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# Energy Performance of Buildings – The European Approach to Sustainability

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**ABSTRACT:** This paper presents the European approach to improve sustainability in the building sector, which has a very high potential for considerable reduction of energy consumption in the coming years. By approving the Energy Performance in Buildings Directive the European Union has taken a strong leadership role in promoting energy efficiency in buildings in Europe, that will be the most powerful instrument developed to date for the building sector in Europe.

**Keywords:** Sustainable buildings, energy performance, energy legislation

## 1. INTRODUCTION

'Sustainable development' has been defined best by the Brundtland Commission as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs, [1]. Adequate and affordable energy supplies have been key to economic development and are central to improving social and economic well-being, and human welfare and raising living standards. Even if energy is essential for development, it is only a means to an end. The end is good health, high living standards, a sustainable economy and a clean environment.

Much of the current energy supply and use, are based on limited resources of fossil fuels and are environmentally unsustainable. Pollutants are produced, emitted or disposed of, often with severe health and environmental impacts. Combustion of fossil fuels is responsible for urban air pollution, regional acidification and the risk of human-induced climate change.

The UN Framework Convention on Climate Change required the adoption of policies and measures to reduce and limit greenhouse gas emissions in order to stabilise their emissions by 2000 at the 1990 level.

The European Climate change programme (ECCP) was established in June 2000 to help identify the most environmentally cost-effective measures enabling the EU to meet its target under the Kyoto Protocol, namely an 8% reduction in greenhouse gas emissions from 1990 levels by 2012. Energy use in buildings accounts for almost half of all CO<sub>2</sub> emissions in the EU and the building sector was identified as providing the largest potential for CO<sub>2</sub> reduction by 2012 and it was also identified to play an even more important role beyond 2012, where the European Commission's proposal for a Sixth Environmental Action Programme foresees a cost-effective energy saving potential of between 22% and

40% of the energy consumption in the sector by the year 2020.

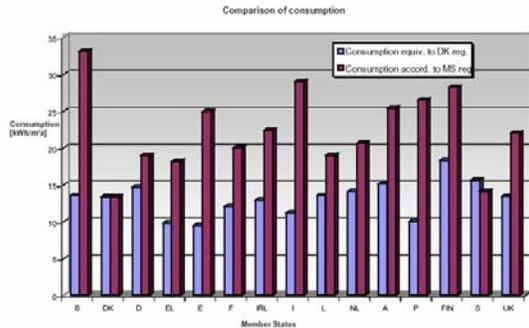
In its Green Paper "Towards a European Strategy for Energy Supply", [2] the Commission highlighted three main points:

- The European Union will become increasingly dependent on external energy sources; enlargement will reinforce this trend. Based on current forecasts, if measures are not taken, import dependence will reach 70% in 2030, compared to 50% today.
- At present, greenhouse gas emissions in the European Union are on the rise, making it difficult to respond to the challenge of climate change and to meet its commitments under the Kyoto Protocol. Moreover, the commitments made in the Kyoto Protocol must be regarded as a first step; climate change is a long-term battle involving the entire international community.
- The European Union has very limited scope to influence energy supply conditions. It is essentially on the demand side that the EU can intervene, mainly by promoting energy savings in buildings and in the transport sector.

The residential and tertiary sectors have been shown to be the largest overall end users, mainly for heating, lighting, appliances and equipment, see the next section. Numerous studies and practical experience show that there is a large potential for energy savings here, probably larger than in any other sector, [3].

Figure 1 shows the results of a comparison of thermal building regulations in the European Union. It showed that rather extreme differences exist in building regulations even after these have been made comparable by correcting for climatic differences using so-called "degree days". The comparison was made by using the model building regulation of Denmark and applying it to each EU Member State after climatic correction. The results illustrates that an

European initiative to improve the energy performance of buildings by promoting improved thermal insulation regulations to a level already attained by some countries could result in substantial energy savings for the EU as a whole.

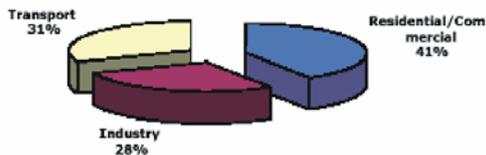


**Figure 1:** Energy consumption in EU Member States according to their existing national building regulations compared to the Danish model regulation adjusted for climatic differences, [4].

