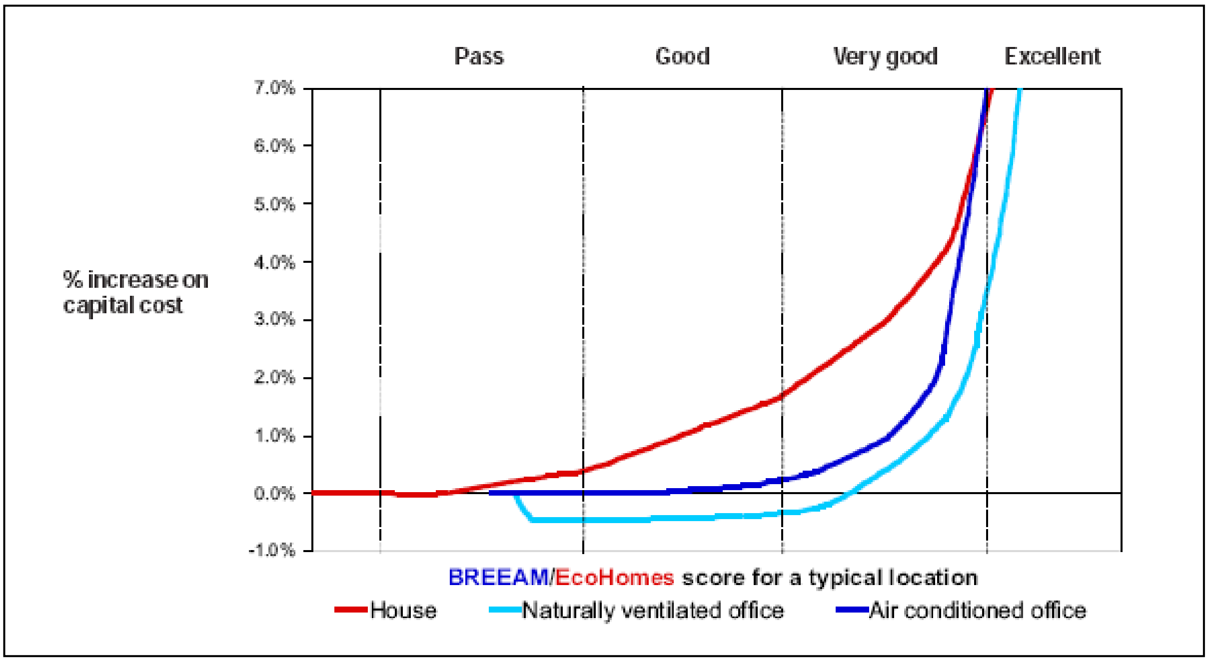
In conclusion, when asked about how to measure the 'greenness' of a building, one can do worst than to assess a building against one of the leading methodologies, BREEAM, LEED or the local equivalent.

Costs of "Green" Buildings

Relatively little is known about the cost of sustainable building. It is still cheaper and quicker to ignore environmental concerns, and going for the environmental accreditation that both LEED and BREEAM require is an expensive process (as independent consultants need to be appointed and evidence needs to be collected and submitted to prove that the credits or points are deserved). Sourcing the right materials, using the right professionals and securing suitable design features has an 'environmental levy' that businesses are not always willing to pay. However, many beneficial features have little or no additional capital cost but deliver benefits in use, hence it is a myth that a more sustainable building will always cost more than a traditional one.

A study undertaken by BRE and Cyril Sweett investigated the cost of achieving different BREEAM ratings and concluded that the environmental performance can be increased by 1-3 of the (lower) ratings for less than 2 per cent additional capital cost [1].

Figure 1 Increasing capital costs against environmental performance for three building types



Source: "Costing Sustainability" BRE Information Paper 4/05

The graph indicates the marginal increase on capital cost to achieve BREEAM and EcoHomes ratings at the time of the study (2003-4) for three different types of building:

- A house
- A naturally ventilated office
- An air-conditioned office

Although the buildings were chosen to represent a typical building for each category, the results can only be seen as indicative since there are a number of variables that affect the cost of any scheme not least of them size, location, site conditions, planning constraints, build quality, etc.

Nevertheless, environmental performance can be increased 1-3 ratings for less than 2 per cent additional costs if the conditions are optimum and the most cost-effective measures are implemented. In the case of a naturally ventilated office a negative increase was achieved (a net saving) due to the reduced cost of plant compared when with standard build cost.

It is only when trying to promote ‘good’ or marginal ‘very good’ projects to ‘excellent’ that costs begin to escalate but even then only by about 7%, although the figure shows a sharp increase at that point. This relatively modest capital cost increase can only be achieved if early decisions are made regarding basic form and servicing solutions. Cost-effective solutions are dependent on a design and specification with BREEAM in mind from the very beginning of the project. ‘Greening’ a building that has been designed without a sustainability brief will undoubtedly be more expensive and potentially achieve less satisfactory results in terms of comfort, operational and maintenance costs over the lifetime of the building.

Estimates based on American projects assessed through LEED, initially indicated an increase of 0-3 per cent in capital cost for the lower ratings and up to 6.5 per cent for the highest ratings. A later review of 138 buildings with varying commitment to the environment (93 non-LEED and 45 LEED seeking buildings) found the overall costs to be indistinguishable. There were wide variations in the building cost but “there was no statistically significant difference between the LEED population and the non-LEAD population” [2].

This study was revisited in 2006 [3] achieving essentially the same results: there is no significant difference in average costs for green buildings as compared to non-green buildings.

However, average costs are not be a true indication of additional costs to achieve a particular rating. Figures published by the USGBC (and considered conservative) show that there are no extra costs to achieve basic certification but that going for silver incurs about 1.5 per cent premium and up to 7 per cent for platinum. According to independent surveys of those meeting LEED certification, the average costs are reported to be about 3 per cent extra rather than the zero figure provided by the USGBC (for basic certification). With silver at 2.5 per cent extra, plus the 3 per cent for basic certification, we are still only at 5.5 per cent extra costs to build green.

Research carried out by CB Richard Ellis compared the standard costs of construction in England for a 12-storey, 50 unit development totalling around 80,000 sq.ft. with a theoretical zero-carbon development of the same size. This goal goes well beyond either BREEAM excellent or LEED platinum but it is the current long-term ambition of local government in England.

The design, by architects Lewellyn Davies Yeang, is set to a zero-carbon standard for green design and construction, albeit excluding procurement or demolition. To narrow the scope of this research and to define the type of product being analysed, it was assumed that:

- the development is within urban Britain;
- it is of tower design;
- the design and mix has a typical city occupier mix of mostly professionals and young families;
- although Llewelyn Davies Yeang approach to building design is site-specific, we have attempted to remove issues of aesthetic.

Our analysis of the model green development reveals a build cost premium of around 12.5 per cent. Still a modest sum given the very demanding goal of a near-zero carbon development.

Although more research is needed to provide salient information on the cost implications of going ‘green’, the most cost-effective way to achieve a higher rating is to act early. Increasing design time to integrate sustainability at the outset will produce both capital and running cost savings whilst late considerations and variations tend to increase costs significantly.

Another important consideration is the cost of not-going green. With increased levels of legislation and with more transparency about the performance of buildings through the implementation of the Energy Performance of Buildings Directive (EPBD), one can imagine a situation where if there was a choice between two similar buildings in similar locations and offered at a similar price, one that was green and another that was not, naturally most investors or occupiers would choose the green option.

There will be a detrimental effect on the value of the ‘less’ green building if it has a lower occupancy rate than the green building. However, there are not enough green buildings available at this point to make that a common scenario.

Encouragingly, ongoing technology advancements make a zero-carbon standard a realistic goal. A combination of lower technology costs with long-term increasing energy prices will further improve the viability of currently marginal green technologies. With continued wide public and governmental support, we can expect real examples to be developed in the near future.

Consumer willingness to pay

According to recent survey results completed at St James’ Kennet Island development in Reading, England, consumers are willing to pay some portion of the cost increase for green developments. The St James’ envirohome concept, including the cost of installing key green features, was explained to prospective purchasers at the show home. The survey revealed that four-fifths of residents would pay up to £3,000 for each of a select group of green features, including solar PV tiles, solar hot water tiles, PowerPipe hot water heat exchangers, grey water recycling and wind turbines. However, this figure is less than the cost of installation for all of these items with the exception of grey water recycling.

While 30% of consumers indicate a willingness to pay over £10,000 for a fully fitted ‘envirohome’, a majority valued the envirohome at a level well below its full cost. It is clear that the goodwill of consumers, while significant, is insufficient for adoption of green technology at current prices. The survey demonstrates that without a recognized cost savings from adopting green technology, consumers consistently undervalue the true cost of these features.

Higher Returns from “Green” Buildings?

A recent study based on data collected by the CoStar Group shows some evidence that greener buildings are attracting real financial benefits to investors. The sample of green buildings in their database is small but nevertheless useful (435 buildings rated using Energy Star[3] compared with 238,808 Non-Energy Star buildings). From these buildings, a selection complying with a specific set of criteria was analyzed.

The criteria used for filtering the database included:

- Only Class A office buildings
- 200,000 square feet or more
- 5 stories or more
- Built since 1970
- Multi-tenanted

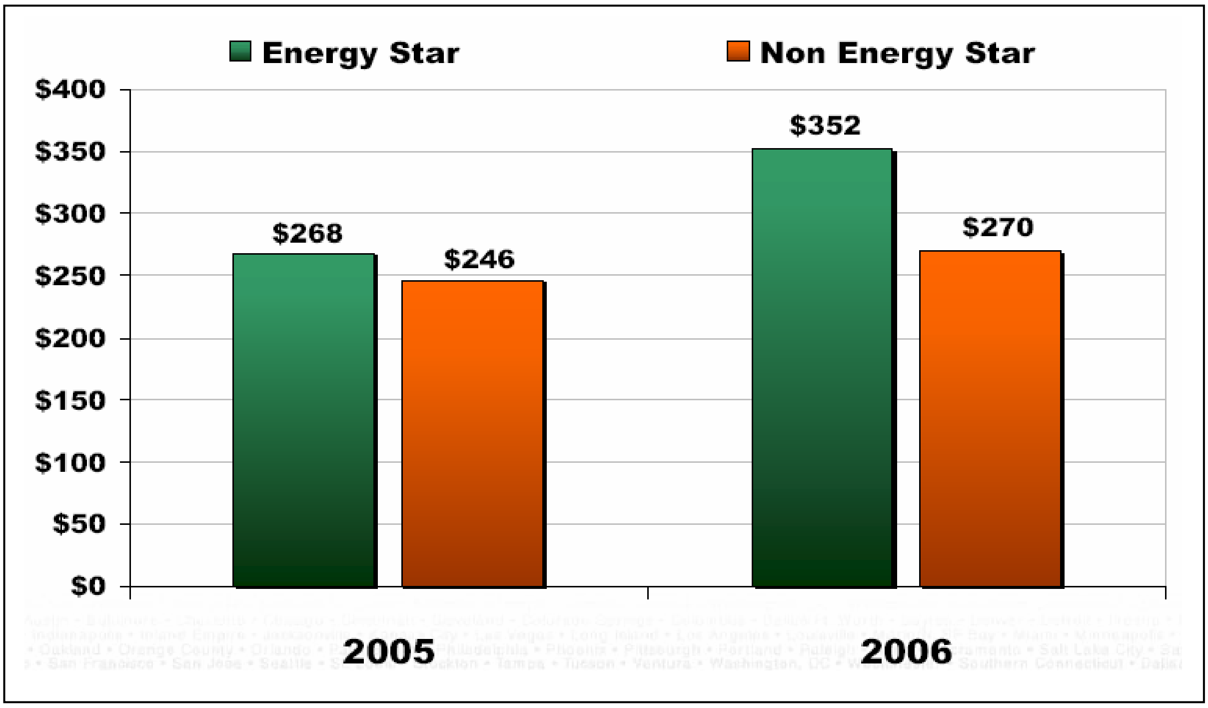
This resulted in a sample of 223 buildings rated using Energy Star compared with 2,077 Non-Energy Star buildings.

The study found that Energy Star buildings had consistently higher occupancy dating back to the fourth quarter of 2004 [4].

Other significant results are shown in the following two figures. They show that an Energy Star building sold for an average of $352 per square foot in 2006, 30 percent higher than a non- Energy Star building, which sold for an average of $270 per square foot. Energy Star rated building also commanded higher rental figures.

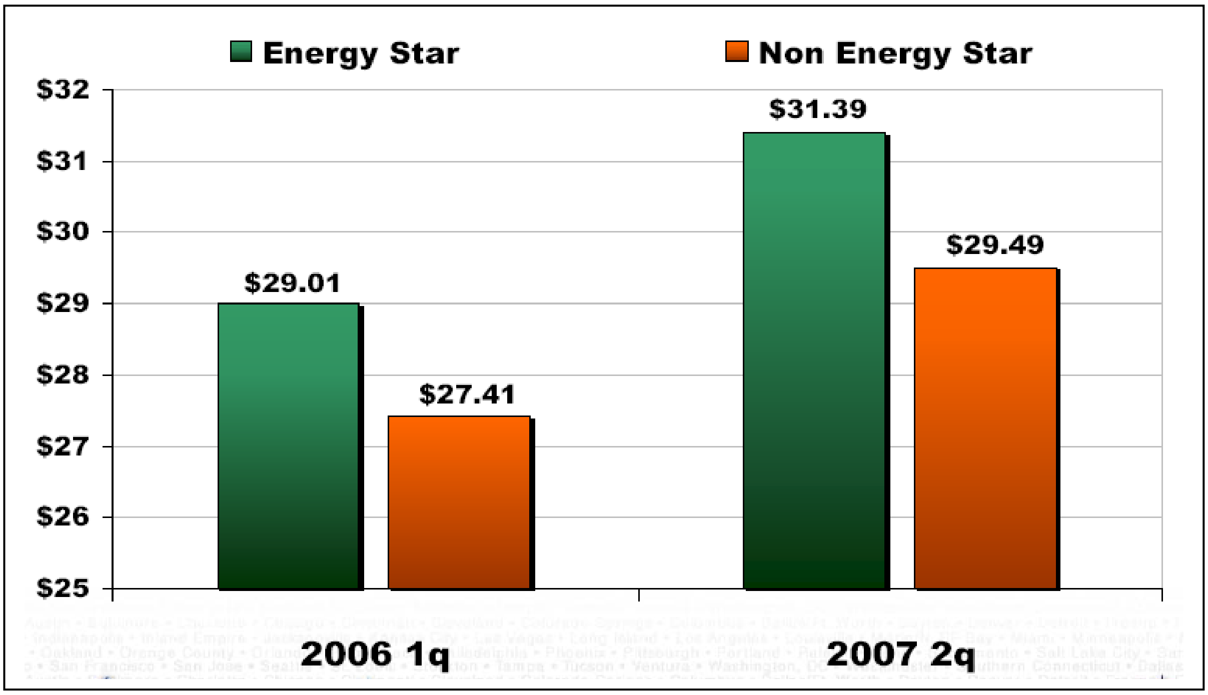
[3] Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy providing an energy performance rating of the building energy consumption profile. It has a narrower scope than LEED but can be used as a proxy for ‘green’ buildings in the context of the study as Energy Star buildings are those within the 25% most efficient buildings for energy conservation.

Figure 2 Sales Price ($/sq.ft.)



Source: CoStar Group

Figure 3 Direct Rental Rates ($/sq.ft.)



Source: CoStar Group

It is early to derive overarching conclusions from these early results and short history of data, but we would continue gathering evidence in-house and monitoring data gathered by others in order to inform the investment community as well as developers and other stakeholders.

Conclusions

Local factors are crucial to the relevance of most of the assessment and rating methods that are currently in use. Even if the same methodology is used, you cannot compare two buildings with equal ratings if they are in two different countries, or even in different cities, they are only comparable with similar buildings in a similar location assessed with the same criteria. One cannot assume automatically that a top-rated LEED building is as environmentally benign as a top-rated BREEAM building in all aspects. This is due to the trade-off between the different issues assessed and the system of points used, but you can at least be sure that you are choosing a “greener” building than others in the local stock with a lower rating.

When asked about how to measure the ‘greenness’ of a building, one can do worst than to assess a building against one of the leading methodologies, BREEAM, LEED or the local equivalent.

There is some evidence that if the client brief ensures that the design integrates sustainability at the outset, any extra costs attributable to the building being ‘greener’ will be minimum.

A number of CEO’s believe that to be successful in the 21st century business environment, organisations have to take account of the need to manage risk effectively and use resources efficiently. As a result, there is now often board level acknowledgement that being green is an important market differentiator and that sooner rather than later, this will be reflected in share’s and asset values.

Location and price are always going to be the key drivers when making property decisions. Nevertheless, increasingly, both investors and occupiers are including green issues in their decision-making criteria. Certification of buildings in accordance with the EPBD and against established methodologies like BREEAM or LEED, will make these decisions easier.

The research carried out by CB Richard Ellis illustrates that a combination of legislation and consumer philanthropy is currently insufficient to meet the goal of zero- or near zero-carbon developments.

An individual’s sense of duty to future generations for carbon reduction can be translated into a financial contribution. In addition, savings from adopting green features provide a payback, which can offset the upfront green premium. As technology becomes more reliable and accessible, we will see payback periods shorten to a point where green features can provide a real return on up front investments. A combination of lower technology costs with long-term increasing energy prices will further improve the viability of currently marginal green technologies.

The convergence of public sentiment, legislative pressure and technological advances is driving the Green Agenda forward. Consumers are also making real contributions through goodwill and premiums paid due to energy costs savings on green features. However, we still have not reached the point where climate change goals can be achieved by market forces alone.

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Encouraging Efficiency Investments With a New Energy Risk Management Approach

Jerry R. Jackson, Texas A&M University, College Station, Texas USA

Abstract

Energy-efficiency initiatives play a primary role in the European Union's (EU) policy initiatives to reduce energy use and carbon emissions. However, commercial establishments are typically reluctant to invest in more efficient equipment. More specifically, decision makers at these organizations often use short payback requirements, bypassing many attractive efficiency options. The effectiveness of many EU policies requires a longer-range financial view of efficiency investments. For instance, purchase incentives and information programs are likely to provide limited impacts, relative to their potential, if individual decision-makers continue to require short paybacks before investing in more efficient systems.

Studies of investment behavior show that traditional conservative payback criteria are used to avoid risk, focusing only on the near term. A risk management approach that manages rather than avoids risks would promote longer-term evaluations, benefiting individual organizations and society as a whole. What has been lacking to facilitate this transition to modern risk management principles is a framework that provides the same simple quantitative decision variables that make payback analysis so widely-used in facility energy management.

Energy Budgets at Risk (EBaR)®[1] is a new quantitative energy risk management framework that guides decision-makers in evaluating both the risks and rewards of energy-efficiency investments over the life of the investment while explicitly considering energy price and other investment uncertainties. EBaR analysis reflects an extension of Value at Risk (VaR), the widely used financial industry risk management tool, providing an analysis framework familiar to chief financial officers and financial administrators at many organizations. EBaR applications can achieve net energy cost savings of 20 to 30 percent of current energy costs while meeting risk tolerance and budget flexibility of individual organizations.

This paper discusses current efficiency investment behavior and presents the EBaR analysis framework with an illustrative case study example. The final section of the paper draws on the author's experience working with both government agencies and energy consumers to identify EU policy options that encourage efficiency investments.

Introduction

Energy-efficiency initiatives play a primary role in the European Union's (EU) policy initiatives to reduce energy use and carbon emissions. The commonly accepted view that current buildings' energy use can be reduced by at least one-quarter with cost effective efficiency measures is consistent with the EU target of a 20 percent reduction in energy consumption by 2020 (European Commission, 2005; Bertoldi, 2007). Energy price increases over the last several years have certainly increased the cost-effective potential.

There is evidence that the efficiency-related energy savings potential in commercial buildings is even greater than the conventional wisdom; for instance, Phillips Lighting reports that only 1 percent of lighting in European commercial buildings use daylight or occupancy controls and two-thirds of lighting equipment is based on old lighting technologies developed prior to the 1970s (van Deursen, 2007; Verhaar, 2007). While Phillips' assessment may overstate the pace of lighting efficiency changes, especially in new buildings, technology advance over time undoubtedly provides a large lighting efficiency potential. For example the most efficient fluorescent lamp and ballast systems (e.g.,super T8 lamps with electronic ballasts) available today use half the electricity of the older technologies and provide 50 percent greater lamp lifetimes than standard lamps. (Sach, et. al, 2004). An effective use of lighting controls, compact fluorescent lamps, new lamp fixtures, LED exit lighting and other technologies can reduce lighting use in buildings by as much as 70 percent resulting in total building electricity savings of approximately 20 percent. Selection of Energy Star office equipment, controllers for plug loads and other existing energy saving technologies can also have significant energy savings impacts in many commercial buildings. Even without early replacement, the impacts of high-efficiency boilers and chillers could be substantial by 2020. These observations suggest that commercial buildings could potentially provide considerably more than their share of the targeted 20 percent savings.

Building and equipment standards are an important element in achieving commercial efficiency increases, excluding the most inefficient equipment and building practices; however, most commercial sector energy-efficiency potential can only be achieved by inducing building owners to voluntarily invest in more efficient equipment and building structures. National Energy-efficiency Action Plans of individual EU countries include a variety of policy initiatives designed to promote voluntary efficiency improvements including purchase incentives, financing programs, and information programs.

