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Buildings and Climate Change

Status, Challenges and Opportunities

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BUILDINGS AND CLIMATE CHANGE

Status, Challenges and Opportunities

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ABBREVIATIONS

AIA	American Institute of Architects
ASEAN	Association of Southeast Asian Nations
BEMs	Building energy management systems
BRIC countries	Brazil, Russia, India and China
CDD	Cooling Degree Day
CDM	Clean Development Mechanism of the Kyoto Protocol
CER	Certified Emission Reduction
CHP	Combined Heat and Power (plant)
CIB	International Council for Research and Innovation in Building and Construction
CO2	Carbon dioxide
Cx	Commissioning
DMS	Demand side management
DX cooling	Direct Expansion cooling
EC	European Community
ECCP	European Climate Change Programme
ECTP	European Construction Technology Platform
EE	Energy efficiency
EPBD	Energy Performance of Building Directive
EPI	Environmental Performance Index
EPS	Expanded polystyrene
EST	Environmentally Sound Technologies
EU	European Union
Eurima	European Insulation Manufacturers Association
FAO	Food and Agriculture Organization of the United Nations
FIEC	European Construction Industry Federation
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
GNI	Gross National Income
HDD	Heating Degree Day
HVAC	Heating, Ventilation and Air-Conditioning
IEA	International Energy Agency
iiSBE	International Initiative for Sustainable Built Environment
IPCC	Intergovernmental Panel for Climate Change
ISO	International Organization for Standardization
ITCs	Information and Communication Technologies
JI	Joint Implementation Mechanism of the Kyoto Protocol
LEDs	Light emitting diodes
LPG	Liquefied Petroleum Gas
MToe	Million Tons of Oil Equivalent
NG	Natural Gas
NOx	Nitrogen Oxides
OECD	Organization for Economic Co-operation and Development
PER	Process Energy Requirement
PPP	Public Private Partnership
PRESCO	Practical Recommendations for Sustainable Construction
R&D	Research and Development
RIBA	Royal Institute of British Architects
SME	Small and Medium-sized Enterprise
SUD	Sustainable urban development
UIA	International Union of Architects
UICB	Union Internationale des Centres du Batiment
UN	United Nations
UNCDR	United Nations Center for Regional Development
UNCHS	United Nations Centre for Human Settlements
UN/ECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNU	United Nations University
XPS	Extruded polystyrene
WGBC	World Green Building Council
WWF	Worldwide Fund
ZEO	Zero-energy office

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DISCLAIMER

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Executive Summary

Worldwide, 30-40% of all primary energy is used in buildings. While in high- and middle-income countries this is mostly achieved with fossil fuels, biomass is still the dominant energy source in low-income regions. In different ways, both patterns of energy consumption are environmentally intensive, contributing to global warming. Without proper policy interventions and technological im-provements, these patterns are not expected to change in the near future.

On the global level, knowledge regarding the energy use of building stocks is still lagging be-hind. Generally speaking, the residential sector accounts for the major part of the energy consumed in buildings; in developing countries the share can be over 90%. Nevertheless, the energy consumption in non-residential buildings, such as offices and public buildings and hospitals, is also significant.

The pattern of energy use in buildings is strongly related to the building type and the climate zone where it is located. The level of development also has an effect. Today, most of the energy consumption occurs during the building's operational phase, for heating, cooling and lighting purposes, which urges building professionals to produce more energy-efficient buildings and renovate existing stocks according to modern sustainability criteria. The diversity of buildings, their distinct uses and extended life cycle pose a challenge for the prescription of energy conservation measures. Specific solutions are needed for each situation, such as for the construction of new buildings, for the renovation of existing ones, for small family houses and for large commercial complexes. Energy consumption can be reduced with thermal insulation, high performance windows and solar shading, airtight structural details, ventilation and heat/cold recovery systems, supported with the integration of renewable energy production in the building. These strategies apply to buildings in both warm and cold climates. Site and energy chain planning also influence the energy efficiency of the individual building. However, technological solutions will only be helpful when building occupants are committed to using energy-efficient systems in an appropriate way. There are many factors that influence the energy consumption behavior of individuals, such as gender, age and socio-demographic conditions. Educational and awareness raising campaigns are therefore crucial in the process of ensuring the energy efficiency of buildings.

The end of the functional service life of a building may inhibit renovation projects – when the building or its parts are no longer suitable for the needs of the building user. In refurbishment proc-esses, basically the same rationale applies as in the construction of new buildings. Since the opera-tional energy is the major cause for greenhouse gas emissions in residential or commercial buildings to be renovated, this should be the first aspect to be taken into account when considering the improvement of the energy efficiency of building stocks. Moving towards the idea of life-cycle responsibility and introducing effective commissioning processes will help to ensure the efficient life-cycle performance of the building.

The high investment costs involved, the lack of information on energy-efficient solutions at all levels, as well as the (perceived or real) lack of availability of solutions to specific conditions, are considered as the major barriers to implementing energy efficiency measures in buildings. In addition, there can be a number of organizational barriers, such as different decision making levels, privatization/deregulation processes, different stakeholders deciding on the energy system and shouldering the energy bill respectively, etc.

It is clear that there are no universal solutions for improving the energy efficiency of buildings. General guidelines must be adjusted to the different climate, economic and social conditions in different countries. The local availability of materials, products, services and the local level of technological development must also be taken into account.

The building sector has a considerable potential for positive change, to become more efficient in terms of resource use, less environmentally intensive and more profitable. Sustainable buildings can also be used as a mitigating opportunity for greenhouse gas emissions under the flexible mechanisms of the Kyoto Protocol and should be considered as a key issue for the post Kyoto period.

Decision makers understanding the logic behind the behavior of different actors is important for successful development and deployment of policy instruments and technological options. Provid-ing benchmarks on sustainable buildings is an essential requirement for decision makers to take the correct course of action to encourage energy efficient buildings. Solutions aiming to improve the energy efficiency of buildings and construction activities should be disseminated widely, making use of existing or new technology transfer programmes. Influencing market mechanisms and encouraging research and development projects, as well as public-private partnerships, are of paramount importance for this endeavour.

1 Introduction

THE BUILDING AND CONSTRUCTION sector is a key sector for sustainable development. The construction, use and demolition of buildings generate substantial social and economic benefits to society, but may also have serious negative impacts, in particular on the environment. Areas of key concern include energy use with associated greenhouse gas (GHG) emissions, waste generation, construction materials use and recycling, water use and discharge, and integration of buildings with other infrastructure and social systems.

The building and construction sector typically provides 5-10% of employment at national level and normally generates 5-15% of the GDP. It literally builds the foundations for sustainable development, including housing, workplace, public buildings and services, communications, energy, water and sanitary infrastructures, and provides the context for social interactions as well as economic development at the micro-level. Numerous studies have also proven the relationship between the built environment and public health.

At the same time, the building and construction sector accounts for the largest share in the use of natural resources, by land use and by materials extraction. Energy use, liquid and solid waste generation, transport of construction materials, and consumption of hazardous materials are other examples of negative environmental impacts from this sector. In OECD (Organisation for Economic Co-operation and Development) countries, buildings are responsible for 25-40% of total energy use. In Europe, buildings account for 40-45% of energy consumption in society, contributing to significant amounts of carbon dioxide (CO2) emissions. The building sector thus offers the largest single potential for energy efficiency in Europe: more than one-fifth of the present energy consumption and up to 45 million tonnes of CO2 per year could be saved by 2010 by applying more ambitious standards to new and existing buildings. This would represent a considerable contribution to meeting the Kyoto targets and is also an important contribution towards securing the energy supply of the European Union (Maldonado 2005).

A number of national and international initiatives and efforts have been developed by the building and construction sector itself to promote more sustainable buildings. Nevertheless there is still a clear lack of initiatives aiming at addressing global issues from a life-cycle perspective of the built environment. A prime example of the kind of issues that have fallen behind is the integration of the built environment as an active sector under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. While the built environment contributes with 30-40% of energy use and associated greenhouse gas emissions, there are but few activities in this sector benefiting from incentives provided under the Kyoto Protocol.

CO2 emissions are currently greatest in industrialized countries, although estimates suggest that developing countries will increasingly contribute to global warming in the coming decades (Figures 1.1 and 1.2). In the United States, CO2emissions per capita equal 20.1 tonnes, almost twice those of countries such as China and Brazil, 16 times higher than India and 50 times higher than Nigeria and Sudan. If highly-populated developing countries follow the same unsustainable production and consumption path as developed countries, the consequences will be significant. The challenge is to determine how industrialized countries can manage their environmental impacts, while developing countries can achieve economic growth in a sustainable way (Figures 1.3 and 1.4).

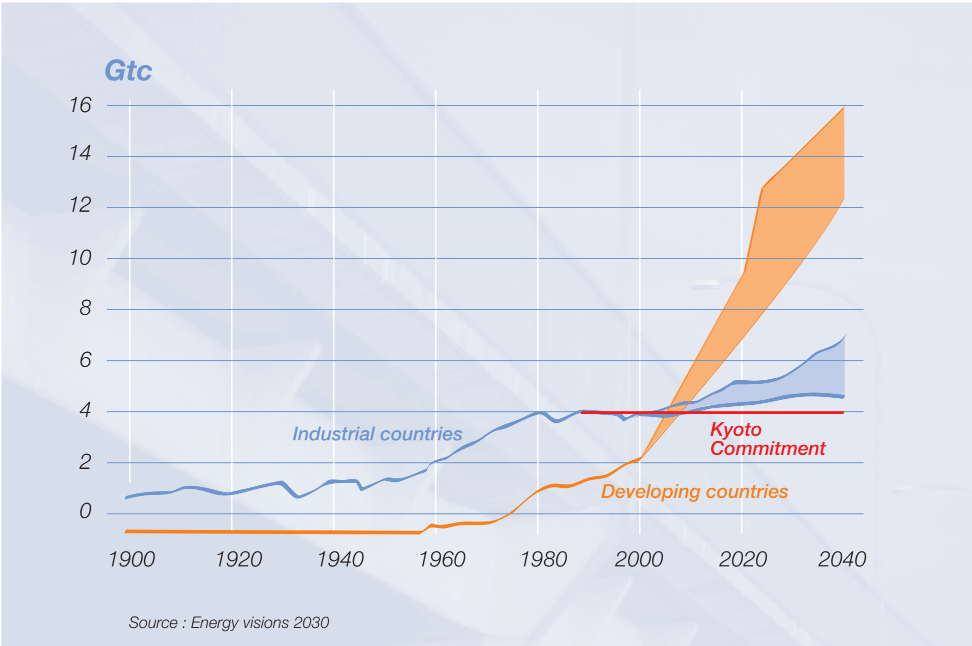
CO2 Emissions : CO2 emissions calculated using the IEA energy data and the default methods and emission factors from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC/OECD/IEA Paris, 1997.

Fig. 1.1
CO2 emissions per capita in the world.

Source : IEA Statistics 2006

More than half of the world's population lives in urban areas, and over 80% of the population lives in developing countries (UN 2004, see also Annex 1). Due to population growth and economic development, construction activities are now more intense than ever. Total consumption growth increased by 4.6% from 2003 to 2004 and is expected to exceed 5% annually over the next four years, with China and India growing fastest (Davis Langdon, UNEP 2006). Construction output is estimated to vary between 3,000 billion and 4,200 billion dollars per year (Figure 1.5). The aim of this report is to assess how energy use in buildings can become more sustainable, and how related greenhouse gas emissions can be minimized. For this purpose, factors affecting the ability and willingness of building and construction sector stakeholders to adopt energy efficiency are analyzed, as are measures to reduce the stakeholders' share of greenhouse gas emissions.

Fig. 1.2
After 2020 major parts of CO2 emissions will come from developing countries.



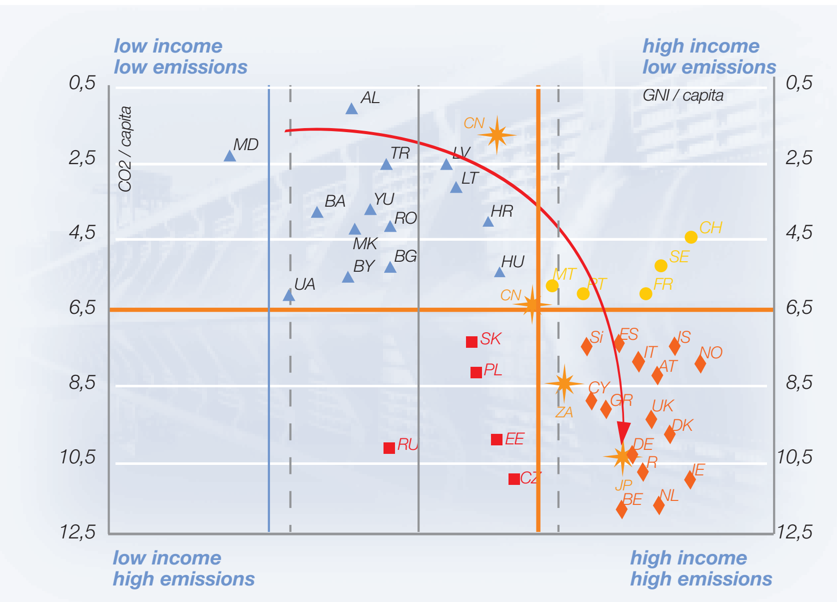


Fig. 1.3
The correlation between GNI/capita and CO2 emissions per capita in different countries.

Source : Asia Pro Eco 2005

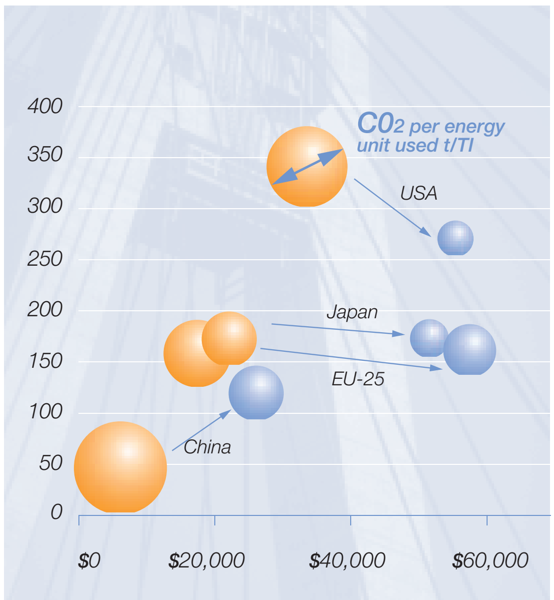


Fig. 1.4
The extent of change needed in energy efficiency (represented by the position on the graph) and carbon intensity (represented by the size of circles).

Source : WGBC 2005

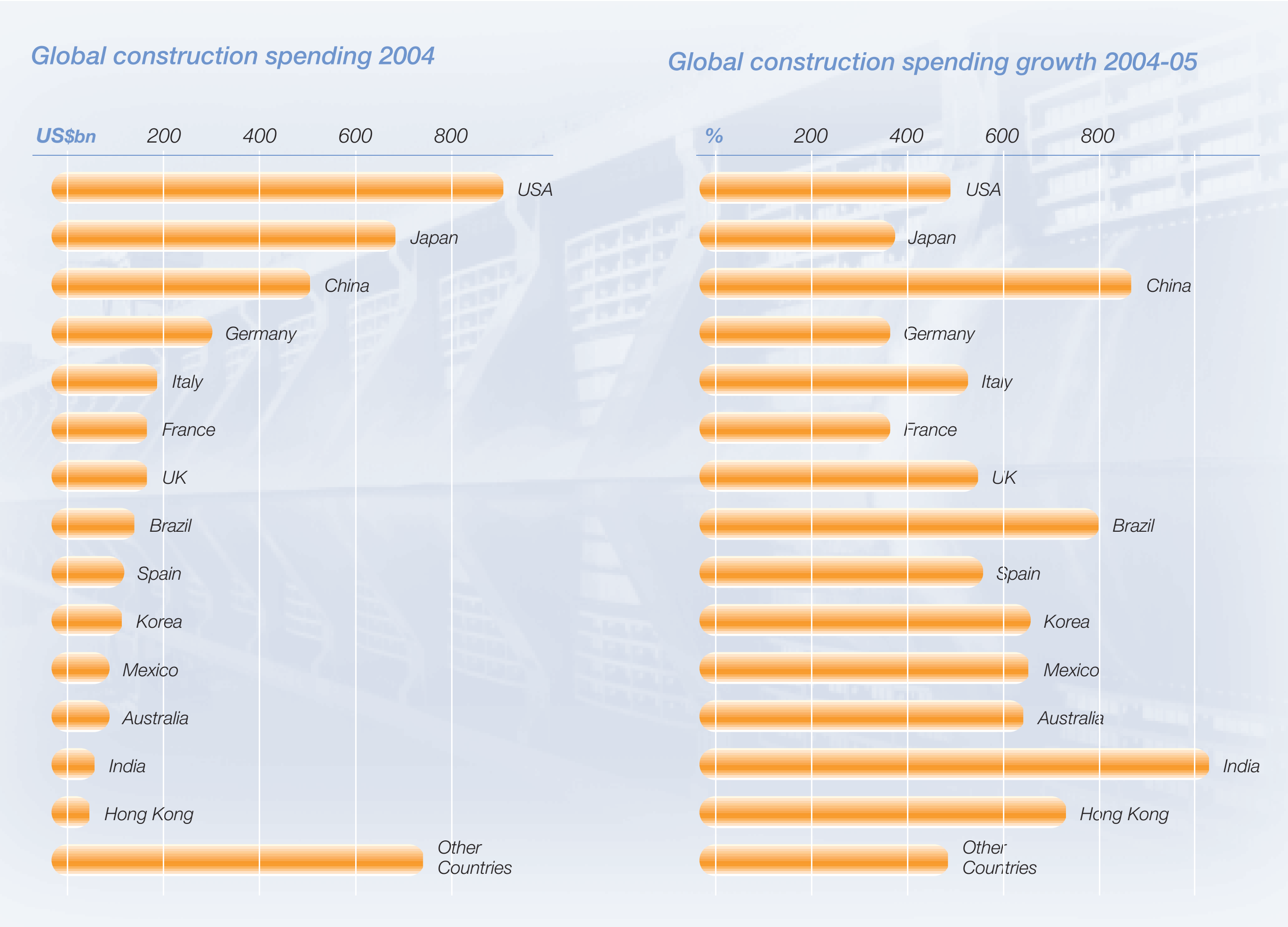


Fig. 1.5
Global construction spending and growth 2004-2005.

Source: Davis Langdon 2005.

This report consists of seven chapters. Chapter 1 is this introduction. Chapter 2 "Baselines" aims to provide an overview of how energy is used in buildings, discussing the distribution of the energy used over the building's life cycle, the shares of different energy end-use purposes and the distribution of energy consumption among different building sectors and types. Chapter 3 "Opportunities for Energy Efficiency in Buildings" explores how energy efficiency in buildings can be boosted by improving different components of the buildings. Components such as building materials, envelope, energy systems, human behavior are described, as are site planning and energy chain planning. Chapter 4 "Energy Efficiency Models" introduces a number of energy efficient solutions, such as passive and low- and zero-energy buildings. Chapter 5 "Encouraging Energy Efficiency" explores policy aspects of sustainable and energy-efficient buildings. Analyses of possible ways in which energy efficiency of buildings can be integrated under the instruments of the Kyoto Protocol are presented in chapter 6 "Buildings and the Kyoto Protocol". This chapter is followed by a set of recommendations in chapter 7, references and annexes. Throughout the report, empirical case studies and country-specific examples have been included in boxes to better illustrate the dynamics in place.

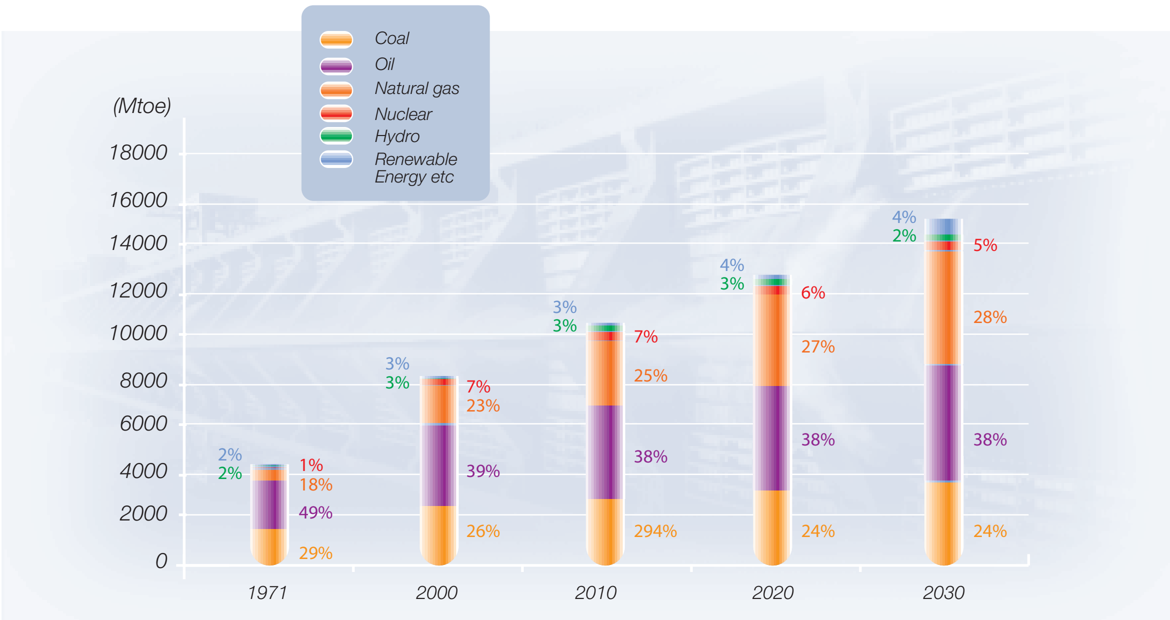
As will be explained in later chapters, this report considers the use of energy in five phases of the building's life cycle: (i) the manufacturing of building products and components; (ii) the transportation of building products and components to the construction site; (iii) the construction itself; (iv) the operational phase; and (v) the final demotion and recycling. Although energy consumption is significant in all these phases, in this report emphasis is given to the operational phase of the building, the most energy-intensive phase.

EVERY YEAR, THE WORLD consumes around 7,500 Mtoe (million tons of oil equivalent) of en-ergy (Figure 2.1). In 2003, three countries – China, Russia and the United States – were the leading producers and consumers of world energy. Altogether, these three countries produced 39% and consumed 41% of the world's total energy supply (IEA 2002, 2005; EIA 2005). While primary energy consumption will grow by almost 50% from 2005 to 2030 (Figure 2.2), the shares of different energy sources are not expected to change significantly in the near future. This means that, in the near future, more fossil fuels will be used to meet energy demands, increasing the greenhouse gas emissions further.

The building sector is responsible for a large share of the world's total energy consumption. The International Energy Agency (IEA 2005) estimates that buildings account for 30-40% of the worldwide energy use, which is equivalent to 2,500 Mtoe every year. Accordingly, studies carried out by the OECD suggest that residential and commercial building sectors are responsible for about 30% of primary energy consumed in OECD countries, and for approximately 30% of the greenhouse gas emissions of these countries (OECD 2002b, 2003). These studies also indicate that energy consumption by the building sector in OECD countries has continually increased since the 1960s and will continue to do so in the coming years.

In non-OECD countries the situation is also worrying. On one hand, many middle-income countries rely on fossil fuels to meet the energy demand in their building stocks. On the other hand, in the low-income rural areas of Africa, India and China the main energy source for more than 70% of the population is traditional biomass such as wood, animal dung and crop waste (Figures 2.5 and 2.6). In addition, kerosene and paraffin are still widely used for lighting in the rural areas of developing countries. By using wood biomass these practices contribute to deforestation and desertification processes, decreasing the capacity of existing carbon sinks to absorb CO2 from the atmosphere. Today, around 2.4 billion people depend on biomass – wood, agricultural residues and dung – for cooking and heating. That number is expected to increase to 2.6 billion by 2030. According to a forecast presented by the IEA (2002), in 2030 biomass use will still represent over half of residential energy consumption in developing countries. The change of this trend largely depends on efforts to alleviate rural poverty and improve the living conditions of these populations (Figure 2.7).

This chapter describes the overall use of energy by the building sector. After analyzing how energy is consumed over the building's life cycle, it explores how energy consumption is distributed among different building sectors and types. Attention is primarily given to the operational phase of the building, and the shares of energy consumed for heating, cooling, lighting and other appliances in different countries and by different types of buildings. These analyses are complemented with practical examples, which illustrate energy sources in different building phases and sectors, as well as the effects of climate, building type and building technology.



Source : IEA/World Energy Outlook 2002 (Agency for Natural Resources and Energy, Government of Japan 2006).

Fig. 2.1 *Outlook for world energy supply / demand by fuel.*

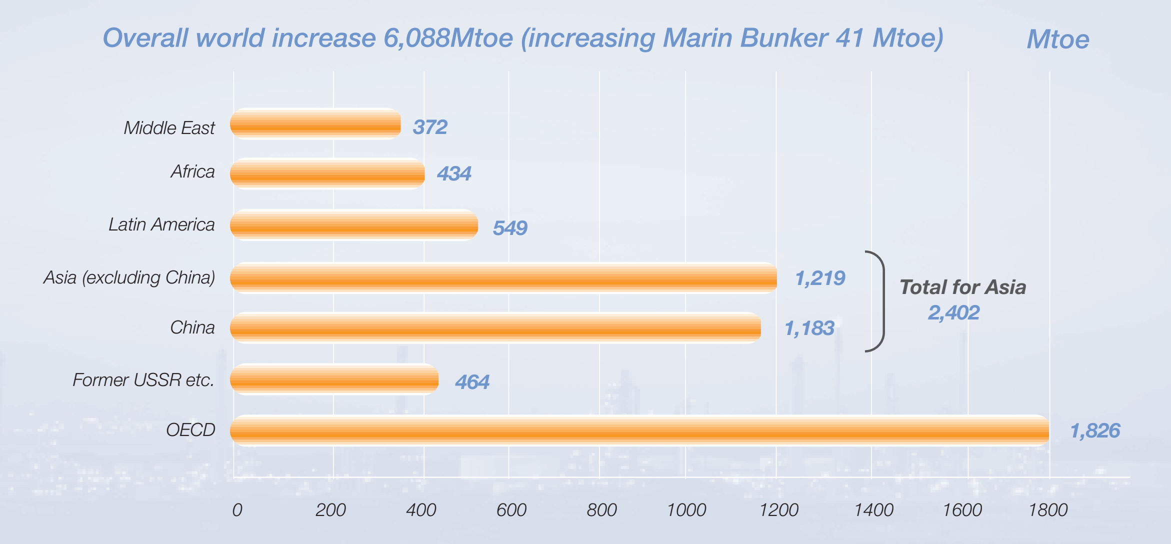


Fig. 2.2
Growth in the demand for primary energy among regions of the world (2000-2030).

Source : IEA/World Energy Outlook 2002 (Agency for Natural Resources and Energy, Government of Japan 2006).