The European Union has taken a strong leadership role in promoting energy efficiency in buildings. While there are some individual countries that are playing an exemplary and leading role, most are following the lead of the Commission, the European Parliament and the Council of Ministers. This is among other things highlighted by the Directive on the Energy Performance of Buildings, which, once in full implementation phase, will be the most powerful instrument developed to date for the building sector in Europe

**2. ENERGY USE IN EUROPE**

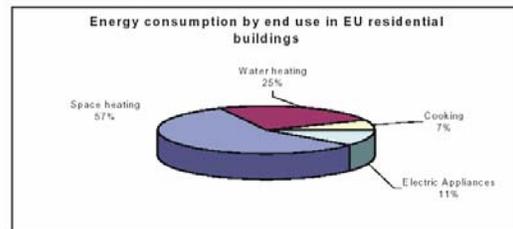
The total final energy consumption in the EU in 1997 was about 930 Mtoe, [5]. A simplified breakdown of this demand shows the importance of buildings in this context. About 41 % is used in the residential and tertiary sectors, most of it for building-related energy services. Of this 2/3 is used in homes and 1/3 is used in commercial buildings. 31% of the total energy consumption is used for transport and 28% in the industry, [5].



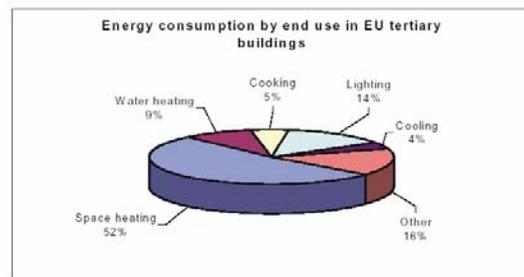
**Figure 2:** Distribution on sectors of total energy consumption in EU in 1997, [5]

Space heating is by far the largest energy end-use of households in EU Member States (57%), followed by water heating (25 %). Electrical appliances and lighting make up 11% of the sector’s total energy consumption, see Figure 3. For the tertiary sector,

see Figure 4 the importance of space heating is somewhat lower (52 % 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.



**Figure 3:** Energy consumption in the residential sector, [5]



**Figure 4:** Energy consumption in the tertiary sector, [5]

**3. ENERGY PERFORMANCE DIRECTIVE**

All EU member states apply minimum standards, especially for new buildings, but considerable differences exist in the level of energy performance required in these standards, as it is seen in Figure 1, which indicate a large potential for improvement and a need for measures to realise this potential in the most cost-effective way. The Directive on the Energy Performance of Buildings, [6], is designed to promote the improvement of energy performance of buildings in member states. It entered into force on January 4, 2003 and compliance is foreseen at the latest by January 4, 2006 in all EU member states.

One of the benefits of this directive is, that it provides an integrated approach to different aspects of buildings energy use, which until now only a few member states were doing, and that all aspects are expressed in simple energy performance indicators. The integrated approach allows flexibility regarding details, giving designers greater choice in meeting minimum standards. In order to achieve a certain degree of harmonisation of assessment of buildings for designers and users throughout the EU, a common methodology based on an integrated approach is established.

However, it should be recognised that the largest potential for energy saving is in the renovation of existing buildings and they should meet higher standards as regards energy performance when they are renovated. In order to address this issue, the most appropriate measure seems to be to introduce

certification of buildings. In order to raise awareness, and at the same time remedy the major market imperfection that owners have no incentives to invest in buildings they rent out, the certification of public authority buildings or certain other buildings with high energy consumption, which are frequented by the public, should be displayed in the buildings, along with recommended and current indoor temperatures and relevant climatic factors.

In order to assist in developing a common methodology, standards bodies and others are involved in the implementation process. While all EU member states are free to implement on their own, there has been great emphasis on Communitywide collaboration.

### 3.1 Objective

Article 1 in the directive states the objective that is to promote the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness.

In the Directive requirements are given as regards:

- (a) the general framework for a methodology of calculation of the integrated energy performance of buildings;
- (b) the application of minimum requirements on the energy performance of new buildings;
- (c) the application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation;
- (d) energy certification of buildings; and
- (e) regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old.

### 3.2 Adoption of a methodology

Article 3 in the directive states, that member states shall apply a methodology, at national or regional level, of calculation of the energy performance of buildings on the basis of a general framework. The energy performance shall be expressed in a transparent manner and may include a CO<sub>2</sub> emission indicator.