Casual empirical observations suggests, however, that these incentives designed to promote the purchase of more efficient technologies are likely to be relatively ineffective since unrealized cost-effective energy-efficiency potentials already represent a significant but apparently unattractive financial incentive. If commercial decision-makers currently avoid cost effective energy-efficiency investments that could save 25 percent of energy costs, one must question how much additional energy efficiency can be achieved with new financial incentives.

This reluctance of commercial firms to invest in energy-efficient technologies is widely recognized. For instance, a recent report by McKinsey & Company for Germany noted that energy-efficient technologies are widely available and cost effective but seldom adopted because companies lack necessary information and expertise (United Press International, 2007). Is lack of information and expertise truly the primary obstacles to efficiency investment? Both casual observation and studies of efficiency investment behavior provide evidence that factors other than information and expertise are more important in limiting efficiency investments, making EU programs aimed at promoting voluntary efficiency improvements likely to be relatively ineffective in their current forms.

Many efficient technologies have nearly identical outward appearances and installation requirements and have been available for years, with energy savings touted in trade publications, labels, packaging and point-of-sale advertisements. For instance, high efficiency lamps and ballasts and lighting controls have been available for more than twenty years, and require no special expertise to evaluate and install. However, as noted in the Phillips Lighting references above, lighting controls are not widely used in European commercial buildings and a large fraction of lamps and ballasts use at least twice as much electricity as their most efficient alternatives.

Interesting insights on investment behavior are provided by a detailed study of efficiency choices of more than nine thousand small and medium US manufacturing firms (Anderson and Newell, 2002). Studies of capital budgeting practices indicate that these results are also indicative of practices in the UK and throughout Europe (Chen and Clark, 1994; Pike, 1996; Sandahl and Sjogren, 2003; Lefley, 2003). A US Department of Energy program administered by professional engineers at more than a dozen universities provides free one to two day onsite energy audits and detailed energy-efficiency investment analysis. Analysis results are presented in a written report and an onsite presentation to company decision-makers with information on costs and energy savings of detailed energy-efficiency options for each facility. Each company is contacted six months later to determine which efficiency investments have been undertaken. By evaluating investment costs and energy cost savings of the marginal investment (the least attractive investment actually undertaken), an implied payback requirement threshold is determined. All investments with shorter paybacks were accepted and those with longer paybacks were rejected.

The average payback threshold was 15 months, equivalent to an internal rate of return (IRR) of about 70 percent. Internal rate of return is the annual yield calculated over the life of the equipment. In other words, on average, investments with paybacks longer than 15 months or IRRs less than 70 percent are rejected. Given a 10 percent financing interest rate, these companies are rejecting investments that provide a 60 percent annual profit. This long-running program was designed specifically to overcome information and expertise issues mentioned in the McKinsey report. Decision makers in the study had complete information and free access to relevant expertise. However, the willingness of these companies to invest in energy efficiency appears to be no greater than companies who did not participate in the program. One of the primary conclusions of this study was that government information programs, which in this case also provided expert assistance, do not appear to result in greater levels of efficiency investments.

In addition to information and expertise, a variety of explanations have been offered in an attempt to explain the reluctance of firms to invest in energy efficiency[1]. While various management, organizational, institutional and financial market barriers have been cited, empirical studies have generally been unsuccessful in establishing any of these factors as significant reasons explaining the observed reluctance to invest in energy efficiency (Metcalf,1994; DeCanio, 1993; Brown, et. al, 2001). One other factor that is mentioned in most discussions of efficiency investment is risk associated with energy prices, operating characteristics and other uncertainties. However, little effort has been expended to determine the way in which these uncertainties impact investment decisions. The next section offers an explanation of how energy efficiency investment uncertainty and risk limit these investments.

Energy-Efficiency Investment Decision-Making

Capital budgeting is the planning process used to determine which long-term investment projects will be undertaken. Energy-efficiency investments are considered part of the capital budgeting decision-making process. Payback (PB) analysis (investment cost divided by annual savings) plays a dominant role as a capital budgeting investment tool. A survey of studies on investment behavior over the past two decades, mostly reflecting UK and European firms, indicates that between 70 and 90 percent of firms use payback analysis as their primary capital budgeting investment criterion (Pike, 1996).

Payback analysis has serious deficiencies when applied to evaluating energy-efficiency investments. The greatest shortcoming is that savings beyond the payback period are not considered. For example, the long lifetime and associated stream of costs savings, of a high-efficiency boiler replacement does not enter into a payback analysis.

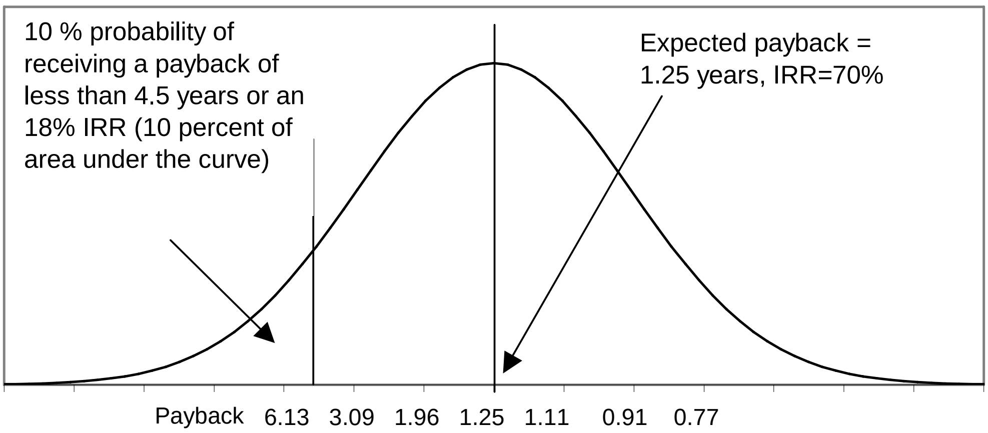
Why do organizations use the simplistic PB analysis rather net present value (NPV) or internal rate of return analysis (IRR) analysis[2] taught in universities? Conducting NPV analysis requires information on future energy prices, equipment performance, and other factors that reflect considerable uncertainty. Uncertainty is included in the NPV framework by adjusting the discount rate (reducing the value of future savings); however, no satisfactory methodology exists to determine the appropriate risk-adjusted discount rate.(Keat and Philip, 2006) From a management perspective there is significant value in using a simple, intuitive and easy-to-apply payback rule to screen out risky projects. Short payback requirements consider project returns only in the first several years where there is the least uncertainty. Projects qualified with short payback requirements are almost “sure things.”

If the efficiency investment lifetimes and uncertainty over investment returns are similar for all efficiency investments, then using the expected engineering estimate and a short payback requirement to limit the probability of an unacceptable outcome is a perfectly sensible approach to insure a minimum return based on the expected, or average, return.

The relationship between investment risk and a payback decision rule is illustrated in Figure 1 using the 15-month payback criterion reported in the study above. The figure shows a distribution of investment outcomes. A distribution is appropriate because uncertainty surrounding energy prices, operating hours, equipment performance and other factors creates a distribution of likely investment outcomes. The mean or expected investment payback is 15 months or 1.25 years. If we define risk as the probability of an unacceptable outcome, in this case the probability of realizing a payback of less than 4.5 years, a rule that requires the expected energy savings to provide a payback of 1.25 years is equivalent to a rule that requires investments to have less than a 10 percent probability of achieving less than a 4.5 year payback.

It is easy to see from Figure 1 why using short paybacks is attractive as a simplified management tool to limit investment risks. The expected payback is reasonably easy to calculate and, as long as the

Figure 1. Payback Limits Investment Risk



Investment lifetimes and distribution of returns is the same for all potential investments, a payback rule is an easy way to avoid risk, in this case realizing a payback of less than 4.5 years or an internal rate of return (IRR) of 18 percent. Internal rates of return are a more traditional financial criterion; the payback rule, under these assumptions, provides a perfect proxy for traditional IRR measures.

The problem in using payback to screen out risky investments is that to be effective the rules must be defined with a worst-case scenario; otherwise, risky investments will slip through the process. Any efficiency investment with less uncertainty over performance, operating hours, or any of the other variables will be summarily rejected even though it may actually meet the risk tolerance objectives of, in this case, providing less than a 10 percent probability of achieving an IRR of less than 18 percent.

Payback rules also break down for investments with longer lifetimes than the standard since there is no way of capturing benefits of longer streams of energy cost savings with payback analysis. For example, the newest T8 fluorescent lamps have lifetimes of 30,000 hours rather than 20,000 hours for standard T8 lamps; however, this distinction is missed since payback equals only the initial cost divided by annual cost savings. Any investment that provides returns over a longer period than what is used to develop the initial payback rule may be inadvertently rejected.

The costs of bypassed efficiency investments caused by conservative payback requirements are considerable. In addition to creating unnecessary carbon emissions and over-using scarce energy resources, individual commercial establishments are foregoing increases in cash flow because annual energy costs savings are nearly always greater than annualized investment costs.

Clearly a payback rule is too rigid to guide investment decisions concerning the diverse array of energy efficient technologies available on today's markets. On the other hand, financial managers' preferences for easy-to-evaluate decision rules eliminates NPV and other textbook approaches that require questionable adjustments to discount rates to account for risk.

Recognizing that energy-efficiency investments are different than most capital budgeting decisions provides a way out of this apparent difficulty. Most capital budgeting decisions are strategic in nature and have important risk elements that are difficult to quantify. For example, the value of adding a new production line depends on economic forecasts and strategic responses of competitors. Making a bad decision could result in investing in plant and equipment that may operate for a shorter period than expected depending on market conditions and competitor responses. However, energy-efficiency investments are a much simpler investment problem; these investments provide the same services (heating, lighting, and so on) at a smaller cost. As long as the facility is occupied, there is no chance the investment will be abandoned. Risk associated with an efficiency investment is therefore much easier to quantify with formal risk analysis than other more strategic capital budgeting decisions. Energy-efficient technology investments are more similar to financial market investments than to traditional capital budgeting investments.

The following section translates the energy-efficiency investment decision process into a portfolio management problem to illustrate how modern financial risk management principals resolve difficulties presented by payback analysis.

Energy-efficiency Investments as a Portfolio Management Problem

Risk associated with financial investments has increased significantly over the last several decades because of volatility in international exchange rates, commodity prices, interest rates, and geopolitical events. Financial markets have developed an impressive array of instruments that investors use to hedge these risks including financial futures contracts, options contracts and other contractual arrangements that limit the impact of adverse price movements.

Investment portfolio management has developed in lockstep with these market developments; financial portfolio managers depend heavily on an array of quantitative tools to assess risks and returns associated with portfolios and to evaluate benefits of including new investments in existing portfolios. The most widely used quantitative tool is "value at risk" or VaR which measures the probability that portfolio losses over some period will exceed a set amount at a predetermined confidence level. A daily VaR of $1 million at a 99 percent confidence level means the probability that the portfolio will lose more than $1 million in a day is less than 1 percent. That is, losses of more than $1 million can be expected to occur no more than 4 days in a year. VaR statistics are calculated using historical data on returns of the individual stocks or other financial investments in the portfolio.

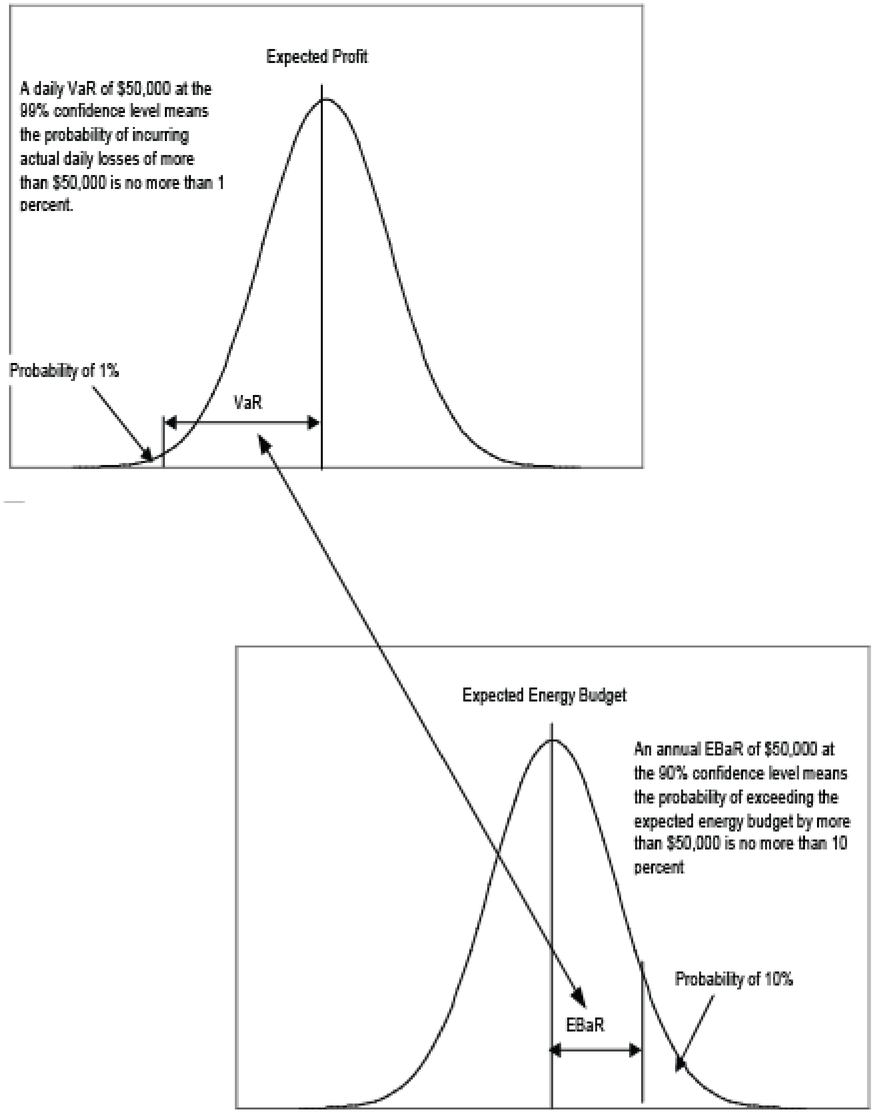
Financial regulatory agencies require VaR statistics from individual financial institutions to measure capital adequacy. VaR statistics are used in the Basel II international agreement to insure appropriate risk-taking by international financial firms. Other at-risk measures such as earnings-at-risk and profits-at-risk are commonly used by corporate chief financial officers and other financial administrators to measure, evaluate and react to risk.

Managing energy budget and investment risk can be viewed as a process similar to managing financial portfolio and investment risk. Each energy-using component in a building's energy budget portfolio can be considered a separate investment with a return that represents its energy use. Replacing existing fluorescent lamps with high-efficiency lamps can be viewed as replacing an existing investment with a new investment. The return on the investment portfolio that includes all energy using equipment and structural components is represented by annual energy costs. In this case optimizing the portfolio means minimizing the returns or annual energy costs given some level of risk. Energy use associated with an optimized portfolio can be reduced only by increasing the level of risk associated with the entire portfolio.

Energy Budgets at Risk or EBaR®[5] is a new energy budget and investment analysis framework developed by the author of this paper. EBaR extends and applies value at risk (VaR) concepts to define energy budgeting and efficiency investment analysis within a quantitative risk management framework. Not only have these analytical applications been vetted in the international financial community, their application provides a set of simple decision variables comparable to the decision-making simplicity of payback analysis.

The correspondence of VaR and EBaR analysis is illustrated in Figure 2 where risk associated with a stock portfolio and an energy budget portfolio are quantified. The expected energy budget and the probability that actual energy costs will exceed the budget (the budget variance) are specified in the same way that portfolio losses are specified in VaR analysis.

Figure 2 Correspondence of VaR and EBaR Budget Analysis



Energy Budgets at Risk (EBaR) Investment Analysis

Figure 2 illustrates the application of EBaR budget analysis to evaluate energy budget risk or risk of exceeding a given budget variance. A more important application with respect to efficiency programs is EBaR investment risk analysis. As indicated in Figure 1, energy-efficiency investment risk can be measured by the probability that the investment will fail to meet a critical investment return threshold. Risk tolerance is measured by the organization's maximum acceptable probability. Every potential efficiency investment outcome reflects a distribution created by uncertainty associated with future energy prices, weather, operating characteristics and so forth.

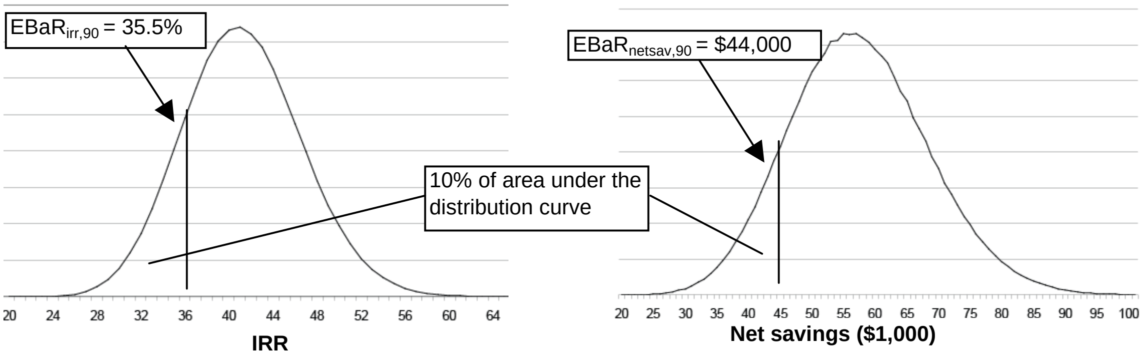
Energy-efficiency investment decision variables are derived from distributions of investment returns and net savings which reflect energy costs savings beyond the annualized cost of the equipment.

EBaR investment analysis provides two decision variables including:

- $EBaR_{irr,x}$ is an investment form of the EBaR statistic showing the smallest expected investment internal rate of return (IRR) at a given confidence level, x. An $EBaR_{irr,95}$ = 35 percent indicates that the likelihood of achieving an internal rate of return of 35 percent or more is 95 percent.
- $EBaR_{netsav,x}$ is the smallest net savings (energy cost savings minus amortized cost of the equipment, including financing costs) at a given confidence level, x. An $EBaR_{netsav,x}$ = $30,000 indicates a 95 percent likelihood of achieving a net savings of $30,000 or more.

Actual distributions of IRR and net savings for the case study described in the next section are shown in Figure 3 to illustrate these definitions. EBaR statistics are shown for a 90 percent confidence level (10 percent of the area under the curves is to the left of 35.5% and $44,000).

Figure 3. EBaR IRR and Netsavings Definitions



Applying EBaR Analysis

EBaR is illustrated in this section with a case study energy-efficiency application. The case study facility is an owner-occupied, five story, 120,000 square foot Austin, Texas, office building constructed in 1988. Building operating hours are 8:00 A.M. to 6:00 P.M. Monday through Friday. The facility uses natural gas for space heating and some water heating units and electricity for all other end uses. The HVAC system has a variable air volume ventilation system. HVAC system setbacks occur at 6:00 P.M. with normal settings restored at 7:30 A.M. The HVAC system in the building has not been recommissioned (that is, tuned up). The lighting system has an average connected load of 2.0 W/square feet. Standard high-efficiency ballasts are used with T12 lamps. Little attention has been paid to energy efficiency since the building was constructed. The annual electricity use is 16.42 kWh/square foot and natural gas use is 35.1 kBtu/square foot.

Energy bills are about $200,000 per year for electricity and $50,000 for natural gas, up by about 25 percent for electricity and 80 percent for natural gas since 2002. The building owner is concerned about the continuing impact of high energy bills and wants to consider measures to reduce energy costs and to avoid the impacts of the volatile natural gas market.

Two efficiency options are considered for the case study facility. The first is a package of lighting technologies, and the second is an HVAC recommissioning effort including installation of an energy management and control system. Lighting efficiency options include replacing T12 lamp/ballast systems
with super T8 lamp/electronic ballasts, delamping (removing some lighting fixtures), installation of occupancy and day lighting controls in selected areas, and replacement of selected incandescent lamps with compact fluorescent lamps. The lighting manufacturer's representatives conducted lighting analysis and estimated savings of 483,000 kWh per year and 145 kW peak electricity use. The total cost of the lighting retrofit program to the owner is $100,000 based on a fixed cost contract that includes an efficiency incentive payment of $38,000. Electricity savings are approximately 20 percent.

Analysis of the HVAC system showed an oversized and poorly designed system. The HVAC contractor has offered a recommissioning that will completely update the HVAC system in addition to a building energy management control system. The contractor estimates savings of 30 percent for AC electricity use (after lighting changes) and 65 percent for natural gas heating use. Cost of the HVAC component is $125,000 after receiving an energy-efficiency credit of $32,000.

A summary of the efficiency investments is shown in Table 1.

Table 1 Investment Analysis Summary

Item	Value	Item	Value
Total investment cost	$295,000	Estimated energy cost savings	$98,000
Efficiency incentive payments	$70,000	Net cash flow	$58,300
Customer investment cost	$225,000	Internal rate of return	42.30%
		Payback	2.3 years

Without the efficiency incentive payments, the payback is 3.0 years. With an incentive payment of $70,000 the payback is 2.3 years, which is still longer than the building owner's 2-year requirement. Consequently, even though this investment would reduce the building's annual energy costs by 38 percent, the investment would not be made because it fails the payback criteria. From the owner's perspective, investments with expected paybacks greater than 2 years carry too much risk of unacceptable investment returns.