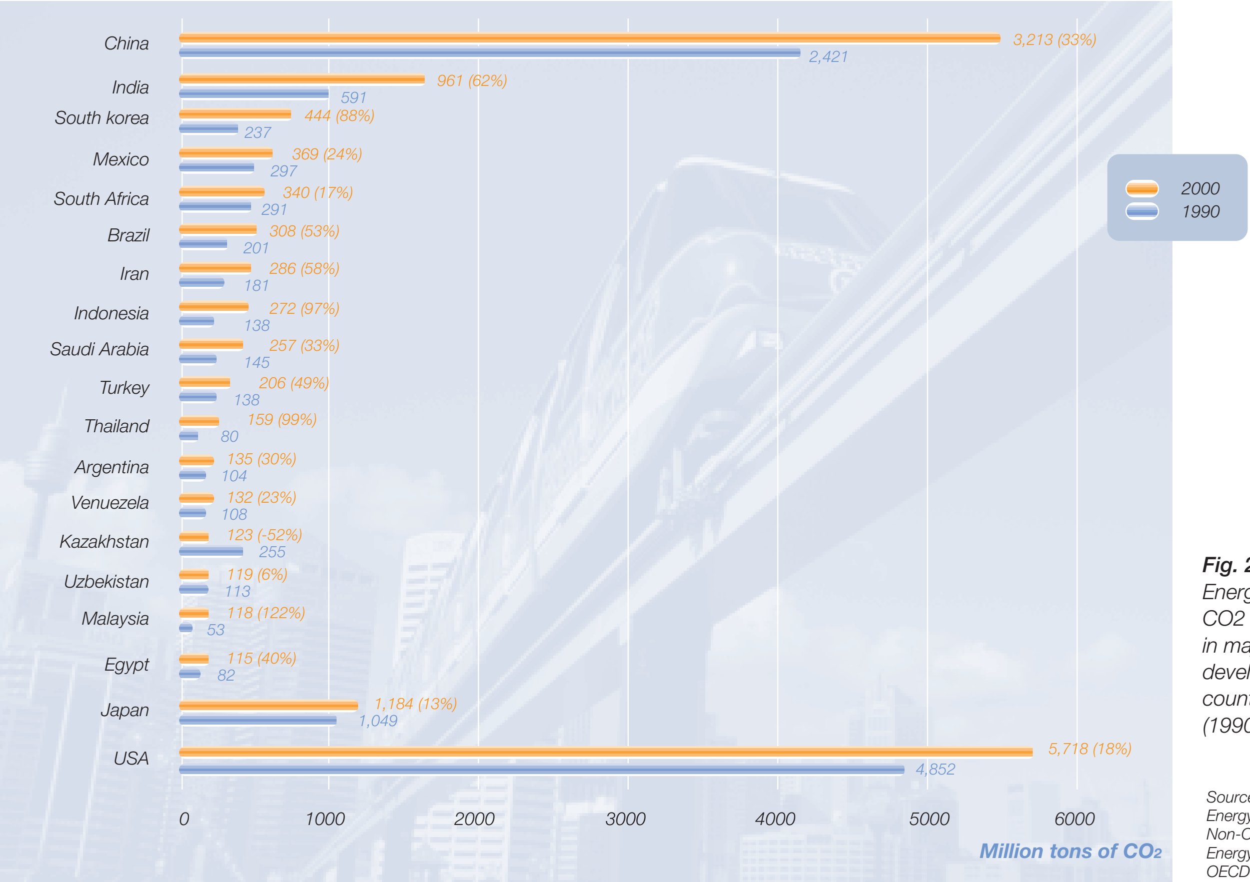


Fig. 2.3
Energy-related CO2 emissions in major developing countries (1990-2000).

Source : OECD/IEA, Energy Balances of Non-OECD Countries, Energy Balances of OECD Countries.

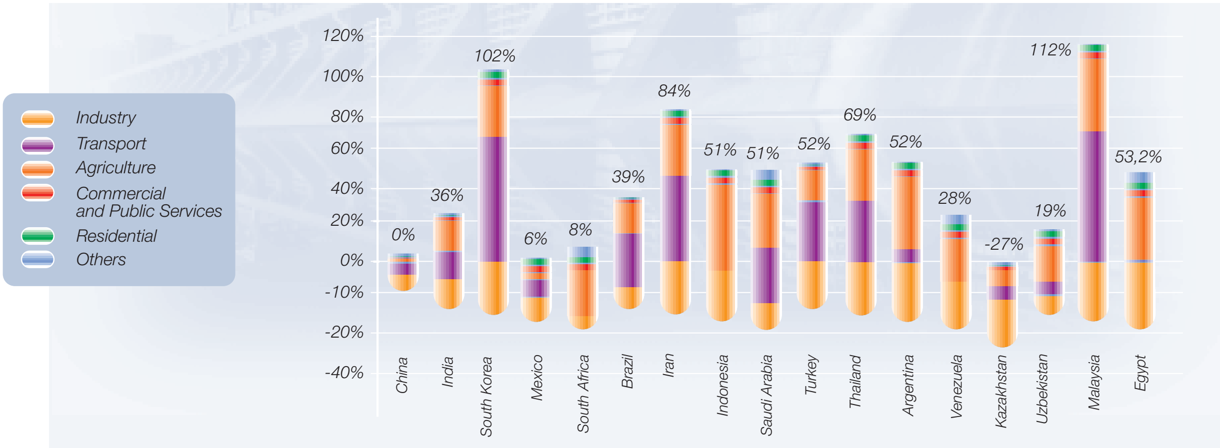


Fig. 2.4
Sectoral changes of final energy consumption in major developing countries.

Source : OECD/IEA, Energy Balances of Non-OECD Countries, Energy Balances of OECD Countries.

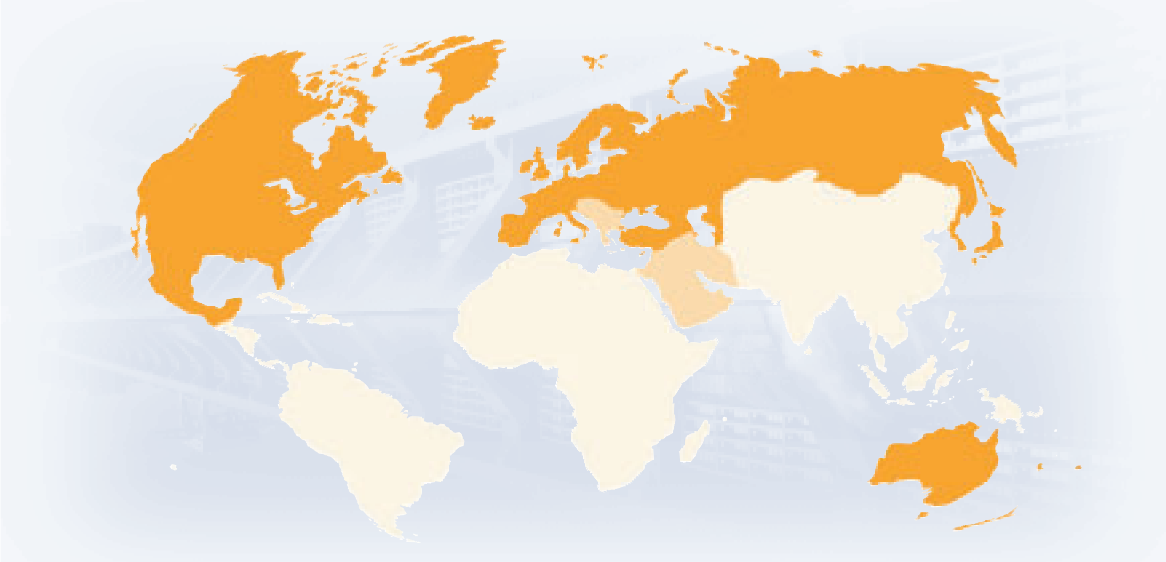


Fig. 2.5
Share of Woodfuels in National Energy Consumption.

Source: IEA 1996.

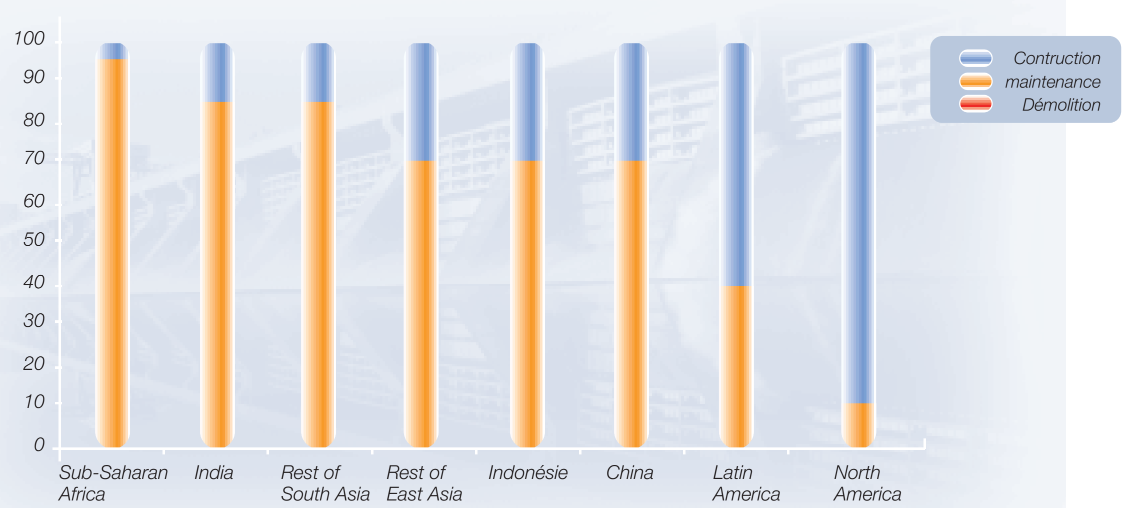


Fig. 2.6
Share of Traditional Biomass in Residential Energy Consumption, 2000.

Source: IEA 2002.

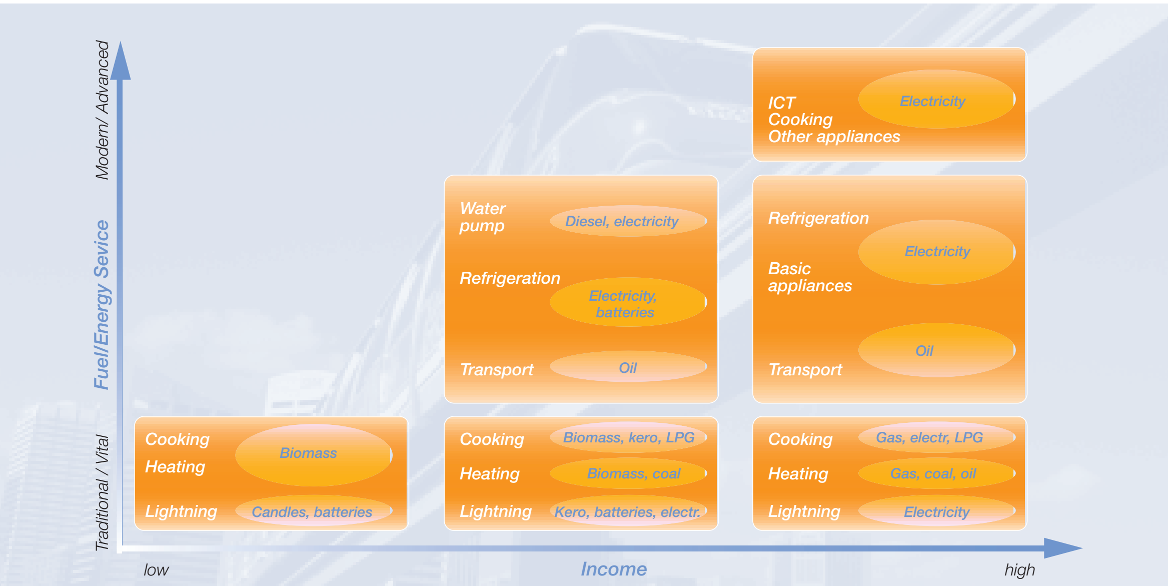


Fig. 2.7
Example of household fuel transition.

Source: IEA 2002.

2.1 Distribution of the energy use over the life cycle

Modern buildings consume energy in a number of ways. As analyzed by Jones (1998), energy consumption in buildings occurs in five phases (Figure 2.8). The first phase corresponds to the manufacturing of building materials and components, which is termed embodied energy. The second and third phases correspond to the energy used to transport materials from production plants to the building site and the energy used in the actual construction of the building, which are respectively referred to as grey energy and induced energy. Fourthly, energy is consumed at the operational phase (operation energy), which corresponds to the running of the building when it is occupied – usually estimated at 100 years, although this figure varies from country to country (see, for instance, OECD 2002b). Finally, energy is consumed in the demolition process of buildings as well as in the recycling of their parts, when this is promoted (demolition-recycling energy).

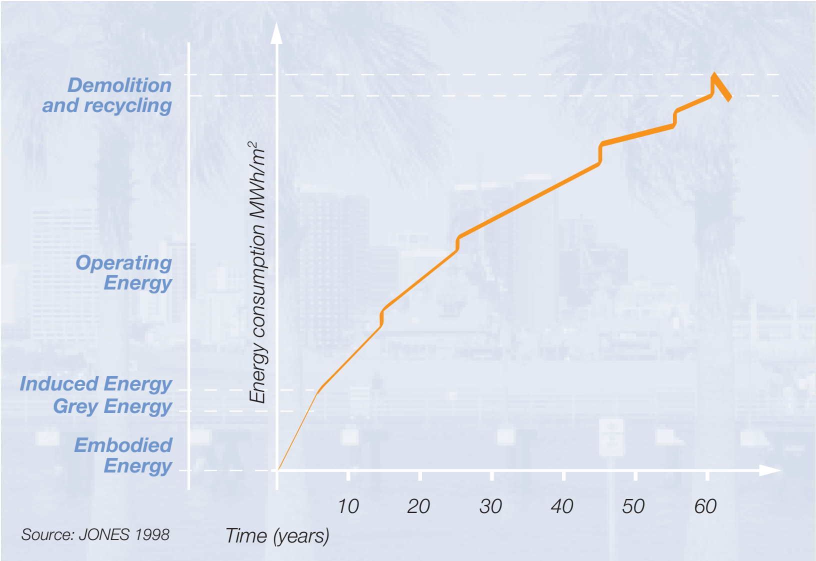


Fig. 2.8
Energy consumed in the life of a building, estimated at 60 years.

Buildings are large users of materials with a high content of embodied energy. Embodied energy corresponds to energy consumed by all of the processes associated with the production of building materials and components. This includes the mining and manufacturing of materials and equipment. Every building is a complex combination of many processed materials, each of which contributes to the building's total embodied energy. Embodied energy is proportional to the level of processing required by a material. The more complex the material is and the greater the amount of processing that is required, the higher is the amount of energy consumed. High levels of embodied energy imply higher levels of pollution at the end of the production line, as the consumption of energy usually results in emissions. Concrete, aluminium and steel, for instance, are among the materials with the highest embodied energy content and they are also responsible for large quantities of CO2 emissions. According to the World Resources Institute, 9.8 million metric tonnes of CO2 are generated from the production of 76 million metric tonnes of finished concrete in the United States (Steele 1997). Plastic is another energy-intensive material: it needs about 15 stages of synthesis; at each stage energy is required and pollutants are generated. The final product contains only 0.002% of the raw material used for its manufacture (Smith et al. 1998), although many other materials may simultaneously have been derived from the raw materials. In aggregate terms, embodied energy consumption accounts for a significant share of the total energy use of a country; in the case of the United Kingdom, estimates suggests that 10% of the total energy consumption is embodied in materials, i.e. used for their manufacturing (Ibid.). Yet, by far most energy is consumed not for construction but during the use the buildings. Energy is used for heating, cooling, lighting, cooking, ventilation and so on during the period that the building is in use. Over the years this adds up to significantly more energy than is used for manufacturing building materials and for constructing the building itself. In the United Kingdom, estimates suggest that buildings are responsible for the consumption of around 50% of the total commercial energy available in the country during the operational phase, generating some 300 million tonnes of CO2 per year (Edwards 1996; Smith et al. 1998). This corresponds to about 50% of the total national output. The United States Energy Agency estimates that the building sector accounts for around 35% of the country's primary energy use; transportation accounts for 28% of the total energy consumed in the United States, thus being less intensive than the building sector. European studies suggest that buildings are responsible for around 45% of CO2 emissions over the 'cradle to grave' aspects, in addition to also causing significant use of water and discharge of wastewater (see, for instance, Working Group for Sustainable Construction 2001). On the other hand, in low-income countries, especially in rural areas, most of the operational energy is used for cooking and lighting by means of burning wood or other types of biomass. The use of biomass does not necessarily contribute to climate change as biofuels are renewable, unless harvested in an unsustainable way, but they often cause serious indoor pollution.

Construction costs do not need to increase substantially due to the improvement of the building's energy efficiency. Typically construction costs increase by 3-5% due to the introduction of energy-efficient solutions, although this figure may vary according to construction type. Lowering the overall energy consumption has a direct positive impact upon life-cycle costs. In addition the following benefits can be listed:

- Increase in reliability;
- Increase in indoor air quality;
- Decrease in natural resource use;
- Considerable decrease of energy costs over the life-time of the building;
- Improving comfort due to improved energy efficiency in buildings. This may also in-crease productivity in service buildings;
- Creation of employment as a result of increased activity in energy improvements in buildings.

Box 2.1 Life cycle assessment

Different studies and initiatives have used life cycle assessments to measure the impacts of energy consumption in different sorts of building stocks in a quantitative way. Junnila (2004), for instance, uses the LCA method to study environmental impact of four office buildings: one of the buildings is located in the United States and the others are in Finland. Another study carried out by Japanese scientists presents similar values, although it does not separate material and constructionrelated energy that are both included in the construction value (Suzuki & Oka 1998). A Swedish survey (Adalberth et al. 2001) focuses on residential buildings. The percentage of energy used in each life-cycle phase of the buildings in these three surveys has been combined to Figure 2.9.

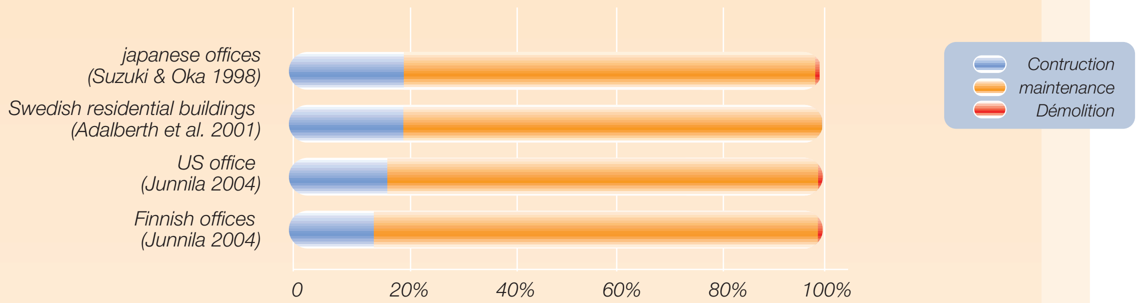


Fig. 2.9
Energy consumption by life-cycle phase in some buildings.

Source : Junnila 2004

Besides these studies, the Athena Institute in Canada has developed a life cycle assessment approach to measure the sustainability of buildings: the Environmental Impact Estimator (cf. www.athenaSMI.ca). Some further examples are presented in Annex 1.

In many poor countries, improvement in energy efficiency can also bring other kinds of benefits, especially in rural regions. As already mentioned, energy in buildings is, in many of these countries, mainly used for heating and cooking and is mostly based on biomass (wood, dung, crop residues), which is usually collected by women and children. A reduced need for energy would increase their available time for other important activities, such as education. The poor quality and efficiency of their cooking stoves leads both to over-collection of wood, increasing deforestation and desertification processes, and high levels of indoor pollution. The United Nations Environment Programme estimates that poor indoor environment cause about two million premature deaths per year, the majority being children. Improving the energy efficiency of rural settlements in low-income regions is therefore crucial for improving the quality of life of the rural poor. Despite these benefits, however, low-energy building alternatives have not yet been widely implemented. There are several reasons for this, which will be discussed in chapter 5.

Some country examples of energy use in different building phases and sectors and the technological options that can lead to improvements in the building's energy efficiency are provided in the following sections. More examples can be found in Annex 1.

2.2 Distribution of energy consumption among different building sectors and types

In most countries, residential buildings are responsible for a major part of the energy consumption of the building sector, even if the share of commercial buildings such as offices is also important. Studies indicate that, on average, buildings in Europe account for 36% of the energy use: the non-residential sector accounts for 8.7% and the residential sector for 27.5% of the total (Earth Trends 2005; ATLAS 2006.). The breakdown of the non-residential sector in Europe is presented in Table 2.1.

Studies carried out in Brazil indicate that, in 2003, Brazil's total energy consumption corresponded to 2.1% of the world's annual total energy consumption. The building sector (commercial, residential and public services) accounted for about 20% of total energy use and for about 42% of the electricity use. The shares of different building sectors of the total electricity use are presented in Box 2.3 (EarthTrends 2003; CSLF 2006; Delbin et al. 2005). In total, the residential sector consumes 23% of the country's electricity, while the non-residential sector is responsible for 19% of the consumption. In contrast, in low-income rural regions such as the sub-Saharan Africa, estimates suggest that the residential sector accounts for as much as 56.2%, while commercial and public sectors only account for 2.2% of the total energy consumption (Figure 2.10). The following boxes illustrate the energy consumption pattern of different countries and building sectors.

Table. 2.1
Europe, non-residential buildings.

Breakdown of Surface and Energy Consumption by Subsector of the Non Residential Sector

Sub Sector	% of Total Area	% of Total consumption
Retail	24	23
Office24	18	21
Sport Facilities	4	7
Education	20	13
Health Care	11	13
Hotel Restaurants	6	9
Residential Community Buildings	14	10
Transportation Buildings	3	4

Source : Source: Atlas 2006.

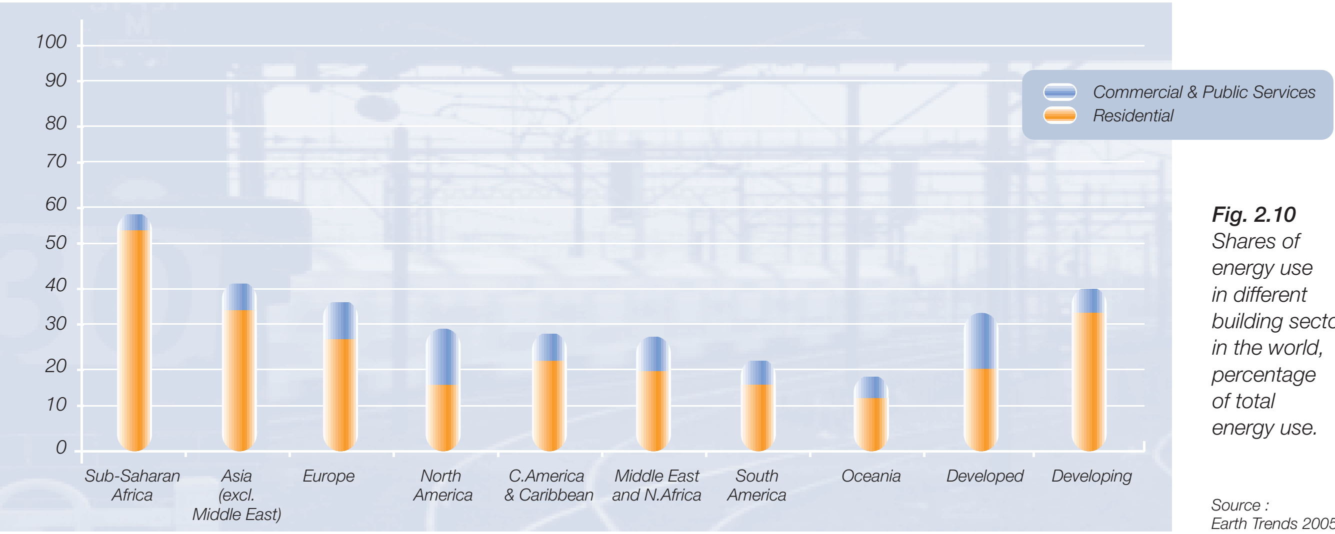


Fig. 2.10
Shares of energy use in different building sectors in the world, percentage of total energy use.

Source : Earth Trends 2005.

Box 2.2 Office buildings in Brazil

Office buildings in São Paulo, Brazil, are heavy users of energy, mostly due to the acclimatization systems they require. According to the local utility Eletropaulo, air-conditioning accounts for around 48% of the total energy consumption of the office space in São Paulo, while lighting is responsible for 24%, pumps and elevators for 13%, and office equipment for 15% (Eletropaulo 2002). In the past few years, the company has initiated several information campaigns to alert consumers of how energy can be saved, indicating that energy waste in offices may reach 15% of the total consumption, leading to increased bills, infrastructure overload and compromising the efficiency of office equipments.

Table. 2.2
Energy consumption in buildings in Brazil.

Sub Sector	Consumption of electricity %	TWh in 2003
Residential	23	85
Commercial	11	41
Public	8	30
Total	42	156

Source : Delbin et al., 2005.

> Box 2.3 Energy use in China

In China, buildings account for 42% of the total energy use, the residential sector alone covering about 38% of this. The most significant fuel in residential energy use in China's rural areas is biomass in rural areas, which provided 65% of all fuel use in 1999. Of this, 42% constituted agricultural waste or crop residues and 22% firewood. In rural areas 80% of fuel was biomass (52% stalks and 28% firewood) but virtually no biomass was used in urban areas. Coal (including coal products) was dominating in urban areas at 44%, but only comprised 15% in rural areas. (Yutaka et al. 2005).

In China, the average annual energy use per capita in urban areas is 972 kWh (3.5GJ), in rural 3250 kWh (11.7GJ), and for all areas 8.2GJ (1999). Rural use is greater as compared to the urban use, due to the low efficiency of biomass combustion for cooking and space heating. In 1999, per capita average consumption in China was 52% of the Japanese level in 1999, comparable to Japan in 1976. I (Ibid.).

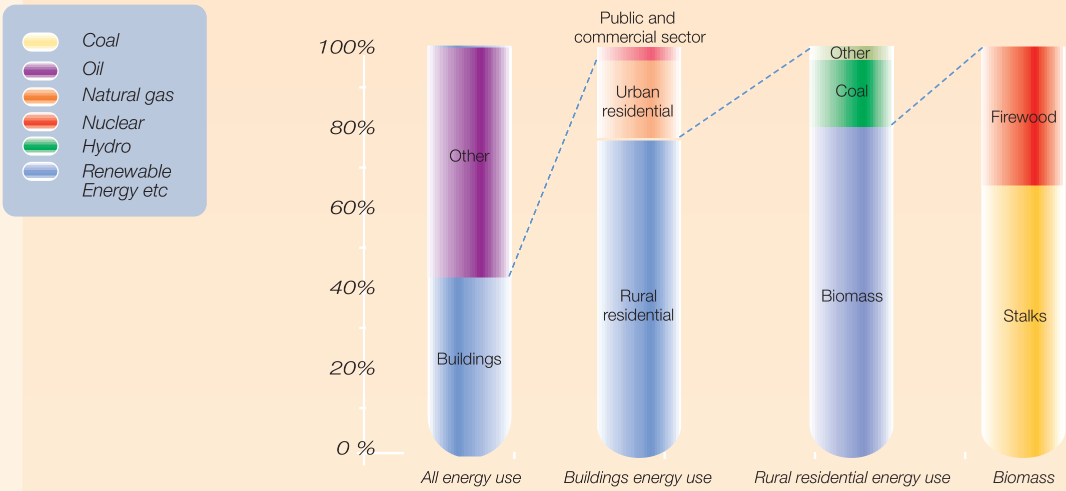


Fig. 2.11
Distribution of Chinese energy use.

Source : Yutaka et al. 2005.

China is also an illustrative example of how rapid urbanization can lead to negative environmental impact. As reported by the Chinese Research Academy for Environmental Sciences, the living space of the average Chinese was expected to grow from six square meters in 2001 to twelve square meters in 2005. During the next decade, about 300 million people will move to cities in China. If buildings continue to be operated according to current standards, the environmental impact of this demographic pressure on cities will be enormous. Assuming that 300 million people would require 75 million apartments (4 persons per apartment), and taking into account the new demand of an average apartment of 81 m² (which is considerably more than stated before), and by using the same building technology as the one used today (energy use for space heating 71 kWh/m²), the overall consumption would be 431 TWh. By using energy-efficient technology the consumption could be reduced to 35 kWh/m² the overall consumption being 213 TWh.

Compared to the total energy use in China, which was 10,400 TWh (896 Mtoe) in 2003 (IEA 2005) the energy saving potential is very important from the national energy perspective.