The general framework for the calculation of energy performance of buildings is:

1. The methodology of calculation of energy performances of buildings shall include at least the following aspects:
  - a. thermal characteristics of the building (shell and internal partitions, etc.). These characteristics may also include air-tightness;
  - b. heating installation and hot water supply, including their insulation characteristics;
  - c. air-conditioning installation;
  - d. ventilation;
  - e. built-in lighting installation (mainly the non-residential sector);

- f. position and orientation of buildings, including outdoor climate;
  - g. passive solar systems and solar protection;
  - h. natural ventilation; and
  - i. indoor climatic conditions, including the designed indoor climate.
2. The positive influence of the following aspects shall, where relevant in this calculation, be taken into account:
    - a. active solar systems and other heating and electricity systems based on renewable energy sources;
    - b. electricity produced by CHP;
    - c. district or block heating and cooling systems;
    - d. natural lighting.
  3. For the purpose of this calculation buildings should be adequately classified into categories such as:
    - a. single-family houses of different types;
    - b. apartment blocks;
    - c. offices;
    - d. education buildings;
    - e. hospitals;
    - f. hotels and restaurants;
    - g. sports facilities;
    - h. wholesale and retail trade services buildings;
    - i. other types of energy-consuming buildings.

### 3.2 Setting of energy performance requirements

Article 4 requires member states to ensure that minimum energy performance requirements for buildings are set. It is allowed to differentiate between new and existing buildings and different building types. It is also required that member states review these requirements at regular intervals (not longer than five years) "to reflect the technical progress in the building sector."

Article 5 states that for new buildings with a total useful floor area over 1000 m<sup>2</sup>, the technical, environmental and economic feasibility of decentralised energy supply systems based on renewables, CHP, district or block heating or cooling and heat pumps shall be taken into account before construction.

Article 6 states that for existing buildings also with a total useful floor area over 1000 m<sup>2</sup> requirements can be set for either the entire renovated building or only for renovated systems or components.

### 3.3 Energy performance certificate

Article 7 states that energy performance certificates are required when buildings are constructed, sold or rented out and must be made available to the owner or by the owner to the prospective buyer or tenant. The validity of a certificate cannot exceed 10 years. The article further states: "Member States shall take measures to ensure that for buildings with a total useful floor area over 1 000 m<sup>2</sup> 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.” Article 7 also states that the range of recommended and current indoor temperatures and other relevant climatic factors may be clearly displayed as well, in order to ensure a balance between demands for energy performance and indoor environment.

Figure 5 shows an example of a energy performance certificate from Denmark.

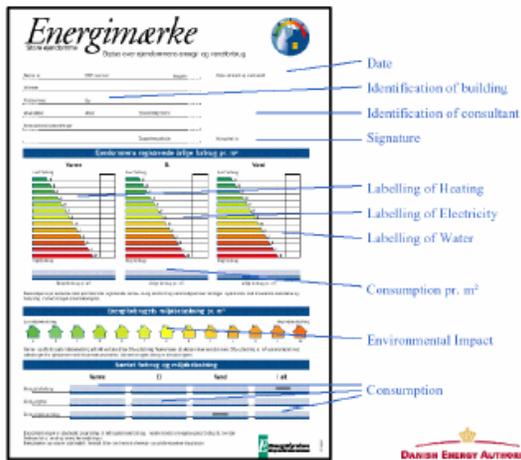


Figure 5: Danish Energy Performance Certificate for Buildings.

### 3.4 Inspection of boilers

Article 8 states that either the member state “lay down the necessary measures to establish a regular inspection of boilers fired by non-renewable liquid or solid fuel of an effective rated output of 20 kW to 100 kW” or “take steps to ensure the provision of advice to the users on the replacement of boilers, other modifications to the heating system and on alternative solutions which may include inspections to assess the efficiency and appropriate size of the boiler.” The impact of the second option has to be “broadly equivalent” to the first one.

### 3.5 Inspection of air-conditioning systems

Article 9 states that member states “shall lay down the necessary measures to establish a regular inspection of air-conditioning systems of an effective rated output of more than 12 kW.

### 3.6 Independent experts

Article 10 states that member states are required to ensure that “drafting of recommendations on the inspection of boilers and air-conditioning systems for the certification of buildings” are undertaken by independent qualified and/or accredited experts.