How does this investment fare when evaluated with the EBaR risk management framework? Uncertainty surrounding electricity prices, natural gas prices, weather and operating performance must be specified to answer this question. Operating performance includes performance variations as well as variations in operating hours, equipment utilization, energy savings estimation errors and other factors. This uncertainty is represented with distributions for each variable. Details on the development of these distributions are available in Jackson (2008) and will be summarized here.

Historical natural gas price variation is used to define likely high and low values around the current price for future years. Changes in natural gas prices impact the local utility's electric prices because about half the electricity generating capacity is fueled with natural gas. The relationship between natural gas prices and electric prices is estimated statistically. An evaluation of energy savings estimates provided by the manufacturer and ESCO for the lighting and HVAC projects suggests a range of uncertainty of +- 15 percent for the lighting program and +- 20 percent for the HVAC program. Variations in HVAC energy use are also caused by weather variations; these relationships are estimated statistically with historical building and weather data. Finally, additional random variations caused by unidentified factors are characterized statistically.

Table 2 summarizes the sources of variation in components that determine energy-efficiency investment returns, their impact on energy cost component and their development.

Table 2 Sources of Variation in Energy-efficiency Investment Returns

Variable	Impact on Cost	Source
Natural gas price	Energy price	Range of likely values based on history
Electricity price	Energy price	Statistical relationship based on natural gas prices
Operating performance	Energy savings	Manufacturer, ESCO and energy manager evaluations
Weather	Energy savings	Statistical relationship: HVAC energy use and weather data
Random	Energy savings	Statistical characterization based on historical data

Savings from efficiency investments are determined by multiplying lighting and HVAC program savings by electric and natural gas prices. However, since the factors in Table 2 are represented with distributions, determining the distribution of energy cost savings outcomes requires repeatedly sampling information from each distribution and saving the results. This Monte Carlo analysis process is widely used in every branch of social science, engineering, finance, business and other areas to translate variability in inputs (prices, weather, and so on) in a process (building energy use) to determine a distribution of outcomes (IRR and net savings). Figure 3 shows the resulting output IRR and net savings distributions.

Representing investment returns (IRR) and investment profits (net savings) with the distributions in Figure 3 is not a "user-friendly" presentation for most financial and other executives. Selecting several levels of risk that match potential decision-maker risk-tolerance provides more transparent decision statistics. Table 3 and Figures 4 and 5 show IRR and net savings (savings after deducting financing costs) in presentation format for the lighting and HVAC investment.

Table 3 Efficiency Program Returns

Confidence Level	Minimum IRR (%)	Minimum Net Cash Flow
Expected	42.3	$58,300
90%	35.5	$44,000
95%	33.5	$40,000
97.50%	32.4	$37,800

Figure 4 Investment Internal Rates of Return (IRR)

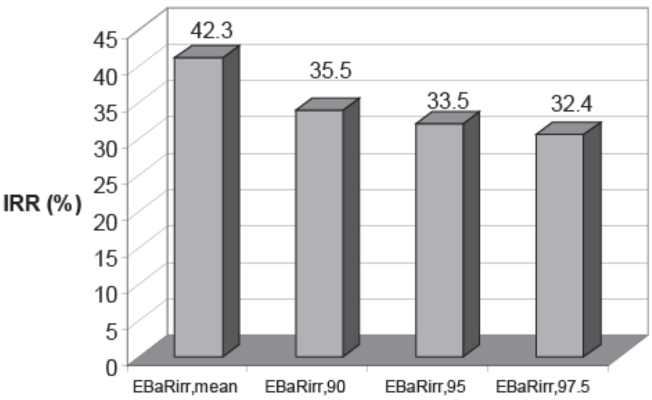
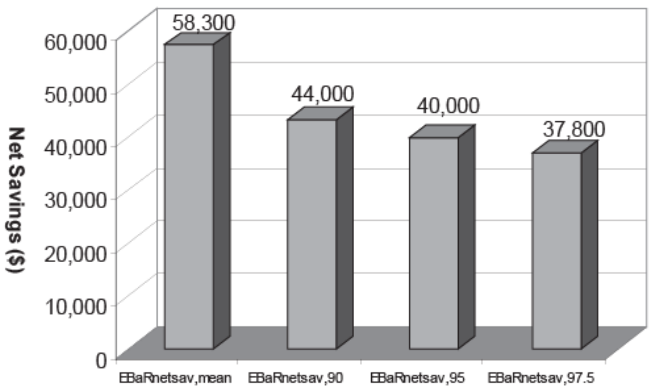


Figure 5 Investment Net Savings



As indicated in the table and figures, this investment with an expected value payback of 2.3 years and 42.3% IRR has virtually no chance of providing an IRR less than 32.4% and yielding an annual net savings of less than $37,800. In other words, even in a "worst-outcome" situation likely to occur with a probability of only 2.5 percent, the energy-efficiency investment will increase annual cash flows by $37,800.

While a payback approach requires a short expected payback to insure against unacceptable investment returns, EBaR provides information on the least attractive returns likely to occur at various confidence levels. EBaR manages to provide this information in a simple decision-variable framework like payback analysis; however, EBaR avoids all of the limitations of payback analysis. Investments with varying lifetimes, savings throughout the life of the equipment and a comprehensive and explicit accounting of the uncertainty associated with every aspect of the analysis is included in EBaR analysis. The EBaR analysis framework also allows the analyst to evaluate impacts of alternative assumptions on input variable uncertainty and to identify the importance of uncertainty surrounding each variable on the distribution of investment returns.

In this case study, expected returns are great enough and the risk of unacceptable results is small enough to recommend the investment. The impact of efficiency investments on the expected annual energy budgets can now be evaluated. Figure 6 shows the expected budget before and after the investments and expected budget variances at three confidence levels. Not only have the investments reduced the expected annual energy budget from $250,000 to $168,200, the size of likely budget variances (the amount by which actual costs exceeds the budgeted amount) is reduced by about 45 percent. Both the annual budget and budget risk have been significantly reduced.

Figure 6 Expected Annual Energy Budgets Before and After the Investment

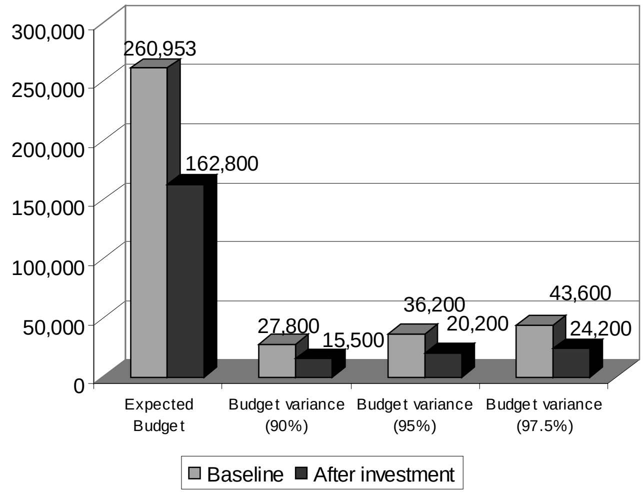
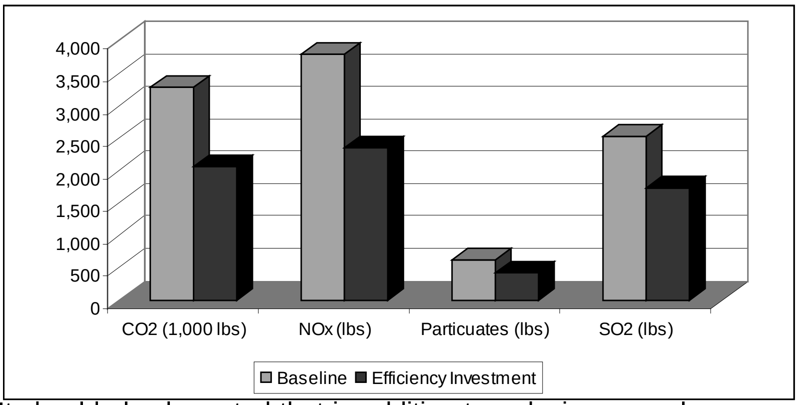


Figure 7 shows annual baseline of CO_2, NOx, particulates and SO_2 emissions along with emissions after the lighting and HVAC investments. Carbon emissions are reduced by 37.4 percent and reductions in other emissions range from 31 to 38 percent.

Figure 7. Reductions in CO2 Emissions



It should also be noted that in addition to reducing annual energy costs and budget volatility, energy-efficiency investments also increase the capital value of the building. Increases in cash flow reflected in the net savings statistic translate directly into greater net income for real estate owners increasing its market value.

EU Policy Applications

The case study application summarized above illustrates advantages of applying the EBaR energy risk management approach to assess the financial, energy-savings and emissions-reducing impacts of energy-efficiency investments. EBaR analysis is shown to provide the simple decision process preferred by decision-makers who currently rely on payback analysis. Rather than avoiding risk with an imprecise rule that overlooks many profitable investments, EBaR quantitatively determines investment rewards and risk for individual efficiency investments in a way that allows individual commercial establishments to evaluate investments based on their budget flexibility and risk tolerance. EBaR also shows the corresponding increase in cash flow resulting from energy savings that exceed the cost of financing the investment. Finally EBaR incorporates varying equipment lifetimes, energy price uncertainty and other issues ignored with payback analysis.

Several recent developments are likely to contribute to greater interest by building owners and occupants in more meaningful energy-efficiency investment analysis methods. The European Energy Building Performance Directive (DPBD) now being implemented will undoubtedly contribute to greater awareness of energy use and carbon emissions for individual buildings. The growing use of measurement and verification (M&V) methods, developed largely for use in performance contracts where the contractor is required to meet specific energy reduction goals, provides a methodology to assess both pre and post investment energy use characteristics. The International Performance Measurement and Verification Protocol (IPMVP) provides an internationally accepted, consistent and reliable framework to determine energy-efficiency savings.

While these developments, along with higher energy prices and greater public attention to carbon emissions set the stage for greater commercial buildings efficiency investments, traditional payback and hurdle-rate investment analysis applied by decision-makers can be expected to continue to limit the benefits of information programs, efficiency incentives and other efficiency-related programs.

EU countries can promote greater energy efficiency by establishing EBaR or similar energy risk management analysis as a standard analysis format for evaluating financial aspects of efficiency projects. Just as banks and financial institutions are required to perform value-at-risk analysis to satisfy capital adequacy requirements, larger commercial establishments, ESCOs and other significant participants in the energy-efficiency market should be required to conduct and provide EBaR-type energy-efficiency risk management analysis.

EBaR is a newly introduced public domain concept described in detail in *Energy Budgets at Risk (EbaR)®: A Risk Management Approach to Energy Purchase and Efficiency* (Jackson, 2008); consequently, its application has not yet been included in existing public policies. The following policy initiatives are suggested as options that public agencies may consider in promoting more cost-effective energy-efficiency investments.

- Require larger commercial organizations to conduct standardized EBaR analysis for a standard set of energy-efficiency options for their facilities.

- Require licensed equipment providers and ESCO companies to provide standardized EBaR analysis results to their clients covering a standard set of efficiency options.

- Require recipients of energy-efficiency subsidies to conduct standardized EBaR analysis for a standard set of energy-efficiency options for their facilities.

- Include user-friendly information on the financial benefits of EBaR investment analysis in existing efficiency information programs.

- Provide separate information programs on EBaR analysis including workshops to teach analysis application basics. Work with industry trade groups and other organizations to provide educational programs and to promote energy risk management financial analysis.

As carbon reduction and other green goals become more important in defining energy-related policies, it is important to remember that improving building energy efficiency is one of the most effective available carbon-reducing policy initiatives. As illustrated with the case study in this paper, efficiency investments reduce building owners' energy bills and budget volatility, reduce energy use and greenhouse gas emission and increase building owner's cash flows and property values. Promoting an EBaR energy risk management framework may be the most cost-effective environmental program available to EU programs.

End Notes

1. Energy Budgets at Risk (EbaR)® is a registered trademark of Jerry Jackson. The source for Figures 4 - 7 in this paper is *Energy Budgets at Risk (EbaR)®: A Risk Management Approach to Energy Purchase and Efficiency Choice*, John Wiley and Sons, Inc., Hoboken, New Jersey. March, 2008. Figures are used with permission of the author and publisher.

2. Net present value analysis (NPV) analysis compares future energy cost savings with the current cost of the investment. Internal rate of return (IRR) analysis, which reflects the annualized return on the investment over its lifetime, is equivalent to NPV analysis when applied to efficiency investments.

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Cold Comfort for Kyoto: the Link between Air-conditioning in Commercial Buildings and Consumer Lifestyle Choices

Pedro Guertler, Association for the Conservation of Energy
Jacky Pett, Pett Projects

Abstract

Although energy efficiency in commercial buildings is becoming more of a recognised issue for property professionals, the requirement for active air-conditioning is still seen as a “must have” in order for a property to be judged to be of “investment quality”. Air-conditioning in the residential sector is extremely limited in Europe, but as experience of air-conditioning in the commercial sector grows it can affect consumers’ lifestyle expectations beyond the workplace, which may act as a driver for more US-style patterns of adoption of cooling systems for the home.

This paper examines the scenarios for cooling growth and reports on a model of the effects on energy consumption and carbon dioxide (CO_2) emissions. It shows that, in the UK, unconstrained rise in air-conditioning use would negate 60 per cent of the efficiency gains from changes in building regulations since 2000, even though adoption is modelled only for the southern parts of England that are most affected by climate change. The paper then considers the policies that might be needed to persuade the consumer to adopt different cooling solutions. These in turn suggest that options in commercial buildings need to be reconsidered in a consistent and coherent manner.

Introduction

Employment in Europe is increasingly concentrated in what is termed the tertiary sector – commercial, retail, governance and ancillary services, rather than manufacturing and industrial processes. So when a European Directive focuses on the energy performance of buildings, that focus falls on the buildings within which the majority of people actually experience the result of energy used for internal temperature controls and other services, rather than on buildings where energy is used in direct proportion to production. Internal comfort becomes an important issue in the determination of the quality of a building by valuation surveyors (Gibson 2000), as it is related to productivity in the workplace and the image that the organisation using the building wishes to present to its clients, an important factor in maintaining its reputation.

Internal temperature control has become synonymous with air-conditioning in the minds of many facilities managers. In many countries, building a new prestige commercial building without air-conditioning is seen as a risky, if not foolish, business practice. During our previous research (Wade *et al* 2003) one property developer cited the difficulties experienced in letting a non-air-conditioned office, even in the UK, with a temperate climate that only occasionally experiences heat-waves. This is because such a building is not seen as being of investment quality (Pett & Ramsay 2003). Consequently, there is an inexorable rise in air-conditioned commercial buildings in Europe, with 27% of commercial buildings having air-conditioning in 2003 (Waide 2004), anticipated to exceed 55% in most European regions by 2020 (TNO 2007).

The question arises: what effect does the experience of air-conditioning in the workplace have on the demand for air-conditioning at home? In the US, growth was rapid between 1951 and 2001, when 76% of homes had some type of air-conditioning, compared with 80% penetration in commercial buildings (Waide, op.cit.). In Japan, 85% of homes are air-conditioned, and 100% of commercial buildings (*ibid.*). If the commercial sector continues to adopt air-conditioning in Europe, what could we expect the residential consumer to do? What impact would that have on CO_2 emissions?

This paper reports on an analysis of this problem for the UK, taking into account the forecasts of climate change for the 2020s and beyond, using the models from the UK’s Climate Impacts Programme. Although the UK is expected to experience only slight summer and winter temperature increases, the main impacts will be felt in the southern parts of the country, where not only do the majority of the population live and work, but the majority also work in the tertiary sector.

First, we present the approach to the model and the scenarios of behaviour that would influence rates of adoption of active air-conditioning. This is followed by the results of the modelling, showing the impact on CO_2 emissions. We then discuss the implications of this rise in emissions compared with the constraints imposed through other policies for CO_2 emissions reductions, and discuss the policies needed to ensure that the lowest carbon cooling options are adopted. Finally, we discuss the impact of those policies on the workplace, and the parallel policies and cultural changes needed in the workplace to lead to the adoption of low carbon solutions for commercial buildings.

Modelling increase in air-conditioning and its impacts in the UK

Employment in Europe is increasingly concentrated in what is termed the tertiary sector – commercial, retail, governance and ancillary services, rather than manufacturing and industrial processes. So when a European Directive focuses on the energy performance of buildings, that focus falls on the buildings within which the majority of people actually experience the result of energy used for internal temperature controls and other services, rather than on buildings where energy is used in direct proportion to production. Internal comfort becomes an important issue in the determination of the quality of a building by valuation surveyors (Gibson 2000), as it is related to productivity in the workplace and the image that the organisation using the building wishes to present to its clients, an important factor in maintaining its reputation.

Forecasts of increased adoption of air-conditioning in the home have to take into account not only economic and market factors, but also climatic influences and perceptions of comfort. In addition, with the growing awareness of the impacts of climate change, together with policy approaches to reducing CO_2 emissions, some allowance needs to be made for segments of the market that would be slow to adopt air-conditioning as a result of policy instruments but also principles.

The main thesis relating to use of air-conditioning was that once it was switched on, it would remain on until it reached a standard temperature setting, such as 21˚C. Just as heating degree days (HDDs) are well established to assess the number of hours heating is needed over the course of a year, so cooling degree days (CDDs) can be used for the same effect for air-conditioning use. One problem in doing this is that there is no agreed standard for the base temperature for cooling degrees to be measured from. Another is that climate change predictions suggest that using historic records is unrealistic, since 11 out of the last 13 years have been the hottest on the global record. In the UK, with no heatwave, and flooding across the country in May and June, 2007 still averaged one degree higher than the long-term average, so that the year was the third warmest since UK-wide records began in 1914. In this 94-year series, the last six years (2002-2007) have become the six warmest (Met Office 2007).

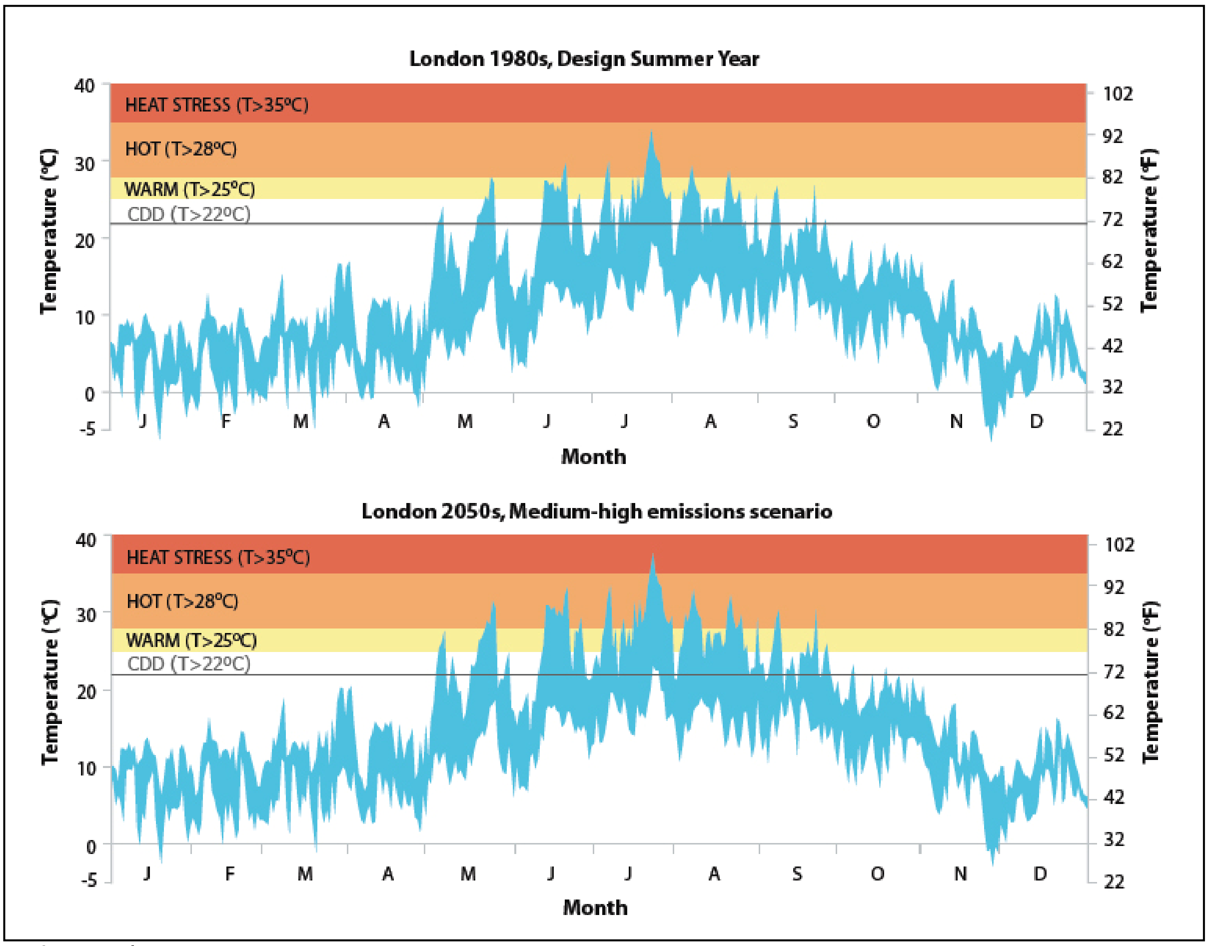
For these reasons, the model used the UK Climate Impacts Programme's (UKCIP) climate models to provide input on climate scenarios for 2020s, 2050s and the 2080s compared to the present. These show that under any of their three emissions scenarios, it is the south-east, other southern areas and the eastern regions that are most affected by seasonal temperature increases, with hot summers becoming a regular occurrence. New models have recently been published, but the work in this model is based on the 2002 reports. Mean temperature changes do not really describe the impact for people in terms of likelihood of buying air-conditioning, or using it. Peak temperatures and heatwaves are the key drivers in this respect.