Box 2.4 Europe

By using existing technology, e.g. insulation of buildings, Europe could reduce greenhouse-gas emissions from the building sector by approximately 400 million tonnes – more than the total EU commitment made in Kyoto.

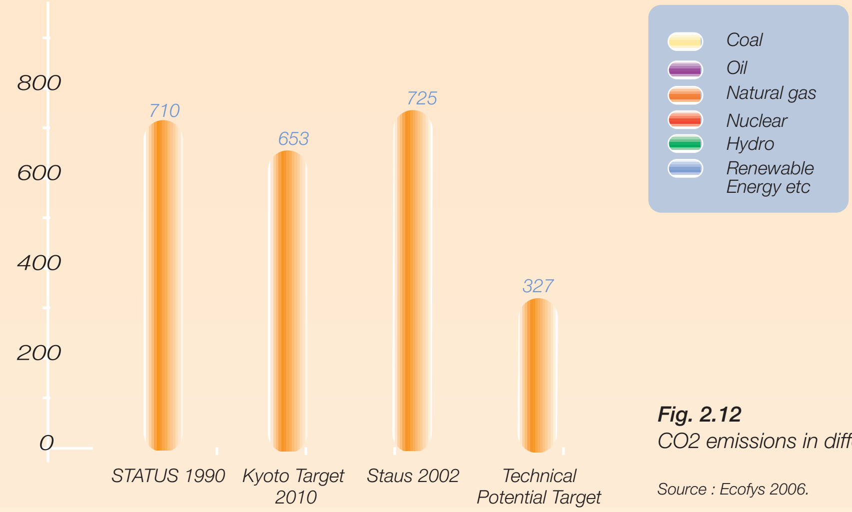


Fig. 2.12
CO2 emissions in different scenarios.

Source : Ecofys 2006.

Box 2.5 Residential, Commercial & Institutional sector in Canada

The Residential, Commercial & Institutional (RCI) sector of the Canadian Greenhouse Gas Inventory includes emissions from fuel combustion in buildings for space heating and cooling (excluding electricity use) and water heating. As indicated in Figure 2.13, the total energy use for this sector was 614 TWh (2210 PJ) in 1999. Main sources were natural gas (48%) and electricity (41%). In 1999, this sector contributed slightly more than 10% of Canada's 699 Mt CO2 eq (mega tonnes of CO2 equivalent) greenhouse-gas emissions. In 1999, total emissions from this sector were 71.9 Mt – 43 Mt (60%) from the residential sub-sector and 28.9 Mt (40%) from the commercial and institutional sub-sector (Environment Canada's Greenhouse Gas Division 2002).

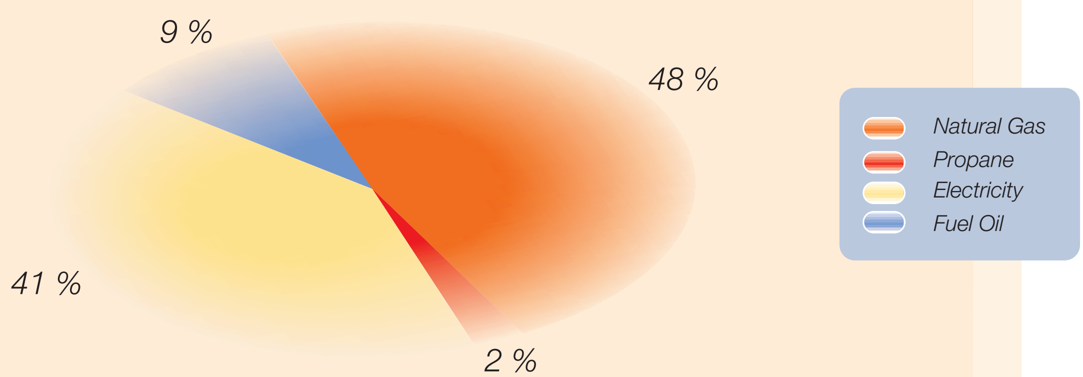


Fig. 2.13
2.13 Fuel use in Canadian RCI (Residential, Commercial and Institutional) sector in 1999.

Source : Environment Canada's Greenhouse Gas Division 2002.

2.3 Shares of different energy end-use purposes

The pattern of the energy use of a building first and foremost depends on the building type and the climate zone where it is located. In addition, the level of economic development in the area is also influential in shaping the energy use pattern. Currently one third of the world population has no ac-cess to electricity; more than 80% of whom are located in South Asia and sub-Saharan Africa (IEA 2002). In rural areas of sub-Saharan Africa, cooking accounts for between 90% and 100% of the av-erage household energy consumption (Karekezi and Kithyoma 2004). Examples of the shares of different energy uses during the operational phase of the building are shown in Figure 2.14. In terms of international averages, most residential energy in developed countries is consumed for space heating (60%, although not as important in some developed countries with a warm climate, but in this case energy may be used for cooling purposes) with this application followed in order by water heating (18%) and domestic appliances (6% for refrigeration and cooking, 3% for lighting) with other uses accounting for 13%. However, there are substantial variations. In Japan, for instance, the share for space heating is as low as 28% (ATLAS 2006). In the United States, most of the energy used in buildings is due to acclimatization systems (space heating, ventilation and air conditioning, totalling 64%), followed by water heating (24%) and lighting (12%).

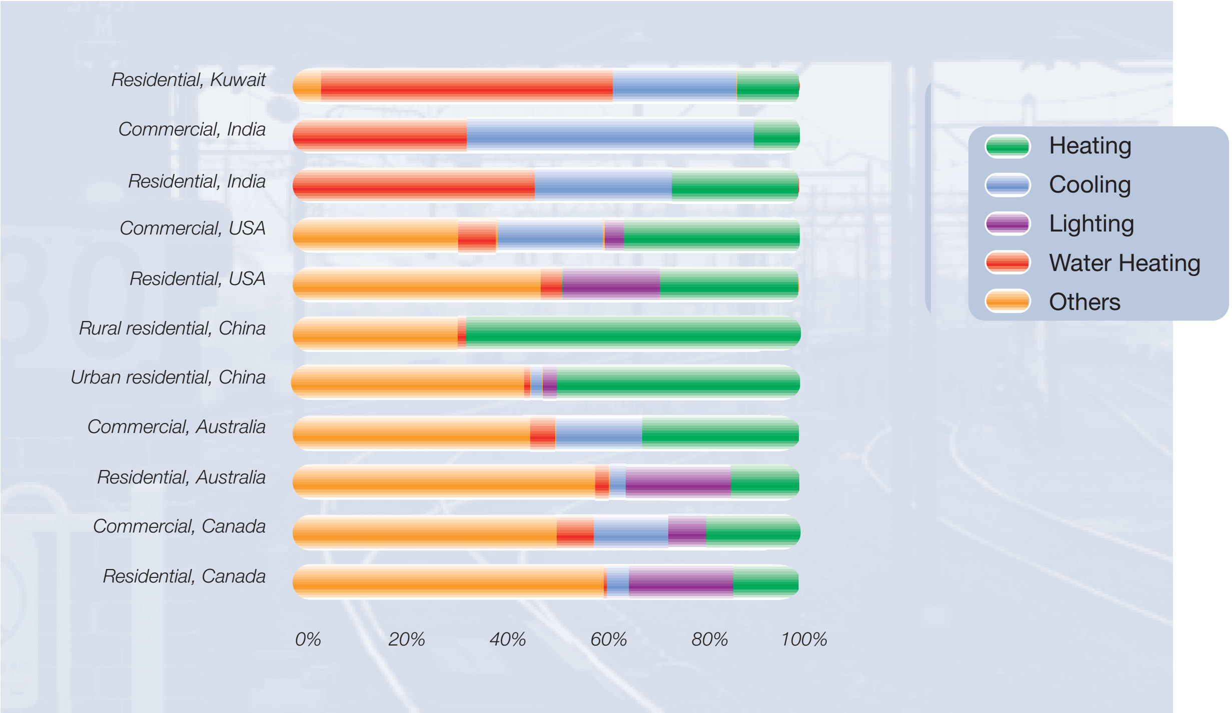


Fig. 2.14
Shares of different energy end-use purposes for residential and commercial buildings in some countries.

Source : Al-Sayed Omar Assem and Al-Ragom 2005, CMIE 2001, Sustainable Energy Authority Victoria 2004, U.S. Department of Energy 2006, Office of Energy Efficiency; Natural Resources Canada 2006.

The effects of climate, building type and the building technology are presented below.

Climate

Climate zones are defined according to the number of heating and cooling degree day values (HDD and CDD). Heating degree days are calculated by adding the temperature differences between indoor temperature demand and outdoor temperature for each day over the heating period. Similarly cooling degree days are calculated by adding cooling demands. As an example of the effect of climate, energy end-use shares by climate zone in residential buildings in the United States are shown in Figure 2.15.

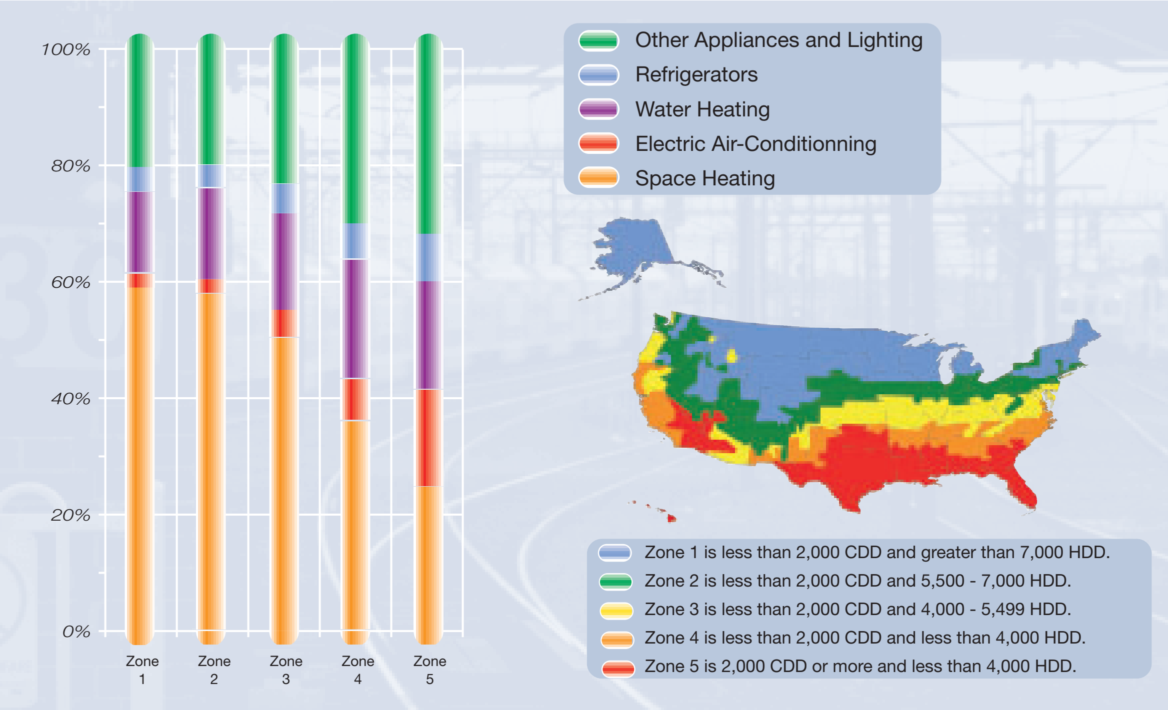


Fig. 2.15
Energy consumption in US residential buildings.

Source : US EIA 2001

Building type

Building type usually sets different requirements for the indoor climate and internal loads. In order to fulfil these requirements, different amounts of energy are needed. Electricity consumption of different types of US buildings is shown in Figure 2.16.

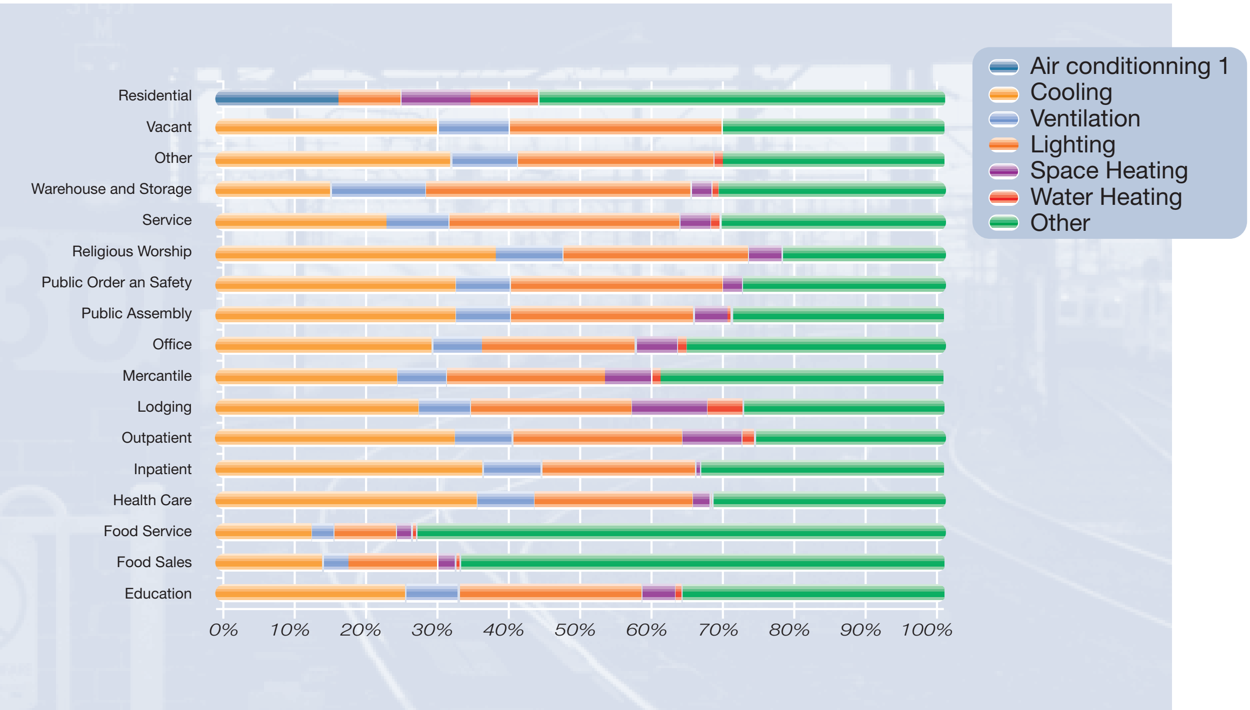


Fig. 2.16
Electricity use by building type in USA. Space heating seldom uses electricity. Residentia building statistics have both cooling and ventilation included to one field, air conditioning.

Source: US EIA 1999.

Building technology and climate

To demonstrate the impact of the climate differences and building technologies, simulations were made for residential and office buildings in New York (USA), New Delhi (India), Beijing (China) and Madrid (Spain). The simulations were made with a simulation tool, ENERGY-10™. The simulated buildings were high-rise structures, ten storeys high, with 1000 m2 per storey. The simulations were made for a reference case and for a low energy case. Details for the buildings can be seen in Table 2.3.
As shown in Figures 2.17 and 2.18, highest reductions are achieved for heating or cooling energy. In New Delhi, the heating demand is almost negligible; therefore it is evident that the heating energy savings are small. Because of a high cooling demand the highest reductions in cooling energy is achieved in New Delhi. Lighting energy demand for offices is the same in all climate regions. It is clear that the focus for energy-efficient measures are different in different climate regions. In New Delhi, the focus must be put on cooling energy reduction in both office and residential buildings, in New York and Beijing on the other hand, heating energy plays an important role.

OFFICE BUILDINGS	Reference Case	Low Energy Case
Average U-value [W/m2K]	0,841	0,532
Window shading	none	40 deg latitude
Window glazing U-value	2,78	1,48
HVAC system	DX cooling with gas furnace.	DX cooling with gas furnace.
heat/cool performance	eff=80%, COP=2,6	eff=90%, COP=3,8
RESIDENTIAL BUILDINGS	**Reference Case**	**Low Energy Case**
Average U-value [W/m2K]	1.382	0,548
Window shading	none	40 deg latitude
Window glazing U-value	2,78	1,48
HVAC system	DX cooling with gas furnace.	DX cooling with gas furnace.
heat/cool performance	eff=80%, COP=2,6	eff=90%, COP=3,8

Table. 2.3
Building characteristics of the simulated cases. The U-value determines the heat loss due to transmission in relation to the temperature differential between the interior and the exterior.

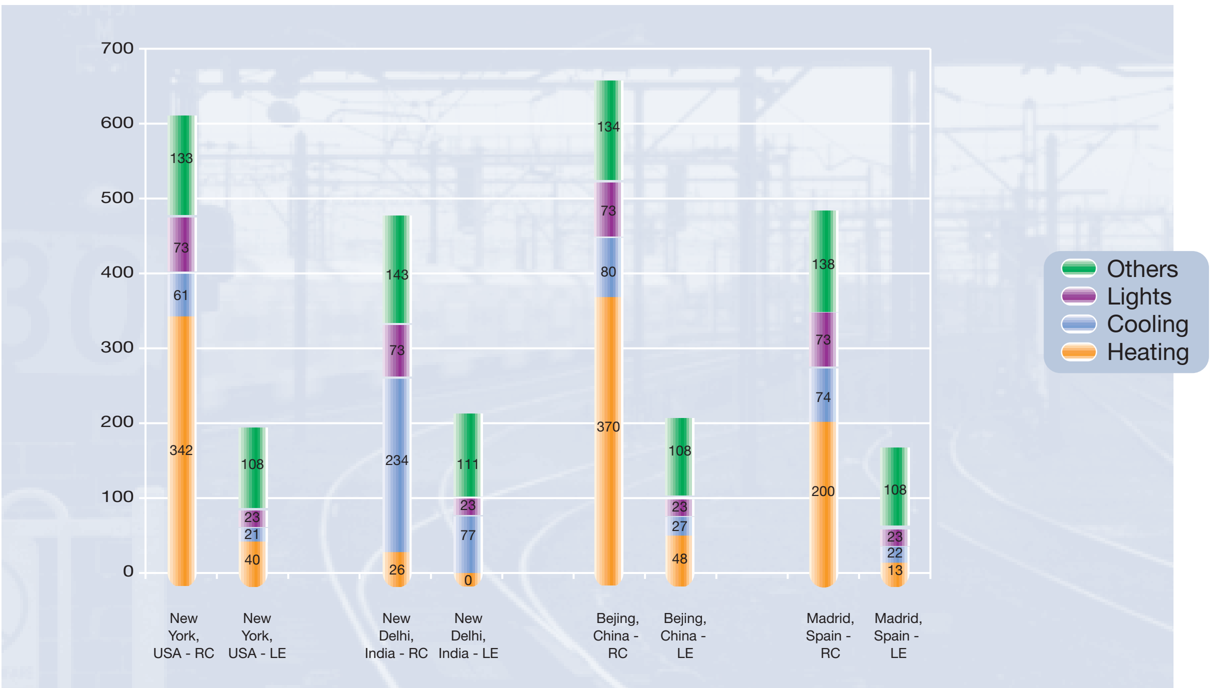


Fig. 2.17
Energy consumption in the simulated office buildings.

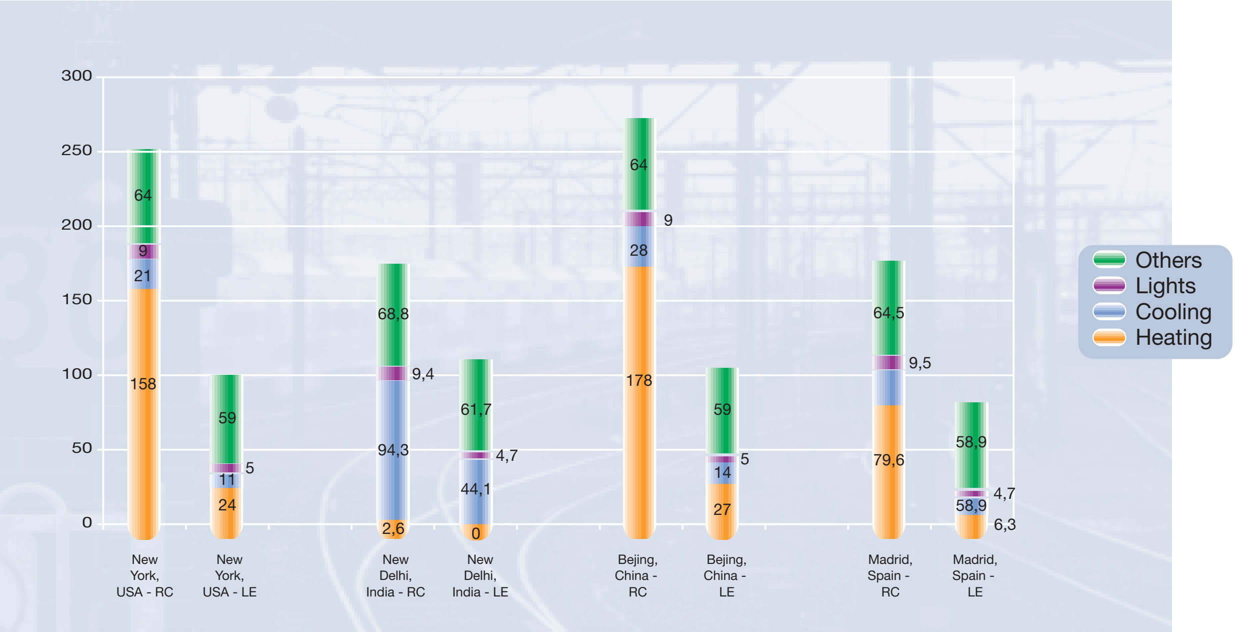


Fig. 2.18
Energy consumption in the simulated residential buildings.

Interaction of the systems

The reduction of energy use in one system can affect the energy use in another system. In buildings in Bangkok, lighting savings lead to significant reductions in energy used for cooling and ventilation systems (Figure 2.19, left). These savings contributed to up to a third of the total combined energy savings in lighting and HVAC (Heating, Ventilation and Air-Conditioning) (Figure 2.19, right). Effects vary considerably, depending on the type of building but the pay-back time was in all cases less than three-years (Busch et al. 1993).
Even in the extreme case of Sweden, commercial buildings enjoy a net HVAC benefit from lighting savings. According to studies at Chalmers University, typical modern Swedish buildings re-quire cooling even at an outdoor temperature of -10° C. This is because of considerable internal heat generated by people, lighting and other energy-using equipment (IAEEL, newsletter). A rule of thumb is that about one watt of air cooling energy savings result from every three watts of lighting energy savings. In other words, if the total lighting load is reduced, additional net energy savings of 30-40% can be expected (Lighting design lab 2006).

Technological options for improving the energy efficiency of buildings heavily depend on the climate zone where the building is sited. Figure 2.20 illustrates the priorities that have to be given in terms of technological options according to the climate zone where the building is located.

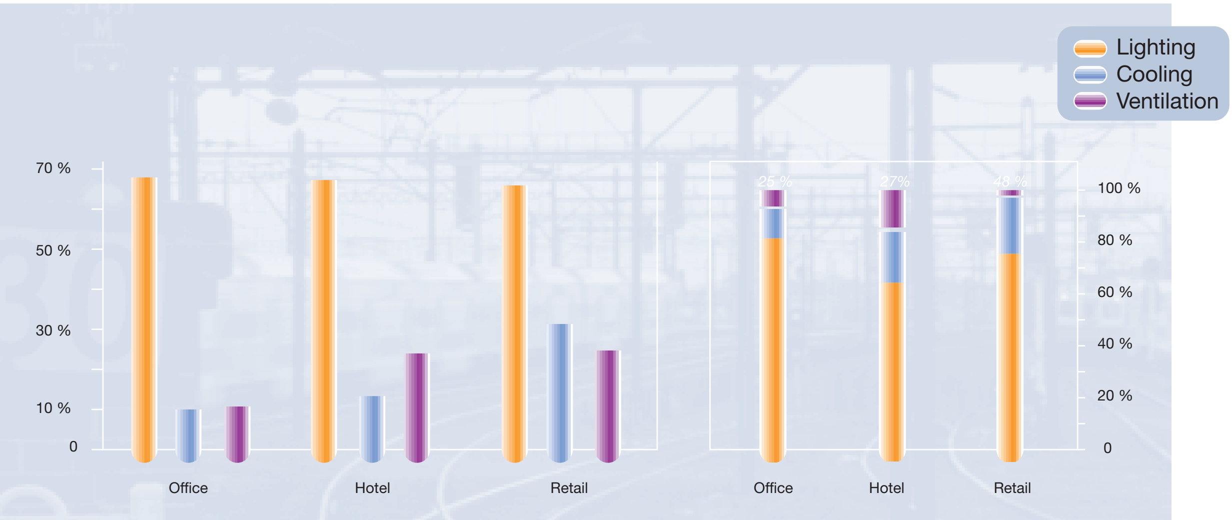


Fig. 2.19
Different energy systems also interact with each other. Lighting-HVAC interactions in Thailand.

Source: Busch et al. 1993.

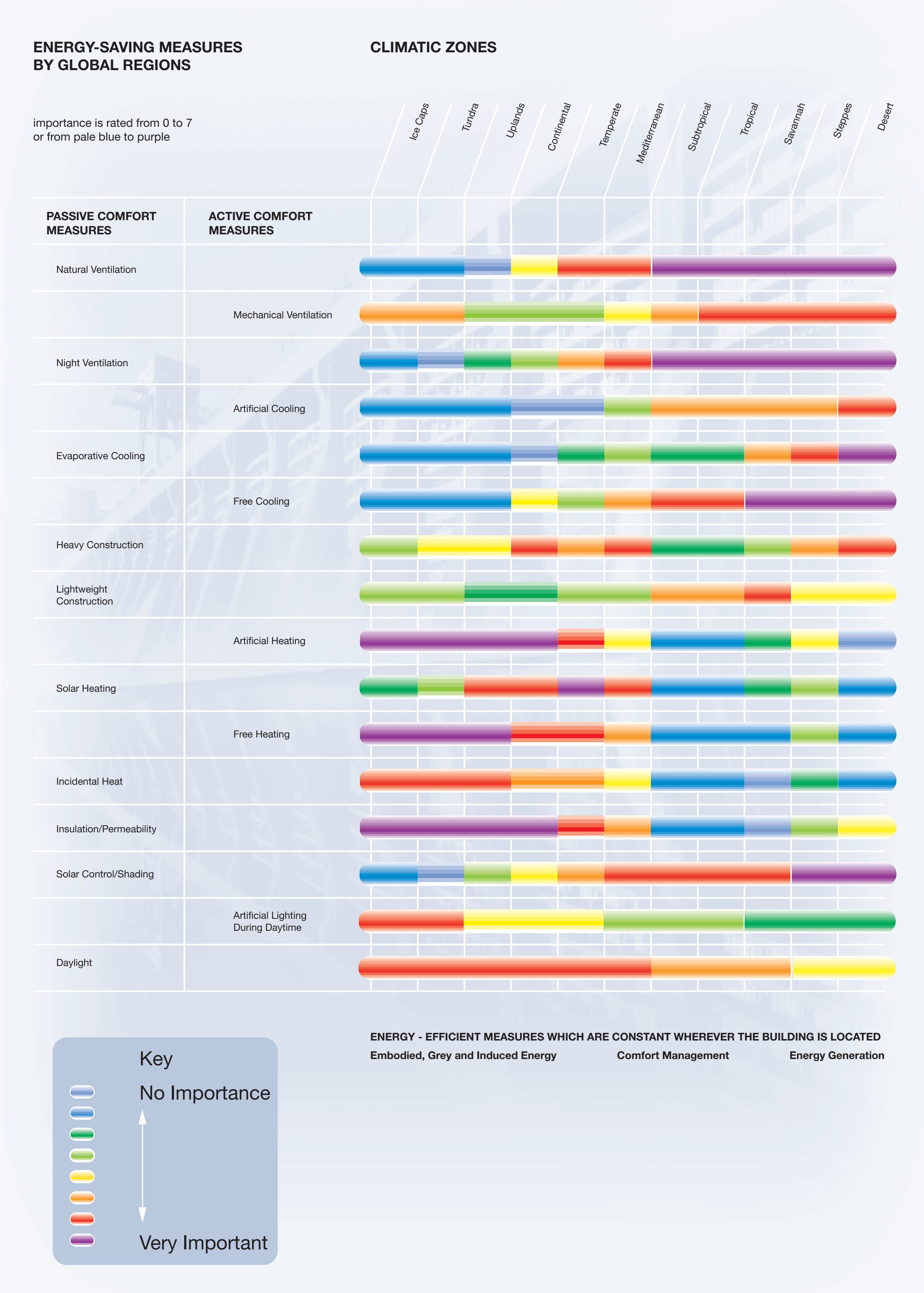


Table. 2.20
Energy saving measures by global regions.