### 3.7 Final Remarks

The “European Directive on the Energy Performance of Buildings (2002/91/EEC) is the most significant measure that has been adopted by the EU to reduce greenhouse gas emissions from buildings.

All EU member states are developing their plans to implement the EPB Directive and have until January 2006 to have the implementation in place.

Most countries have achieved to have a common methodology for calculation of energy performance of new buildings in place, while procedures for energy performance certification and inspection of boilers and air-conditioning systems are still missing in many countries.

## 4. IMPLEMENTATION OF EPD IN DENMARK

The energy situation in Denmark is in many ways the same as for other European countries, see figure 6. The main difference is that Denmark is an energy exporting country and has a relatively high share of renewable energy.

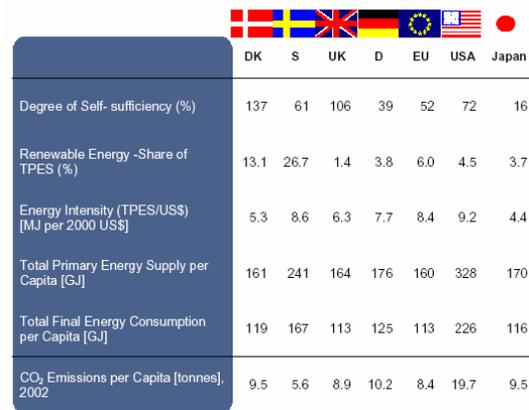


Figure 6: International comparison of the Danish energy situation, [7].

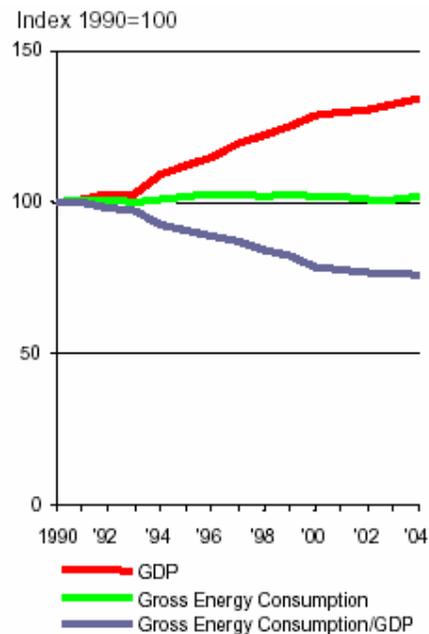


Figure 7: Development of GDP, gross energy consumption and energy intensity, [7].

The energy consumption has been stable due to a 20 per cent improvement in energy intensity between 1994 and 2005, see figure 7. The Kyoto commitment is to reduce GHG emissions by 21per cent in the first

budget period 2008-2012, compared to 1990, which is far from reached at the moment.

As a basis for a new action plan on reduction of the energy consumption a number of investigations were performed. It was concluded that an economic reduction in the industry of 25% was possible, [9]. Another investigation concluded that a reduction of heating consumption in the residential sector of 45% before 2015 and up to 80% in the long term (before 2050) was possible, [10]. Table 1 summarises the socioeconomic potential for reduction of energy consumption until 2015 in Denmark.

Type of Employment	Energy consumption 2003 (PJ)	Socioeconomic reduction potential until 2015 (%)
Room heating	217,6	24
Industrial process	66,5	25
Lighting	24	24
Cooling/freezing	15,1	28
Electric motors	12,4	15
Ventilation	11,9	40
Pumping	8,4	35
Other uses	71,3	24
Total	427,2	24

**Table 1:** Socioeconomic energy saving potential, [11].

A new action plan on energy efficiency was approved by the government in December 2004 and released in early 2005. The energy conservation action plan is a forward-looking, market-based path, [12].

Basic principles for reorientation of the energy conservation drive are:

- Cost-efficiency.
- Promote competitiveness and welfare through low energy bills for companies and consumers.
- Focus on realisation of large, profitable savings potentials with low-cost measures
- A balanced approach in relation to the various sectors and energy applications.
- A market-based approach that promotes well-functioning and efficient markets for energy-efficient, profitable products and solutions.
- Prioritisation of international, and especially EU, initiatives.
- Promote the development of more efficient products that can help business development and exports, i.a. through research & development.

The new action plan calls for tightening the energy requirements in the building code by 25-30 % from 2006 and a further 25 % from 2010. The new action plan calls for a general target for reducing energy consumption in all sectors (not transport) of 1.7 per cent per year until 2013.