The UKCIP scenarios measure peak temperature by counting the number of days where the daily-average temperatures exceed the baseline temperature. This baseline is defined at the 90th percentile of the 1961-1990 temperature data. The peak temperature therefore captures the hottest remaining 10%, i.e. the average temperature of the hottest 9 days in a 90 day summer. For southern England in winter this is 11°C and in summer it is 23°C. By comparison, for Scotland these figures are 7°C and 17°C. The scenarios show that the peak temperatures will vary around the country and with the emissions scenario. In general, the change in the 2020s is only about 1.5°C in the south, but in the 2050s it is up to 4°C. By the 2080s, temperatures increase by 4-7°C in the Southwest, and around

2°C in Scotland. The number of days that these high temperatures occur is also calculated: around the country, except in Northwest Scotland, the number of days exceeding the baseline changes from 9 days by definition (10% of 90 days) to about 20 by 2080. In SW England, the daily-average temperature is likely to exceed 30°C about once every ten days instead of two or three times over the summer as a whole (Hulme et al 2002).

However, these are average-daily temperatures and only hint at the peak temperatures experienced in the day time. Further work by the Chartered Institute of Building Services Engineers (CIBSE 2004) models future 'hot' summers using hourly temperatures instead of daily means. Hot summers are used for worst case scenarios, indicating future risks from extreme temperature which can be hidden in mean forecasts. Figure 1 shows the historical temperature record from the 1980s and its projection in 2050. This graph is useful because we can see both peak temperatures and how long was spent at or above a particular temperature over the course of a year. Under the medium-high emissions climate scenario, it can be seen that temperatures in a hot 2050s summer will peak in the heat stress zone (T>35°C) and the time spent above 25°C has risen dramatically (Hacker et al 2005).

Figure 1: Design Summer Years for 1980 and 2050



Hacker et al 2005

The period above 22°C increases even more so, to include half the period between July and September and also parts of May. This directly influences the number of cooling degree days.
We use the UKCIP-selected 22°C as the maximum temperature above which cooling is needed on the basis of standard building engineering practice. CDDs are then calculated in the same way as HDDs, where the day's average temperature above 22 becomes the degrees of cooling that is summed for the year. Under the UKCIP baseline conditions, between 2100 and 2300 HDDs are required in southern England (3000-4000 in Scotland). CDDs are 310-330 in southern England, 20-50 in Scotland (Wu & Pett 2006).

The next challenge to the model is to determine how to model adoption and use of air-conditioning in response to these temperature changes.

In evidence to the House of Lords Select Committee on Science and Technology (2005), representatives of the Institute of Refrigeration made a number of points about the size of the market and its rate of growth, including that its split is approximately 95% commercial and 5% residential. In homes, market penetration is less than one per cent, probably less than half a per cent as a best estimate, and end-users commonly either buy very cheap equipment rather than the best on the market, operate the equipment badly and tend not to maintain it in an optimum fashion. The Institute representatives went on to compare market growth in buildings with the market for air-conditioning in cars: ten years ago the penetration in that market was probably about 10% of new cars, mainly in the luxury segment of the market. In 2004 about 75% of new cars had air-conditioning. They pointed out differences in the markets' characteristics. For cars the turnover is relatively short — replacement for cars is every few years — and in the residential situation it is quite complicated to retrofit air-conditioning (ibid.). The Institute therefore would not expect dwellings to reflect transport air-conditioning growth, but they were alert to a growing trend.

There is a fear that adoption will mirror US trends where it is perceived that air-conditioning is a 'must have' in any household. In fact, where retrofit is concerned, and comparing use against the north-western US, which has a similar type of climate to the UK, use of air-conditioning 'all summer' increased from 6.7% in 1981 to 14.7% in 1997, and using it 'not at all' dropped from 7.3% to 3.7% in the same period (EIA 2000 in Wu & Pett 2006). However, there is a significant trend to install central air-conditioning units rather than wall units — which would be expected to be the main purchase in the UK. Once purchased, the theory is that people will use them and grow more accustomed to controlling their environment to provide a high degree of comfort.

What drives this use in the UK and how can it be incorporated into a model? To answer this we calculated the proportion of people who would choose to use air-conditioning in the home for a given temperature range. The factors involved in this were:

- The 'personal comfort zone'. Although work on dynamic adaptation provides increasing understanding of thermal comfort (e.g. Lopes *et al* 2007), we developed an approach by setting the mean temperature and comfortable temperature range for the population, and assuming a normal distribution.
- Cost, which should include both upfront and running costs with the former probably being more critical.
- The degree to which air-conditioning outside of the home (such as at work) defines individuals' personal comfort zone.
- Fashion or social status, which could imply more or less cooling requirement.

Four model population groups were defined to represent each influence:

A. The whole population.
B. The population who can afford air-conditioning. We have used the distribution of households paying higher rates of council tax (bands D to H), assuming they adopt air-conditioning as a lifestyle option[1].
C. Assumes that rural dwellers experience a 'fresher' temperature and are more resistant to air-conditioning than urban dwellers. The distribution of urban and suburban dwellers is taken from the English House Condition Survey 2001 regional data (ODPM 2003).
D. Assumes that people decide to use air-conditioning based on whether their work environment is air-conditioned. Air-conditioning incidence is principally high in the commercial sector, including offices, retail and leisure. The data on professional occupation is taken from the 2001 Census (ONS 2006), and uses an assessment of office quality variation by region previously developed by ACE (Pett & Ramsay 2003).

[1] This may be correct in the early years, but data from the USA shows that in practice there is little difference in uptake of air-conditioning between socio-economic classes (cited in Waide 2004)

These groups are used to determine the population size, in South England, who will buy air-conditioning. Because the aim is to identify the scale of unconstrained growth it is assumed that a mature market exists, i.e. everyone in the group who is uncomfortable has purchased air-conditioning. It must be noted that the population groups show considerable overlap and cannot be added together – high-income, urban-dwelling office workers are not uncommon. Groups C and D both represent different aspects of experience of air-conditioning in respect to their residential choices, but with potentially different population sizes. The groups are not adjusted over time and therefore it is assumed that the population is stable with respect to the four groups.

One factor was left, though, which was the individual choice (or peer pressure) of whether to turn the air-conditioner on or not — the Comfort Scenario.

For this we made extensive use of the work done by Elizabeth Shove and Heather Chappell at Lancaster University (2004). The Future Comforts project worked with stakeholders to define four Comfort Scenarios. It addressed both heating and cooling issues, examining the relationship between climate change, conventions of thermal comfort and the built environment. In it, Shove and Chappell describe a matrix of attitudes to thermal comfort (Table 1) and conclude that there are four possible scenarios:

I. **The comfort zone extends** — People are comfortable in a much wider range of indoor temperatures, and they expect to be colder during the winter and warmer during the summer. Seasonal fashions would be geared towards providing comfort indoors without contributing to climate change. Building designs would only need to maintain temperatures within more 'elastic' definitions of comfort so that resource consumption would be significantly reduced.

II. **Indoor climates diversify** — In this scenario, regional climate differences are positively valued through, for example, local cultural reinvention. This would massively reduce the environmental cost of comfort for a moderate climate and we can expect people to accept and adapt to rising temperatures. This scenario is less probable since standards are presently anticipated to converge globally.

III. **Standardised efficiency** — In this case conventions of comfort and clothing stabilise but far more efficient ways of providing and delivering precisely defined conditions of 'comfort' are developed, such as new forms of technology, better controls, or climatically sensitive passive design strategies.

IV. **Escalating demand** — Interpretations of comfort will develop in ways that are even more demanding than those of today. People, for one reason or another, expect to be even warmer during the winter and even cooler during the summer. The energy demand will increase as a result along with associated emissions.

Table 1: Theories of Comfort

	Theory	**Concept**	**Temperature characteristic**	**Achieving comfort**
Physiological	Biological heat balance	Natural climate as the threat to human productivity – a threat to be kept at bay	22°C 'thermal monotony'	More efficient air-conditioning
Adaptive	Physiological / behavioural adaptation	Modify the external climate: mediate and transform but do not exclude	Indoor conditions 'float' with external ones and provide variety of experience	Natural ventilation exemplars and adaptive standards
Social Convention	Social and cultural experience	Mediated indoor climates; thermal needs and thermal conditions defined by	From 6 to 30 °C depending on society	Promote diversity in meanings, experiences and expectations

		socio-cultural and socio-technical worlds prevailing		

adapted from Shove and Chappell 2004

The first two Comfort Scenarios suggest that air-conditioning does not become a major threat, and the level of use will be linked to the frequency of ‘hot’ days. In scenarios III and IV however, the assumption is that not only will air-conditioning be used all the time to maintain indoor temperatures within the range defined by cooling degree days, but it could be used to deliver unreasonably low indoor temperatures during peak heat periods.

These four Comfort Scenarios were used in the model to define the average daily-mean temperature levels at which the populations would turn on and turn off their air-conditioners — their Comfort Zones.

The Comfort Zone is a normal distribution which specifies the comfort range of the population. Most of the population is comfortable at the average temperature whilst fewer are comfortable at the extremes. We define the normal distribution using the mean comfort temperature and the standard deviation, the temperature range within which a fixed proportion of the population is comfortable.

The modelling takes Scenario III as the baseline to set the mean comfortable temperature and temperature range. We use outdoor temperatures because this is the basis of the CDD and HDD. The mean comfortable temperature is set halfway between the HDD (15.5°C) and CDD (22°C) limit, ie 19°C. We must assume that most of the population will be out of their comfort range at the CDD or HDD limit and therefore switch on their system. For simplicity we set the CDD limit at one standard deviation, which is 84% of the population.

Comfort Scenario I specifies a much wider range of comfortable temperatures but the same comfort mean. We therefore move the first standard deviation to 26°C, an increase of 4°C from the 22°C in Scenario III, which we believe is realistic.

Comfort Scenario II has no mean temperature or range. This is because people have adapted to whatever climate changes have occurred, however unrealistic this may be.

Comfort Scenario IV demands even lower summer temperatures and therefore the mean temperature has dropped to 17°C. Since the range does not change, the 84% limit (1 SD) falls to 20°C.

Table 2: Population comfort zones

Comfort Scenario	Mean temp [°C]	SD [°C]
I	19	±7
II	n/a	n/a
III	19	±3
IV	17	±3

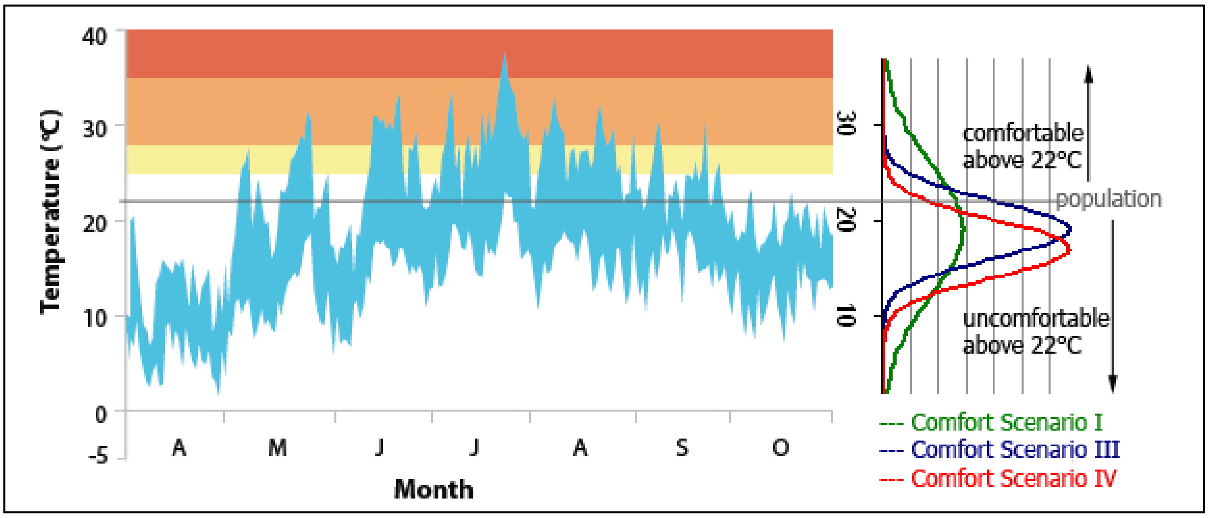
The following paragraphs quantify two methods for analysing the cooling demand. We can assume cultural lock-in of the 22°C limit and the uncomfortable population proportion changes, or move the temperature limit so it represents 84% of the population and recalculate the CDD.

Cooling demand at 22°C limit for varying population proportions

By plotting the population against the Design Summer Year (DSY) chart (Figure 2) we can see what proportion of the population is uncomfortable at a given temperature and how long they will stay in it. Comfort Scenario III is drawn in dark blue and the population below the 22°C line is uncomfortable at any temperature above 22°C. This is the majority of the population (defined at 84%). However, in Scenario I (shown in green), a smaller proportion is uncomfortable (66%) and would need cooling. In

Scenario IV (shown in red) 95% of the population demands cooling. The CDD can be adjusted accordingly to give the proportional population weighted CDD (PCDD, Figure 3).

Figure 2: Population comfort zone illustrated against a DSY

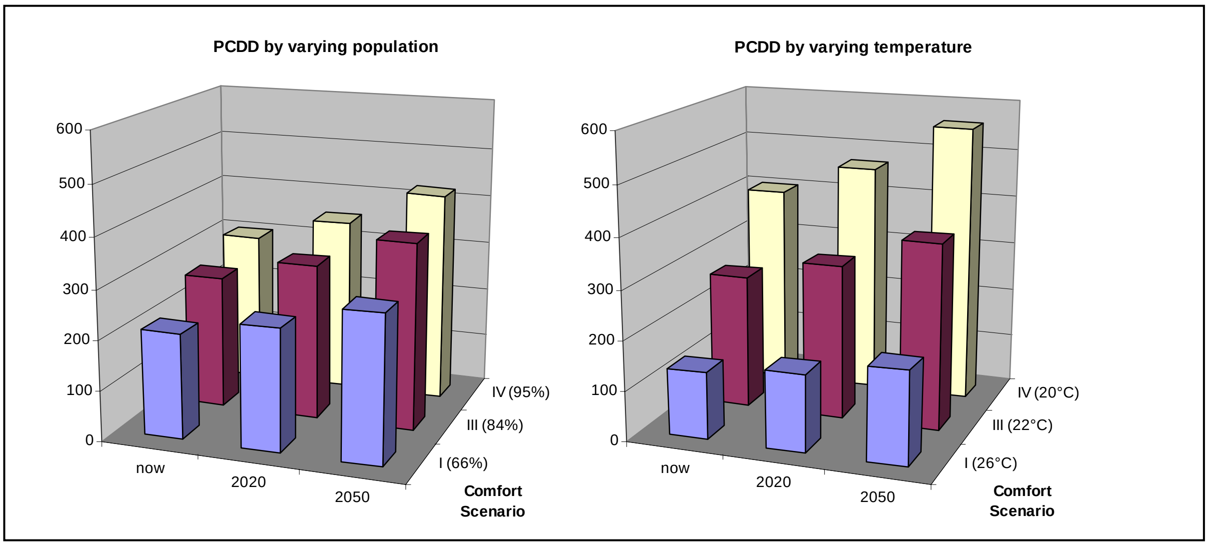


Cooling demand for 84% of the population at varying temperatures

The comfortable temperature limit for 84% of the population is 26°C, 22°C and 20°C under Scenarios I, III and IV. As we have seen above, however, the CDDs do not change linearly with temperature.

From the DSY, we estimate the CDD halve when the limit is 26°C and multiplies by 1.5 at 20°C. This is applied to 84% of the population (Figure 3).

Figure 3: PCDD variation



These initial results suggest the greatest risk, and most effective method of reducing air-conditioning use arises from changing the expected temperature, rather than limiting the population demanding cooling at 22°C. However, a number of critical assumptions are made which need further research.

The final air-conditioning demand indicator is calculated by multiplying the PCDD by the population size of each group. The results of this are fed into the calculation of electricity demand and climate forecasts to produce the energy demand and CO_2 emissions under current forecasts.

Results of modelling using scenarios

As shown in the previous section, a comprehensive demand model in which a population cooling degree demand can be calculated from outdoor temperature increases and personal comfort zones under four Comfort Scenarios has been developed. It assumes that all those who wish to purchase cooling technologies do so, and that electricity demands of those technologies follows the predictions of the Market Transformation Programme and others, which models energy consumed for a household of three people with one C rated (EER=2.3) 10,000 BTU single unit air-conditioner sufficient to cool a south facing 25m2 living room2. Because the house is not occupied during the hottest period of the day, the air-conditioner is only used for 8 hours of each degree day (Wu & Pett 2006).

Four Population Groups were considered under four Comfort Scenarios. However, Population Groups C and D were very similar in size, so the difference between the energy use and emissions was negligible, and the results are intermediate between Population Group B (those who can afford it) and the population as a whole (group A). Comfort Scenario II assumed no take-up of air-conditioning, so uses no additional energy and produces no modelled emissions. The results are shown in Table 3 where the mean daily temperature trigger point is shown in brackets.

Table 3: Estimated residential air-conditioner use: Population Group A

	Scenario I (26°C)		Scenario III (22°C)		Scenario IV (20°C)	
Year	**Energy /TWh**	**Emissions /$MtCO_2$**	**Energy /TWh**	**Emissions /$MtCO_2$**	**Energy /TWh**	**Emissions /$MtCO_2$**
2020	3.8	1.6	7.6	3.3	11.0	4.9
2050	4.6	2.0	9.1	3.9	14.0	5.9

Population Group B

	Scenario I (26°C)		Scenario III (22°C)		Scenario IV (20°C)	
Year	**Energy /TWh**	**Emissions /$MtCO_2$**	**Energy /TWh**	**Emissions /$MtCO_2$**	**Energy /TWh**	**Emissions /$MtCO_2$**
2020	1.7	0.7	3.5	1.5	5.2	2.2
2050	2.1	0.9	6.9	1.8	10.0	2.7

These figures agree in magnitude with the Market Transformation Programme (MTP) projections (MTP 2006) but not in detail, as the MTP include in their model neither growth in residential use nor climate change drivers. The free market (total population) group shows energy consumption varying by as much as 7.2 TWh to a maximum of 11 TWh in Comfort Scenario IV by 2020. However Scenarios I (shown in the table) and II (no adoption of active air-conditioning, so zero emissions) suggest some adoption of air-conditioning can be absorbed within the system as, in winter, a reduction in Heating Degree Days is expected. Population Group B, where purchase is constrained by affordability, shows a similar pattern.

The UK Building Regulations in the residential sector are predicted to save 5.5 $MtCO_2$ (1.5 MtC) across this period, assuming that the latest zero carbon building targets do not change the market before their introduction date of 2016 (ref and check dates). From our analysis, free market purchase of air-conditioning could negate 15% to 90% of these Building Regulations savings. Emissions from residential air-conditioning could be as high as 5.9 $MtCO_2$ in 2050, allowing for improvements in energy efficiency but using the MTP's assumption for medium-term carbon intensity of electricity (i.e. for 2020; MTP 2007a). By 2050, depending on power supply policy and the resultant energy mix, carbon intensity ought to be lower, but could be similar, or perhaps higher – of course with corresponding implications for air-conditioning emissions. In the next section we examine the policy implications for the residential sector, and consider whether there are interventions that could be

[2] Calculated using manufacturers sizing guide
http://www.delonghi.co.uk/feature_pages/air_conditioners_feature/air_conditioners_microsite.php
An EER 2.3 10,000 Btu air-conditioner uses 0.8kW.
Energy =air-conditioning demand *# hours unit is on in a degree day*energy consumption of unit/people per house
=air-conditioning demand*8*0.8/3 (in kWh)

made to persuade the consumer towards the lower carbon options of Scenarios I and II. We then ask what these approaches imply for policies for cooling in the commercial sector, which continues to drive the market for improvements in air-conditioning (MTP 2007b).