Source: Jones 1998.

3 Opportunities for Energy Efficiency in Buildings

THE DIVERSITY OF BUILDINGS and their distinct use imply major differences for the adoption of energy conservation models. No single model or legislative rule can be effective in all cases. The energy sources used, methods applied and equipment added need to be tailored according to individual needs. In addition local conditions of new construction, existing buildings, small family houses and large commercial complexes also have to be considered. The same applies to building codes, operation guidelines and the monitoring of their implementation.
Attention should be drawn to the energy source for heating and cooling of the building giving preference to renewable sources such as solar heat or bio fuels for heating. Heat pumps, based on outdoor air heat source can be an energy-efficient way to heat a building. Energy quality should also be considered. The use of low-quality sources, such as ground heat and district heat return has a good potential for energy efficiency in buildings.
Construction techniques developed in different periods may play an important role on the buildings' energy consumption balance. In Finland, for instance, buildings that were constructed in the 1930s and 1940s can be considered as more efficient, compared to more recent ones. On average, they consume more limited amounts of energy (97% of them consume less than 60 kWh/m3/year), although this may imply that comfort requirements in these buildings are not always met in the best way. Likewise, in Brazil commercial buildings constructed in the 1960s and 1970s also tend to be more efficient in terms of energy consumption, when compared to newer ones, as they explored a number of passive solutions, such as thermal mass and sunshades, decreasing the need for acclimatization systems. Nowadays, by following global architectural approaches based on glass envelopes, buildings in Brazil tend to overheat during the summer, requiring more energy for their acclimatization systems to cope.
Due to their long life cycle, buildings that will be operating in the decade of 2030 have already been built in their majority. As technologies opted for today have a long-term effect, urgent attention is required not only to introduce more sustainable solutions, but also to promote refurbishments when necessary. However, renovations aiming to improve the energy efficiency of buildings do not by themselves guarantee the reduction in energy consumption in the long run. If users want to improve their indoor comfort, the building net energy consumption may still increase.
In this chapter, a review of the energy efficiency opportunities in the construction process and in buildings is undertaken, including building materials, envelope design, energy supply, human behavior and site and energy chain planning. The focus will be put on the operational phase of the building and on solutions that have been demonstrated in full scale, such as pilot facilities or commercial applications.

3.1 Building materials

Each year, some three billion tonnes of raw materials – 40-50% of the total flow in the global econ-omy – are used in the manufacturing of building products and components worldwide (Roodman and Lenssen 1995; Anink et al. 1996). Raw materials for the building sector are extracted, processed, transported, added in the construction phase and finally disposed. All these stages imply a number of environmental impacts. In particular, the building sector is a heavy consumer of materials with high embodied energy content, such as aluminium, cement and steel, whose production usually depends on the use of fossil fuels, resulting in CO2 emissions.
Embodied energy can be saved through the right choice of building materials. Studies show that the total energy consumption in manufacturing of steel beams is two to three times higher and the use of fossil fuels is 6 to 12 times higher, as compared to the manufacturing of glulam beams. The waste handling of both materials can either give or use energy. Therefore, the difference in energy consumption over the life cycle between steel beams and beams in glulam depends strongly on how the materials are handled after the building demolition (Petersen et al. 2002). Dutch studies reveal that an increase in wood use could reduce CO2 emissions by almost 50% as compared with traditional construction (Goverse et al. 2001).
Lightweight building construction materials, such as timber frames, usually have lower em-bodied energy compared to heavyweight construction. This is not necessarily the case if large amounts of light- but high-energy materials such as steel or aluminium are used. Typical figures of embodied energy for some Australian materials are given in Annex 2 as an example of the differences between various materials. Generally speaking, the more highly processed a material is the higher its embodied energy. These figures should be used with caution because:

> The variation can be big between different countries;
> The actual embodied energy of a material manu-factured and used in one place will be very different if the same material is transported by road to ano-ther remote place;
> Aluminium from a recycled source will contain less than 10% of the embodied energy of aluminium manufactured from raw materials;
> Materials with high embodied energy, such as stainless steel, will almost certainly be recycled many times, reducing their lifecycle impact (Milne 2005).

Besides minimizing embodied energy, it is also important to produce buildings with a high recycling potential in order to reduce the use of energy and resources over an extended length of time. Recycling of buildings is a relatively new concept and has only been assessed in a few studies. One of these studies was carried out in Sweden, where two cases were analyzed: (i) the building as it was built with a large proportion of reused materials and components; and (ii) the building as if all materials and components had been new. The results showed that the environmental impacts of reused materials corresponded to about 55% of the impact that would have been caused if all materials had been new. The reuse of clay bricks and roofing clay tiles accounted for the main decrease in environmental impact. In addition, these materials can be transported over quite long distances and still present environmental benefits (Thomark 2000). Other studies show that by using recycled materials 12% to 40% of the total energy used for material production could be saved (depending on the study). There are several reasons for the mixed results. Important differences between the studies include recycling forms, recycling rates and material composition in buildings. Despite the differences, however, the overall results indicate a considerable amount of potential energy saving through reuse of building materials (Ibid.).

According to an Australian study, the reuse of building materials can commonly save up to about 95% of embodied energy that would otherwise be wasted. Savings from recycling of materials for reprocessing varies considerably with savings up to 95% for aluminium but only 20% for glass. That is because some materials, such as bricks and roof tiles, suffer damage losses up to 30% in reuse. Of course, it should also be kept in mind that the

Box 3.1 Embodied energy in Australian buildings

CSIRO research has found that materials used in the average Australian house contain the following levels of embodied energy. Materials with the lowest embodied energy intensities, such as concrete, bricks and timber, are usually consumed in large quantities. Materials with high energy content such as stainless steel are often used in much smaller amounts. As a result, the greatest amount of embodied energy in a building can be either from low embodied energy materials such as concrete, or high embodied energy materials such as steel (Milne 2005).

ASSEMBLY	PER EMBODIED ENERGY KWH/M²
WALLS	
Timber frame, timber weatherboard, plasterboard lining	52
Timber frame, clay brick veneer, plasterboard lining	156
Timber frame, aluminium weatherboard, plasterboard lining	112
Steel frame, clay brick veneer, plasterboard lining	168
Double clay brick, plasterboard lined	252
Cement stabilised rammed earth	104
FLOORS	
Elevated timber floor	81
110 mm concrete slab on ground	179
200 mm precast concrete T beam/infill	112
ROOFS	
Timber frame, concrete tile, plasterboard ceiling	70
Timber frame, terracotta tile, plasterboard ceiling	75
Timber frame, steel sheet, plasterboard ceiling	92

Table 3.1
Embodied energy in different building parts.

Source : Lawson 1996.

Box 3.2 Cement production

The cement industry is estimated to contribute to 5% of all anthropogenic CO2 emissions. On average, 50% of these emissions stem from chemical changes of the raw material, 40% from fuel combustion and 5% from both electric power and transport (Kruse 2004). There are several ways to produce cement, each using different amounts of energy (see Figure 3.1). A modern dry process, which can use as little as 830 kWh/ton of clinker, is more efficient than a wet process (1,390 kWh/ton – 1,670 kWh/ton of clinker). Increasing blended cement production, which includes materials that do not require processing in the cement kiln (such as fly ash or slag), reduces CO2 emissions as well as energy consumption. Consequently, the more wide-spread use of Best Available Technologies (BATs) could substantially reduce energy consumption in this sector. In China, for instance, where about 40% of the world's cement is produced, there could be savings of 390 TWh (1.4 EJ) in the cement industry per year if China had the same energy technologies as Japan (Kruse 2004; WBCSD 2005).

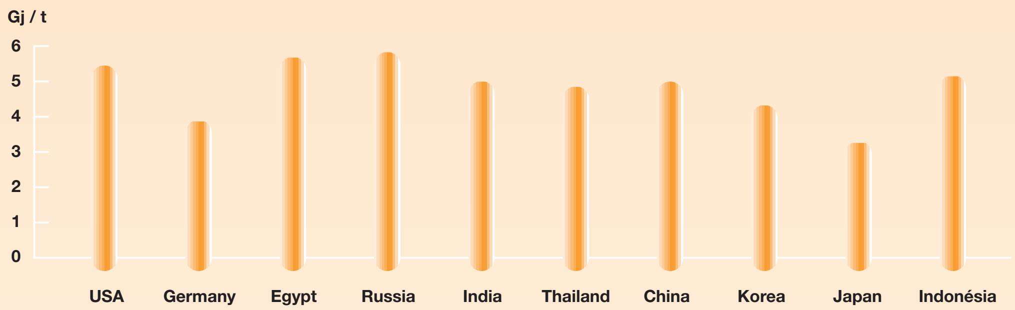


Figure 3.1
Primary energy intensity of cement production. The scale equals to {0, 278, 556, 833, 1111, 1389, 1667} kWh/t.

Source: WBCSD 2005.

single most important factor in reducing the impact of embodied energy is to design long life, durable and adaptable buildings (Milne 2005). By extending the life span of a building, the energy and costs associated with demolition and construction of new buildings are deferred until later.
In conclusion, buildings should be designed with due consideration to factors such as local climate, transport distances, availability of materials and budget, balanced against known embodied energy content.
When choosing a building material, these guidelines should be followed:

- Design for long life and adaptability, using durable low maintenance materials;
- Ensure materials can be easily separated;
- Avoid building a bigger house than you need. This will save materials;
- Modify or refurbish instead of demolishing;
- Ensure materials from demolition of existing buildings, and construction wastes are re-used or recycled;
- Use locally sourced materials when possible (including materials salvaged on site) to reduce transport;
- Select low embodied energy materials (which may include materials with a high recycled content) preferably based on supplier-specific data;
- Avoid wasteful material use;
- Specify standard sizes, don't use energy-intensive materials as fillers;
- Ensure that off-cuts are recycled and avoid redundant structures. Some very energy in-tensive finishes, such as paints, often have high wastage levels;
- Select materials that can be re-used or recycled easily using existing recycling systems;
- Use efficient building envelope design and fittings to minimize materials (e.g. an energy-efficient building envelope can downsize or eliminate the need for heaters and coolers, water-efficient taps allow downsizing of water pipes, etc);
- Ask suppliers for information on their products if not provided (Milne 2005).

3.2 Envelope

A well-insulated thermal envelope without thermal bridges is a passive way to obtain a low heat/cool demand and improved thermal comfort. There are two key components to a well-insulated building shell: high levels of insulation with minimum thermal bridges and airtight constructions. The climate differences are mirrored in the traditional buildings that range from not-insulated (usually quite heavy) constructions in the south, designed mainly for summer conditions, to fairly well insulated heavy or light constructions in the north, designed primarily to comply with winter conditions. In many countries there are already requirements for the thermal qualities of different parts of the envelope (cf. IEA Annex 36).

High levels of insulation are accomplished by constructing a thicker than normal wall and filling it with an insulation material. However, simply adding more insulation does not turn a conventional assembly into a high-performance assembly. The wall system and junctions between building components have to be carefully designed to be airtight and avoid thermal bridges or discontinuities. As more insulation is added, the thermal discontinuities become more important.

A certain thickness of insulation gives the largest effect if applied externally, because the largest possible numbers of cold bridges are broken. Furthermore, the importance of air tightness to the heat demand and to the durability of the constructions must not be underestimated. Very few insulation materials are airtight in themselves and their insulating effect is due to still air in small cavities and depends on them being built into airtight constructions.

Mineral wool is the insulating material dominating most markets, but a number of other typical insulation materials exists, including aerated concrete, light clinker, cell glass, expanded polystyrene (EPS), extruded poly-styrene (XPS), polyurethane, perlite, cellulose fibres, fibre boards and woodcrete. Increased interest in environmentally-friendly buildings by product manufacturers has resulted in the creation of a group of 'alternative insulation materials'.

A study commissioned by the Eurima (European Insulation Manufacturers Association, Eurima 2002) reveals that by applying a good level of thermal insulation to the buildings in Europe, the target of the Kyoto Protocol could be easily achieved.

Windows are still the least insulating part of the thermal envelope with a heat loss coefficient that is typically 4 to 10 times higher than the one of other thermal envelope elements. At one time this lead to the use of very small window areas at the expense of the daylight level, but concurrently with development of improved insulating glazing, the size of typical window areas has again increased. Windows are built up of a number of components (glass, gas filling, spacer, frame) that can be combined so that in each case the window meets the requirements for insulation properties, daylight conditions, solar shading, noise reduction, etc.

Most glazing choices involve a trade-off between the requirements for air conditioning, space heating and electric lighting (Figure 3.2). For instance, clear glass lets in lots of visible light and solar heat, thus reducing the need for heating and electric lighting, although it increases the need for cooling relative to reflective glass. Chromogenic glazing has the potential to improve performance in both parameters (Madison Gas and Electric 2006).

Related to how the building envelope is designed, is also how the building is placed in the lo-cal context: a building should always be designed with attention to passive solar issues, such as orientation and sitting, glazing size and location, natural ventilation, as well as shading strategies. This implies positioning of windows in strategic locations so as to capture sunrays, but avoid glaring, and also to capture air while ensuring the building's structural stability. After having optimized these "passive solutions", the builder should also consider the use of energy-efficient materials, such as high-efficiency windows, insulation, bricks, concrete, masonry, as well as interior finishing products.

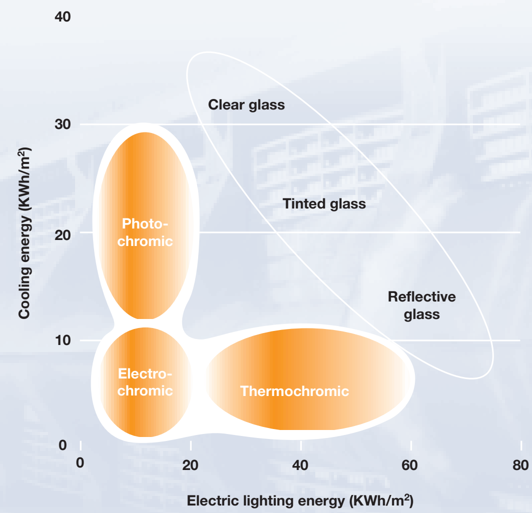


Figure 3.2
Lighting energy versus cooling energy for different glazing types.

Source: Madison Gas and Electric 2006.

3.3 Energy supply

The operational energy normally accounts for the major part of the total energy used in buildings. Therefore it is of great importance to have an energy-efficient system, i.e. which provides good in-door conditions without consuming too much energy. After exploring passive solutions as above described, the builder should review options for also making use of more active solutions increasing the building's energy performance. These can include energy saving appliances, lighting controls and thermostats, activated blinds, fans, efficient heating and cooling systems, solar water heating systems, as well as heat recovery systems, wind turbines and photovoltaic cells. It should be noted that energy systems are usually designed to last at least 30 to 40 years and if they are not chosen carefully, the potential to change to a different energy source may be lost for this period. The energy distribution system in a building also has impact on the energy efficiency of the entire energy system. Low temperature heating systems are distribution systems with large areas, for example floor, ceiling or wall heating, enabling use of lower temperatures on the heat carrying media (normally circulating water). This means higher efficiencies for the energy systems and better possibilities for utilizing renewable energy sources. Low temperature heating systems also have other advantages. The lack of radiators gives advantages in furnishing, the indoor air quality is improved and especially floor heating is comfortable and enables a lower indoor air temperature, which gives additional energy savings of approximately 5% per degree. More information about these systems can be found, e.g. in the LowExGuidebook (see LowExGuidebook 2005).

In the so-called Passive Houses there is no conventional heating system at all. The building is designed to have such a low heating demand that it can be satisfied with the ventilation air (see more information about passive houses in chapter 4.3). The absence of a heating energy system gives many advantages. The building design is less complex, less planning needs to be done, no space needs to be allocated for a boiler and radiators and the building services systems require less maintenance, in addition to contributing towards savings in investment costs.

There are many technologies for providing the cooling of buildings in an energy-efficient way. These technologies can use low energy sources because of their distribution systems with big areas, enabling temperatures close to the desired room temperature. More information about these systems can be found in the LowExGuidebook (see LowExGuidebook 2005). Also, an effective use of passive cooling strategies (e.g. night-cooling, solar chimneys) will enhance the energy efficiency of the cooling system.

An effective use of energy in lighting is another essential part of house design. This depends on the following issues:

- The availability of natural lighting indoors;
- The efficiency of the electrical components: lamps, ballasts and luminaries;
- The lighting controls, and especially how they take advantage of available daylight;
- The maintenance regime.

Box 3.3 Air-conditioning in China

The installation of efficient heat pump-based air conditioning units instead of average air conditioning units in Chinese households would result in a savings of more than 4.2 PWh (15 EJ) (including transmission & distribution losses) until 2030. This would translate into energy savings of 139 TWh (0.5 EJ) in 2010, which would equal about 1.1% of total Chinese energy consumption in that year, or, for comparison, about 20% of Germany's electricity consumption in the year 2002 (WBCSD 2005).

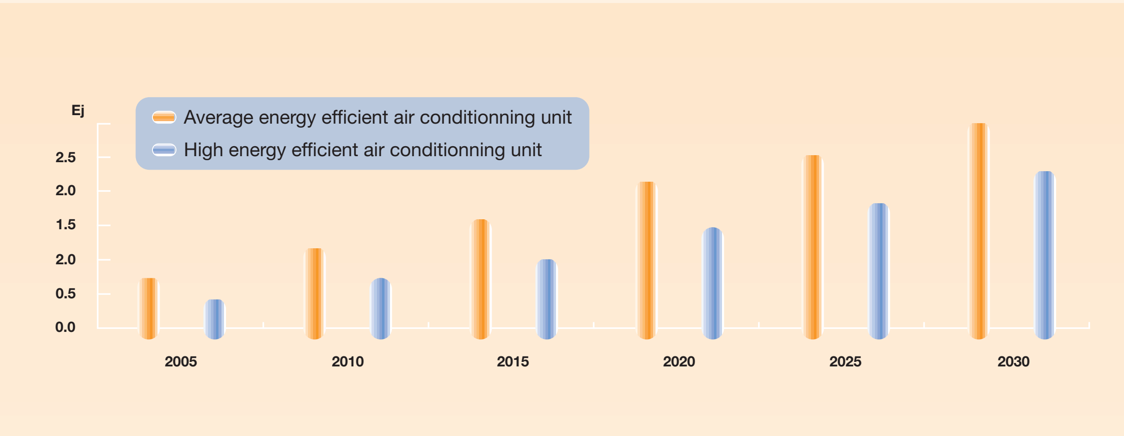


Figure 3.1
Energy consumption of the air conditioning units in selected years. The scale equals to {0, 139, 278, 417, 556, 694} TWh.

Source: WBCSD 2005.

Box 3.4 Light emitting diodes

One way of enhancing lighting energy efficiency is using energy-efficient lamps, such as fluorescent lamps or light emitting diodes (LEDs). LEDs are highly efficient. In traffic signal lights, a red traffic signal head that contains 196 LEDs draws 10 W versus its incandescent counterpart that draws 150W. Various estimates of potential energy savings range from 82% to 93%. Some LEDs are projected to produce a long service life of about 100,000 hours.

LEDs offer benefits such as small size, long lamp life, low heat output, energy savings and durability. They also allow extraordinary design flexibility in colour changing, dimming and distribution by combining these small units into desired shapes, colours, sizes and lumen packages. Currently, relatively low overall light output, poor colour rendering and questions about advertised service life may indicate that LEDs, while very useful in many applications, are not yet ready for 'prime time' in some architectural applications. (Lighting Design Lab 2006).

Reliable information about the costeffectiveness of LEDs is hard to find since the technology is rather new, especially the technology replacing conventional lighting in buildings.

When planning energy efficiency in lighting, it is necessary to consider daylighting and electric lighting, both individually and in conjunction with one another. An extensive use of natural lighting can provide considerable energy savings but the other environmental aspects of large glazed areas must be taken into account, especially thermal comfort during sunny weather, as mentioned above. Important aspects to remember when working to improve lighting energy efficiency are the following:

> Using light where and when necessary but without over illuminating.
> Using efficient fittings, lamps and ballasts, control lighting efficiently and keep fittings and lamps clean (IEA Annex 36).

Since cooking is a major energy use in many developing countries, it is worth also discussing it at this point. As mentioned before, biomass is the main energy source for cooking in rural areas of developing countries. Although biomass is regarded as a renewable energy source, it causes a number of other problems than greenhouse gas emissions. Fetching wood is a time consuming activity which is mostly carried out by women and children, hindering them from tending to other important activities, such as school work. Harvesting in an unsustainable manner (essentially without ensuring regrowth) also causes deforestation and desertification processes in some cases. This in turn enhances the greenhouse effect. Replacing traditional fuels at least partly with solar cookers and effective stoves would reduce the negative effects of the current energy use pattern in developing countries. In addition, avoiding burning biomass indoors for cooking and heating would contribute to reduced indoor air pollution and associated respiratory diseases.

Energy systems also include other appliances, such as refrigerators, freezers, washing ma-chines, televisions, etc. Many of these electrical appliances are already marked with different energy labels, which help consumers to choose energy-efficient products. For example, by choosing a freezer with the European A-labelling will save 45% of energy compared to an average freezer.

Figure 3.4
Energy labels can help consumers to choose energy efficient products.

Source: DEFRA 2006.

3.4 Human behavior

People do often not behave consistently with their level of concern about environmental problems. In fact, environmental considerations are probably only to a smaller extent determining human behavior. Many other factors play a role, such as cost of in terms of time, money or effort, and people's ability to behave in certain way. People also have to be aware of the environmental effects of individual actors in order to behave in an environmentally-friendly way.

Studies have shown that individuals usually estimate the power consumption of their appli-ances on the basis of their function and size, rather than the actual power rating. They think, often wrongly, that large appliances take more power than smaller ones. They also tend to overestimate the power consumed by lighting and other visible applications, while underestimating the energy needed for heating water and other less visible applications. It has proven difficult to change these misconceptions through simple information campaigns. Campaigns targeted more specifically at the individual's personal circumstances are more likely to be effective. The following boxes describe how gender, socio-demographic differences and different building users can influence energy use in buildings.

Box 3.5 Gender

In a study conducted in Finland it was found out that even gender can influence the use of energy (Karjalainen 2006). It appeared that women are less satisfied with room temperatures than men, prefer higher room te peratures than men, and feel both uncomfortably cold and uncomfortably hot more often than men. Although women are more critical of their thermal environments, men use thermostats in households more often than women.

In the tests, women adjusted room temperatures higher than men to fulfil their current temperature preferences. In the controlled experiments, men and women were dressed similarly, and there was no gender difference in clothing insulation, so the gender difference in temperature preference cannot be explained by clothing. Experience of thermal comfort at home and in the office was also studied. In offices, dress codes and trends do influence clothing and clothing insulation. In practice, this means that women wear lighter clothing than men on average. In Finland, women dress quite similarly to men – for example, among women, trousers are more common than skirts (especially in the younger age groups). Presumably there is a difference in clothing insulation by gender, although statistical information on indoor clothing in Finnish workplaces is not available. However, it is clear that the gender differences in thermal comfort which were found in this study are so significant that they can only partly be explained by clothing.

It is important to understand the adaptive role of clothing in maintaining thermal comfort. The respondents were asked what their principal action is when they feel uncomfortably cold and uncomfortably hot. When they feel cold, the principal action by 52% at home and 58% in the office is to put more clothes on. Clothing is not adjusted that often when feeling hot: 8% of people at home and 9% of people in the office take some clothing off to solve the problem in the first place, but the most common principal action when feeling hot is to open a window (47% and 34% of people at home and in the office, respectively).

Box 3.6 Socio-demographic groups

Research carried out in the Netherlands shows that differences between socio-demographic groups are not always straightforward. Highly-educated people often use more heating energy, for instance, even though their home is likely to be better insulated. Young people have more wall and floor insulation in their homes, while middle-aged and elderly people take more small energysaving measures.

So while one group displays more environmentally-friendly behaviour on one level, on another they are less environmentally friendly than other groups. The relationship between environmentally relevant behaviour and income or household size is fairly straightforward: The higher the income and the larger the household, the greater the environmental burden. However, there are clear economies of scale in larger households, because people share appliances and services, making individual energy consumption relatively low (Steg 1999).

Box 3.7 Office workers

In a European study called 'Energy-efficient behaviour in office buildings - EBOB' it was found that the investigated buildings (in Sweden, Finland, France, Italy and the Netherlands) were not as energy efficient as planned. The main reasons were:

- *Maintenance personnel having low status and low educational level;*
- *Higher internal heat loads than presumed;*
- *Lack of information to the users;*
- *Difficulties using the controllers;*
- *Motivational problems for putting the opinions into practice;*
- *The windows were often left open when leaving the room in order to obtain fresh air;*
- *The computers were not switched off when not used;*
- *The office workers neglected to switch off the lights when leaving the work space.*

The EBOB study indicated that:

- *Energy savings can be reached by designing systems which persuade people to choose the 'best action' from an energy saving point of view;*
- *Energy savings can be reached by systems which choose the 'best action' from an energy saving point of view;*
- *User interface with energy optimization or comfort optimization could obtain energy savings and result in an energy-efficient behaviour of end-users;*
- *The most effective way to influence the end-user is likely by providing her/him information through the control system by an adequately designed interface (EBOB 2006).*

3.5 Site and energy chain planning

It is not only the building itself that has an influence on the energy efficiency. The location and the context into which it is placed, and how the surroundings are planned, also play important roles.
The building design and the construction techniques have to be in accordance with the local environmental conditions. This means paying attention, among others, to the local climate, prevalent winds and urban fabric, so that individual buildings will be able to fit well (individually as well as collectively) within the spatial structure of the place and be less resource intensive by exploring issues such as natural daylight and passive cooling/heating, according to the local requirements (Girardet 1997, 2001). Individual buildings may also contribute to enhance urban green areas, not only on the surface, such as on the roofs and ground, but also vertically on the envelope. There are now interesting examples of buildings that have developed vertical gardens, which not only contribute to balancing energy use in their interiors by minimizing

cooling loads, but which also help to reduce pollution and urban warming. Vertical gardens can also help in carbon sequestration processes.
Transport is another important consideration, indirectly impacting the energy efficiency of buildings. In recent years cities have attempted to address urban pollution by applying a combination of land use and transport policies, aiming at creating mixed-use developments (commercial and residential at the same time). In such developments the need for transport between residence and work place is minimized. This system avoids the single-function development and the dominance of the car, thus favouring multi-functional buildings and clean transport systems, e.g. bicycles (see, for instance, Rogers 1997).
Empirical evidence demonstrates that the compact model is successful, not only in terms of relieving some of the urban environmental problems, but also in terms of enhancing the quality of life offered by the city. An example that can be given is the master plan for the Potsdamer Platz in Berlin, designed by Italian architect Renzo Piano, proposing the rehabilitation of a large area of urban wasteland into a mixed use development, including offices, retail, housing, entertainment facilities, and public amenities, also addressing public transport issues. In this case, broader (local) urban planning strategies are decisive for implementing compact, mixed-use developments. However, clients and architects may also play a role in this regard and propose mixed land use and accessibility to public transport as part of their environmental planning strategies.
Active policies and programmes to improve the environmental performance of buildings are crucial. These could involve not only the design of better master plans but also the promotion of other solutions such as urban cooling where applicable, through urban agriculture and by expanding green areas to alleviate the heat-island effect by improving natural shading, heat-absorbing and humidifying capacities. A study performed by the Lawrence Berkeley National Laboratory in Los Angeles, where trees and high albedo surfaces (higher reflectivity of solar energy) were theoretically added to about 15% of the city, indicates that peak summer temperatures have dropped by 10o C, and smog production decreased by 10% – equaling the removal of three to five million cars from the roads (Rosenfeld 1999).