In June 2005, the Danish Parliament approved and published the new energy requirements for the building regulations of small houses and for the general building regulations. These fulfil requirements

for articles 3, 4, 5 and 6 of the Energy Performance in Buildings Directive. The new requirements come into force January 1, 2006. The new requirements will reduce energy consumption by 25-30 % in new buildings.

A new law on Energy Savings in Buildings was also approved in June 2005. It will require energy labelling of all public buildings every five years, regular energy labelling of all large buildings (over 1000 sq. m. gross area) for trade and services as well as for apartment blocks. For building and apartments for sale or rent, the energy label is only valid 5 years. Energy labelling includes inspection, certification and advising. All new buildings have to be labelled to ensure fulfilment of the energy requirements in the building regulations.

The new requirements for energy consumption in new buildings set requirements for primary energy consumption for heating, cooling, domestic hot water, ventilation and lighting (not included for residential buildings). In the calculation of the primary energy consumption electric energy is weighted with a factor of 2.5 in relation to heating.

The primary energy consumption for residential buildings must not exceed:

$$\left(70 + \frac{2200}{A}\right) kWh/m^2 year$$

where A is the heated floor area of the building.

The primary energy consumption for other buildings must not exceed:

$$\left(95 + \frac{2200}{A}\right) kWh/m^2 year$$

In order to classify a building as a low energy building class 1 or 2, respectively, the energy consumption must not exceed:

$$\text{Class 1: } \left(35 + \frac{1100}{A}\right) kWh/m^2 year$$

$$\text{Class 2: } \left(50 + \frac{1600}{A}\right) kWh/m^2 year$$

Besides requirements on the energy consumption the building regulations also puts requirements on airtightness (1,5 l/s m<sup>2</sup> floor area at a pressure difference of 50Pa) and heat loss (6W/m<sup>2</sup> envelope, except windows and doors, at a temperature difference of 32 K). The latter means that the average U-value for the building envelope must not exceed 0,19 W/m<sup>2</sup>K.

## 5. IMPLICATION FOR THE BUILDING SECTOR AND FUTURE TRENDS

The new requirements for energy consumption in building in Denmark from January 2006, that implies a reduction of 25-30%, can be achieved by existing technology and typical structural solutions. It will require additional insulation thickness in building envelopes, more efficient ventilation, heating and lighting systems and a more optimal building design,

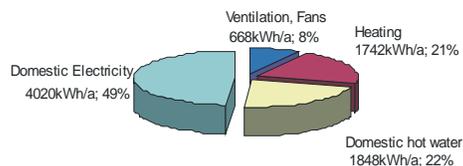
but it will not require any radical changes in building construction.

However, by 2010 the requirements for energy consumption in new buildings will be tightened to class 2 low energy building requirements and by 2015-2020 to class 1 low energy building requirements. In order to fulfil such requirements typical U-values for building envelopes must be below  $U=0,1\text{W/m}^2\text{K}$  and for windows and glazed areas below  $U=0,8\text{W/m}^2\text{K}$ . Heat recovery efficiency should be about 75-85% and energy use for transport of air below  $500\text{J/m}^3$  air. This will require development of new construction solutions, new types of building envelopes, and development of new building materials.

On the other hand it has already been demonstrated in a number of demonstration projects that performances according to the requirements for Class 1 can be achieved. One example is a building project in the south western part of Sweden, which has similar climate as Denmark, see figure 8.



Total Energy Consumption 8278 kWh/år ~ 70kWh/m<sup>2</sup> year



**Figure 8.** Measured performance of rowhouses, Lindås, Sweden.

It is seen for Class 1 buildings, where the energy use for heating, ventilation and domestic hot water is optimised, that the energy consumption for electric appliances in the household covers about half of the total consumption, which is a radical change from the typical situation, see figure 3.

The main challenge in the coming 5-10 years will be to implement the experience from these demonstration buildings in the main stream construction work and further develop and optimize construction principles, envelope types and building components and systems to make these new technologies competitive in the market.

## CONCLUSION

This paper has presented the European approach to improve sustainability in the building sector. The Energy Performance in Buildings Directive will be the most powerful instrument developed to date for the building sector in Europe to promote energy efficiency in buildings. There is a high socioeconomic potential for energy savings and the main challenges is to develop and optimize new competitive building solutions.

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