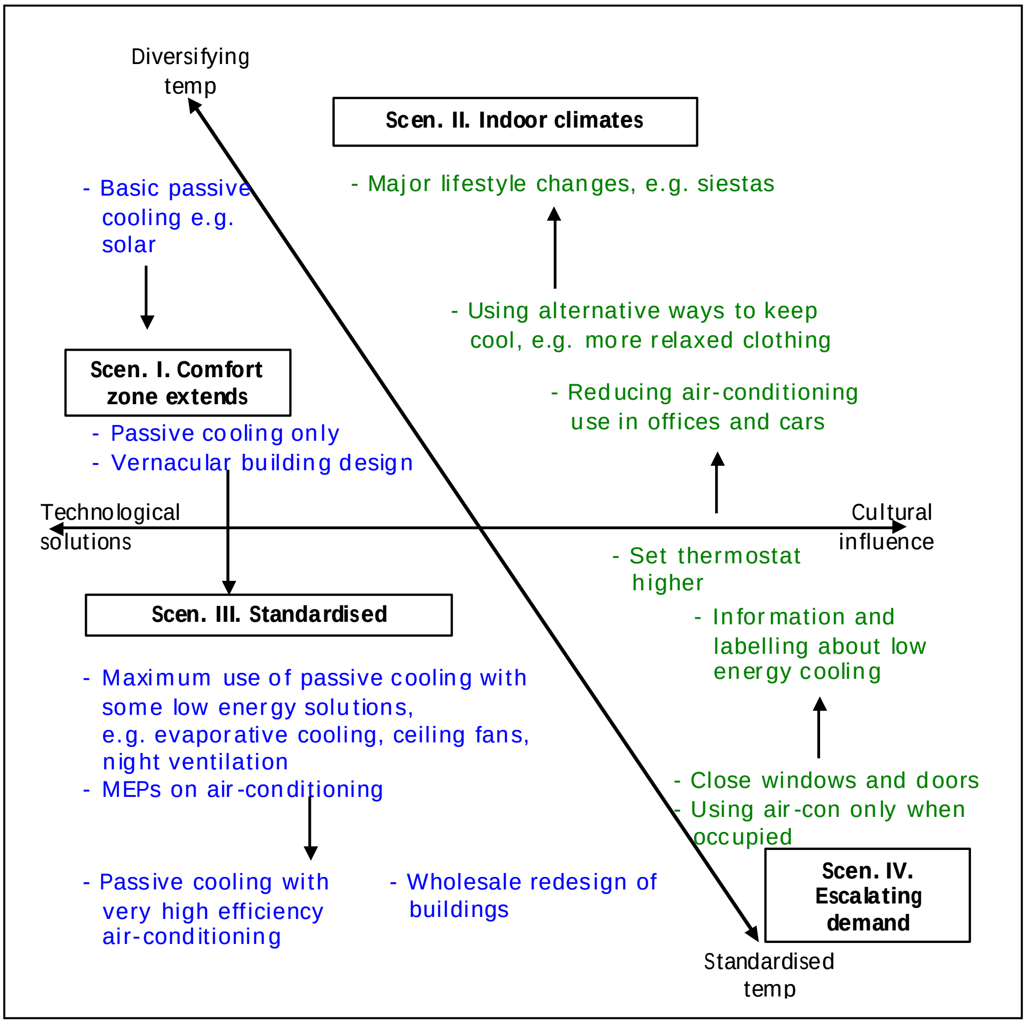
Policy implications for the residential sector

The approach to cooling demand can be made from two different angles — changing our environment and changing our attitude to the environment. The two approaches intersect, and policies combining the two, such as minimum energy performance standards (MEPS) and labelling, have proven effective. The main decision, therefore, is the point of intersection which will determine at what level CO_2 emissions are controlled. This in turn may determine whether more effort needs to be expended in developing a comfort scenario more akin to I or II, which are strongly behavioural, or III or IV, which rely more on technical achievements and their market penetration.

Policies must be revisited regularly based on the most up-to-date climate change scenarios. For example, if temperatures of 42°C occurring twice a week were predicted moving towards 2080, it is clear much stronger policies would have to be adopted to improve buildings. Deadlines for reviewing and acting on the information should be drawn up now to ensure the policies are introduced sufficiently early to be effective, particularly as, unlike commercial sector, residential buildings generally have a much longer life expectation, so that lifecycle emissions take place over typically 60 years or more, compared with as little as ten years in the office sector (Pett & Ramsay 2003).

In Figure 3 we express the policy focus diagrammatically to show the relationship between diversifying attitudes to temperature versus standardised temperatures on the one axis, and technological versus cultural solutions on the other.

Figure 3: Schematic of scenarios, and attitude and policy responses



It can be seen that for Scenario I, the focus is on passive cooling measures, including adoption of vernacular design for new buildings, and solar shading or use of solar energy to drive active systems where they must be used. Such technologies may offer less control and are unable to lower temperatures by as much but still within the range of comfort for all but the most extreme temperatures — e.g. taking the lower and upper limits for comfort at the 10% and 90% deciles rather than at the current standard.

Scenario II focuses on standardised efficiency, using passive and low-energy solutions wherever possible. Achieving this Comfort Scenario can be attempted through best practice usage, such as setting thermostat temperatures for cooling at 25°C. Campaigns which highlight the huge increase in energy use and its climate impacts could persuade people to raise the temperature slightly.

Scenario IV, 'escalating demand' is based upon the premise that air-conditioning offers the greatest control over the environment and is a silver bullet for achieving closely defined temperatures in a wide range of situations. This scenario would mean air-conditioning is perceived not only as a necessity, but an opportunity to provide relief against outside temperatures. The energy consumption must therefore be reduced by minimising the air-conditioning load, through passive building measures, and maximising systems' efficiency. Because demand is so high building designs must be re-examined and the highest efficiency standards set through ambitious MEPS and labelling. Maintaining and servicing cooling equipment also becomes a priority and legislation such as the Energy Performance of Buildings Directive's Article 9 would need to be extended to smaller units.

Finally, in scenario III, the solution is to value regional climate differences since very little climate control or cooling is allowed. This requires a strong element of 'return' to non-technological solutions, and will be difficult in countries where the majority of the buildings are already built in a style that does not allow for adaptation to vernacular cooling technologies such as those found in Mediterranean and African climates. Alternatives could include societal changes to work and education patterns, such as adopting a siesta, which has already been mooted in a light-hearted way. This would actually be easier than adapting buildings wholesale, as less investment is needed, provided there is agreement by all sectors of business and industry. Further analysis is needed as other factors are involved, including child care and traffic patterns. The fashion industry could receive a boost, as a wider range of clothing would be required to fit the new acceptance of temperature ranges.

Policy implications for commercial sector

One of the key issues for our study is that the rise of cooling demand in the home is largely influenced by what people experience at work, when shopping, during entertainment, and so on. Therefore none of the policies suggested in the previous section can be introduced without a parallel and even vanguard of policies for commercial buildings so that residents can experience and see changes for themselves.

Research in this area is already quite advanced, with Glass For Europe sponsoring work from TNO on the options for reducing emissions in air-conditioned buildings using solar glass (TNO 2007), and Aebischer's work at CEPE on the implications of climate change on commercial sectors in different European regions, where emissions are strongly influenced by the carbon intensity of the electricity supply (Aebischer et al 2006). However, these and others tend to focus on a business-as-usual perspective for active cooling systems. Only TNO include an option where substitution of passive systems for active ones is a realistic solution. Thus, through our assessment, policies for the commercial sector to achieve satisfactory cooling under Comfort Scenario III are the ones currently under scrutiny for reducing CO_2 emissions to achieve Kyoto commitments and the targets considered at the UN climate change conference in Bali (December 2007). The approaches on MEPs, top runner solutions and, importantly, research on adaptive indoor comfort and its relationship with outside temperatures, do no more than accept an engineered solution to a narrow range of indoor temperatures. The challenge would be to implement and increase in that range, following the Japanese example of relaxing the office dress code through the Cool Biz programme and raising the thermostat setting to 28˚C (JLGC, 2005).

However, the more we move towards the diversifying temperature/cultural solutions axis, the more policies will need to be integrated with others. For example, a move towards Comfort Scenario I would require a review of workplace statutory health and safety temperatures, and towards Scenario II a review of workplace practices including hours of work, flexible working, school and transport co-ordination, and much more. A return to vernacular architecture in city centres, where air quality is also a serious issue, provides a technical and architectural challenge, but buildings such as the Commerzbank Tower Frankfurt and 30 St Mary Axe London (the 'Gherkin'), both designed by Sir Norman Foster & Partners, are intended to provide cool air circulation through natural airflow inside the building envelope. However, in a speech to the BRE annual conference 2005 Sir Norman regretted that British executives still wanted to keep the air conditioning on. Clearly cultural issues play a major part here. These are issues which require further research, not only technological and behavioural but also wider cultural issues.

Summary & Conclusions

Taking into account the likely development of the UK's climate, particularly in the South and East of England, there is a high risk of increased take-up of active air-conditioning solutions to indoor comfort, spear-headed by users' experience in the commercial sector, which for many is their place of work.

The expectations of comfort play a key part in determining the approaches that may be needed if electricity demand from active air-conditioning are to be contained. There are already attempts being made to build commercial buildings which do not rely on active air conditioning, but societal preferences, at least in the UK, seem to require the technology fix rather than an adaptive response. Policies which recognise that societal response is a function of our everyday experience appear to hold more promise for a change of perceptions of comfort, but these need to be addressed across all our everyday experiences, integrating workplace, school, travel, recreation and home, in order to enable influences in one area to take root. Barriers to policy implementation may be way outside the narrow focus normally taken by the policy maker.

There are numerous ways in which the market for air-conditioning, both residential and commercial, could develop. To minimise the risk of this contributing significantly to CO_2 emissions, particularly in the potential growth market represented by the residential sector as informed by the commercial sector, an integrated policy approach is required. This must be an approach that views the demand for comfortable indoor environments as a whole, a system which is informed by everything on the spectrum from the external climate at one end, to individuals' internal perception of comfort at the other, regardless of the type of indoor environment.

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Programmes and Energy Services

High Efficient Circulation Pumps for the Building of Vienna

Georg Benke, e7 Energie Markt Analyse, Vienna
Edgar Hauer, MA27 - MA 27 – EU-Strategie und Wirtschaftsentwicklung, Vienna

Abstract

The city of Vienna is one of the major building proprietors in Austria. Apart from office buildings, there are buildings for public infrastructure (schools, retirement homes, public transport, etc.). Annually, the city of Vienna spends about 100 million Euros in energy costs. In total there are currently about 3,100 buildings. In addition, about 22,000 flats are owned by the municipality of Vienna.

The city of Vienna wants to make its contribution to climate protection with an urban efficiency program – called SEP (Städtisches Energieeffizienz Program der Stadt Wien, i.e. Urban Energy Efficiency Program, www.sep.wien.at)[1]. The program is based on technical energy efficiency measures and awareness-raising activities. Fuel switch and the use of alternative energy options are not the main focus – the message is “to raise energy efficiency”. SEP comprises and co-ordinates more than 100 single measures for the city’s demand-side energy policy up to 2015.

Main measures are:

- Promotion of energy-efficient technologies in the field of outdoor lighting
- Promotion of efficient and innovative ventilation and air conditioning systems
- Gradual conversion to traffic signal systems based on LED technology
- Promotion of energy-efficient circulation pumps

The effort of SEP to increase energy efficiency is foremost focused on municipal buildings, i.e. those owned by the city. The measures to promote energy-efficient circulation pumps are based on the know-how attained in the EU program "energypluspumps" [2] and the results of the German program Optimus [3]. It is estimated that about 115,000 MWh electric energy - which is equivalent to the output of a power plant of up to 60 MW - can be saved through the replacement of old inefficient pumps. In addition, adjusting the hydraulic balance especially in the larger administration buildings can reduce the heat consumption by 5 to 15%.

To start raising awareness for this subject, a comprehensive technology guideline was published, describing high-circulaton pumps, the energy efficiency label, and hydraulic balance. The main target audience of this brochure were people responsible for building maintenance. A second, smaller folder was produced for the end user. The main message of this folder was to install “A” labelled energy pumps only. First experiences with installers show that there is a lack of information about this innovative pumps and special training for installers is necessary.

For the successful implementation of the program, awareness of the city administration has to be increased. Further, it is also necessary to change the requirements for heating installations within public calls. The coming months and years will show if SEP - and in particular the program for circulation pumps – will be successfully implemented in Vienna.

History of “SEP”

On 1st July 2004, the municipal council of the Austrian capital Vienna decided that the Viennese energy Department (MA 27) should create an energy-saving concept for the whole city. The resulting energy-saving concept entitled "Municipal Energy Efficiency Program” (SEP) provides guidelines for the energy demand of the city until the year 2015. Among many measures it is also the target to increase the use of highly efficient circulation pumps.

Due to the liberalisation of energy markets many opportunities for the local legislature in the field of energy applications are restricted (mainly building regulations, etc.). At European level, the rapidly growing dependence on energy supply from abroad forces measures to reduce this dependence. The measures can be classified in three areas:

- Development of renewable energy sources
- Reduction of fossil energy in the transformation and distribution chain (e.g. CHP policy, improving the efficiency of power plants)
- Reduction of the energy demand

The city of Vienna has decided - notably in contrast to the national energy policy – to focus its energy policy on the demand side.

Energy consumption in Vienna

In 2003, the energy consumption of Vienna was 135,040 TJ (37,511 GWh). This represents 12.7% of the energy consumption of Austria. Looking at the type of energy used, oil is the main fuel accounting for about 38%, followed by gas (23%) and electricity (22%). District heating accounts for 15%. In total the energy consumption increased from 1990 to 2003 by 38%. While coal almost entirely disappeared, the share of all other energy sources grew [1].

The share of energy used by sector is as follows:

- 34% households with 46,436 TJ
- 31% traffic with 41,495 TJ
- 24% public and private services with 32,068 TJ
- 12% producing sector and agriculture with 15,040 TJ

Energy outlook

In order to estimate the future energy consumption within Vienna, several scenarios were developed. These include a "business-as-usual" (BAU) scenario as well as a savings scenario (SPAR). For the BAU scenario it was assumed that until 2015 no additional energy measures would be implemented. Thus, for the period from 2003 to 2015 a total increase in energy consumption of 12% (approximately 1% per year) is predicted. The highest increase will be experienced in the field of traffic. The total energy consumption of private households is estimated to increase by 3% from 2003 to 2015. The energy consumption in the sector of private services will increase by about 21% from 2003 to 2015. Therefore measures should focus on this sector.

Based on the planned improvements in the SPAR scenario, the increase in energy consumption will be reduced from 12 % to +7%. This is equivalent to an annual saving of 640 TJ (180 GWh) compared to the BAU scenario for the period 2003 to 2015. The saving is about 9% of the energy used in Vienna without the energy for traffic and transport (Transport and traffic is about 30% of the energy consumption in 2003).

In the SPAR scenario the highest savings will be achieved in households. The total consumption will be reduced by 6% from 2003 to 2015 (in the BAU scenario the energy consumption is rising by 3% in the same period). In the field of space heating this corresponds to about 300 TJ (82 GWh).

The private service sector should save about 200 TJ (55 GWh). This will be mainly (about 50%) achieved in room heating. The reduction of energy consumption by public services will increase from -2% in the BAU scenario to -11% in the SPAR scenario.

Measures in the SPAR scenario

To achieve the SPAR scenario a comprehensive package of measures was developed. Besides the measures for households, private service companies and industry, several measures concern the city of Vienna as a public service company itself. Energy management will play a major role. By establishing an energy monitoring system, the habits of users and the consumption shall be made transparent. As part of the documentation also the heating structure will be recorded. This is part of the creation of energy certifications according to the implementation of the EPBD.

One focus of SEP is to increase the efficiency of the heating and cooling technology, as well as to increase the market penetration of energy-efficient applications, heating systems, and electrical appliances. The use of energy management systems in the private and public services sectors is a basis for further measurements and also assists in determining the outcomes of implemented measures. This requires, in any case, an accurate collection of energy data as well as an accurate energy accounting system. Thus, the energy consumption - particularly in the public sector - will become more transparent.

Targets of the city administration itself

The city of Vienna is one of the major building owners in Austria. Apart from office buildings, there are buildings for the public infrastructure (schools, retirement homes, public transport, etc). In total there are currently about 3,100 buildings. Annually, the city of Vienna spends about 100 million Euros for energy consumption in these buildings. In addition, there are about 22,000 flats owned by the municipality of Vienna.

In its own sphere the City of Vienna wants to achieve annual energy savings of 15 GWh supported by the following measures:

- In 2008 an energy monitoring system will be established in all city owned objects.
- By 2015, stabilisation of the electricity consumption of office equipment of the city administration.
- In the field of public lighting energy consumption has to be reduced by 5% until 2015 compared to 2004.
- In the future all tenders of the city of Vienna, particularly in the area of buildings, have to pay closer attention to energy efficiency criteria.

Structure of the measures

Within SEP the energy efficiency and energy saving measures can be structured according to the following sections:

- households
- private service companies
- public sector
- industry
- agriculture
- traffic
- Cross-sectoral and accompanying measures

The measures concerning circulation pumps

One measure of SEP targets the increase of high circulation pumps within the city owned buildings, private service buildings, and in private households. In 2005 a European classification and voluntary labelling scheme was introduced for circulators in heating applications, with the aim of increasing the market share of high efficient circulation pumps. "A" labelled circulation pumps need approximately 70 % less energy than commonly installed pumps- very efficient pumps even need less than 80% energy. Common new pumps have the label C and are about 30% more efficient than installed pumps. Still more than 90% of the new installed pumps are pumps which fix speed and the energy label with C or D.

Figure 1 shows the description of the measure for promoting highly efficient circulation pumps. All the 100 different measures within SEP have similarly structured descriptions: The first part is a short description of the situation. In the second section the instruments which will be used are mentioned: the first column describes the instrument the second column the responsibility within the city of Vienna, and in the third column the means by which the instrument is implemented are described.

Figure 1: Program to support the use of energy efficient circulation pumps

Nummer: H06	**Forcierung energieeffizienter Umwälzpumpen**	Sektor: Haushalte

Beschreibung

Der Stromverbrauch von Umwälzpumpen in Heizsystemen wird oft unterschätzt bzw. sogar übersehen, obwohl bis zu 10% des Haushaltsstroms von diesen verbraucht werden können. Dabei könnte der Einsatz moderner energieeffizienter Technologien dazu beitragen, bis zu 70% dieses Verbrauchs einzusparen. Bestehende Heizungssysteme sind meist mit Umwälzpumpen auf Basis von Asynchronmotoren ausgestattet, die einen niedrigen Wirkungsgrad aufweisen, oft falsch eingestellt und obendrein meist überdimensioniert sind. Die Leistungsaufnahme beträgt je nach Einstellung üblicherweise 35 bis 110 Watt.

Bei der energieeffizienten Umwälzpumpentechnologie werden Permanentmagnetmotoren eingesetzt, die erheblich höhere Wirkungsgrade aufweisen. Dadurch ist nur mehr eine Pumpenleistung von rund 10 Watt erforderlich. Durch die elektronische Steuerung kann die Pumpe optimal unterschiedlichen Volumenströmen des Heizungssystems angepasst werden.

Diese hochenergieeffizienten Umwälzpumpen sollen sich unterstützt durch Maßnahmen am Markt durchsetzen und mittelfristig die herkömmlichen Technologien ablösen.

Zielrichtung:
Hochenergieeffiziente Umwälzpumpen als Standardprodukt etablieren

Instrumente

Instrument	Zuständigkeit	Umsetzungspfad
Entwicklung eines Leitfadens für den Einsatz energieeffizienter Pumpen	SEP-Koordinationsstelle	Technische Grundlagen und Informationen recherchieren Leitfaden an die Zielgruppen verteilen
Bewusstseinsbildung bei den Installateuren (Ausbildungsschwerpunkt)	SEP-Koordinationsstelle unter Einbindung WKO und Innung	Kooperationsmöglichkeiten mit Innung und WKO suchen Fachinformation zusammenstellen und an Installateure verbreiten (Berücksichtigung im Zuge der verpflichtenden Heizsysteminspektionen)
Schwerpunktaktionen bei Messen gemeinsam mit Herstellern und Energieberatung	SEP-Koordinationsstelle	Kooperationsmöglichkeiten mit Herstellern suchen und Messekonzept entwickeln

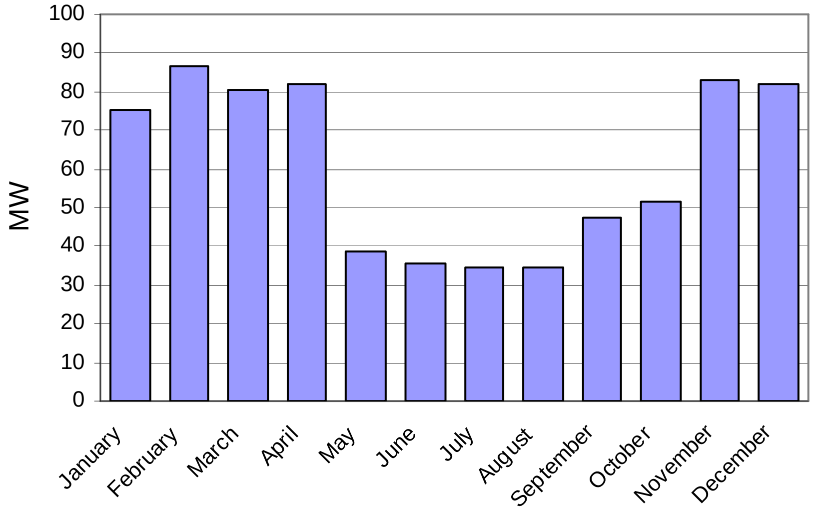
Figure 1 shows the description of the measure for promoting highly efficient circulation pumps. All the 100 different measures within SEP have similarly structured descriptions: The first part is a short description of the situation. In the second section the instruments which will be used are mentioned: the first column describes the instrument the second column the responsibility within the city of Vienna, and in the third column the means by which the instrument is implemented are described.