In summary, in order to minimize the environmental impact, a residential or commercial dis-trict should consume as little energy and produce as little waste as possible. This can be achieved by placing buildings close to each other, taking advantage of existing infrastructure, ensuring a functional public transportation system right from the beginning and having a system for the sorting of waste that is easy for the end-user. Locally available renewable energy sources should be utilized and the whole energy chain should be taken into account already in the planning phase.

4 Energy Efficiency Models

THERE ARE DIFFERENT LOGICS in pursuing the energy efficiency of buildings, ranging from lower to higher technological approaches. This chapter presents models that can be applied to im-prove energy efficiency in buildings, including low- and zero-energy buildings, passive housing de-sign, energy-plus buildings, EcoCities, refurbishment aspects and commissioning processes.

4.1 Low-energy buildings

A substantial amount of research work has been invested in North America and Europe to develop practical solutions for low-energy buildings. Theories have been tested in model buildings and the evolvement of results has been largely based on the method of trial and error.

Today the definition of low-energy building can be divided into two specific approaches: the concept of 50% and the concept of 0% (Zero-Energy or Passive House, see next sections). The percentage numbers indicate the amount of energy these buildings use in comparison with the standard building constructed in accordance with current building regulations.

A building constructed using the 50% concept consumes only one half of the heating energy of a standard building. It is typically a traditional building constructed by using standard solutions. The low energy consumption is based on an increased level of thermal insulation, high performance windows, air-tight structural details and a ventilation heat recovery system.

In the IEA Solar Heating and Cooling programme, low energy houses were built and evalu-ated. The buildings were located in the following countries: USA-Arizona, USA-Grand Canyon (California), Belgium, Canada (Brampton and Waterloo), Denmark, Finland, Germany (Berlin and Rottweil), Italy, Japan, the Netherlands, Norway, Sweden and Switzerland. Unfortunately none of the buildings are in Africa or South America (the strategies and technologies used in the buildings can be seen in Annex 3).

The lessons learned from the project were the following:

> It is possible to design low-energy buildings that have high thermal comfort, good indoor air quality, and low environmental impact. The average total projected energy consumption of the evaluated buildings shows a reduction of 60% of the typical consumption in residential buildings.

> The total energy consumption does not differ very much from country to country. This is partly be-cause the consumption for water heating, lights and appliances is relatively independent of climate, while the building codes are adopted to the prevai-ling climate in each country. The insulation levels are generally low in countries with mild climates and high in countries with cold climates. The energy consumption per square meter, therefore, does not differ as much as one would expect when looking at the climate differences.

> To make a proper evaluation it is necessary to consider the total energy use, and not to focus on space and/or water heating alone. It is also impor-tant to consider both heating and cooling, as seve-ral countries found that focusing on one season only could lead to problems during the other sea-son. Also, reducing cooling loads was often a greater challenge than reducing heating loads.

> Buildings function as a system, where the different technologies used are integral parts of the whole. The order in which the technologies are introduced into the design appears to be quite important. As a rule of thumb the best economics are achieved if different energy efficiency measures are considered in the following order:, energy-conservation techno-logies are considered first, passive solar second and active solar third. In most cases all of these techno-logies are used, often in combined systems. It is therefore wiser to develop whole building concepts rather than to develop specific technologies.

> Passive solar gains can make a major contribution to space heating in all climates and do not lead to overheating if proper solar protection is used. Heat recovery from exhaust air in the ventilation system is common in low energy buildings.

> Designing new, innovative building concepts re-quires a multi-disciplinary design team. The energy aspects should be considered at the early design stage, and the architects and engineers should work together from the start. The concept of Inte-grated Design Process and Integrated Design So-lution are important in this regard and are now rapidly developing (Harvey 2006). The question be-came recently a priority theme for the CIB, Interna-tional Council for Research and Innovation in Building and Construction (cf. www.cibworld.nl).

> Training of builders and on-site supervision is parti-cularly important in low-energy build-ings. In low-energy buildings, the energy consumption is more strongly influenced by construction practices and by user behavior than in conventional buildings, For instance, air tightness and the avoidance of thermal bridges is much more important in a well-insulated building than in a traditional building, and the tightness of the ductwork is more critical as these buildings have more equipment (IEA 1997).

4.2 Zero-energy buildings

Zero-energy buildings are buildings that produce as much energy as they consume over a full year. This approach represents one of the most challenging solutions in terms of environmentally responsible construction, requiring state-of-the-art, energy-efficient technologies and renewable energy systems such as solar and wind power. 'Zero energy' means that the energy provided by on-site renewable energy sources is equal to the energy used by the building. This solution minimizes the building's impact on the environment and does not reduce the indoor comfort of the users.

Zero-energy buildings are increasingly important in developed countries. They are seen as a potential solution to mitigating global warming and other environmental problems. It is also an alternative to economic vulnerabilities, such as the dependence on fuel imports of fossil fuels.

Energy can be stored on site, in batteries or thermal storage. The grid can be used as seasonal storage via net metering, as some buildings produce more in the summer and use more in the winter, but when the annual accounting is complete, the total net energy use must be zero or better (less). For individual houses, a number of microgeneration technologies can be applied to provide heat and electricity to the building. These can include solar cells and small scale wind turbines for electricity and biofuels or ground source heat pumps, solar thermal collectors, solar electricity and micro combined heat and power installations for heating. Zero-energy buildings are usually connected to the main electricity grids, in order to be able to cope with possible fluctuations in demand. However, some zero-energy buildings are totally off-grid, thus functioning in an autonomous way.

A building that is approaching net energy consumption of zero may be termed a near-zero-energy building or an ultra-low-energy building. Buildings that produce a surplus of energy are known as energy-plus buildings, which will be described below.

Box 4.1 WWF zero-energy housing project

The Worldwide Fund for Nature (WWF) zero-energy housing project in the Netherlands is part of WWF's anti-climate change campaign. According to WWF, in order to prevent global warming, CO2 emissions have to be reduced by 60-80%, which represents a tremendous challenge but also an opportunity to explore and develop new strategies for energy saving. An example of these strategies is the zero-energy housing project, constructed in collaboration with Dutch building associations. It includes 200 housing units in five municipalities.

The general goal of this project was to achieve very low energy consumption standards, up to 50% less as compared to other housing projects constructed in the same period, using mostly sustainable energy sources. The houses use passive solar energy, PV systems, co-generation, conservatories, thermal power station, sun rooms, solar collectors, and heat recovery systems. Wood comes from certified sources. This project played an important role in rendering energy standards for new dwellings in the Netherlands more demanding. The WWF zero-energy houses have the panda logo.

Box 4.2 Zero-Energy Office: PTM ZEO Building

The Malaysia Energy Centre (Pusat Tenaga Malaysia) headquarters is a zero-energy office (ZEO) building, the first of its kind in South East Asia. Its objective is to provide a platform that serves to pull the Malaysian building sector towards adopting more sustainable solutions. In addition, the PTM ZEO aims at demonstrating that its energy standard can be as low as 50 kWh/m2/year, and that the use of renewable energy can give the building a zero-energy status. This is a very efficient consumption of energy. According to the Malaysian Building Energy Index guidelines, the ceiling index for the Energy Efficient (EE) building category is 135 kWh/m2/year.

PTM ZEO Building, in addition, serves as a showcase for the development of sustainable building technologies for the Malaysian building industry that will also help to facilitate and catalyze international co-operation on sustainable buildings in hot and humid climates.

4.3 Passive houses

A passive house is a building in which a comfortable interior climate can be maintained with-out active heating and cooling systems (Figure 4.1). The house heats and cools itself, and is therefore 'passive'. These houses are also called zero-energy houses in some parts of the world.

For European passive construction, prerequisite to this capability is an annual heating requirement that is less than 15 kWh/(m_a), not to be attained at the cost of an increase in use of energy for other purposes such as electricity. For the northern parts of Europe (above latitude of 60º) the annual heating requirement is limited to about 30 kWh/(m_a). Furthermore, the combined primary energy consumption of living area of a European passive house may not exceed 120 kWh/(m_a) for heat, hot water and household electricity. With this as a starting point, additional energy requirements may be completely covered using renewable energy sources (Figure 4.2). This means that the combined energy consumption of a passive house is less than the average new European home requires for household electricity and hot water alone. The combined end energy consumed by a passive house is therefore less than a quarter of the energy consumed by the average new construction that complies with applicable national energy regulations (Figure 4.3). A passive house is cost-effective when the combined capitalized costs (construction, including design and installed equipment, plus operating costs for 30 years) do not exceed those of an average new home. In Table 4.1, the basic features that distinguish passive house construction are shown (Passive House Institute 2006).

Figure 4.1
A passive apartment building in Finland..

Photo: Mikko Saari, VTT.

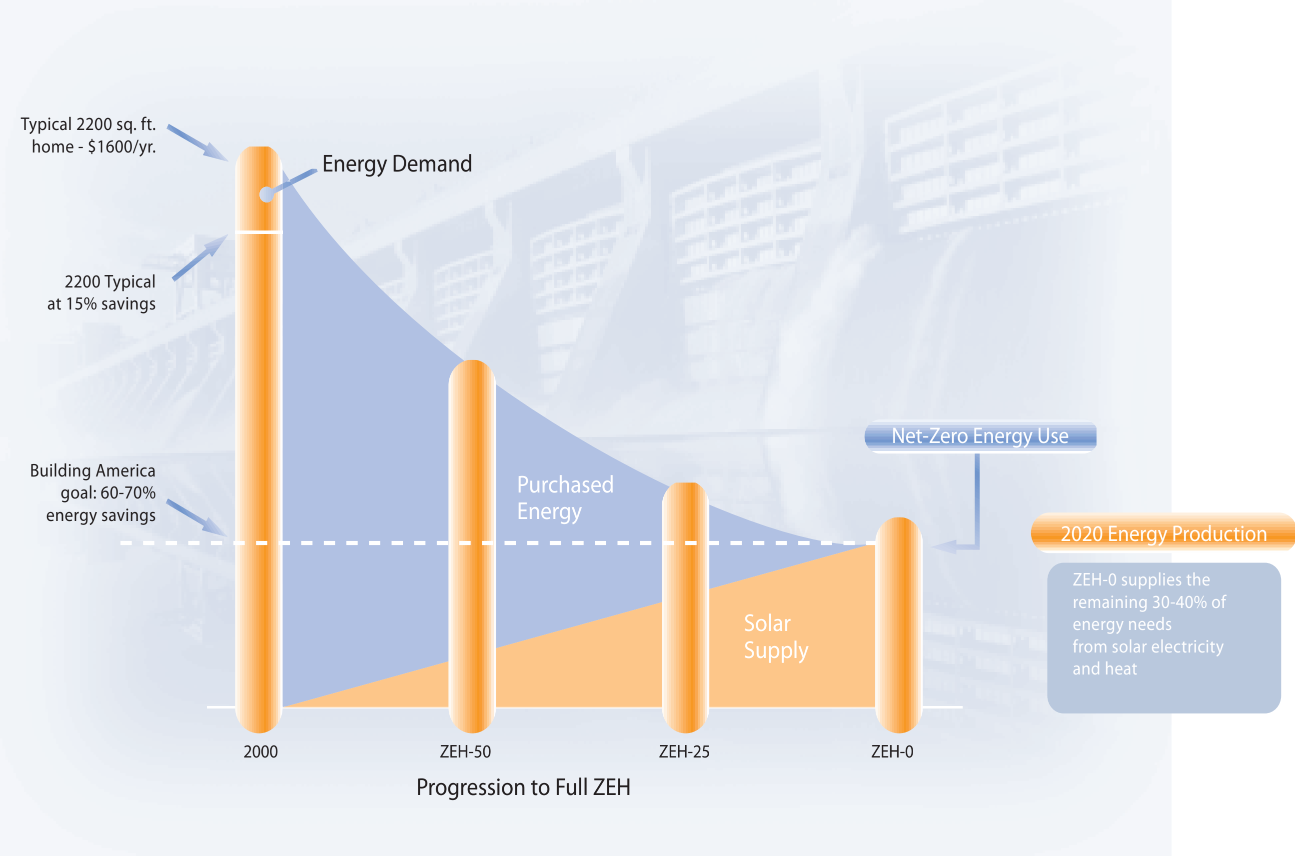


Figure 4.2
In the United States, the aim is to progress to a Net-Zero Energy House (ZEH) by 2020.

Source: DOE 2006.

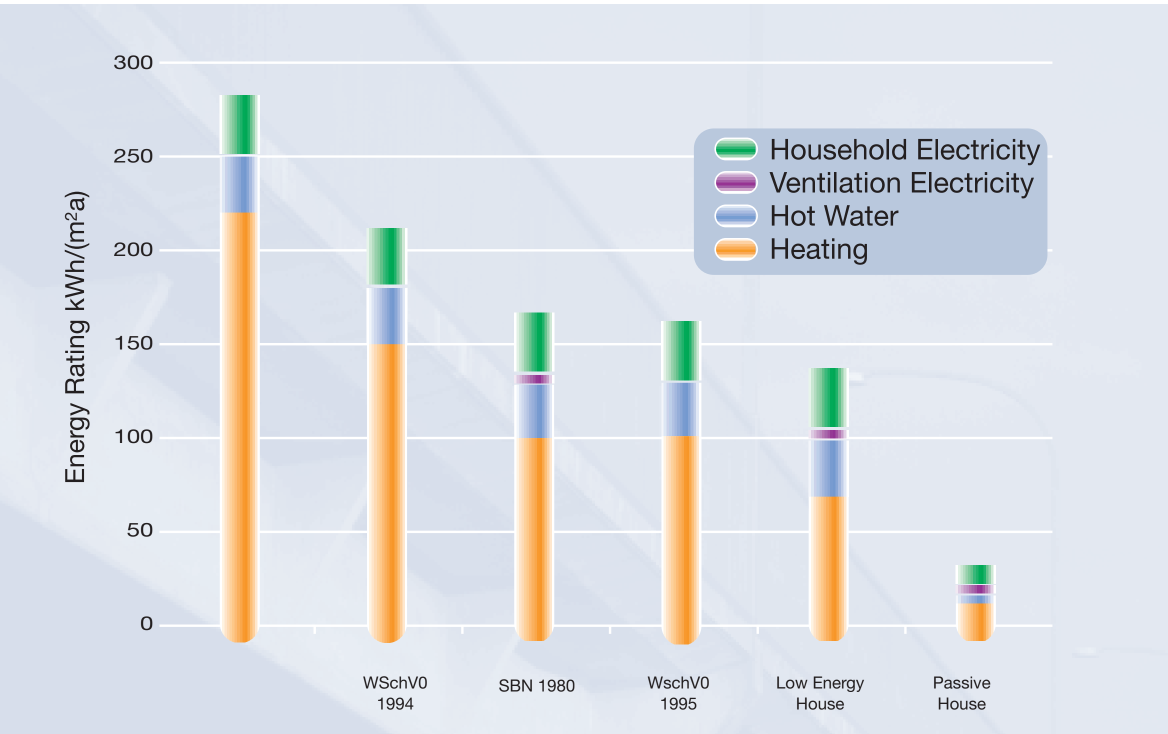


Figure 4.3
Comparison of energy ratings of homes. WSchVO = German Heat Protection Regulation SBN = Swedish Construction Standard

Source: Passive House Institute 2006.

Box 4.3 Possible impacts

In Finland a study calculated the overall impact of energy-efficient buildings on energy consumption. The calculations were made for Finland and for detached houses only. Assuming that all new houses built from 2006 onwards were to be passive houses with an energy consumption of 30 kWh/m², the total energy saving compared to Business As Usual would be 15% in year 2030. The relatively low percentage is due to the building stock's long life cycle. From these calculations we can draw the conclusion that in order to achieve significant results in the following decades much emphasis needs to be put on the existing building stock and its renovation, at least in the more developed countries.

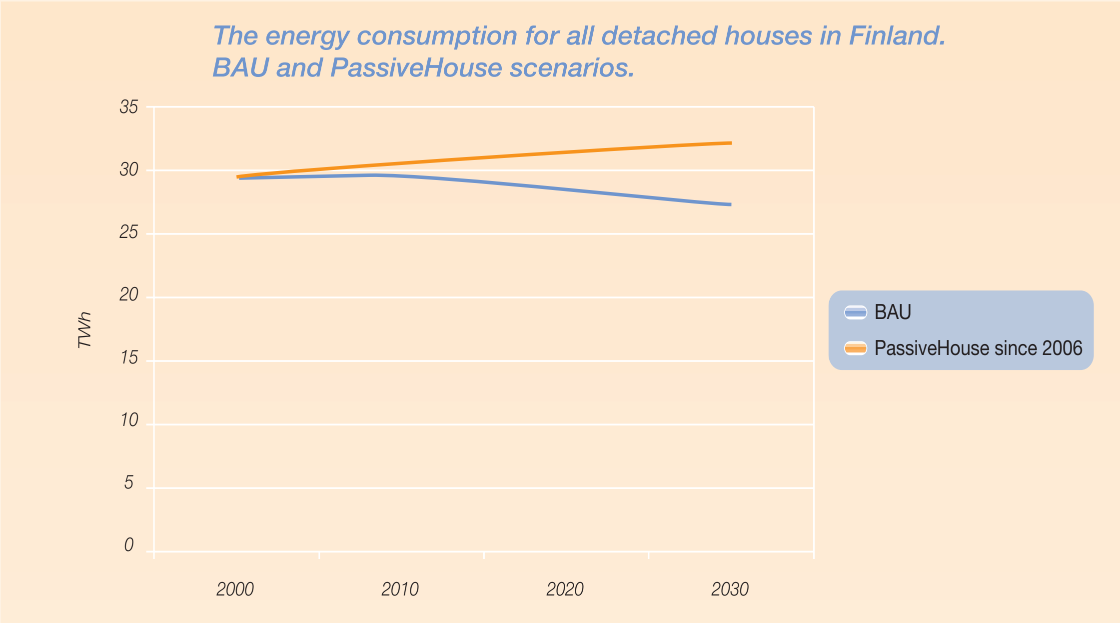


Figure 4.4
Comparing the energy consumption in two scenarios: Business as Usual and only passive houses being built from the year 2006 onwards.

Source: WBCSD 2005.

Compact form and good insulation :	U-factor ≤0.15W/(m²K)
Orientation and shade considerations :	Passive use of solar energy
Energy-efficient window glazing and frames :	U-factor ≤0.80W/(m²K) (glazing and frames, combined) solar heat-gain coefficients around 50%
Building envelope air-tightness :	Air leakage ≤0.61/hour
Passive preheating or fresh air :	Fresh air supply trough underground ducts that exchange heat with the soil. This preheats fresh air to a temperature above 5°C (41°F), even on cold winter days
Highly efficient heat recovery from exhaust air :	Heat recovery rate over 80%
Hot water supply using regenrative energy sources :	Solar collectors or heat pumps
Energy-saving household appliences :	Low energy refrigerators, stoves, freezers, lamps, washers, dryers, etc. are indispensable in a passive house

Table 4.1
Characteristics of passive houses.

Source: Passive House Institute 2006.

4.4 Energy-plus buildings

As passive building technologies are already demonstrated and are being commercialized (especially well progressing in Germany), some pilot projects are dealing with energy-plus buildings – buildings that produce more energy than they consume over a year. The extra energy is usually electricity produced with solar cells, solar heating and cooling, insulation as well as careful site selection and orientation.

Box 4.4 European Construction Technology Platform

The European Construction Technology Platform (ECTP) is an industry-led consortium that has defined a vision for a sustainable and competitive construction sector by 2030. It is also a network of European National Technological Platforms in Construction and the Built Environment.

The ECTP is an ambitious initiative which aims to achieve leadership in competitiveness, addressing the major technological challenges facing the construction industry over the coming decades. It has defined research targets, such as 'Make all new buildings cost-efficiently energypositive' and 'Develop energy-positive retrofits for existing buildings'. Key themes that it aims to address include sustainability of the construction industry (reductions in energy consumption, emissions, waste, minimizing visual impacts), safety for both construction workers and society in general and improvements in efficiency and productivity in the supply and procurement chains. The platform will consider new and existing infrastructures.

In its present form the ECTP is supported by representatives of a number of important stakeholder organizations in Europe. The platform is open to all those who wish to participate.

Box 4.5 PREBAT building research programme in France

The French government has launched an ambitious strategic plan called "Factor 4" aiming at reducing 75% of the French greenhouse gas emissions by 2050. For the building sector, this means an improvement of energy efficiency by a factor 4 or 5 compared to the current average consumption (400 kWh/m2). For new and existing buildings, this translates into low energy buildings with a high level of renewable energy integration. This has to be achieved under acceptable economic and social conditions with regard to comfort, health and environmental considerations. This also requires changes in individual behaviour, improving the quality in construction and renovation, and providing advantageous financial support (public and private). To serve this strategy, a national research and demonstration programme for low energy in buildings was launched within the French Climate Plan.

The so called PREBAT programme (2005-2009) is based on a large partnership between government ministries (ministry of housing, equipment, ecology, research, industry and energy) and national agencies (ADEME – the French Environment and Energy Management Agency, the innovation financing agency OSEO-ANVAR, the national research agency ANR, the agency in charge of existing dwelling ANAH and the town renovation agency ANRU). The general objectives of this programme are: modernise existing buildings, anticipate tomorrow's new buildings, design and build energy efficient buildings.

The main stages of Factor 4 will be:
To conduct a review of the state of research activities in France and abroad,
To consider components, equipment and their integration in buildings,
To develop simulation and management tools and construct demonstration and concept buildings.
Socio-economic aspects and monitoring will be integrated in all stages to ensure the realism of concepts to be developed.

4.5 EcoCities

In order to render the building energy efficient, the whole energy chain has to be considered, includ-ing the local environmental conditions, community issues, transportation systems and working and living structures.

EcoCities are settlement patterns for sustainable cities, which were developed in a project supported by the European Union. The project had several goals, including:

> Maximize respect for natural and anthropogenic context: landscape, nature, agriculture, urban tis-sue, genius loci, culture, infrastructure, mix of uses, local economy;
> Maximize mental well-being and community fee-ling: health and recreation, cultural identity;
> Optimize interaction with municipal and regional material flows: water, energy, food (Gaffron et al. 2005).

In the planning of the energy chain in EcoCities, the availability of energy sources, especially renew-able sources, must be taken into account. Also the functionality of the whole energy chain (production – transmission – consumption and, in some cases, storage) needs to be considered in order to obtain an optimal solution. The energy chain for buildings in EcoCities include the following items:

> Low-energy houses;
> Low-temperature heating systems;
> Low-temperature heat distribution system;
> Use of renewable energy sources whenever possible;
> Heat production as near as possible;
> Electricity production can be centralized.

Low temperature heating systems are recommended, as they are able to use many types of energy sources, including renewable and waste heat sources. They fit well into low energy houses, because the low heating power demand of the house itself. When low temperature heating systems are used in the house, then the whole heat distribution system can be designed to low temperatures (45-70° C), which may have positive influence on the whole energy chain. E.g. when return flow of district heating network is used, it affects the CHP (Combined Heat and Power) plant:

> Distribution losses decrease;
> Share of electricity production increases;
> The efficiency of the power plant increases.

4.6 Energy-efficient refurbishment

In refurbishment processes, basically the same principles apply as in new construction. The operational energy is the major cause for CO_2 emissions in houses to be renovated and this should be the first issue to be addressed. This can be achieved by using, among others:

> Energy-efficient envelope;
> Good insulation level;
> Modern window technology;
> Controlled ventilation and heat recovery of the exhaust air;
> Low-temperature systems in the heat distribution;
> Energy-efficient electrical appliances;
> Hot water production using renewable or regenera-tive sources (solar, heat pumps, waste heat from industry, etc.).

Improving the thermal properties of the existing building envelope is, in many cases, one of the most logical solutions in order to reduce the building's energy consumption. As a consequence, this is also one of the most important strategies in building retrofit. The level of improvement achieved through a renovation of the building envelope often depends on a combination of factors. Interventions may involve windows, doors, walls and roofs. An unbalanced intervention between different components can lead to unsatisfactory results (IEA Annex 36).
Adding insulation is found to always produce cost savings when the measures are done at the same time as other renovations are occurring. For example, the additional cost of upgrading the thermal properties of a roof will be less significant if it is done at the same time as the roof is being repaired. However, even when the action is done solely to upgrade the insulation levels it is often still cost-effective. In terms of non-coupled insulation upgrades two areas are of particular note:

> Due to the lower costs of fitting roof and cavity wall insulation, they provide a return on investment in all European countries. In warm and moderate climate zones the benefits are significant.
> Due to low current standards of insulation in the warm climate zone, non-coupled renovations almost always result in cost savings. With the increased level of air-conditioning in southern Europe, this finding suggests that buildings will put an increased strain on electricity demand, if insulation levels are not addressed (Eurima 2005).

4.7 Life-cycle performance

One effective way to improve the life cycle energy performance of buildings is to use so-called "commissioning". Commissioning means a systematic process guaranteeing that a building performs as designed and required by the functional needs of users. The primary goal of building commissioning, from an energy perspective, is to verify and optimize the performance of energy systems within a building over the entire life-cycle (IEA Annex 40, 2006). Other performance indicators should be considered when commissioning a building, including economic, social and other environmental aspects.
A Finnish commissioning project related to IEA Annex 40 was developed to analyse methods and tools for the commissioning process during different phases of the life-cycle of buildings and building service

> Box 4.6 European project SUREURO

In Europe, the annual rate of increase of the total housing stock is rather low (between 0.8% and 2%). The residential building stock is not only renewing very slowly, it also consists largely of older constructions. More than 70% were built before the first energy crisis, one-third of the dwellings are more than 50 years old (ATLAS 2006).

The European project SUREURO has developed models and systems that provide housing organizations, local authorities, town planners and construction companies, among other interested parties, opportunities to perform sustainable refurbishment processes within a normal time schedule and budget. The SUREURO models and systems offer considerable environmental improvement and energy savings. They include the SUREURO Sustainable Checklists, which help to implement and consider various sustainable and conventional issues at every step of the refurbishment process, from diagnosis phase to operation phase (SUREURO 2006).

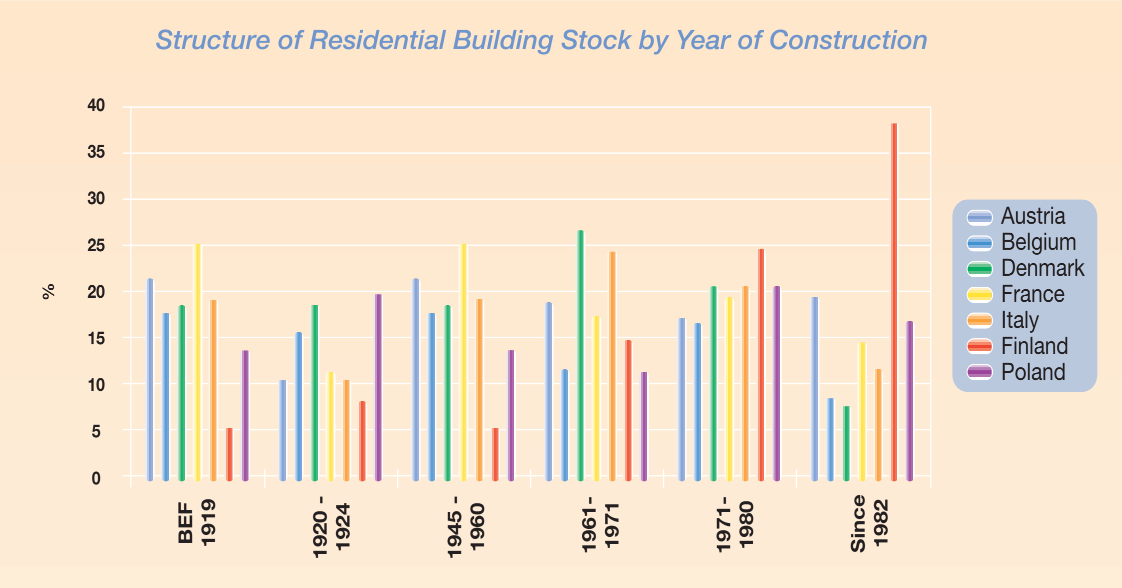


Figure 4.5
The European housing stock is already quite old.

Source: ATLAS 2006.

systems. A systematic approach for the life cycle commissioning of buildings was developed (see Figure 4.6). The methods developed can be divided into those supporting the design, commissioning, acceptance, continuous maintenance and reporting. Check lists and descriptions of appropriate commissioning methods were developed for each phase. Both manual and automated methods were included in the tools. The results of the project were published in a guide book as well as on the web

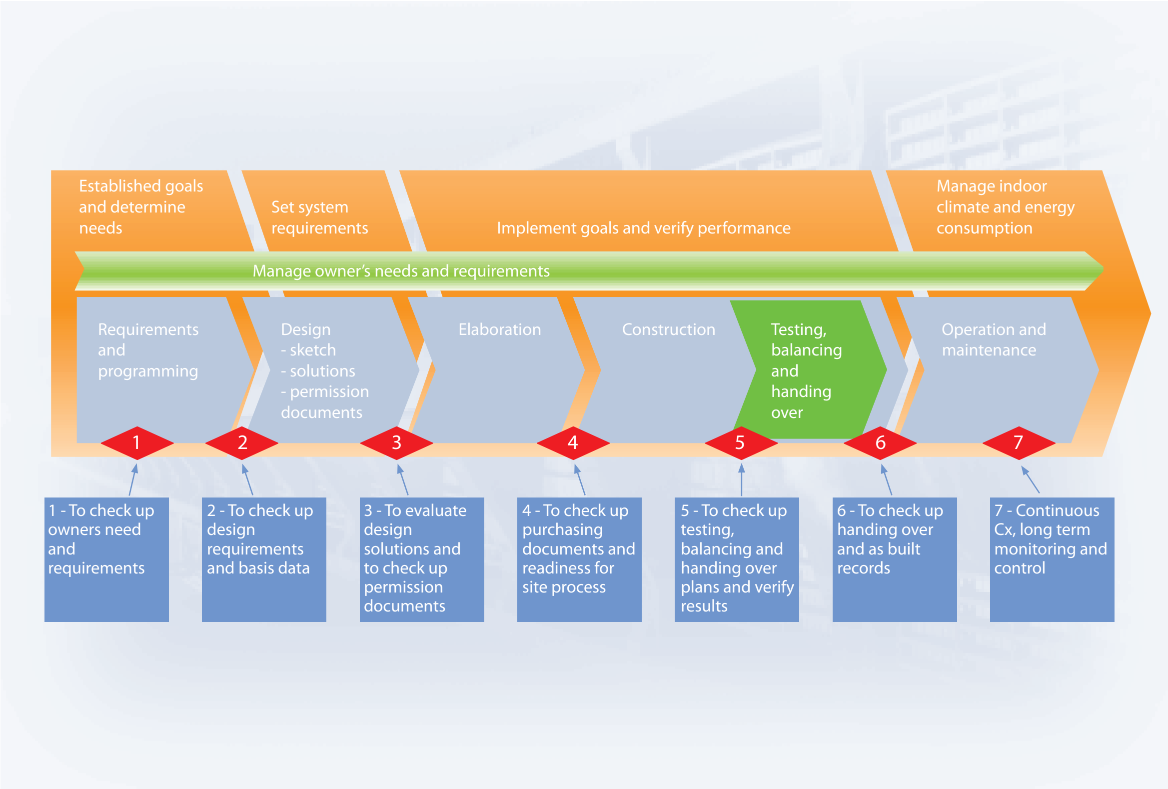


Figure 4.6
Commissioning systems for the different phases of building life cycle. *Source: ToVa Final report 2006.*

(ToVa Final report 2006). It was concluded that it would be advantageous if a construction project had a commissioning leader who is responsible for realizing targets of building performance and energy efficiency. This responsibility includes the design of targets and tasks, and the selection of commissioning methods. In large projects the commissioning team may consist of several members. In small projects the responsibility may be given to a designer who is sufficiently experienced in issues of building performance and energy efficiency. Needs of building owners and end-users should de checked before the design phase starts. All the performance and energy efficiency indicators should be included into contract documentation in an understandable way (Ibid.).

5 Encouraging Energy Efficiency

THE BUILDING SECTOR BELONGS to a complex industrial chain, involving a wide range of ac-tors, an extended life cycle of products and user preferences implications, making it one of the most complex environmental policy target groups (OECD 2003). In order to achieve large scale energy efficiency improvements, a range of different approaches may be required, each one tailored to local level needs. Many tools, whether they constitute legislation, economic incentives, technical access, R&D programmes or other tools, need to be based on wider governmental policies.

Policies can take many different forms. This chapter presents but a few examples of policies aiming at improving the energy efficiency in buildings. The instruments include legislative measures, economic incentives, technology transfer programmes, and information and education campaigns at different steps of the whole process, from land use planning to building permits. This chapter also explores barriers discouraging stakeholders to pursue energy efficiency.

5.1 Legislative instruments

There are different strategies for using legislative instruments to control the energy consumption level of buildings (Figure 5.1). Scandinavian countries generally use national building codes and standards, which regulate physical, thermal and electrical requirements of building components, service systems and equipment. The regulations also cover indoor conditions, health and safety standards, operation and maintenance procedures and energy calculation methods. Some codes accept limited compensation between building components; for instance, the glass area may for instance be increased, if the exterior wall insulation is also improved.

Building codes are crucial to help induce the improvement of the energy efficiency of the building sector. A number of building codes currently include energy performance standards, limiting the amount of energy that buildings can consume.

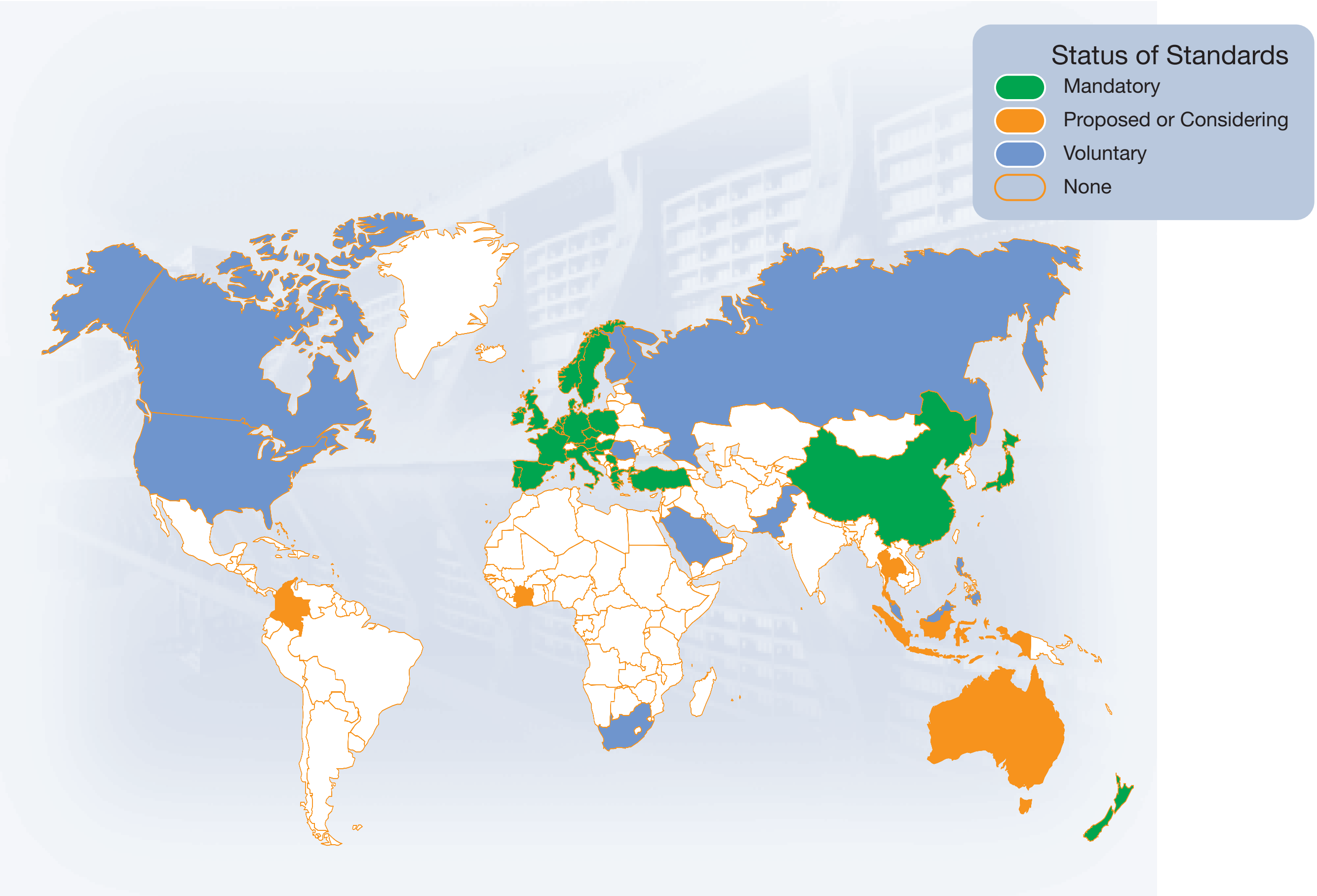


Figure 5.1
Status of building standards.

Source: Busch 2000.

The boxes below describe energy efficiency policies in China, India, Europe Union and Russia.

> Box 5.1 China

The promotion of low energy consumption technologies in the construction sector is high on the agenda at the Chinese Ministry of Construction. In order to achieve the established target that energy consumption in new buildings should be 65% less than in existing buildings, the Ministry has established an energy consumption standard for the construction sector. The government has established a tax and fees rebate system for low-energy buildings to encourage their construction.

Another way to improve the energy efficiency in new buildings discussed in China is to apply 'feebates' for energy hook-ups, just as for efficient cars. Under the feebates system, you either pay a fee or receive a rebate when you connect to gas or electric system. The amount paid or received depends either on the size of your subscription or on how efficient your building is. The fees pay for the rebates, which make this system cost neutral and politically attractive. The main difference between building codes and appliance standards systems on one hand, and the 'feebates' on the other hand, is that the first one does not offer any incentive to exceed the requested efficiency level, while the second one drives continuous improvement: the more efficient you are, the bigger rebate you get. The 'feebates' approach encourages making decision at the very beginning of the design process. Feebates to save energy have been tried only in small-scale U.S. experiments but are already successfully used by some water and wastewater services providers (Hawken et al. 2000).

China has the largest construction volume in the world with almost two billion square metres of new buildings completed each year in urban and rural areas. Currently more than 80% of these are categorized as high-energy buildings. Energy consumption per floor space is at least two to three times higher in China than in developed countries, while the comfort level is quite low. However, the absence of relevant standards and regulations has slowed down low-energy consumption technology implementation in the construction sector. Mechanisms to encourage the adoption of this technology from the government have had insufficient results and there are no relevant standards to guide professionals in the construction sector, such as architects and civil engineers.

The REEP (renewable energy & energy efficiency partnership) project 'Promoting Low-energy Buildings in China' will investigate current low-energy buildings across three Chinese cities and the strategies used to reduce their energy consumption. This information will then be compared to best practices in Europe, including low-energy building standards and design codes. The policies and promotion employed by both Chinese and European cities will be developed as case studies. The result will be a proposal for new legislation regarding low-energy buildings construction for submission to the Chinese government in order to ensure that appropriate policies and building codes are implemented to encourage and deliver the required reduction in energy consumption.

> Box 5.2 Energy efficiency policies in India

Due to the increasing economic activities in India in early 1990:ies, and the accompanying increase in energy intensity, energy supply could not meet energy demand in the electricity sector. After measures launched by the government in the second half of the 1990s, aiming at restoring the financial viability of state owned power utilities were unsuccessful, a new Electricity Act was passed in June 2003. In addition the Energy Conservation Act was established to provide a framework for promoting energy efficiency in India. The Bureau of Energy Efficiency (BEE) was set up to facilitate implementation of the provision of the Act. Launching the BEE action plan for promoting energy efficiency in the country, Prime Minister Vajpayee announced in 2002 that all the governmental organizations should reduce their energy consumption by 30% and Private Organizations by 20% over a period of five years. Improvement in the building sector is also on the agenda in the BEE's Action Plan (Singh & Michaelowa 2004).

> Box 5.3 EU – Directives

In the EU, directives are widely used for regulating various environmental themes. The Directive on the energy performance of buildings has been in force since January 2003. The main elements of the directive, which must be implemented by all EU members, are:

- *An agreed method for calculating the energy performance of buildings;*
- *Minimum energy performance requirements, for new buildings and for major renovation of existing buildings larger than 1000 m^2;*
- *Energy performance certificates to be made available when buildings are constructed sold or rented out;*
- *Regular inspection of boilers and air conditioning systems;*
- *Member states must implement energy efficiency improvement measures to save energy;*
- *National energy saving target will be set to 9% for the ninth year of application (2011) of the Directive;*
- *Member States need to publish guidelines on energy efficiency and energy savings as a possible assessment criterion in competitive tendering for public contracts; Member States need to ensure the availability of efficient, high quality energy audit schemes which are designed to identify potential energy efficiency improvement measures and which are carried out in an independent manner, to all final consumers, including smaller domestic, commercial and small and medium-sized industrial customers (EU 2006).*

The Energy Performance of Buildings Directive (EPBD) has been shown to capture only 10% of the technical potential. Taking 2010 as an example, it is expected that by then the EPBD will lead to an annual capital investment cost of 3.9 billion euros. However, the annual energy costs savings from buildings will be leading to an annual saving of 7.7 billion euros. This is a profit of 3.8 billion euros a year for Europe. By 2015 the annual profit is projected to be 6.9 billion euros a year. Extending the EPBD would extend the profits. Taking again 2010 as a reference year, extending the rules on renovation to all buildings (at the moment buildings below 1000 m2 are not covered) would lead to an annual profit of 7.5 billion euros (Eurima 2005).

Other European legislation on the energy efficiency of buildings includes the following:

- *SAVE Directive to limit CO2 emissions by improving energy efficiency;*
- *Hot-water boilers (Council Directive 92/42/EEC on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels);*
- *Construction Products (Council Directive 89/106/EEC on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products);*
- *Energy Labelling of household appliances, concerning for instance household electric refrigerators, freezers and their combination, electric ovens, air-conditioners, lamps and dishwashers (EU 2006).*

In late 2003 the European Commission also proposed a new Directive on the promotion of end-use efficiency and energy services to enhance the cost-effective and efficient end-use of energy in Member States. This directive is still under legislative process thus not yet being in force. This directive also concerns the building and construction sector, because the energy services meant in the proposal include indoor thermal comfort, lighting comfort, domestic hot water and product manufacturing. Its objective is to save an additional fixed amount of energy every year equal to at least 1% of previous consumption in each Member State, leading in 2012 to an annual improvement in energy efficiency of around 6%. Upon adoption, it will provide the necessary targets,
mechanisms, incentives and institutional, financial and legal frameworks to remove existing market barriers and imperfections for the efficient end use of energy. The proposal sets out clear mandatory targets for annual energy savings at Member States' level and for the share of energy efficient public procurement for the period 2006-2012.

Box 5.4 Russia

The law 'On Energy Saving', passed by the State Duma and approved by Council of Federations in 1996, sets up the fundamental legal base for the development of regulatory documents relating to energy efficiency of buildings in Russia. The requirements for energy consumption prescribed by state standards, technical rules and regulations are mandatory to the entire territory of the Russian Federation (Matrosov 2006).

According to clause 4 of the law, the state energy saving policy is based on the following principles:

- *Priority of efficient use of energy resources;*
- *State supervision over rational use of energy resources;*
- *Mandatory accounting and reporting of produced or consumed energy resources by legal entities, as well as of energy resources consumed by individual households;*
- *Inclusion of energy efficiency indices in the state standards for equipment, materials, structures, vehicles;*
- *Commitment of legal entities – producers and suppliers of energy resources – to the principles of efficient use of the energy resources (Matrosov 2006).*

According to clause 5 in the state standards for energy-consuming products in the order established by the Russian Federation legislation, energy-consuming products shall have indicators of their energy efficiency. For mining, production, processing, transportation, storage and consumption of energy resources, efficiency indicators and indicators of energy consumption for heating, ventilation, hot water supply and illumination of buildings are required (Matrosov 2006). Refer to Box 5.21 about the practical application of these requirements.

5.2 Economic instruments and incentives

The building sector is usually guided by regulations and standards in its approach to how to design, build and operate buildings, including what energy systems to fit the buildings with, and how these are operated. Within the framework provided by regulations and standards, however, the behavior of the sector is very much based on economic considerations. Considerations that are typically limited to a rather short time horizon, and seldom take into account the energy efficiency over the entire life span of the building. Economic instruments and incentives are therefore recognized as very important means for encouraging stakeholders in the building sector to adopt more energy efficient approaches in design, construction and operation of buildings.
Economic instruments and incentives typically provides an economic advantage to energy efficient approaches, e.g. through reduced tax rates, improved loan conditions, or increased rates of return on investments. The purpose of economic instruments and incentives is also to change the market conditions in a way that makes energy efficient buildings more financially attractive than ordinary buildings. Economic instruments are often more efficient than regulations and standards as the benefits (or drawbacks) of the incentives can be calculated as an economic cost or saving, which can be directly translated to the value of the investment (or of building itself).
Market forces are powerful. In various countries, experience in promoting rating systems and other initiatives has developed a significant body of knowledge that proves that sustainable behavior is profitable in many ways – not only in energy savings. It seems that profit is the strongest trigger of environmental change.

Examples of economic instruments that can be applied to improve the energy efficiency of buildings are provided below. These include rating systems, tariffs and energy audits as well as initiatives undertaken in the European Union and flexible instruments adopted in the Netherlands.

Box 5.5 Rating systems

World Green Building Council (WGBC) members promote rating programmes on green building which take two different approaches. One consists of market-based programmes, such as LEED (US, Canada and India), where the requirements are all voluntary. The other is related to government-owned regulatory programmes, such as CASBEE in Japan, EEWH in Taiwan, and the emerging systems in Hong Kong and Singapore. While some of the standards (or targets) appear to be as high as those in the market-based systems, their adoption appears to be limited primarily to government projects only (except in Japan where CASBEE is mandated for all projects in several jurisdictions). The private sector is encouraged to adopt the higher performance standards voluntarily, but there appears to be very limited uptake. When the system is government-owned, the existence of private-sector GB councils to support the rating systems (with consensus-based development and updates, education, project and practitioner certification, reviews, and manufacturer and other industry involvement) is severely constrained; in particular, essential revenue streams are denied to the councils.

Box 5.6 Tariffs

'The user pays' method is an effective principle in energy management. The energy tariffs can be structured so that the fixed and variable utility costs are covered by corresponding fixed and variable fees. Thus energy utilities can maintain constant unit prices in changing conditions and end users' motivation for energy conservation remains. Scandinavia is moving towards liberalized energy markets and dynamic tariffs, which include different rates not only for summer and winter, day and night, but also for low and high demand periods. The cost recovery ratio is almost 100% and the billing is based on consumers self reporting of metered heat, electricity and water consumption. The utilities carry out trend monitoring and occasional double-check readings.

Pricing policies in Scandinavia reflect deregulation and real supply costs, added with abundant national taxes, including fuel dependent environmental tax of approximately 20%. Group subsidies are not used and thus large consumers get cheaper energy than households and other small users.

Box 5.7 Energy Audit Programme

An Energy Audit is defined as a systematic procedure that obtains an adequate knowledge of the existing energy consumption profile of the site, identifies and scales the cost-effective energy saving opportunities and reports the findings. It is a voluntary programme. In countries such as the Netherlands and Finland, for instance, it is promoted with government subsidies.

The term Energy Audit as such specifies in general only the content of the working method but does not define the actual scope, thoroughness or aim of the work. In practice there are different levels of instructions given for the auditing work. Many of these different approaches fulfil the criteria of a 'model', which is a good term to be used in order to separate the standard procedures from the 'do-as-you-like' procedures.
The cost of an energy audit is based on the auditors' fee, the labour cost of the client's own personnel or both. The audit cost is typically a model specific feature but has a strong connection to the subsidy policy on the audit programme level. The cost naturally depends on the technical systems and areas of energy use covered in the audit and on the thoroughness of work, among others. The main options for the audit cost are:

- *Fixed cost (and/or time of audit work);*
- *Project specific cost with a maximum limit;*
- *Project specific negotiated cost;*
- *Energy savings based cost (AUDIT II 2003).*

Box 5.8 Europe – promotional initiative

The GreenLight Programme is a voluntary pollution prevention initiative encouraging nonresidential electricity consumers (public and private), referred to as Partners, to commit towards the European Commission to install energy-efficient lighting technologies in their facilities when it is profitable, and lighting quality is maintained or improved. GreenLight was launched on February 7th 2000 by the European Commission Directorate General Energy & Transport.

The objective of the GreenLight programme is to reduce the energy consumption from indoor and outdoor lighting throughout Europe, thus reducing polluting emissions and limiting the global warming. The objective is also to improve the quality of visual conditions while saving money.

The core of the programme is a registration form, signed by the Partner and the Commission, in which the Partner commits to profitably up-grade or install alternative systems which improve lighting quality and reduce electricity consumption in existing or new spaces.

While the Commission does not provide actual funds for the lighting upgrades (because they pay for themselves), it provides support to the Partners in the form of information resources and public recognition (plaques on building, advertisements, exclusive use of the logo, awards, etc.). It also seeds other benefits in economic terms, comfort parameters and marketing standing as a 'green or environmental conscious company'.

Box 5.9 Flexible instruments in the Netherlands

The Dutch government offers a number of flexible instruments to help the building sector improve its environmental performance. In addition to subsidies for energy audits, it offers 'green mortgage' and tax incentive systems for sustainable building initiatives as an attempt to offset possible additional costs that the implementation of sustainable building measures sometimes require.

The Dutch government also makes use of environmental permits and a set of covenants to influence the environmental and energy performance of the building sector. Environmental permits are usually required for large-scale construction projects. They represent, for municipal environmental departments, a way to influence building stocks' environmental performance, by compelling certain projects to undergo environmental audits. In contrast, covenants are a consensus-oriented environmental policymaking procedure, by which negotiations play an important role. As a traditional instrument used by Dutch environmental policymakers, covenants are usually based on the ALARA (As Low As Reasonably Achievable) principle, by which environmental impacts may be reduced as much as possible.

As zero impact is practically unfeasible, efforts should be made to reduce the impact only where it is either intolerable, or where its reduction cost is reasonable. For new buildings construction, this means applying all available measures to mitigate the environmental impacts and to improve the building's environmental performance (not only regarding energy) as long as they do not entail exorbitant additional costs, which would hamper the economic feasibility of the investment. Although most covenants applied to the building sector are elaborated according to the ALARA principle, they may also be based on the National Packages for Sustainable Building, an initiative of the Ministry of Housing, Spatial Planning and Environment, originally introduced in1996. Endorsed by authorities and different stakeholders from the different branches of the building sector, the packages are a set of voluntary measures that should be taken by the sector in order to render the relationship between buildings and the environment more sustainable. They contain specifications promoting environmentally-friendly solutions, covering residential and non-residential building as well as the larger urban design scale. More recently, new packages have been issued trying to shift the emphasis from new buildings to renovation and maintenance of existing building stocks, including demolition and recycling aspects.

5.3 Technology transfer programmes

The Intergovernmental Panel for Climate Change (IPCC) has compiled a report on Technology Transfer issues, called 'Methodological and Technological issues in Technology Transfer' (Metz et al. 2001). In that report, technology transfer is defined as the broad set of processes covering the flows of know-how, experience and equipment and is the result of many day-to-day decisions of different stakeholders involved. A number of social, economic, political, legal and technological factors influence the flow and quality of technology transfer. Essential elements of successful transfer include consumer and business awareness, access to information, availability of a wide range of technical, business, management and regulatory skills locally, and sound economic policy and regulatory frameworks. Technology transfer that meet local needs and priorities are more likely to be successful. Interactions and barriers vary according to sector, type of technology and country. Trends in international financial flows that drive technology transfer are also influencing the capacities and roles of different stakeholders. Policy actions therefore need to be tailored to the specific context and interests (Ibid.).
Lessons learned through the sectoral studies in the report include: (i) networking among stakeholders is essential for effective technology transfer; and (ii) most effective technology transfer efforts focus on products and techniques with multiple benefits. Actions that have been effective in technology transfer include a mix of relevant Environmentally Sound Technologies (EST) which will vary, depending upon the climate; the rural-urban distribution, and the historical context. EST transfer activities may include:

(I) government financing for incentives for the construction of more energy-efficient and environmentally-friendly homes;
(II) building codes and guidelines, and equipment standards developed in consultation with industry to minimize adverse impacts on manufacturers;
(III) energy and environmental performance labels on consumer products;
(IV) government programmes for more energy-efficient and environmentally-friendly buildings, office appliances and other equipment;
(V) demand-side management programmes to promote energy-efficient lighting and equipment; and
(VI) R&D to develop products in the building sector that meet community priorities (Ibid.).

Some examples of technology transfer programmes related to the building sector's energy efficiency are presented in Table 5.1.

COMPAGNY	PROJECT COUNTRY	PROJECT TITLE	PROJECT DESCRIPTION
MIC, Maisons internationales du Canada	Slovakia	Transfert of Wood frame Construction Technology Characterized by High Energy Efficient to Slovakia	A viability study to evaluate the development of a local assembly facility for a wood frame construction system in Slovakia
International Centre for Sustainable Cities (ICSC)	Poland	Viability Study to Assess Market Potential for Transfer of Canandian Energy Service Compagny (ESCO) Model to public Buildings in Poland	A multi-stakeholder team assess the technical, legal and financial feasibility of full-scale ESCO projects for school buildings in the city of Katowice
Econoler International	Côte d'Ivoire	Viability Study to Assess Market Potential for Transfer of Canandian Energy Service Compagny (ESCO) Model to public Buildings in Poland	Evaluates the feasibility of undertaking a technology project to promote the application of centralized district cooling system in Côte d'Ivoire through the implementation of an Energy Service Company (ESCO) concept

Table. 5.1
Technology transfer programs related to the built environment, funded by Canadian Initiative for International Technology Transfer.

Source : Source: Atlas 2006.

5.4 Information and education campaigns

Even if access to information does not always lead to energy-efficient behavior, information and education campaigns are of considerable importance in enhancing energy efficiency. Without relevant and up-to-date information people will find it difficult to concretely implement energy efficiency improvements in buildings. Another important point is that the campaigns have to be carried out in the local language taking into account the level of knowledge of the target group.

Good examples of information and education campaigns are provided by the green and sustainable building websites that have been set up by various stakeholders. They offer a wide range of information varying from simple product information to step-by-step guides on how to design and build a sustainable building. This kind of information can be effective especially in countries which have a strong do-it-yourself tradition and high penetration of computers. The following boxes contain information about campaigns undertaken to improve the energy efficiency in buildings.

Box 5.10 Environmental campaigns of energy companies

Several energy companies have started to explore energy efficiency in their premises. Electricité de France (EdF), specified in the brief for the commission of its headquarters in Bordeaux that the complex should be energy efficient. Together with the six main electricity utility companies of the world (Edison, Enel, Hydro Quebec, Kansai, Ontario Power, RWE, and Tepco) EdF is part of the E7 Group, which plays an active role in global electricity issues and is also committed to promote sustainable development, considering environmental management as a high corporate priority.