The energy consumption of circulation pumps in Vienna [4]

In Vienna the main energy sources for room heating are gas (50%) and district heating (30%). Most of the gas heated apartments have wall mounted boilers with an integrated – rather large sized - circulation pump. A typical gas boiler used in a Vienna dwelling has a circulation pump with a delivery head of 5 meters and a delivery volume of 3.5 m^3/h. The power range of the common fixed speed pumps used is between 50 and 95 Watt. Assuming an annual operating time of around 2,600 hours the annual consumption is about 250 kWh. With an average energy consumption of a Viennese dwelling of 2,450 kWh, the circulation pump accounts for about 10% of the whole energy consumption. In total, this kind of dwellings consumes about 68,000 MWh electricity per year.

The 30% of homes which are provided with district heating have a handover either with local transfer stations or transfer stations within the building. Depending on the situation, either the Vienna district heating company FERNWÄRME or the respective building owner is responsible for the electricity consumption of the circulation pumps and hence the electricity costs of the pumps. Larger plants usually have lower specific energy consumption (15 Watt/ apartment). However, the circulation pumps serve the room heating only during the heating season, but operate all year round for the supply of hot water. This results in a total of approximately 35,000 MWh.

Figure 2: Electricity consumption by circulation pumps in Vienna per year (2001)



All in all (including further heating systems like oil boilers, head pumps) it is estimated that within Vienna dwellings about 125,000 MWh is used by circulation pumps. This is about 160 kWh per dwelling or 8.3% of the electricity consumption (without the use of heat). Detailed data on other buildings (services and industrial buildings) are currently not available. A detailed survey is planned within SEP. Therefore, the amount of energy needed for space heating in services and industrial buildings is extrapolated on the basis of energy consumption in households. With this approach, the electricity consumption by inefficient pumps in services and industrial buildings is estimated between 80,000 to 90,000 MWh per year. Thus in total circulation pumps alone consume 200,000 to 220,000 MWh annually in Vienna. That is about 2.8% of the total electricity consumption of the city.

Energy saving potential

The energy consumption of pumps is too high due to the following reason:

1. Use of inefficient pumps
2. Use of oversized pumps
3. Unnecessarily long operating duration of up to 8,760 hours per year.

Large savings are possible in the gas boilers, which have integrated, over-dimensioned, fixed speed pumps.

In the field of district heating a potential energy saving of at least 40% is estimated, probably even up to 50% or 60% (about 115,000 MWh). This would reduce CO_2 -emissions by 80,000 tons (converted to a winter month this means a reduction in power plant capacity of 60 MW).

Economy

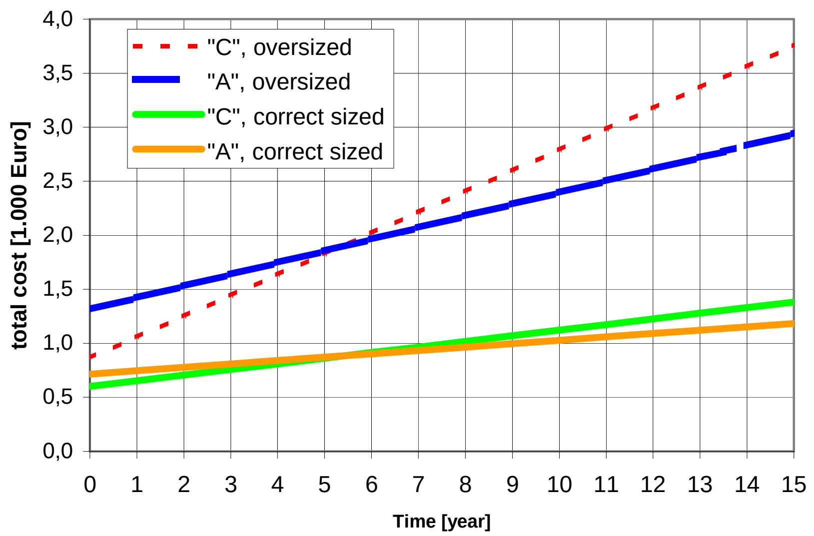
The cost-effectiveness of implementing an efficient pump technology is also impressive. A large office building with a heat demand of 150 kW needs a circulation pump with a delivery head of 3.3 meters and a delivery volume of 6.5 m^3/h. In reality the design data are much higher. Table 1 and Figure 3 show a comparison between commonly installed pumps and new efficient technology.

Table 1: Remediation options for pump replacement (pump price, annual electricity consumption)

	Installed pump with low efficiency	Common pump (oversized)	Efficient pump (oversized)	Common pump with the correct size	Efficient pump with the correct size
Investment costs [Euro]		864	1,313	605	716
Energy label	D	C	A	C	A
Annual energy consumption (kWh)	2,750	1,750	751	473	284

Pump selection and power consumption determined with data from Grundfos (webcaps)

Figure 3: total cost (price of the pump, electricity costs) for circulation pumps over 15 years for various modernization solutions.



From Figure 3 it can be seen that the correctly sized pumps are immediately more cost effective than the over-dimensioned pumps. The higher investment cost of A pumps is paid-off by lower energy costs after less than 6 years. This example demonstrates the importance of the correct sizing of the pump. In comparison to the technology installed now (oversized D-pump) about 90% or 2,500 kWh can be saved per year.

Challenges!

To achieve these savings, the following barriers have to be kept in mind:

Circulation pumps are not ordered directly by the final energy consumer. They are a part of a service (heating) or a larger product (boiler). The main arguments for an inefficient pump are the installation costs and the fuel costs for the heating system. Energy efficiency and operating costs play a minor role in purchasing decisions as the purchaser or installer of the heating appliance is not the payer of the eventual energy bill (the tenant of the building/dwelling). The circulation pump is seen as a part of the heating boiler.

Field studies in Vienna show the following results [5]:

- Circulation pumps are not known as a relevant energy consumer. Thus, awareness rising is very important.
- The energy consumption of installed circulation pumps is worse than expected.
  - The power load of about 75% of the pumps is 100 Watt.
  - The power load of the other 25% of pumps is even higher.
  - 60% of the pumps are running permanently at least during the heating period.

- Installers do not see their market opportunity: Their opinion is that the energy saving is not worth the investment.

In addition, the main arguments of the local district heating supplier against the increased use of highly efficient circulation pumps are additional costs caused by different type of fuse**,** but also required clutch plays.

As a first reaction to this market analysis, about 500 households in Austria (mainly in Vienna) are being interviewed (February to June 2008) regarding their circulators. This will estimate the knowledge and awareness levels of end users about their circulation pumps, and a strategy will be developed to address this market group.

Priorities for the promotion of the pumps

In order to change the current situation, as part of the Vienna energy program (SEP), the following activities will be carried out:

- Folder for end users
- Technical guideline for experts
- Public relations
    - Seminars
    - Press releases
    - Participation in competition
    - Participation in trade fairs
    - Participation in the German program CO_2-online
    - Advertising vy email
- Training: Training for installers
- Public procurement: Ökokauf ("Green-Shopping")

City owned buildings

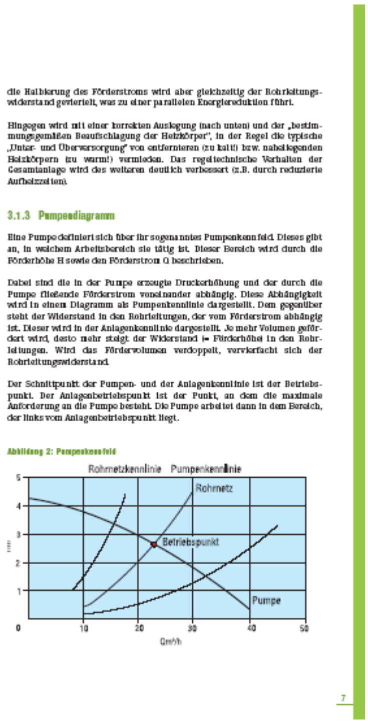
The city owned buildings are the focus of the program. Currently a monitoring system is implemented. It will include information about the heating systems and circulation pumps. First interim results are expected in mid-2008. Currently it is not specified how the program will work within the city owned buildings. Maybe there will be especially trained employees who will take care of hydraulic balance and who will control the work of the installers. To address building managers within the different departments of the city, several seminars and mailings will be organized.

The city owned buildings serve both as best practise objects as well as a role model for the market. The public procurement ÖKOKAUF can be used. Currently it is checked in which way special know how about hydraulic balance can be required within the reference of a tender. The special know how should be documented by a training session during the last year or several reference projects.

Technical guideline

To raise the awareness of decision-makers a 40 page information booklet was written (available in German only). The main target group were relevant employees of the City of Vienna, but also installers and interested citizens. The booklet was mailed to all relevant building experts within the city. The feedback about and interest in this guideline are highly satisfactory. Within the first two months about 1,000 downloads were made. Other Austrian cities and counties (e.g. Salzburg) are interested in adapting this guideline for their needs.

Graph 4: Technical guideline about circulation pumps
(download: www.wien.gv.at/wirtschaft/eu-strategie/energie/pdf/technologieleitfaden-umwaelzpumpe.pdf)



die Halbierung des Förderstroms wird aber gleichzeitig der Rohrleitungswiderstand geviertelt, was zu einer parallelen Energiereduktion führt.

Hingegen wird mit einer korrekten Auslegung (nach unten) und der „bestimmungsgemäßen Beaufschlagung der Heizkörper", in der Regel die typische „Unter- und Überversorgung" von entfernteren (zu kalt!) bzw. naheliegenden Heizkörpern (zu warm!) vermieden. Das regeltechnische Verhalten der Gesamtanlage wird des weiteren deutlich verbessert (z.B. durch reduzierte Aufheizzeiten).

3.1.3 Pumpendiagramm

Eine Pumpe definiert sich über ihr sogenanntes Pumpenkennfeld. Dieses gibt an, in welchem Arbeitsbereich sie tätig ist. Dieser Bereich wird durch die Förderhöhe H sowie den Förderstrom Q beschrieben.

Dabei sind die in der Pumpe erzeugte Druckerhöhung und der durch die Pumpe fließende Förderstrom voneinander abhängig. Diese Abhängigkeit wird in einem Diagramm als Pumpenkennlinie dargestellt. Dem gegenüber steht der Widerstand in den Rohrleitungen, der vom Förderstrom abhängig ist. Dieser wird in der Anlagenkennlinie dargestellt. Je mehr Volumen gefördert wird, desto mehr steigt der Widerstand (= Förderhöhe) in den Rohrleitungen. Wird das Fördervolumen verdoppelt, vervierfacht sich der Rohrleitungswiderstand.

Der Schnittpunkt der Pumpen- und der Anlagenkennlinie ist der Betriebspunkt. Der Anlagenbetriebspunkt ist der Punkt, an dem die maximale Anforderung an die Pumpe besteht. Die Pumpe arbeitet dann in dem Bereich, der links vom Anlagenbetriebspunkt liegt.

Abbildung 2: Pumpenkennfeld

The content is as follows:

- The circulation pump – the heart of the boiler
- PUMP ABC
- Overall pump calculation
- Technology of the pump
  - The old technology
  - The new technology
- Pump selection
- Energy consumption in Europe, Austria and Vienna
- Energy saving potential in Europe, Austria and
- Energy label
- Economic issues
- Hydraulic balance
- List of pump manufacturers on the market in Austria
- How to order energy efficiency
- List of pumps available in Austria

Training

In the year 2008 special training for installers will be offered – the main message will be the hydraulic balance. A first course will take place on April 23rd.

Folder for end users

To raise the awareness of the end user a folder was written, besides media work. This 8-page folder has the main message: "If a change of the circulation pump is considered, an A-labelled pump should be installed, as it is highly cost-effective". The print run is about 10,000 and it will be distributed through fairs, events, etc.

Conclusion

To realise the energy saving potential in circulating pumps for heating applications, it is very important to raise the awareness about circulation pumps and their high energy consumption. At the moment few people are concerned with this situation. The technical guideline in Vienna is a large step forward to change this situation. First feedback about the situation also demonstrate that the use of circulation pumps is only one side of the coin. Even more important is the correct size of the circulation pumps and hydraulic balance – which brings mainly energy savings in heat for large buildings. But the hydraulic balance is not all: rather the boilers should be installed better. This would result in even higher efficiency.

Reference:

[1]: Städtisches Energieeffizienz- Programm; Magistratsabteilung 27 – EU-Strategie und Wirtschaftsentwicklung; Dezernat Energie Schlesingerplatz 2, 1082 Wien; Wien 2007 download: www.sep.wien.at

[2]: IEE-Project Energypluspumps: Project management: Wuppertal Institute for Climate, Environment, Energy (Project coordinator and central contact); Webside: www.energypluspumps.eu

[3]: http://www.optimus-online.de

[4]: Benke, Georg: Technologieleitfaden Umwälzpumpen; Magistratsabteilung 27 – EU-Strategie und Wirtschaftsentwicklung; Dezernat Energie Schlesingerplatz 2, 1082 Wien; Wien 2007 download: www.sep.wien.at

[5]: 1. SEP-Energieeffizienz-Forum (13. November 2007, Wien), oral presentation of field studies by Viennese installers,

Business Hotel Utility Consumption and Saving Opportunities

Paul Bannister, Exergy Australia Pty Ltd, Australia

Abstract

The utility consumption of business hotels is a key contributor to the overall environmental footprint of the commercial sector, but is less well explored than the office sector.

In this paper, initial energy and water use benchmarks are presented for business hotels in Australia. Comparisons are made with comparable benchmarks from the US and Europe. The breakdown of energy and water consumption into end-use categories is identified and the key functional drivers for these end uses are identified, including space-conditioning, domestic hot water, laundry, meal preparation and swimming pools. Within each of these categories, common energy efficiency opportunities are identified and briefly discussed in terms of the scale of opportunity and the barriers that arise to implementation.

From an institutional perspective, the hotel sector is notable for a number of factors that work against efficient practice. In particular, the ownership and operational structures with large chain hotels tend to mean that there is little investment in back-of-house infrastructure, leading to significant issues with deferred maintenance, obsolete plant and outright failures at a level well beyond that present in the office sector. Furthermore, hotel operations are typically focussed on guest service, leading to a tendency towards over-servicing being used as a first response, while the resultant utility consumption impacts are given a low priority.

Overall it is concluded that the business hotel sector is a unique sector with strong opportunities for efficiency improvement but with significant barriers that need specific attention to enable efficiency gains to be realised on a large scale.

Introduction

The commercial sector is recognized as being one of the key areas for climate change action, owing to its significant impact on the international greenhouse budget. In areas such as office buildings, there is a long history of effort and a good deal of commercial activity towards the improvement of energy efficiency, but this activity is not uniform across the commercial sector as a whole. In this paper, the energy and water consumption of business hotels – one of the less thoroughly researched or commercially worked sub-sectors – is reviewed. For the purposes of this paper, business hotels are defined as typically multi-storey hotels, generally in city locations, with facilities geared towards business travelers and short-stay recreational travelers, i.e. without significant in-room cooking facilities and with only small recreational facilities (such as a small swimming pool and a gym). In the Australian context, this is particularly differentiated from the resort hotel and apartment hotel sector, which respectively have far larger recreational facilities and significant in-room kitchens.

The approach taken in this paper is firstly to examine some preliminary benchmarks developed in Australia for energy and water consumption, and then to examine savings opportunities as identified in a batch of 15 energy audits undertaken in Australia. The nature of the savings opportunities identified is then discussed in the context of the institutional and operational parameters of hotels.

Benchmarks for Energy and Water

Benchmarking is becoming recognised as a key methodology for the assessment of energy efficiency opportunity. This is evidenced by initiatives such as the European Building Performance Directive, Energy Star in the US [1] and the Australian Building Greenhouse Rating (ABGR) scheme in Australia [2]. The benchmarking study presented in this paper is derived from a preliminary benchmarking study conducted by the authors for the Department of Energy, Utilities and Sustainability of the New South Wales Government as part of the National Australian Built Environment Rating System (NABERS). NABERS is the broader environmental rating suite within which ABGR operates [3].

Existing Benchmarks

There are some international precedents for hotel energy and water benchmarks, including:

- o Energy Star for Hotels [1]
- o UK Construction Industry and Research Association benchmarks (CIRIA) [4]
- o World Wildlife Fund (WWF) benchmarks [5]

Within Australia there has also been previous work conducted by the Department of Industry, Tourism and Resources (DITR) of the Australian Government [6].

The various benchmarks use different methods for categorising hotels, making broad-based comparison difficult. As a result, a sample 300 bed hotel has been used to generate results for each benchmark. The results are listed in Table 1 and Table 2 below. It can be seen from the tables that:

- There is a reasonable consistency in mean energy figures with only a slight modulation indicated for climate.
- There is a wide range of water figures with strong indications of links to service levels and climate
- There is no consistent index for assessment of energy or water, although per bed or per bed night appear to be the more commonly favoured;

Table 1. Comparison of energy benchmark performance levels for a sample 300 bed hotel.

Location	**Energy Star**	**WWF (Based on “Satisfactory”)**	**DITR**
Warm temperate (Sydney)	53 GJ/room 1036 MJ/m²	970-1045 MJ/m²	95 GJ/room 1050 MJ/m²
Tropics (Darwin)	55 GJ/room 1064 MJ/m²	970-1150 MJ/m²	95 GJ/room 1050 MJ/m²

Table 2. Comparison of water benchmark performance levels for a sample 300 bed hotel.

Location	**CIRIA**	**WWF (Based on “Satisfactory”)**
Warm temperate (Sydney)	0.12 m³/bed (no pool, UK climate) 0.3 m³/bed (with pool, UK climate)	0.6-0.75 m³/ guest night
Tropics (Darwin)	n/a	0.9-1.0 m³/ guest night

One of the complications in making such comparisons is the relatively wide range of fundamental operational parameters that affect hotel energy consumption, above and beyond any consideration of efficiency. These are discussed in the following section.

Benchmark Development

Compensation for Service Levels

The establishment of a hotel energy or water benchmark is considerably more complicated than for offices, because of the diversity in the sector even within notional categories of hotel. Most existing benchmarks have avoided this issue by retaining a highly simplified approach. However, this reduces the degree to which the resultant benchmarks can be used to assess efficiency, as an individual hotel that may be efficient but provides a greater range of guest services will be penalised relative to a potentially less efficient hotel with fewer guest services. Thus the benchmark has to compensate for service levels.

One well-known indicator for service level is the hotel quality star rating, which is an externally managed system with auditable standards. Indeed, this type of indicator has been used in Energy Star and in the WWF benchmarks. This approach is pragmatic but does carry some risks, as there is still some diversity within star bands and not all hotels are rated. Furthermore, the rating itself permits interchanges between factors that affect energy use and factors that do not. Nonetheless the hotel rating does provide some means of identifying peer groups within the sector, and as such is important.

In addition to the hotel star rating, the following factors are feasible as sources of additional corrections:

- **Number of rooms.** This is a preferred variable for benchmarking, as it is relatively well defined;

- **Number of beds.** This is a further size variable but with greater ambiguity due to the variable relationship between guest numbers and the number of beds actually provided.

- **Floor area.** This factor is strongly correlated to the number of rooms but is not measured to any consistent metric by the industry and as such is not a preferred index for hotel size.

- **Scale of meeting/conference facilities.** This varies independently of other factors and can be a significant contributor to the overall energy use of an individual site.

- **Scale of restaurant facilities**. While this is to some extent correlated to hotel quality, other independent factors also play a strong role.

- **Swimming pools.** The scale of swimming pools offered varies widely, again with a marginal correlation to the hotel star rating.

- **Laundries.** While most hotels have some form of house laundry, this may range from a small facility for washing a few select items (such as uniforms or a guest valet service) to a large facility washing sheets, towels and other linen for more than one hotel.

- **Retail operations.** Many hotels also house some limited independent retail operations. These are typically but not always sub-metered.

- **Level of occupancy.** In principle, the level of occupancy should have a large influence on hotel energy and water consumption, although in practice for energy at least this is not as significant as might otherwise be the case due to the propensity of hotels to provide service to empty rooms in preparation for unexpected arrivals.

Other factors that may be significant for individual hotels include: the provision of staff accommodation, water supply pumping and on-site power generation in more remote locations, the presence of a casino on site, and the provision of supplementary guest services such as health spas, valet cleaning services and executive club facilities.

Data Review

The data for this study was assembled from commercial client information in the possession of the authors based on site studies and other works. As a result, the overall accuracy of source information is considered to be good. The data included:

- Forty business hotels, typically of 4-5 star rating and located in major centres. This sample is distributed across Australia.

- Seven regional hotels of 3 star rating, all of which are located in regional Western Australia.

- Sixteen budget hotels, of 2 star rating, located around Australia.

The data sample is considered preliminary and is not adequate for use in generating a finalised benchmark. Key weaknesses in the data set include:

- Limited client base: the data set related to hotels operated by a small number of hotel operator chains. However, this is an issue of limited importance given the regular changes that occur in hotel operators for a given site;

- Geographical bias: The data set was distributed across Australia but overly biased to Western Australia in the 3 star sub-group.