For this purpose, the group has developed a joint policy framework for implementing related initiatives in both domestic and international markets, as well as for providing information and expertise on the efficient generation and use of electricity.

EdF, another renowned example of an energy efficient building is the RWE AG Headquarters in Essen, completed in 1996. With its 30-storey cylindrical tower of 32 meters of diameter and being one of the German highest buildings, as well as one of the first of such scale to provide natural ventilation, the RWE became a landmark for the entire Ruhr Valley region of how a large scale structure can be more efficient in terms of energy consumption.

Box 5.11 EU – You control climate change

'You control climate change' is the title of an awareness raising campaign that the European Commission launched on May 29th 2006. The campaign challenges individuals to make small changes to their daily routine in order to achieve significant reductions of greenhouse-gas emissions. It offers a wealth of practical and easy-to-do tips while aiming to give people a sense of personal responsibility and empowerment and help them contribute to the fight against climate change. Households in the EU are responsible for some 16% of the EU's total greenhouse-gas emissions, most of which comes from the production and use of energy (EU 2006).

Comprehensive information is available on the campaign web site. Among other things, it explains climate change and its effects and gives some 50 tips how to reduce emissions, ranging from turning down the heating by 1° C to avoiding the stand-by mode of TV sets, stereos and computers and printing double-sided. A carbon calculator assesses the amount of CO_2 saved by each action, and visitors can also download a power-saving screen saver for their computers. In many cases national governments are supporting the campaign through various activities. Wellknown personalities such as pop stars, bands and TV weather presenters will also participate in the campaign.

Box 5.12 Sustainable Buildings in Capetown – The Climate Group 2006

The city's corporate inventory showed that municipal buildings account for 16% of total emissions. To reduce these emissions, in 2002, the Tygerberg Administration headquarters in the suburb of Parow underwent a pilot energy efficient retrofit and employee awareness campaign. This measure has resulted in annual electricity savings of 130,000 kWh, equivalent to 5,600 dollars, and 140 tonnes of greenhouse gas emissions. Two additional buildings have been retrofitted and the largest civic building has been audited, awaiting retrofit funding.

Residential buildings have also been targeted. In the Kuyasa Clean Development Mechanism (CDM) pilot project ten demonstration houses were outfitted with solar water heaters, compact fluorescent light bulbs and insulated ceilings. Benefits of the retrofits include cost savings, improved indoor air quality, more comfortable temperatures, and emissions reductions. This low cost urban housing project has since received international recognition and in 2005 was validated as the world's first Gold Standard CDM project. The scheme will eventually retrofit 2,310 households in Khayelitsha, eliminating around 6,200 tons of emissions annually. (Gold Standard is an independently audited, globally applicable best practice methodology for project development that delivers high quality carbon credits of premium value.)

Box 5.13 Shared-saving systems

In the United States, the National Association of Regulatory Utility Commissioners worked on a task force to change the profit rules of utilities, in order to reward investments in Demand Side Management (DMS) projects. Beyond premium rate of return on efficiency investments, utilities would also start to engage in 'shared-savings' systems. For every dollar saved from the customer, the utility was allowed a small rate of participation in the saving, allowing its stockholders to earn an extra 0.15 dollars, while the customer remained with the saving of 0.85 dollars (Rosenfeld 1999). In this case, 'teaching' the market – including companies – how to be more efficient in energy consumption has become a sound economic solution (Ibid.)..)

5.5 Barriers to energy efficiency

One of the main barriers to the wider adoption of sustainable design and construction solutions is the perception that these incur substantial additional costs. A costing analysis, using real cost data for a broad range of sustainability technologies and design solutions, contradicts this assumption and demonstrates that in many cases significant improvements in environmental performance can be achieved at very little additional cost. Over a life cycle perspective sustainable buildings should normally offer major cost savings.

In some cases, more energy-efficient technologies imply higher investment costs, particularly due to their innovative aspects as compared to conventional technologies. For improved insulation, the higher investment costs are simply because of greater material use. For residential buildings especially, higher investment costs are a major barrier, even though pay back time can be rather short because of energy bill savings. Generally speaking, the problem is that builders' interest is not to keep running costs low; their interest is to keep investment costs low as their profit depends on them. As the actors responsible for the operational phase differ from those involved in the building process, there is usually a conflict of interests which can hamper the introduction of energy-efficient technologies.

The lack of information about energy efficiency is another obstacle, especially relevant for the residential sector. The typical house builder who makes the decisions about energy systems has often very little knowledge about energy efficiency opportunities. Their decisions are made based on how other builders have done and what 'neighbours and friends' recommend. Companies selling houses should inform the customer about life-cycle-efficient solutions instead of just selling the least expensive alternative without considering its running costs.

In addition, and as discussed previously in this report, the human behavior can be a barrier for energy efficiency: energy efficiency cannot only be improved with technological solutions but also depends on the willingness of building occupants to make use of energy saving features in the building. It is thus well justified to invest in education and awareness raising campaigns for tenants and owners of buildings.

As identified by Passiefhuis-Platform (2006), barriers to build passive houses include:

- Individuals do not know that passive houses exist. Information campaigns in the builders own language are needed.
- Individuals, including architects, find it hard to believe that houses without heating system could be feasible in Central and Northern Europe climates, although this technology is already well demonstrated.
- There are not many constructors able to build Passive Houses. It requires some special knowledge, which the constructors are not willing to learn or do not have resources to study.
- Some of the technology needed in a Passive House is still under development, and can not be acquired off-the-shelf.

Building and construction, especially in non-residential buildings, is a complex process involving various actors. The different actors may try to optimize their own part of the process, but there is often no system to optimize the total building process. This can lead to the situation in which some parts are energy efficient but the whole building is not. Moving towards the idea of life-cycle responsibility and introduction of effective commissioning processes will help ensure the efficient life-cycle performance of the whole building.
In contrast, in rural areas of developing countries, energy efficiency is not often a very relevant issue to be considered when people build their houses. The choice of building materials and design are often made according to what is available on the local market or even in local surroundings (like straw or clay). Affordability is also a very important selection criterion. In some parts of Africa such as in Mali and Namibia tin roofs have suddenly become popular, and are regarded as some kind of a status symbol, even though the traditional thatched roof would be cheaper and more energy efficient or comfortable in a hot climate. Of course, tin roofs can have other benefits, like less health risks or less maintenance needed.

In conclusion, the major impediments to increase energy efficiency in the building sector are institutional barriers and market failures rather than technical problems. Even if high-tech competence exists in most countries the institutional and economic conditions have hindered the technical competence to be effectively applied in day-to-day design, construction, and operation of buildings. The need for professional training is also of importance as professionals in small and medium size enterprises need to be aware about new technologies and new processes.
Boxes 5.14-22 provide information about cost analyses and barriers to improve the energy efficiency of buildings.

Box 5.14 Financing energy efficiency in buildings (1)

The wide selection of effective energy conservation measures can be demonstrated by comparing two examples: low energy office buildings in Malaysia and in Shanghai. The extra costs for the energy efficient features incorporated in a low energy building in Malaysia was 10%, with a corresponding pay back time of ten years at current electricity price. The LEO Building resulted in 64% energy saving when standardized against the AEUI value of 130 kWh/m2/year sets by the new Malaysian Standard MS1525:2001 – Code of Practice on Energy Efficiency and Renewable Energy for Non Residential Buildings.

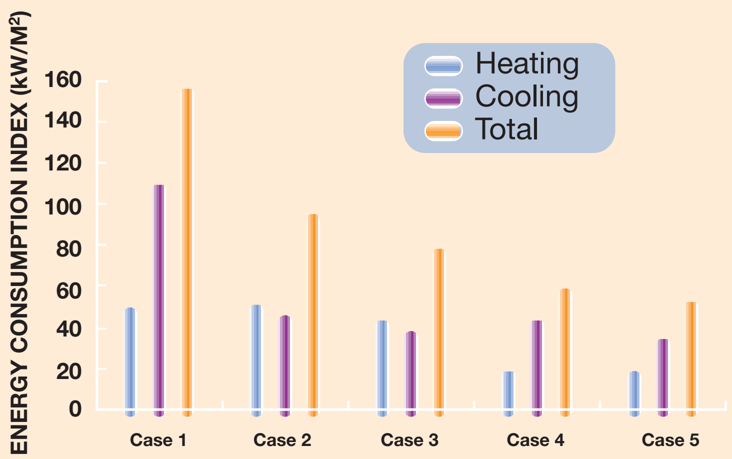
The energy consumption estimates from a Chinese experimental office building show a similar saving potential, using partly very different energy conservation strategies. It must be stated that experimental buildings like these do not change the big picture until such solutions can be brought into the mainstream construction practice, which may still lie far ahead, despite the fact that the technologies are already widely available.

Over-costs of new very efficient buildings in Swiss Minergie Plus programme are between 10-15%; but, in addition to highly reduced operating costs, these buildings, when sold to other owners, appeared to be sold without difficulties at a price 10-15% higher than common buildings, showing that the Swiss market is accepting these over-costs.

The energy efficient experimental Eco-Building in Shanghai resulted in the simulated savings shown in the figure below with the following cases:

Case 1: reference building (no specific energy techniques);
Case 2: window shading devices added;
Case 3: window shading plus advanced glazing;
Case 4: window shading, advanced glazing plus highly insulated envelopes;
Case 5: window shading, advanced glazing, highly insulated envelopes plus natural ventilation.

The biggest contribution to energy saving originates from window shading as showed in the pie diagram.



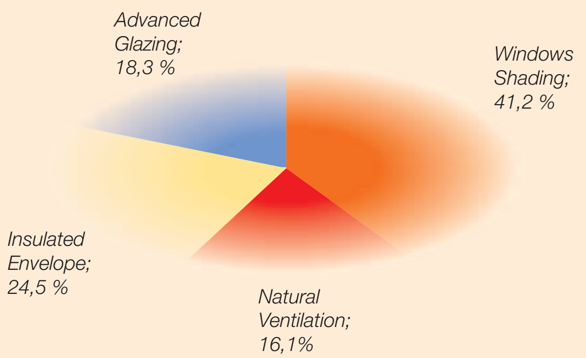


Figure 5.2 and 5.3
Energy efficiency of a Shanghai eco-building. Source: Zhen et al. 2005.

Box 5.15 Financing energy efficiency in buildings (2)

Estimates of the economical potential for energy efficiency by year 2020 in the building sector were made by Jochem et al. (2001) and some examples of these are presented in Annex 3. These estimations vary from 10% (for existing building envelopes in Western Europe) to 75% (for illumination in Japan). Energy saving measures in these estimates concern e.g. insulation, boilers, electric appliances, hot water supply, cooking and shopping centres. In many areas, the possibilities for improved energy efficiency are vast, but a lot of actions are needed from different parties.

An example from Asia shows the range of energy consumption in use (from 78 to 247 kWh/m2/yr) in different buildings located in the same climate region. This gives a picture about the potential of energy efficient new construction, refurbishment and management. High consumption may in part be due to human behaviour, especially if the amount of wasted energy is not known by the occupants and owners, in particular if they are not financially responsible for it.

COMPARISON OF BUILDING ENERGY EFFICIENCY

Rank	Building	Energy Efficiency Index ($kWh/m^2/yr$)	Remarks
1	Wisma Persekutuan Kuantan(1)	78	Per occupied area
2	Kolej univ Tun Hussein Onn (multiple)(1)	85	Per total gross area
3	Securities Commission Headquarters Building	102	Per air-cond area
4	RCBC Plaza, Philippines (3)	106	
5	Menera AmBankt Group, K. Lumpur (4)	114	Per total gross area
6	Kementerian Pertanian (1)	120	Per total gross area
7	Bangunan Rumah Perskutuan, Kl(1)	133	Per air-cond area
8	Wisma Persekutuan, Kota Bharu (1)	134	Per Occupied area
9	Wisma Persekutuan, K.Trengganu(1)	152	Per occupied area
10	National Science Centre(1)	155	Per total gross area
11	Kompleks Pej. Kerajaan Jln Duta (Multi-Blocks) (1)	168	Per occupied area
12	Mike Shopping Mall, Thailand(2)	169	
13	Urban REdevelopment Authority Bldg, S'pore(2)	191	
14	Capitol Tower, Singapore(3)	198	
15	M'sia Inst of Nuclear Technology, Bangi & Dengkil(1)	211	Per air-cond area
16	Menara Mesiniaga IBM, Malaysia	240	
17	BSN HQ, KL(1)	247	
18	Menara PKNS, Selangor(1)	247	Per occupied area

Sources: 1. Pusat Tenaga Malaysia 2. ASEAN Centre for Energy 3. Conference Papers 4. Respective building managers

Table 5.3
Comparison of Building Energy Efficiency in South East Asia.

Source: Securities Commission.

Box 5.16 Intelcity project

The Intelcity project aims to explore new opportunities for sustainable development of cities through the intelligent use of Information and Communication Technologies (ICTs). It will integrate the knowledge of experts in sustainable urban development (SUD) and ICTs to deliver a roadmap that relates the range of potential ICT development options to planning and urban re/development processes.

The project defined three major barriers. The first one concerns the lack of demand for more efficient, sustainable goods and services; the lack of agreed targets and indicators of progress for such sustainable communities. The second major barrier was the lack of effective participation in political, planning and urban development decision making processes. The third serious constraint was considered to be the inadequate education of citizens, planners, real estate owners and developers about more sustainable lifestyles and technologies and the need to build a common understanding of these issues.

Box 5.17 India

The Indian building sector offers a huge potential for greenhouse gas reduction, but only a small part can realistically be tapped by the Clean Development Mechanism (CDM) of the Kyoto Protocol. This is due to the fact that transaction costs may be prohibitive for all but the biggest commercial buildings or large-scale appliance diffusion programmes. The initial focus of the CDM projects should be on service sector buildings such as hotels, headquarters of banks and large companies with high specific energy consumption and with large potential for energy savings (Singh & Michaelowa 2004).

Although the cumulative energy saving potential of the hospitals, schools and other public buildings in India is considerably bigger, the problem is that their energy bills are currently paid directly by the government through the respective ministries supervising their 25 operations. Such a situation completely discourages the operators of these buildings to introduce any energy saving initiatives. However, a large-scale unilateral CDM programme of the Government could change the picture (Singh & Michaelowa 2004).

Box 5.18 European municipalities (1)

In a European project, the reasons for choosing or not choosing low energy solutions were researched in municipalities in nine countries. The main barrier for not choosing these solutions was investment costs, even if life-cycle costs are taken into consideration. The second most important barrier was the lack of information. The information is needed at the very early pre-design phase of the project when also economical strategies are determined. Information is needed both to the technical department and politicians at the municipal level.

The information needed during the decision phase concerns investment costs, energy savings, a general overview of each solution proposed with experience from other projects and its benefits/ limitations. For many, the lack of time is a serious limitation. The information must therefore be easy to find and retrieve, easy to understand and easy to apply. For most of the countries, the information is preferred in their own language. The best way to provide information seems to be newsletters and internet (Thunselle et al. 2005).

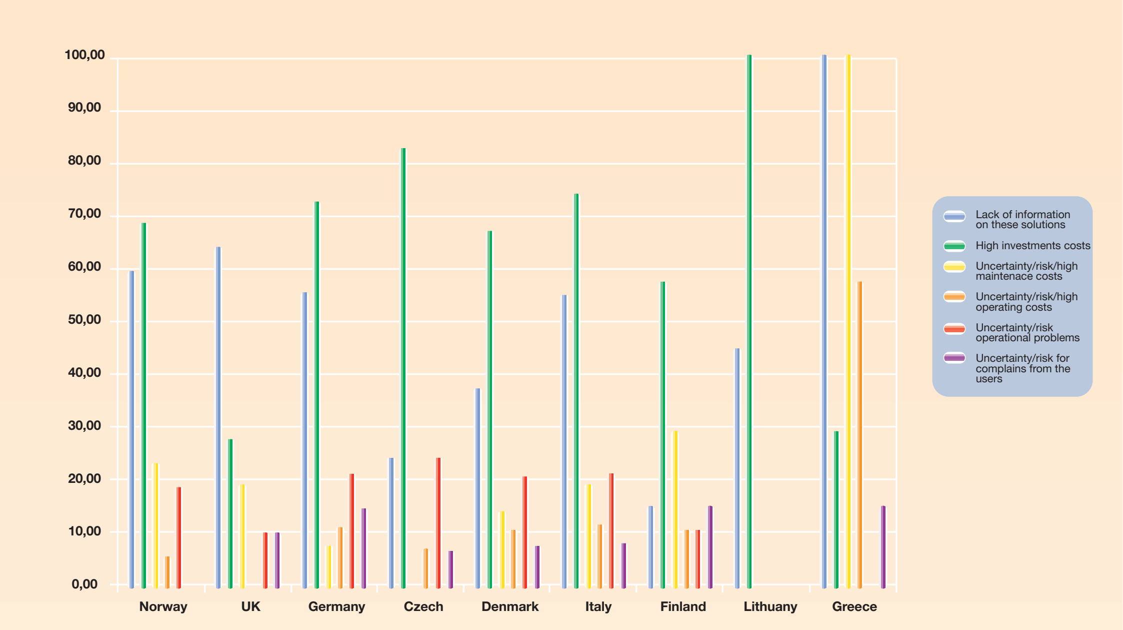


Figure 5.4
The main reason for not choosing the low energy solution. Results of interviews in European municipalities.

Source: Thunselle et al. 2005.

Box 5.19 European municipalities (2)

During the project, a review was also conducted to investigate barriers for energy savings in municipalities. Schools were chosen as examples for municipalities' responsibility. A literature review was done on studies in Norway, Denmark and Sweden. It has been found that there is a lack of studies on barriers. Therefore qualitative interviews were done in ten chosen municipalities in Denmark. The main results of this review are presented below.

Type	Barrier
Economic and decision making progress	Energy decisions are made as a link in political process, that not always is economically rational. Municipalities see energy saving measure es an expense, not as a economical investment. Economical incentives for energy savings are very diffuse or not existing.
Organizational	The responsability for energy decision is given to the building management that not necessarily has energy, technical and economy skills. The link between public buildings and "town hall" is missing. Lack of political and management willingness.
Knowledege/ information	The municipality / institutions lack of knowledge on eneregy saving measures. The theoretical effectiveness of energy saving measures appears as uncertain
Behaviour	If the physical surroundings are shabby, it can be hard to make people change their behaviour. There is a prejudice that it is not possible to influence the employees/students behaviour toward low energy issues.

Table 5.4
Barriers of energy efficiency improvement in municipalities.

Source: EU 2005.

Box 5.20 Malaysia MIEEIP project

Malaysian Industrial Energy Efficiency Improvement Project (MIEEIP) aims at reducing the barriers to energy efficiency and conservation and at giving relevant organizations the opportunity to build institutional capacities for sustainable development. It is co-funded by the government of Malaysia, the Global Environment Facility (GEF), the United Nation Development Program (UNDP) and the Malaysian private sector. The project has conducted audits for 48 factories from eight energy intensive sub sectors. If all measures recommended are implemented, electricity usage will be reduced by 5.6% and fuel demand by 26.7% annually. In monetary terms, energy
will be about 77 million ringgits (20.4 million dollars) with 100 million ringgits (26.4 million dollars) of investment cost. The majority of the investment will have a payback period of 1.9 years. Demonstration projects for reblicability of energy efficiency and technologies and for the sustainability of the activities are currently being carried out.

Box 5.21 Russia

There are many barriers to greater energy efficiency in Russian buildings. The Russian construction industry remains highly centralized, and consists largely of outdated facilities too short on cash to make the required upgrades. Building designers, who have for generations been expected to stand in passive acceptance of state-sanctioned standard designs, lack knowledge of advanced design techniques and new technologies, even those with emerging prospects in the Russian market. Among consumers, the scarcity of information is just as acute. Most apartments lack meters for heat consumption, even at the whole-building level; residents pay flat fees based on floor area, not actual use. Thus they have no way to identify conservation opportunities – and no cost incentive to pursue them (IMT 2006).

Box 5.22 Energy efficiency projects in CIS countries

In 1999, the United Nations Foundation (UNF) approved a two-million-dollar project on energy efficiency for climate change mitigation within the framework of the then EE 2000 Project. The funding was provided to support market formation activities in economies in transition aimed at improving the investment climate for energy efficiency investments so that these could take place in a market environment, that is, on the basis of market criteria. It was also to encourage local and regional authorities to participate in the objectives of the United Nations Framework Convention on Climate Change (UNFCCC) and UNECE environmental accords.

The UNF/UNFIP project 'Energy Efficiency Investment Project Development for Climate Change Mitigation' (ECE-CIS-99-043) started in January 2000. The project covers five east European and CIS countries - Belarus, Bulgaria, Kazakhstan, Russian Federation and Ukraine. It focuses specifically on three areas - municipal lighting, hospitals and district heating. Activities include capacity development and training for private and public officials at the local level to identify, develop and implement energy efficiency investment projects; assistance to municipal authorities and national administrations to introduce economic, institutional and regulatory reforms needed to support investment projects; and the development of energy efficiency investment proposals, with the help of consultants and trainers, for potential investment by commercial banks, private companies and financial service companies.

EE Investment projects are being identified and developed in the participating countries of Belarus, Bulgaria, Kazakhstan, Russia and Ukraine. Major goal is to accelerate energy efficiency market formation activities for the greater participation of private sector investments, products and services in several key areas.

An Ad Hoc Group of Experts guides the implementation of the activities and deals with operational issues. General oversight is provided by the Steering Committee of the EE 21 Project. In order to facilitate proper identification and appraisal of EE projects, the Steering Committee of EE 21 has approved standard Project Identification Form for the following energy efficiency categories:

- *Heat Production and Distribution;*
- *Street Lighting;*
- *EE in Buildings;*
- *EE in industry.*

There are currently about 30 ongoing energy efficiency projects in buildings.

6 Buildings and the Kyoto Protocol

THE KYOTO PROTOCOL is an international agreement, under the United Nations Framework Convention on Climate Change (UNFCCC). Annex B Parties (mainly OECD countries and countries with economies in transition, i.e. mostly former Soviet Union countries) have to establish national programmes for reducing greenhouse gas emissions and to submit regular reports. It sets targets for industrialized countries to reduce their greenhouse gas emissions by 2008-2012 relative to the 1990 base year. These five years are known as the first commitment period. At the moment, 163 countries are Parties to the Convention's 1997 Kyoto Protocol, which entered into force in February 2005. The United States has not ratified the Kyoto Protocol (EU – The Kyoto Protocol 2006, Progress 2005).
In this chapter, a summary of opportunities for including the built environment as an eligible 'activity' under the Kyoto Protocol's flexible mechanisms is presented. The potential for using the Kyoto Protocol as a pull factor for engaging building and construction stakeholders more actively in energy efficiency adoption is assessed.

6.1 The flexible mechanisms

The Kyoto Protocol offers flexibility in the way countries may meet their targets. The Kyoto Protocol contemplates three market-based mechanisms, known as the Kyoto flexible mechanisms: emissions trading between governments with Kyoto targets, the Clean Development Mechanism (CDM) and Joint Implementation (JI). These allow industrialized countries to meet their targets cost-effectively by trading emission allowances between themselves and gaining credits for emission-curbing projects abroad. For example, they may partially compensate for their emissions by increasing 'sinks' – forests, which remove CO2 from the atmosphere. Countries may also pay for foreign projects that result in greenhouse gas cuts, through the JI and the CDM. In this way, reductions can be made where costs are lowest. Detailed rules and supervisory structures have been set up to ensure that these mechanisms are not misused (EU – The Kyoto Protocol 2006, Progress 2005).
The CDM and the JI allow industrialized countries to achieve part of their emission reduction commitments by conducting emission-reducing projects abroad and counting the reductions achieved towards their own commitments. The JI allows for projects in other industrialized countries (Annex B Parties) with Kyoto targets, while CDM projects are carried out in countries without targets, i.e., in developing countries. The two mechanisms also aim to lower compliance costs, transfer advanced technologies to developing countries and foster co-operation between countries with Kyoto targets. The rationale is to save costs and transfer clean technology and know-how to developing countries, helping them to achieve development in a sustainable way (India 2005, China 2005).
CDM credits can be generated retroactively, from 2000 onwards, while JI credits must be generated during the 2008-2012 period. CDM is therefore already operational. A condition for the issue of credits in respect of the reductions achieved is that the projects result in real, measurable and long-term climate change benefits that are additional to what would have happened without the projects (EU – The Kyoto Protocol 2006).

To participate in the mechanisms, Annex B Parties must meet the following eligibility requirements:

- Have ratified the Kyoto Protocol;
- Have calculated their assigned amount of CO2-equivalent emissions;
- Have in place a national system for estimating emissions and removals of greenhouse gases within their territory;
- Have in place a national registry to record and track the creation and movement of ERUs (Emission Reduction Units), CERs (Certified Emission Reductions), AAUs (Assigned Amount Unites) and RMUs (Removal Units) and must annually report such information to the secretariat;
- Annually report information on emissions and removals to the secretariat.

There are currently (January 2007) over 1500 CDM projects registered at the UNFCCC (Figure 6.1), particularly in China, India and in Brazil. Most of these projects concern the energy production side; very few concern the demand side. Some of the manufacturing industries projects relate to buildings and construction: there are several ongoing CDM projects on improving the energy efficiency of the cement production. Other building related activities include the on-site production of electricity for lighting, dissemination of solar-cookers for household use, efficiency improvements and fuel switching measures for a series of public buildings and low-cost urban housing energy upgrade.
Project participants willing to validate or register a CDM project activity need to use a methodology previously approved by the Executive Board or propose a new methodology to the Executive Board for consideration and approval, if appropriate. The methodology essentially describes how to estimate the greenhouse gas emissions if the projects was not implemented (i.e. the business-as-usual scenario). There are currently 79 approved methodologies and many more under consideration. Especially the simplified methodologies for small-scale projects already offer opportunities for building energy efficiency projects. The project size of the small scale projects is typically limited to energy savings under

Box 6.1 Examples of types of projects eligible for CDM support

Small scale energy efficiency improvement projects
As an example, basic guidelines of two approved methodologies for small scale energy efficiency improvement projects are presented here. The technologies may replace existing equipment be installed in new facilities or sites. The aggregate energy savings of a single project may exceed the equivalent of 15 GWh per year. The project boundary is the physical, geographical site of the building(s).

Energy efficiency and fuel switching measures for buildings
This category comprises any energy efficiency and fuel switching measure implemented at single building, such as a commercial, institutional or residential building, or group of similar buildings, such as a school, district or university. Examples include technical energy efficiency measures (such as efficient appliances, better insulation and optimal arrangement of equipment) and fuel switching measures (such as switching from oil to gas). The energy baseline consists the energy use of the existing equipment that is replaced in the case of retrofit measures and the facility that would otherwise be built in the case of a new facility.

Demand-side energy efficiency programmes for specific technologies
This category comprises programmes that encourage the adoption of energy-efficient equipment, lamps, ballasts, refrigerators, motors, fans, air conditioners, appliances, etc. at many sites.

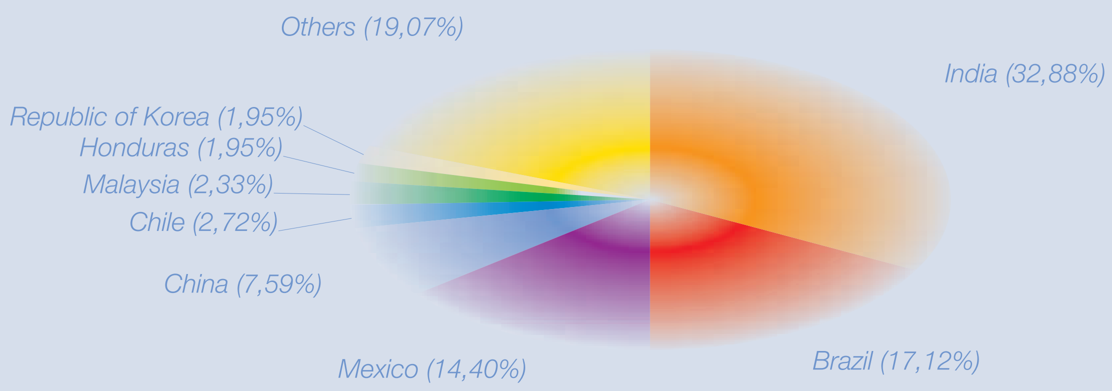


Figure 6.1
Ongoing CDM project activities by country. *-Source: UNFCC 2006.*

15 GWh per year or for energy production under 15 MW. There are no obvious barriers for the built environment to be part of the CDM project activities, except for the fact that there is no approved large scale methodology and the approval process is quite laborious. Once a large scale methodology is approved for building energy efficiency, this will probably stimulate many projects in that area.