- Chain bias. The 2 star hotels were all of a single brand with a strong propensity to a single design approach.

Nonetheless, the data set is considered to have validity to be able to obtain a valid insight into the nature of the hotel sector energy and water consumption prior to a more complete survey.

Energy/Greenhouse Benchmark

As hotels use both electricity and fuels, and there is some interchangeability between these, the energy benchmark was developed in the format of a greenhouse gas benchmark. This allows combination of the different fuel sources in a meaningful manner, and fits with the approach used in the ABGR and NABERS programs. The total greenhouse gas emissions associated with the sites was calculated using 2005 New South Wales coefficients for all states (0.985 kg/kWh for electricity and 0.0713kg/MJ for natural gas; no other fuels were reported in any significant quantities).

A strong primary relationship was observed in the data between star rating and the emissions per room. This was used as the basis for the establishment of the benchmark. In addition, the following preliminary compensations were made to the data:

- Presence of laundry. This was determined by t-test (a statistical test to determine whether the difference in mean between two samples of data has significance) as being a significant correction at 6000MJ/room of gas

- Presence of heated pool. This was determined by t-test as being a significant correction at 19,000MJ/room of gas. In application this was multiplied by the average number of rooms per site (171) and applied as a fixed figure to all sites as it is expected that pool size does not in practice correlate strongly with the hotel size.

- Food covers. A weak relationship between food covers (a hotel operational variable roughly proportional to meals served) and energy was determined. The equation of correlation was $\Delta=6708-14.7f$ where f is the number of food covers per room and Δ is the difference between the benchmark and the actual greenhouse emissions per room (after laundry and pool corrections).

- Conference facilities. No data were gathered on conference facilities in the original data sample so no compensation has been provided.

To determine the impact of star rating on the greenhouse per room, the median, seventy fifth percentile and twenty fifth percentile in greenhouse per room data (after pool and laundry corrections) were calculated for each of the star ratings, to give an aggregated view of the data. Only the median is used for the benchmark, as the benchmark is intended to provide an indication of the performance of the mid-point of the population. The results are shown in Figure 1.

Based on the data, the overall benchmark for median performance M (kg/room per annum) is:

$$M = 5772S + 14.7f + \frac{P}{r} + l - 14171$$

where S is the star rating, f is the number of food covers per room, P is the pool correction (=232,000kg if a heated pool is present) and l is the laundry correction (=463kg/room if a laundry is present) and r is the number of rooms. The relationship between the predicted median and the actual figures is shown in

Figure 2. Note that the average number of food covers per room for sites that reported food covers (579 covers per room) was used for all sites that did not have data in the generation of this graph.

Figure 1. Relationship between laundry and pool corrected greenhouse emissions and star rating. The median relationship shown on the graph was determined using figures weighted for the sample size in each star rating. (noting for instance that the 3.5 star sample consisted of only three hotels)

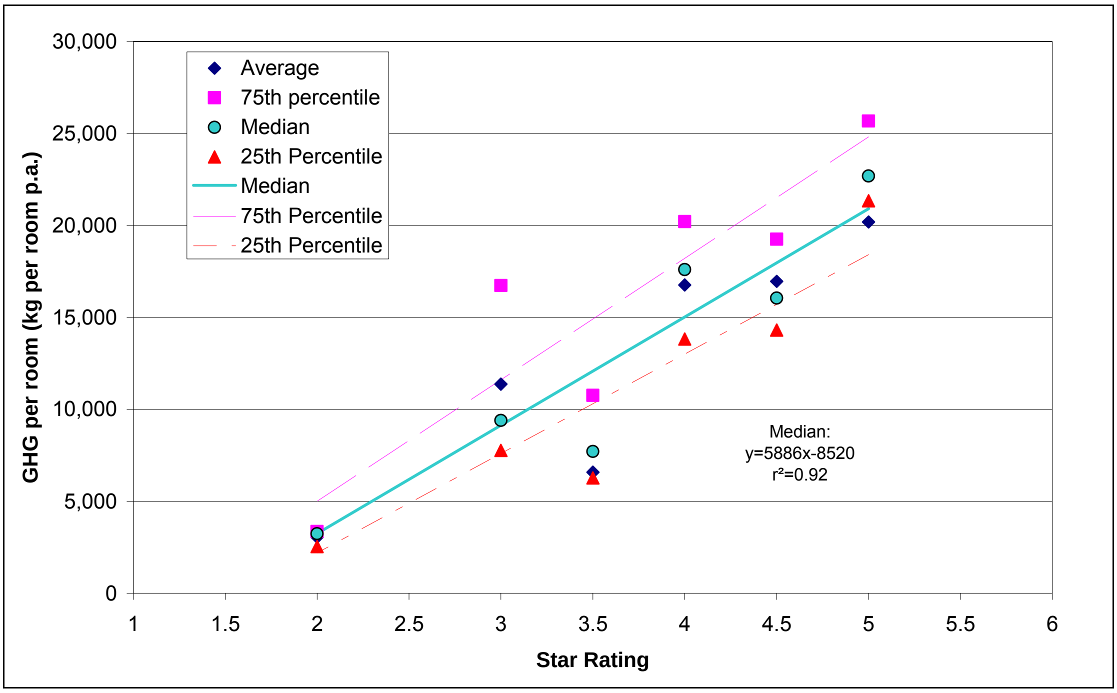
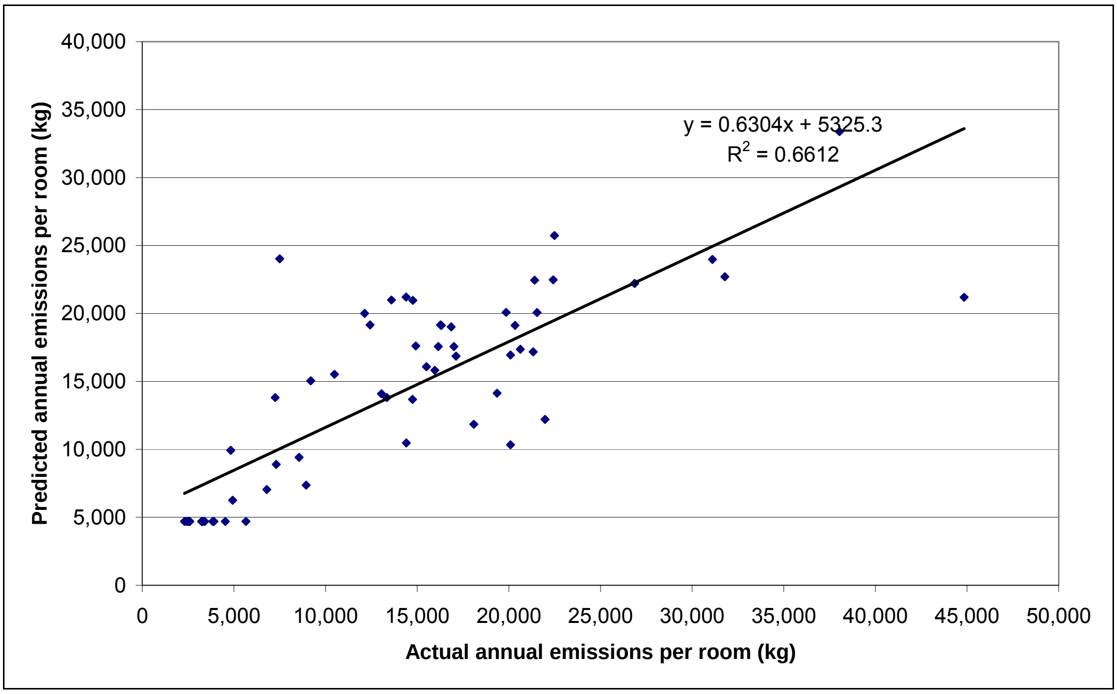


Figure 2. Predicted and actual emissions per room.



It can be seen that the benchmark is a reasonable representation of the data. While the r^2 may appear relatively low at 0.66, it is noted that:

- This relationship becomes stronger (r^2=0.81) when evaluated in terms of total greenhouse emissions.

- A degree of spread is expected, reflecting that there is a range of efficiency levels.

An anecdotal but important confirmation of the benchmark approach is that a brief review of the position of hotels relative to the author's studies of the individual hotels indicates that the vast majority display the correct behaviour relative to the median, i.e. sites below the median show better efficiency than sites above the median.

It is emphasised that the benchmark is preliminary only and that further data are needed. Further work is also required to allow climate effects to be included in the benchmark.

Water Benchmark

A similar approach was used to generate water benchmarks, due to strong similarities in the data. Nominal correction factors were derived for laundries and swimming pools as follows:

- Large frontloading domestic washing machines use around 10 litres of water per kg of washing [7]. The washing of a set of sheets and towels therefore would be expected to use around 30-40 litres of water per room night. This compares with the average water use of 590 litres per room night. As a result the approximation of 40 litres per room night has been used as an adjustment for sites with laundries. This is, however, not a significant adjustment.

- An approximate estimate of pool water consumption is around 60% of pool water volume [8]. For the purpose of this analysis, a pool water correction factor has been allowed in the proposed rating equation and has been set to 120 kilolitres, based on an assumption of 60% loss from a 200m³ pool. Expressed against the range of actual water consumption for sites (2200-109,000 kl) this is clearly only a minor adjustment.

As with the greenhouse benchmark, it was found that a significant level of variability in the data could be accounted for by assuming that different star ratings have different water consumption characteristics. No significant correlation could be determined from the balance of the data with respect to food covers or climate, and so no correction was developed for these factors.

The overall equation for the median annual water use per room in kilolitres based on the current analysis is as follows:

$$M = 45.5S + \frac{P}{r} + L\rho$$

- where *S* is the star rating of the hotel, *P* is the pool correction (120 kl), *r* the number of rooms, *L* the laundry correction (40 litres per room night) and ρ the annual occupied room nights.

The fit of the data to this median (expressed in terms of water use per room) is moderately poor, with an r^2 of only 0.41. This improves to 0.54 if the 3 star regional hotels – which have high irrigation requirements relative to the balance of the data set because of the nature of the individual sites involved - are removed from the analysis. The relationship on a total water consumption basis is somewhat better, with an r^2 of 0.85 being achieved across the full data set.

As with the greenhouse benchmark, this is a provisional benchmark only and is not suitable as a means of directly proceeding towards the development of the rating without further data collection.

Utility Use and Savings Opportunities

The author's organisation has been involved in a significant number of energy audits of hotels. In this section, the results of the 15 Australian sites within this group are summarised, comprising 3.5-5 star hotels in major centres (mainly state capitals) with a total energy consumption of 312 TJ of electricity and gas.

Energy and Water End-Use Breakdowns

As part of the audit process, detailed energy end-use breakdowns were generated. These breakdowns comprised a build up of all energy-using equipment on an hourly basis, reconciled against known usage patterns and, if available, half-hourly utility consumption data. The aggregate of these figures across the 15 hotels is shown in Figure 3 below. It can be seen from the figure that HVAC is a dominating factor; lighting and food-related equipment are also important (the latter supplemented somewhat by the presence of in-room fridges at typically 30-70W continuous load per room). Domestic hot water is also a significant load. Laundries and other loads (including pools) are minor overall although on an individual site the laundry may be more significant.

The water end-use breakdown provided in Figure 4 was generated from water audit data by Seneviratne [9]. It illustrates a typical water end-use breakdown for a hotel with cooling towers and a laundry. It can be seen that guest and public amenities dominate total consumption, followed by kitchens, cooling towers and the laundry. Swimming pools, by comparison, are relatively minor water consumers.

Energy Savings Opportunities

The focus of the energy audits was on the generation of energy savings within relatively short term pay backs (typically under 3 years aggregate across a whole site), reflecting the commercial parameters of the clients involved. While this ruled out the use of more innovative measures, such as renewable energy or more deep-seated modification of existing systems, it does provide a useful review for commercially acceptable measures. Savings measures from these audits have been categorised as follows:

- **Lighting (power density).** Upgrade of lights comprising mainly simple lamp replacements and fitting refurbishments. There is a general perception that halogen and incandescent lamps provide a certain "ambience", resulting in the liberal application of these lamp types throughout hotels for area lighting, particularly in meeting rooms and foyers. Replacement of these lamps with fluorescent alternatives or through the use of the more efficient IRC halogen lamps and electronic transformers was found to be a significant measure at many sites. Other measures included the refurbishment of fluorescent light fittings using delamping, reflectors and/or autotransformers.

- **Lighting (time of use).** Upgrade of lighting control systems to achieve turn-off out of hours. Typical measures included the installation of occupancy sensors in toilets, car parks and back of house areas and the use of timer controls in some locations.

- **HVAC (control).** Upgrade of air-conditioning systems through improvement of control. Hotel HVAC control was found to be poor at all levels, and in particular: building management and control systems were uncommon and where implemented were often very old and poorly programmed; unitary controls were often poorly configured and subject to ad-hoc modifications by the hotel maintenance staff; and time of use control was generally very poor, with an underlying assumption of 24/7 operation being prevalent even in areas that have little or no overnight use. Furthermore, the presence of significant levels of control failure due to lack of maintenance led to the availability of significant savings through the rectification of items such as broken valve and damper actuators and valves failing to provide full shut-off of flow upon closure. In some cases, equipment failure was so prevalent that upgrade to normal operational levels could not be justified on the basis of energy savings alone. In such cases, measures were limited to "work-around" solutions that were economically viable but far from optimal in terms of total savings. Other measures included: modification of chilled water and condenser water control to optimise chiller efficiency, changes to air-handler control algorithms to reduce simultaneous heating and cooling and to improve economy cycle utilisation, changes to chiller staging algorithms and the introduction and control of variable speed drives to pump circuits.

- **HVAC (plant).** Upgrade of air-conditioning plant. Savings in this area were dominated by the replacement of life-expired chillers with new high efficiency (typically magnetic bearing) chillers. The cost of such measures could only be justified because the replacement of the chiller was imminent, and thus the economics could be assessed on the basis of incremental capital cost for high efficiency chillers rather than the full cost. The presence of significant amounts of life-expired equipment was fairly typical of most hotels visited. Other measures in this category included revisions to or deletion of steam generation and distribution systems and modification of boiler systems.

- **Domestic hot water.** Upgrade of domestic hot water generation, distribution and end-use. The most common measure in this area was the reduction of shower flows to below 10l/minute. One of the 5 star hotels in the sample has had 10l/minute showers in place for several years without problem, indicating that the significant numbers of sites with 12-15l/minute shower heads could be upgraded without compromising service levels.

- **Pool.** Upgrade of pool efficiency. This was a minor category as most pools were unheated. However where pools were heated, measures included pool covers and upgrades to the pool heating system (typically through the replacement of gas heating by heat pump or waste heat heating).

- **Laundry.** Upgrade of laundry efficiency. Where sufficiently large laundries were present, laundry heat recovery was considered, primarily as an option to be adopted upon replacement of existing equipment rather than as a retrofit to existing equipment.

Energy savings were calculated for the energy audits through the calculation of the energy end-use breakdown, application of savings estimates to the individual components and aggregation of estimates. Where multiple savings measures affected a single end-use, the savings were estimated by applying the most strongly recommended (typically lowest payback) measure first, followed by remaining measures in order of priority. This approach avoided double-counting of savings. The overall savings identified constituted 25.9% of electricity consumption and 9.4% of gas consumption, equating to a total of 13,450 tonnes per annum of CO_2. These savings figures are estimates only and are not based on post-implementation measurements.

The breakdown of savings for electricity and gas can be seen in Figure 5 and Figure 6 below. It can be seen that HVAC control measures and lighting power density measures strongly dominate the available savings. This reflects the poor maintenance and capital upgrade practices in the hotels, plus the widespread use of inefficient light sources.

Figure 3. Energy end-use breakdown, aggregated across 15 audited hotels. All fuel sources are included within this figure

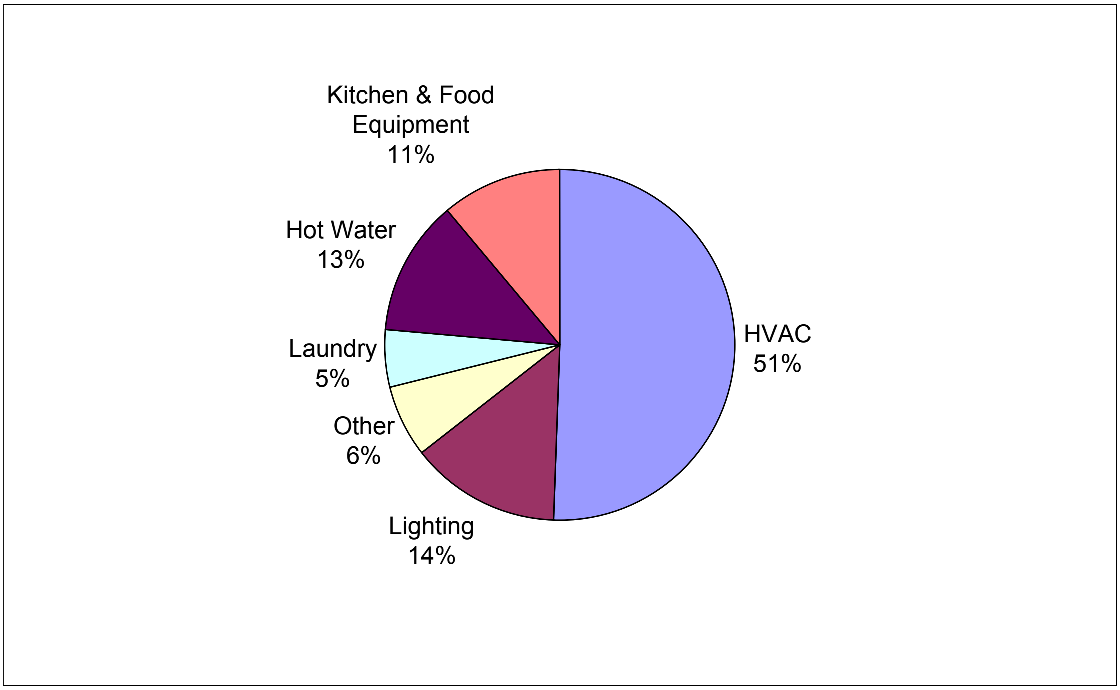


Figure 4. Water end-use breakdown for a typical hotel with cooling tower [9]

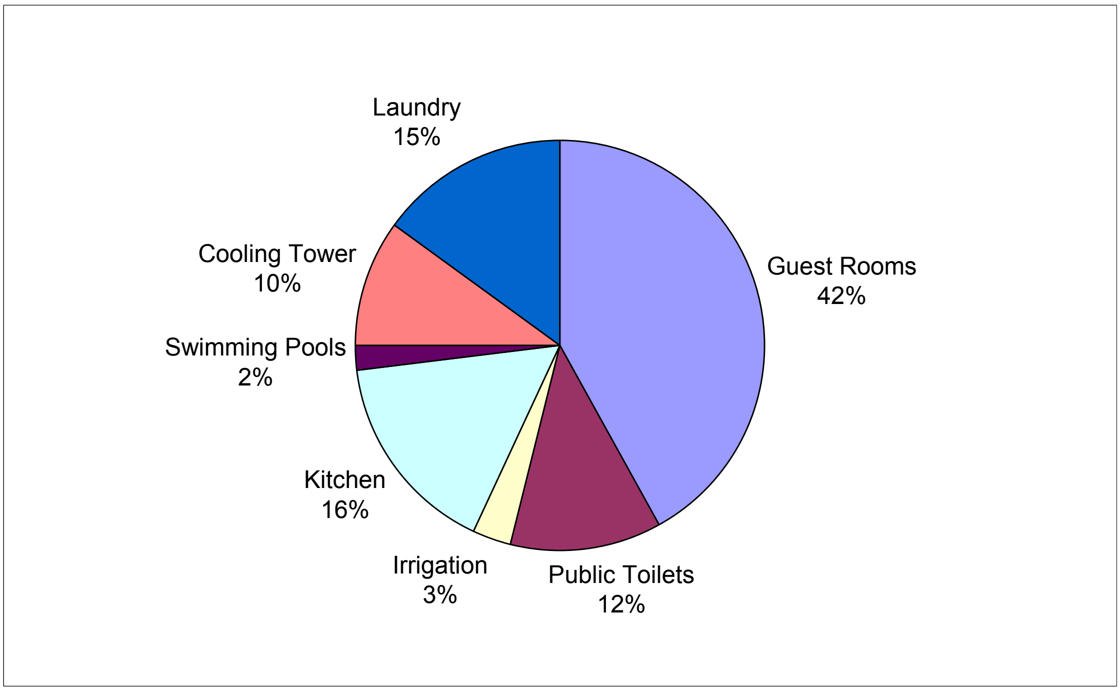


Figure 5. Electricity savings across the audited hotel sample

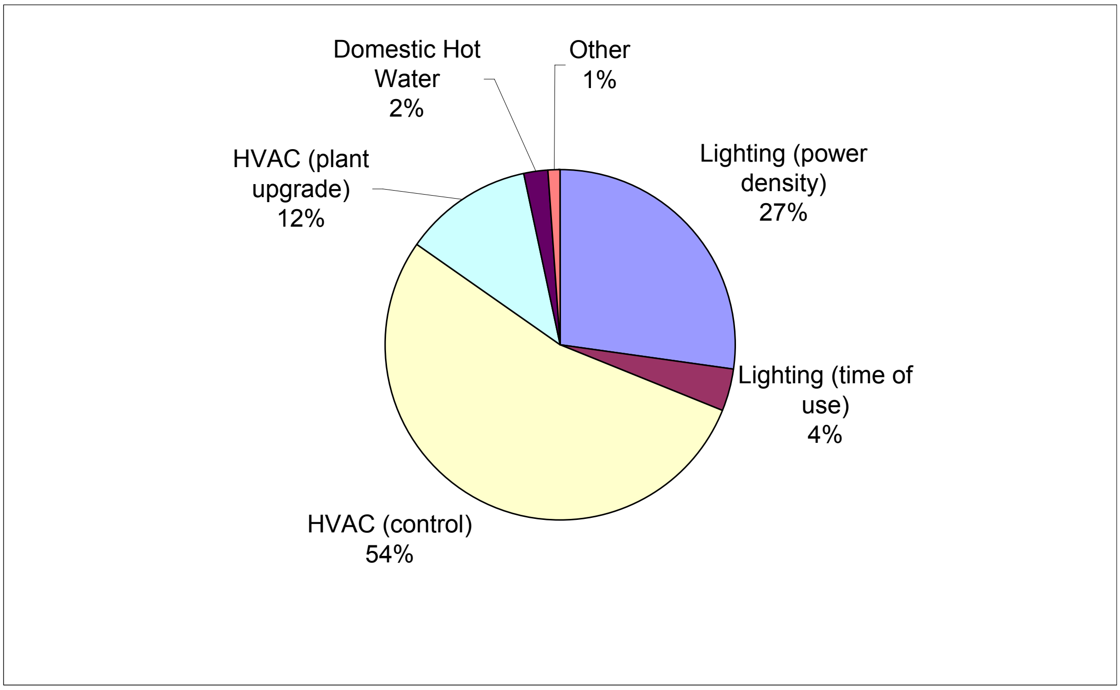
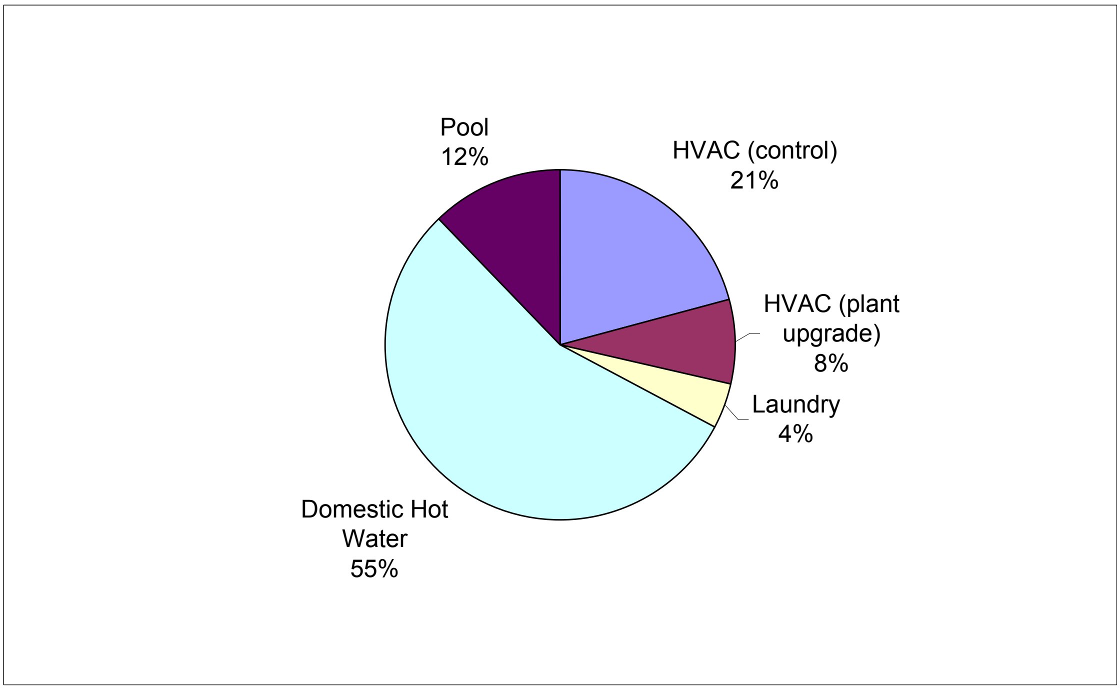


Figure 6. Gas savings across the audited hotel sample.



Institutional effects on energy efficiency in the hotel sector

It is apparent from the nature of the savings opportunities and from the broader experience of conducting the audits that there are a number of institutional effects that affect energy efficiency within the hotel sector. Key factors appear to include:

1. Ownership and management structures. The hotels audited were generally owned by relatively small-scale property investors and operated by hotel management groups. While

this arrangement is not universal, it appears common in Australia. This results in a number of barriers to energy efficiency investment, such as:

a. Owners view the hotels as a revenue-generating investment rather than an asset. This creates an emphasis on short term gains and continuity of income rather than asset protection. As a result, the key emphasis is on enhancing the short term experience of the guest through improved décor rather than attending to the maintenance of the energy using infrastructure.

b. Building on point (a) above, some of the owners were overseas-based and quite remote from the day-to-day operations of the hotels.

c. Hotel management companies also view the hotels as revenue generators, and achieve this through managing the hotels' core business interests rather than the enhancement of infrastructure. They are not generally in a position to invest in the physical infrastructure of the building with their own funds. Furthermore, hotel management contracts are of finite duration and most hotels within the group have had two to three management companies in the past 12 years.

2. Engineering skills and resources. The engineering departments of most of these hotels were very small, with typically a trades-qualified hotel engineer and a team of 2-3 tradesmen for a 200-300 bed hotel. This very limited resource has neither the time nor the skill to manage energy efficiency. Anecdotal evidence also indicates that the pay rates of such staff are poor relative to the office sector. Furthermore, there was a high degree of mobility amongst the engineers, with the typical incumbency appearing to be only 2-3 years. As a result, in many sites part of the energy audit involved discovering and explaining engineering systems in the building to the hotel engineer, who had only recently taken up the position and was not fully familiar with the scope or operation of the systems under their control. Only the 5 star hotels in the audit sample appeared to contradict this pattern, with hotel engineers of a higher level of qualification, ability and far longer term site involvement being present.

3. "The guest experience". While it is obviously the job of a quality hotel to provide a pleasant guest experience, this argument is also used to justify many poor energy efficiency practices, most typically involving 24/7 servicing of areas irrespective of occupancy. Interestingly, it was in some of the higher star rated hotels, where the engineers had a greater technical understanding of the operation of the site, that the primacy of guest service was more likely to be challenged. This demonstrates that many of the service-based arguments for excessive energy use are invalid.

The significant maintenance and plant obsolescence issues identified at many sites are considered to be a direct consequence of the above institutional factors. It was indeed quite shocking in some cases to contrast the quality of interior fitout with the state of the mechanical and electrical services.

Programs for Energy Efficiency in the Hotel Sector

Based on the above, it would appear that any programs for energy efficiency in this sector need to be targeted at the key areas of inefficiency and the key institutional drivers underlying the lack of activity in the sector. Components of potential programs could include:

- **Benchmarking and rating systems.** As discussed in the first section of this paper, it appears viable to benchmark the operational energy and water use of hotels and obtain a meaningful relationship with the level of energy efficiency opportunity from such benchmarks. This also complements the fact that the industry already is quite enthusiastic in its use of key performance indicators for assessing different aspects of business operation. However energy or water benchmarking will only become a major force when it becomes a selection criterion for travellers, either through travel policy changes for major corporates and government or through inclusion in the hotel quality star rating system.

- **Best practice guides, with examples.** The problems with skill levels and the short duration of hotel engineer residency mean that there is a great deal of poorly informed "folk-lore" about what is possible or permissible. Information that shows how different hotels have implemented particular measures without impinging upon the guest experience has a strong role to play in addressing this barrier.

- **Targeted financial assistance.** Targeted financial assistance focusing on the replacement of life-expired plant with new, more efficient plant has the ability to encourage the industry to upgrade its significant backlog of deferred maintenance.
- **Education and training.** The general skills shortage requires that more trained personnel are made available, through improved training and education. Vocational training is of particular importance as the majority of hotel engineers appear to enter the industry as a secondary career.

Conclusions

In this paper draft benchmarks have been presented for water and energy consumption in Australian business hotels. It has been shown that the hotel quality star rating has a significant impact on utility consumption. Results from 15 energy audits of Australian hotels have been summarised, demonstrating the availability of significant savings within relatively short payback periods. It has been identified that the sector is afflicted by a number of poor practices that are significantly a consequence of the structure of the industry as a whole. A range of possible measures to address some of these issues has been presented.

Overall, it is concluded that the hotels sector is a unique sub-sector of the commercial buildings sector and that it has significant opportunity for improved energy efficiency.

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Efficient Schools – Realizing Best-Practice Examples all over Germany

Felicitas Kraus, Nicole Pillen, Stefan Schirmer, Nana Doerrie
German Energy Agency (dena)

Abstract

More than 40 % of the total final energy demand in Europe can be related to non-residential buildings. Therefore Germany is focusing especially on the building stock in order to achieve economic energy savings and to reduce the related CO_2-emissions . Within the existing non-residential buildings the municipal buildings represent the lion's share of inefficient buildings in respect to the energy demand. More than 50 % of the energy consumption of all municipal buildings in Germany are caused by general-education schools. What is needed is a large scale refurbishment of those buildings according to high efficient energy standards, which would reduce costs, CO_2-emissions and would contribute to value retention. Nonetheless, the renovation rate of schools is rather low, due to lack of information and financial resources.

Dena gained a lot of experience with its "EfficientHomes" project for residential buildings, which proved on over closely accompanied 140 projects that existing buildings can be modernized using conventional measures and products so that their energy performance is twice as good as the one of new buildings. Given these experiences and the large potential hidden in the non-residential building stock, dena together with the Federal Ministry for Transport, Building and Urban Affairs started a program for existing non-residential buildings. The overall goal is to establish innovative technologies so high efficient energy standards can easily be met. Because of the complexity of non-residential buildings a pilot project focusing on schools and related municipal buildings such as kindergartens, gymnasiums etc. was set up. Other buildings categories such as hospitals, office buildings, supermarkets etc. will follow. The new program and the pilot projects (which was partly prepared within the GreenBuilding-Project), the objectives and the motivations will be presented at the IEECB'08.

The pilot project know as "Efficient Schools" started 2007. Schools were chosen for different reasons: First of all, the modernization rate is extremely low and school buildings often have a poor quality. Second, modernized schools and kindergartens have a highly PR-relevant role model function addressing and sensitizing: teachers and parents, pupils as well as municipalities and the public. Third, energy costs of non-modernized energy inefficient schools are often burdening the municipal budget. Thus the low current costs of energy efficient schools will note worthy relief the municipality's budget.

"EfficientSchools" is aiming at:

- Testing and establishing innovative and highly efficient refurbishment standards and to speed up the market introduction of energy saving technologies
- Developing energy standards for non-residential buildings that can be integrated in the legislation and into promotional programs
- Increasing energy efficiency for non-residential buildings and taping economic energy savings in the medium-term
- Promoting sustainable modernizations
- generating investments in energy efficiency and renewable
- using realized best practices as role models, for the know-how transfer and PR

Until October 2007 owners of public and non-profit buildings could apply for a participation. So far dena received more than 500 inquiries regarding "EfficientSchools". For the pilot phase nearly 80 schools have been selected all over Germany. They were chosen according to ecologic, economic and social aspects and have to meet several requirements in order to be considered for the "EfficientSchools" project. Schools have to comply with the following energy standards: building code for new buildings minus 20 % or minus 40 %[1]. As most refurbishment start in the summer 2008 the

[1] Both the primary energy demand and specific transmission heat loss need to be 20 % or 40 % less.

future will demonstrate whether the high efficient refurbishment process will be realized as planned and which measures prove to be the most efficient to reach the targeted energy savings. So far the project has make obvious that it extremely important to intensify the information of public and non-profit buildings owners about highly efficient refurbishment. It proved that they have to be strongly motivated, coached and involved. Within the calculation and planning process it also became apparent that an intensified training for architects and planners is absolutely necessary since the majority lacks experiences.

Realizing climate protection targets through greater energy efficiency

Political background.

Climate change as well as the growing worldwide demand for energy call for a strategy to increase energy efficiency. Reducing energy consumption while simultaneously improving modern conveniences and furthermore maintaining the expansion of renewable energy use are the best approaches for the reduction of greenhouse gas emissions. The German Federal Government formulated ambitious climate protection targets at the cabinet's closed session on 23.08.2007 in Meseberg:

- By 2020: Reduction of greenhouse gas emissions by 40 percent below the levels of 1990
- By 2030: Increase in the proportion of electricity generation from renewables to 25-30 percent
- By 2020: Increase in the proportion of electricity generation from CHP to 25 percent

Important parameters for the construction sector were specified in the key elements of the "Integrated Energy and Climate Programme":

- Amendments to the "German Energy Savings Ordinance " (EnEV)
  - Tightening the required standard in two stages: In 2009 to an average of 30 percent and 2012 to a further 30 percent expected
  - Expanding upgrading obligations
- Replacement of night storage heating (only if economical)
- Obligation to use renewable energy sources
- Simplifying heating cost accounting and checking whether abatement of rent is possible for violation of upgrading obligations
- CHP expansion to 25 percent by 2020 through funding and appeals to the industry (limited to 750m apportionment)
- Increasing the steadiness of the CO_2-building rehabilitation programme up to 2011 at current levels (residential buildings 700m €/a)
- Promoting the energetic refurbishment of schools and day-care centres as well as federal buildings.
- Increasing the capital stock of the market stimulation programme to 350 Mio €

Tightening the regulatory policy and reliable financial support programmes are both instrumental in unlocking the enormous potential to save energy in existing buildings. Regulatory policies and support are not sufficient on their own however. Two other important factors have to be promoted simultaneously: Innovation and information.

If highly-efficient refurbishment standards are supposed to be established and in order to reach this goal the requirements of the German Energy Savings Ordinance are to be tightened, there have to be adequate technologies on the mass market. The first tightening of the directive by 30 percent can be met using common technologies currently available. However, the second tightening of the directive, due in five years, by an additional 30 percent calls for immediate efforts to be made from all parties in the field of construction, to bring innovations to the market. The various stakeholders of the construction process, from customers to architects and manufacturers/installers, have simultaneously be suitably provided with information and appropriately trained. The climate protection targets can only be achieved by speeding up the development of innovations and the improved supply of information for various target groups.

Energy efficient school refurbishments are good for the budget and the environment.

There is high untapped energy saving potential for public sector buildings in particular.

Refurbishment backlogs are particularly significant in this area, meaning that in the following years investment in building quality must be increased. Two factors substantiate the high energy saving potential in municipal real estate:

1. In total there are around 176,000 public buildings in the municipal sector.

2. Over 60 percent of energy use and energy costs in the public sector arise in these buildings (communities, administrative districts, urban districts).

Within the general schools sector these figures are even more substantial:

1. Roughly a third of municipal buildings are schools, according to the German Federal Ministry for Education (1999 figures: 52,013 schools, of which 42,433 general education schools and 9,580 vocational schools).

2. In turn these account for more than half of energy use (19 TWh of approx. 37 TWh) and energy costs (1.1bn. €/a of 2.2bn. €/a). Therefore schools require on average around 70 percent more energy than other municipal buildings such as administrative buildings

3. At the same time, there has been a rising tendency with German schools since 1986 to invest more money in stock maintenance measures than in new buildings.

This opportunity must be used to channel investment into energy efficient refurbishing. On average the energy costs for a grammar school amount to approx. 120,000 €/a and for a primary school to less than 20,000 €/a. The predominant proportion of energy use (90 percent) and energy cost (80 percent) in general educational schools is assigned to heating. The bases for this often lie in the low level of technical furnishing in the schools with, at the same time, an unfavourable structural substance, particularly in buildings of the 60s and 70s.The statistics in terms of building ages for school buildings in Germany appear similar to those of residential buildings: around 30 percent of existing buildings are from the years 1870 - 1945, 10 percent from the period between 1945 and 1960 and more than half of school buildings were constructed after 1960. Of these, it is the reinforced concrete skeleton buildings of the 1960s and 70s that causes the most drastic problems.

The dena Project “Efficient Schools”

In 2007, the German Energy Agency (dena) initiated the nationwide project "Efficient Schools" in cooperation with the German Federal Ministry of Transport, Building and Urban Affairs (BMVBS), BASF AG as well as E.ON Ruhrgas AG. All four factors: Regulatory policies, financial support, innovation and information were kept in mind to promote energy efficiency refurbishment in dena’s model project.

In an expert commission energy standards were defined and further requirements for a participation developed. In discussion with the Federal Promotional Bank, the KFW Förderbank, a low investment loan system for the participants was set up. The funding of he pilot project is based on two energy efficiency standards. The following energy specifications must be adhered to:

“German Energy Savings Ordinance (EnEV) requirements for new buildings”

-minus 20%

-minus 40%

These requirements apply to the annual primary energy consumption and the quality of the envelope. In each case proof must be supplied that high air quality is ensured. This will contribute to the overall improved comfort after the refurbishment.

Looking for forward-thinking and ambitious owners of public and non-commercial buildings application had to be send to the dena for a pre-selection . The requirements for a participation not only included energetic standards but also social and economic ones. The applicants were chosen based on their holistic refurbishment concept. 80 projects all over Germany were selected.

Figure: Geographic distribution of participants for the schools project

In a second step the accepted applicants have to provide detailed calculations according to a quite complex DIN standard – the so called DIN 18.599. This process is still going on. The calculation is proved by an independent committee. In the case of an approval the applicant will receive the low investment credit by the Federal Promotional Bank mentioned above. Most of the participants will start the refurbishment in the summer 2008.The refurbishment will be completed within the next 2 – 3 years. After that the energy consumption will be monitored over 3 years. This way it possible to verify that energy efficient refurbishment is economic.

Expert seminars are provide for the building owners, the architects and planners to guide them through the application and calculation process. The seminars already held have proved that the demand for information is high due to the lack of experiences. It became obvious that if the owners of public and non-profit buildings are to be motivated that they have be strongly encouraged and coached.

Great importance is given to the participation of pupils, teachers, parents and the community administration in the refurbishment process. An important measure is to provide sufficient background information on the topic “Energy efficiency in buildings”. Therefore teaching materials for the elementary and high school as well as presentation material for school committees, parents etc. are developed and supplied for the participating schools. For successful publicity master copies for press releases and articles are distributed. A community website for blogs, photos, and comics etc. – the “Energy-saving record school forum” will be another measure to increase the participation of pupils, teachers and parents. It is also planned to organise meetings with the planners, manufacturers and public utility companies to emphasis on the practical aspects of the project.

Two Best-Practice Examples:

Two examples can already be given to demonstrate in which dimension energy savings will be realized. The calculation of a middle school and a vocational school have already been approved. In both projects the very ambitious standard "German Energy Savings Ordinance (EnEV) requirements for new buildings minus 40%" will be applied:

Middle School Gemünden:

Build in: 1963 – 1965

Net floor surface: 3.772 m²

Annual primary energy demand Q_P'':

1. Before refurbishment 203,4 kWh/m²a
2. German Energy Savings Ordinance requirements for new buildings: 155,2 kWh/m²a
3. after refurbishment: 44,10 kWh/m²a
4. below German Energy Savings Ordinance (EnEV) requirements for new buildings: 69,44%

Savings of primary energy: 87,32 %
Savings of greenhouse gas emissions: 174,850 t / a
The measure that will be applied include – in addition to the insulation of the building - a new wooden pellet boiler, a ventilation system with heat recovery, 3-pane-passivhouse windows, energy saving light bulbs and an acoustical ceiling.

Vocational school Oldenburg:

Build in: 1970

Net floor surface: 4.082 m²

Annual primary energy demand Q_P'':

1. Before refurbishment 271,1 kWh/m²a
2. German Energy Savings Ordinance (EnEV) requirements for new buildings: 154,7 kWh/m²a
3. after refurbishment: 70,5 kWh/m²a
4. below German Energy Savings Ordinance (EnEV) requirements for new buildings: 54%

Savings of primary energy: 74%
Savings of greenhouse gas emissions: 205 t / a
The measure that will be applied include – in addition to the insulation of the building - a new wooden pellet boiler and gas condensing boiler (peak load) , a ventilation system with heat recovery, 2-pane insulation windows, energy saving light bulbs regulated by the exposure of daylight.

Figure: Pictures of Participating Schools

Last but not least

The forthcoming tightening of the New Energy Savings Ordinance (EnEV 2007) to an average 30 percent in 2009 and a further 30 percent expected in 2012, turns these projects into trend-setting energy efficient refurbished buildings. They not only provide examples of regulatory policies and the financial support connected to them, but indicate at this stage, with which products – mostly passive house technologies – the buildings can be refurbished with the assurance of a good future. Thus, the model project significantly helps with **market preparation and market launch** for energy efficient products and indicates where the **mass market** will occur in the future.

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Abstract
This book contains the Proceedings of the 5th International Conference on Improving Energy Efficiency in Commercial Buildings - IEECB'08 which was held in Frankfurt, Germany, 10 - 11 April 2008. The IEECB'08 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'08 has provided a 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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