6.2 The Kyoto Protocol as a pull factor

Sustainable buildings can be used as a mitigating opportunity for greenhouse gas emissions under the flexible instruments of the Kyoto Protocol. This could be achieved under the systems of tradable permits as well as under the joint implementation or clean development mechanism projects. At the moment, a number of projects on energy efficiency in buildings – such as those that introduce solar power, more efficient lighting devices, HVAC systems and cooking devices – are eligible for the flexible instruments of the Kyoto Protocol, particularly under the CDM. These projects are, however, still few in number and limited to active solutions, such as PV cells, or other projects making use of technological options. Passive solutions, such as the design of better oriented and ventilated buildings as described in chapters 3 and 4, have not yet been proposed under the instruments of the Kyoto Protocol.
In order to have sustainable buildings, as a concept which encompasses both active and passive technological measures, eligible for the flexible

instruments of the Kyoto Protocol, it would be necessary to:

- Determine energy efficiency benchmarks to be achieved in the main regions of the planet, including energy performance standards and other performance indicators in order to measure the expected energy efficiency of buildings in different contexts;
- Formulate a methodological tool, whose applicability under the flexible instruments of the Protocol should be evaluated. This methodology should be applied to demonstration building projects, so that the reductions of GHG emissions of the building can be verified and compared to regular buildings;
- Establish monitoring systems, so that the buildings can be evaluated annually for their energy performance improvement.

Each Party of the Kyoto Protocol can, according to their own conditions, decide what kind of national emission reduction means will be used for achieving the needed reduction. It is agreed that each Party must implement and/or further elaborate policies and measures in accordance with its national circumstances, such as:

- Enhancement of energy efficiency in relevant sectors of the national economy;
- Research on, and promotion of, development and increased use of, new and renewable forms of energy, of CO2 sequestration technologies and of advanced and innovative environmentally sound technologies;
- Progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors that run counter to the objective of the Convention and application of market instruments (Kyoto Protocol 1998).

In the following section, European Union and Finnish cases is taken as examples to present strategies to reduce greenhouse gas emissions related to building and construction sectors.

European Union

Although not an annex B party, EU has adopted an EU-wide emission reduction commitment of that corresponds to the total reduction commitment of individual member states. To support realization of this commitment the European Commission established the 'European Climate Change Programme' (ECCP) in 2000 to help identify the most environmentally effective and most cost-effective policies and to cut greenhouse gas emissions. Under this umbrella, the European Commission and a wide range of experts have developed cost-effective measures that will help the EU meet its 8% emissions reduction target. So far, about 35 of such measures have been implemented. They include the EU Emissions Trading Scheme, legislation to promote renewable energy sources for electricity production and bio-fuels in road transport, as well as legislation to improve the energy efficiency of buildings and to promote combined heat and power generation (EU – The Kyoto Protocol 2006).

The first ECCP ran during the 2000-2004 period and was continued with the Second European Climate Change Programme. ECCP II was launched in October 2005, to identify further cost-effective measures to reduce emissions post 2012. The focus is on reviewing and strengthening the implementation of the ECCP I measures, on carbon capture and geological storage, emissions from road vehicles, aviation and strategies to adapt to the unavoidable effects of climate change. A summary of implemented and planned EU policies and measures that affect the building performance and construction of buildings defined by the ECCP I & II (ECCP) is presented in Annex 5.

The Directive on the Energy Performance of Buildings (2002/91/EC), previously presented in this report (chapter 5), builds on those measures with the aim of providing an ambitious step-ahead to increase the energy performance of public, commercial and private buildings in all Member States, through cost-effective measures, namely by:

- Setting up a common methodology for integrated buildings energy performance standards, promoting convergence of requirements throughout the EU while accounting for regional climate and other specific considerations;
- Application of these more demanding standards on new and existing buildings;
- Establishing national or regional Certification schemes for all buildings (new buildings, existing public buildings over 1000 m2 of floor area, and all buildings when sold or rented will be required to get a Certificate), to be issued by independent, accredited experts recognized by Member States;
- Inspection and assessment of boilers/heating and cooling installations (Directive 2002/91/EC).

The European Directive on the Energy Performance of Buildings presents a great challenge for the transformation of European building sector towards energy efficiency and the use of renewable energy resources. Governments are required to implement a supporting legal framework by January 4th 2006. Certification of buildings and inspections of HVAC systems and equipment can be postponed by up to three years if there is a lack of accredited experts. However, in order to realize sustainable energy use, local action is essential including awareness raising, training and technical support for different professional groups. For this purpose, the European Commission created a Buildings Platform for central dissemination of information, facilitating co-operation between Member States. Through the Concerted Action for the Transposition of Buildings Directive, the 24 EU countries are jointly discussing all the practical issues related to Certification, Inspections, Training of experts and implementation of the common methodology. Funding is provided to about twenty buildings-related projects through its Intelligent Energy programme (2004-2007). These projects produce videos, brochures and other information materials and supporting numerous conferences and events to pass on the message to the public and professionals throughout Europe (Maldonado 2005).

> Box 6.2 Finland

All countries within EU had to specify in what way they will implement the European Directive on the Energy Performance of Buildings. Finland's national strategy for fulfilling the requirements set by the Kyoto Protocol is provided her as an example. According the strategy, the following measures regarding the use of energy by communities and buildings will be taken:

> *The location of new buildings will be directed towards areas with existing service, traffic and energy infra-structure. Such steering is particularly important as far as the important concentrations of workplaces and commercial services are concerned. At the same time, R & D will be promoted to find community structure solutions which would diminish greenhouse gas emissions caused by such structural factors;*
> *The planning co-operation between the Ministries of the Environment, Trade and Industry and Transport and Communications will be activated to reconcile community development, business policy and traffic policy;*
> *In collaboration with municipalities and the construction business, attractive forms of urban residential living as well as urban communities of small houses with efficient land use will be developed (KTM 2005).*

The objective of the energy subsidies granted for residential buildings is to improve their energy efficiency. Simultaneously, the use of renewable and low-emission energy sources will be promoted, providing indirect opportunities for product development. The current subsidies granted to energy renovations of residential buildings is about 17 million euros annually. A comprehensive analysis of the energy efficiency of energy investment subsidies, as well as of their emission reduction impact, will be performed in 2006. Based on the outcome, the level and allocation of financing will be decided. The Government finds it important to speed up the introduction of nonemission and low-emission forms of heating in small houses (KTM 2005).

For this purpose owners of small houses that change the heating system to a more environmentally friendly one, can apply for a subsidy to cover part of the expenses. Subsidies can be applied for the following actions:

> *Connecting a residential building to district heating;*
> *Installing pellet- or other wood heating system;*
> *Building a ground heat pump system;*
> *Oil heating system replacement with a system that also includes a solar collector.*

In addition subsidies can be granted for investment of a separate solar collector, when it is added as a part of the existing heating system (Ympäristö 2006).

Energy savings will also be promoted through real estate management tools, such as the development of user and maintenance instructions. Moreover, monitoring of energy consumption will be improved with the help of various methods, including better consumption measurements (KTM 2005).

In the construction of new buildings, energy efficiency and low-energy building is promoted through information and R & D activities, including the support allocated to experimental building in residential areas with small houses (Ibid.)

The environmental impact report related to this strategy will address the adverse health impacts related to methane and small particles from the small-scale burning of wood. Information-based guidance to the residents and municipal authorities will be increased to diminish such adverse effects. Moreover, the emission requirements for new solid fuel burners and fireplaces, applicable to individual houses or their consortia, will be both studied and set (Ibid.).

The establishment of commercially operating heating plants fired by forest chips and small-scale wood will be promoted in the low-rise housing neighbourhoods, at the same time guaranteeing that the air creates no harmful health impacts.

As previously mentioned in this report also the use of energy certificates will be activated in Finland in the near future.

7 Recommendations

THE FINDINGS IN THIS REPORT suggest that there are both needs and opportunities for supporting improved energy efficiency and reduced greenhouse gas emissions from the building sector. A number of specific recommendations also emerge from the data collected and these are presented below. The recommendations are developed with focus on interventions that would generate a systematic and lasting impact. By necessity, due to climate conditions, as well as economic and social disparities in different countries, these recommendations need to be put into context and interpreted according to the local situation.

7.1 Rationale for the recommendations

As this report shows, the building sector is generally contributing to a large share of national and global greenhouse gas emissions. The largest part is not generated during manufacturing of building materials or during construction (although emissions from these activities are sometimes also substantial), but in the use phase of buildings. During the life span of buildings energy is consumed for heating, cooling, ventilation, lighting, use of electrical appliances, heating of water etc. The energy consumption profile, and associated greenhouse gas release, for a typical building will however differ between different countries, mainly depending on the climate and level of development. Regardless of the energy consumption in absolute numbers, there almost always exist considerable opportunities to drastically reduce the energy use in buildings. Such reductions can often be realized through proven and commercialized technologies (many times making use of low-tech and/or traditional solutions).

The challenge to achieving energy efficiency, and reduced climate change impact, in buildings is therefore usually not a lack of access to technical solutions, but a lack of signals to the building sector stakeholders to adopt such solutions. Not withstanding this, there is already today a wide range of policies, tools and incentives that are employed to promote sustainable buildings and energy efficiency in buildings in individual countries. These include regulations, standards, certification schemes, economic incentives, awareness raising campaigns etc. While some of these seem to be successful there are still a number of basic challenges that obstructs many of them:

Firstly, most tools and policies fail to take a life cycle approach, and targets conditions only during design or construction, or only apply to the owner or investor of the building (and not the actual user – the tenant who shoulders associated costs). The life time of building is typically 50-75 years, while many tools are only applied at a specific point in time (usually during the construction phase).

Secondly, in most countries (and again with some exceptions) there is still a general lack of knowledge of what constitutes an energy efficient building, and how potential benefits can be quantified or realized. This lack of baseline information is critical as any effort to improve the energy efficiency, must be able to base incentives and tools on indicators for when improvement has been achieved.

Thirdly, buildings are very different from many other greenhouse gas emitting activities (e.g. industry, transport and agriculture) in that they constitute a very large number of small units with a very long life span and diverse stakeholder structure. Tools and strategies that are developed for other activities (e.g. the CDM and JI mechanisms of the Kyoto protocol) are for the moment not tuned to deal with this kind of smaller and diffuse emission sources. Moreover the associated costs and administrative requirements for registering an emission reduction project in a building as a CDM or JI project are usually prohibitive for the building sector stakeholders. The same goes for national or regional emission trading schemes where individual buildings are seldom qualified to participate.

Recognizing the rather different conditions (climate, culture, tradition, economics, availability of materials etc) that applies to the building sector in various countries it is obvious that there is no single universal solution or recommendation that can be given for improving the energy efficiency in buildings.

However, it seems universally true that in most countries the solution requires active involvement of the government to create a suitable framework for energy efficient buildings. In other words, leaving to the private sector to address energy efficiency without any external signals is in most cases not feasible. It is also true that the building sector stakeholders themselves, including investors, architects, property developers, construction companies, tenants, etc. need to understand and ideally support, the tools and strategies the government proposes in order for then to function effectively. For this reason it is essential that the government develop their strategies and tools in consultation with the sector stakeholders and allows input to the design of tools and strategies from all parties concerned.

The kind of stakeholders that should be considered in different capacities when developing tools and policies for energy efficiency in buildings were highlighted during the 'Mainstreaming SBC in SE Asia' workshop in Kuala Lumpur, organized by UNEP, with support from the EU's Asia Pro Eco programme in 2005. Table 7.1 provides a summary of different stakeholders, their roles, priorities and actions towards sustainable building and construction of different building types.

Figures 7.1 and 7.2 are exemplifying the very important role that active policy setting can play in reducing the greenhouse gas emissions from society. These figures show fifteen countries positioned in a matrix based on their Gross National Income per

ACTORS	ROLE	Detached Housing	Multi-unit Housing	Commercial	ACTION
Governement	Policies & Regulations	2	1	2	Establish policies; Enabling mechanisms; Financial dis/incentives; Lead by example as client
Investors	Source of capital	1	2	1	Reduce risk by specifying high performance; Lead by example as client
Developers	Project intitiation & management	1	2	2	Increase level of innovation, responsability and environmental consciousness
Owners	Asset management	2	3	2	Life cycle thinking
Commercila tenants	Maangement of firms	5	5	2	DEmand sustainable building for rental space as policy
Research & education	Knowledge generation & dissemination	3	3	3	Knowledge generation & dessemination
Designers	Creating potential performance	3	3	3	Improve knowledge of new methods and technologies; educate clients, adopt and promote sustainability principies
Facility Managers	Operations & maintenance	4	4	3	Operate building in an environmentally-conscious way; monitor performance & share
Real Estate Brokers	Influencing the market	3	3	3	Improve level of knowledge, then advocatge high performance
Manufacturers & suppliers	Provide products end services	4	4	3	Life-cycle view, be aware of systems integration, broaden networks
Builders	Construct the building	4	4	4	Respect environmental factors while following client requirements; educate & add value
User / occupant	Use the building	2	3	4	Ask for manual; respect sustainable operation needs; participate
Professional associations	Influence work of individual members of firms	4	4	4	Ensure that members improve knowledge & skill; adopt, enable and promote sustainability principles in theirfield; promote cross-disciplinary action
Regulators	Risk management	4	4	4	Be receptive to new approches that support sustainability
Media	Agitate or enthuse	4	4	4	Demand sustainable building
Public	Agitate or enthuse	5	5	5	Demand sustainable building

Table 7.1
Potential role of stakeholders (UNEP 2005)

capita horizontally and their CO2 emissions per capita vertically. The size of the bubbles represents the population of each country. Five of them (Brazil, China, India, Japan and USA) remain present in both figures, whereas ten others change, providing a diversified picture of nations with different climate and socio-cultural backgrounds, boundary conditions and customs.

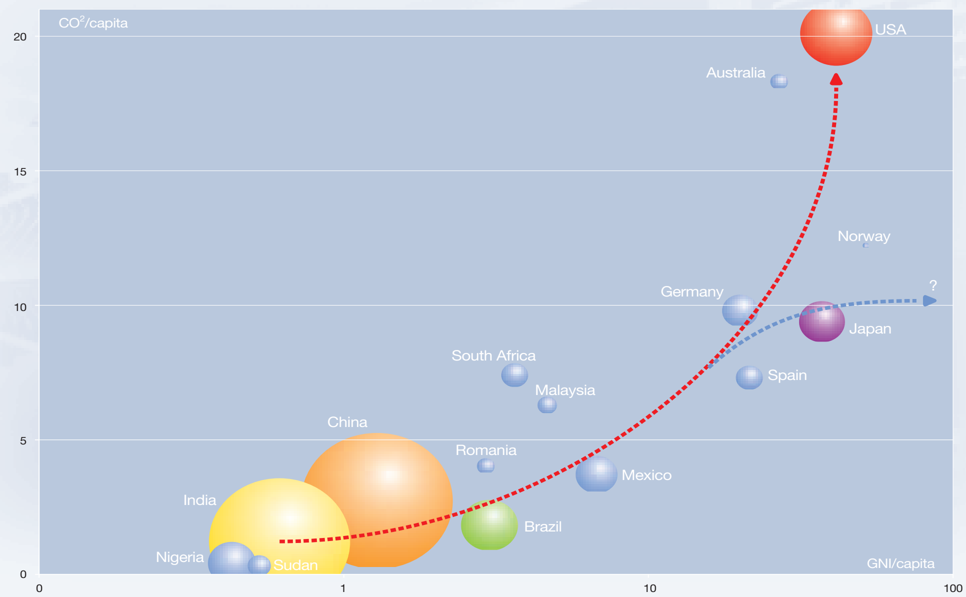


Figure 7.1
Recommendations depend on the position of the country in the figure.)

These two figures suggest that there may be a positive correlation between growing wealth (GNI) and increasing CO_2 emissions, i.e. increased wealth (GNI) normally result in increased levels of CO_2 emissions. However, the graphs also show that in the more affluent countries (right side of the graphs) countries can chose different paths. While e.g. USA and Australia have an almost exponential increase in CO_2 emissions, other countries, such as France and Sweden have managed to keep the emissions almost level even if their GNP has continued to increase. A closer comparison of the countries will show that for example the governments in France and Sweden have also been much more active in encouraging energy efficiency and low carbon approaches in society, than USA and Australia (again as examples). This highlights the importance of governments taking action to enable other stakeholders in society to realize greenhouse gas emission reductions.

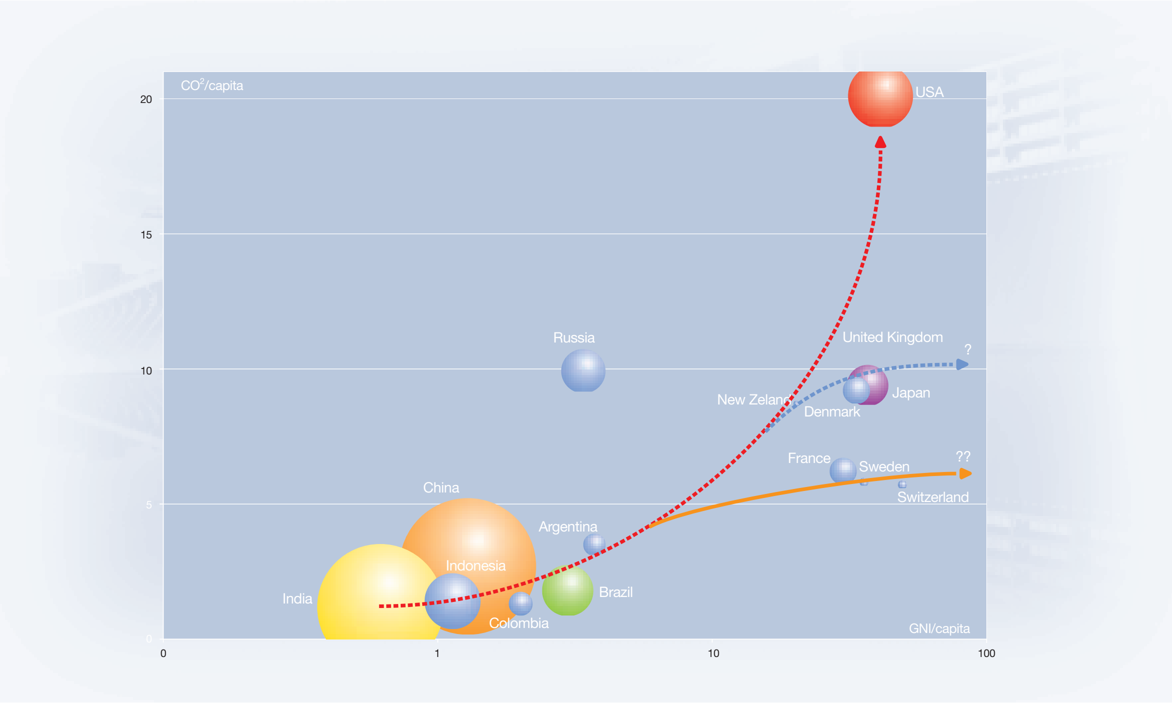


Figure 7.2 *Which direction to go?*

7.2 Recommendations

The following recommendations are given as general guidance for activities that stakeholders may wish to consider in order to promote more energy efficient buildings. It should be kept in mind that each person, organization, authority and company need to interpret these recommendations within their mandate and the local settings in the area they are active in. In other words, an organization such as the Sustainable Buildings and Construction Initiative may wish to take on different recommendations than a local authority in Asia, or an industry association in North America.

Policies

The behavior of the building sector is influenced by a wide range of signals from authorities, customers, financiers, researchers etc. covering virtually any aspect of building activities. Governmental polices have a special role in that they often not only influence the building sector itself, but also the behavior of customers, financiers, researchers and other stakeholders. Policies are however not always designed with consideration of their impact outside the direct target group. E.g. a policy on taxation of renovation works may discourage investors to undertake renovations that would achieve substantial energy savings, in spite of them being profitable over a longer period of time. Clearly there is a need for policies and associated tools (some of which are addressed below) that encourages a wide support for more energy efficient buildings, including policies regarding energy pricing and taxation, awareness and education, technology access, building safety and so on. It is furthermore important that such standards are working in harmony with each other, not sending conflicting signals to the target groups about their desired behavior.
There is already today a wealth of examples of policies that have been adopted and tested to encourage energy efficiency in the construction and buildings sector. While the lessons learned from some individual polices have been documented and the understanding of what policy tools are useful

under what circumstances is slowly building, there has still not been carried out any in-depth analysis of polices or group of policies at the global level. Such an analysis would be valuable to policy makers around the world as a ground for defining and refining new and existing policies towards energy efficiency in buildings.

Benchmarking

The understanding of what constitutes a sustainable building is now fairly well developed, and in some countries certification systems have been adopted based on specific criteria related to the use of materials, water, energy, comfort etc. Not surprisingly however, most countries lack such systems, and there is no universal definition of what constitutes a sustainable building, or even an energy efficient building for that matter. It can be argued that such a global definition would probably be quite meaningless because of the widely different conditions in different countries (compare e.g. a house in Canada with a house in Ghana, where the climate, the entire structure, need for heating/cooling, access to materials, culture and economic considerations are very different). Not withstanding this there is a clear need (as demonstrated earlier in this report) to quantify what may constitute an energy efficient building under different conditions (new/old buildings, different climate zones etc), and to quantify the associated benefits in economic terms, as well as in terms of greenhouse gas emission reductions. Such benchmarks would be necessary to:

1. Develop national standards for energy efficient buildings
2. Support national and international emission reduction mechanisms (funding schemes, trading networks etc) that need to define “business as usual” performance of buildings as compared to energy efficient performance.
3. To provide a basis for identifying and quantifying projected benefits from investments in energy efficient buildings.
4. To support efforts on developing a building sector triple bottom-line reporting standard under the Global Reporting Initiative (www.globalreporting.org)

Regulations

Regulations provide a necessary framework for many activities in society. In most countries, construction activities are subject to more or less well developed regulations and standards, ranging from technical standards, mandatory safety considerations and architectural factors, to environmental requirements and indoor health standards. Regulations exist for construction of new buildings, as well as for renovation of exiting buildings. The regulations are adhered to by various degrees, depending on the perceived relevance of the regulated issue and the level of enforcement. In any case, regulations provide an important yardstick and reference of what is considered minimum standards in the national context. Even if legislation is not always able to bring stakeholders into full compliance, it still fills an important function in underpinning other tools and measures aiming at the same goal (in our case, improved energy efficiency and reduced greenhouse gas emissions).
It is therefore important to ensure that appropriate regulations are in place and that these provide relevant signals on the desired reduction in energy consumption and associated emissions.
Furthermore, such regulations should as far as possible cover the energy use over the entire life span of buildings, and be applicable to new buildings as well as existing ones. It is recommended that governments consider to adopt through legislation realistic and measurable energy efficiency standards for new and existing buildings.

Economic tools

Economic tools may include a wide range of different kind of measures that impact the economics of an activity. Tools may be constraining ones; taxes, fees, price levies etc, enabling ones; rebates, preferential lending opportunities, tax breaks, or tools considered as cost neutral, such as the feebate system (see box 5.1). Since the economic factors (costs and returns on investment) are often the primary considerations when decisions are made on how buildings are designed, constructed and operated, economic tools are often extremely powerful in changing the behavior the stakeholders. Clearly there is a need ensure that suitable economic signals are sent to the building sector, creating market conditions that provide quantifiable economic advantages to buildings that are built and operated so as to achieve energy efficiency.
It is also important to ensure that the economic signals are sent to the correct actors: Economic tools that encourages reducing the energy use may be of great significance for the people living in a house as the energy bill can form a significant part of the operating costs. However, for the investor who pays the cost for building the house, the energy costs may only constitute a very small part of the total costs, and indeed, he may not even have to pay any of them. In such a case the investor is likely to prefer that the house is equipped with the most cost effective energy system (as opposed to the most energy efficient one).
Related to economic tools is also the need to collect data and develop methods that can support financiers to take a more proactive role in identifying and quantifying the economic benefits investments in more energy efficient buildings may have. This is directly related to the first recommendation on benchmarking (above).

Education and awareness raising

Increasing the general awareness about the benefits of energy efficient buildings is a basic requirement underpinning any change in the behavior of decision makers (in authorities as well as in the private sector) and of other stakeholders and users of buildings. This can e.g. be done through inclusion of a curriculum on this subject in education and through awareness raising campaigns. Such efforts should however not be conducted in isolation from other tools but as far as possible be provided together with tools or indicators that can be used to identify energy efficient buildings. Labeling products and rating of buildings (e.g. the LEED system in USA) increase the consciousness investors and users of buildings.

Further research on buildings in developing countries
There is no lack of information about sustainable buildings and construction, or on energy efficiency in buildings in general terms. Many of the studies available, however, refer to the situation in OECD countries and only to a smaller extent to developing countries. As has been acknowledged in this report there is in fact a lack of reliable data about the present situation and future outlook for energy efficiency in buildings in poorer countries, especially in areas with less severe climate. A common assumption is that buildings in such areas do not pose a major concern from the energy and climate change perspective as the energy consumption is very low and/or is mostly generated with renewable energy sources (biofuels). On the other hand, as has been seen in some countries, if such countries follow a similar development path to western countries the energy use and greenhouse gas emissions can rapidly increase with increased levels of development. It can therefore be argued that there is in any case a need to build knowledge also for these countries, so as to be able to support a more healthy, and less energy intensive, development path of the building sector.

Understanding human behaviour

No matter how well designed a building is, its energy performance will in the end very much depend on how the people living in, working in, or otherwise are using the building are behaving and to what extent they make use of energy efficiency provisions. In other words: improved energy efficiency requires conscious choices and responsible use of facilities. The better one understands the logic behind human behavior the better chances one has to succeed with technologies. The understanding of why individuals are behaving in a certain way in relation to indoor climate and purchase/use of energy efficient appliances is still limited, and the understanding of how to influence their behavior in a positive way is even less well understood. Research in this area should therefore be a priority.

Apply new polices in the public sector

The public sector often constitutes a major actor in the building sector, as building owner, tenant, developer and financier. Energy efficiency policies implemented in the public sector and applied when authorities and other public organisations and companies are purchasing, contracting, operating buildings can therefore create a demand for energy efficient buildings that can have a positive impact directly on the market. Governments should seek to explore this opportunity to influence the building sector not only as a regulator, but also as an actor, putting up a good example for others to follow.

Support Technology Transfer

The technology for improving energy efficiency in buildings is already available and is continuously further developed. Not withstanding this is the fact that not all technologies are suitable for all buildings and not everybody has easy access to such technologies and solutions. Section 5.3 in this report describes some technology transfer efforts, highlighting that successful technology transfer constitute many different components functioning together (some of them being covered by other recommendations in this report). Also under the Kyoto protocol, opportunities for enhancing access to technologies need to be further promoted. Making information available about opportunities for, and lessons learned from, energy efficiency improvements is a basic first step to take. Sufficient information about many opportunities can easily be accessed through the internet. However, there is a need to improve this information, in particular in relation to lessons learned from the actual performance of buildings that have applied the energy efficient solutions/technologies. Finally, introducing the building sector to be eligible under the Kyoto protocol mechanisms is a key issue. Working on baseline elaboration through comprehensive methodological tool books has to be considered has a priority.

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Annex 1. Figures Related to Energy Use in Buildings

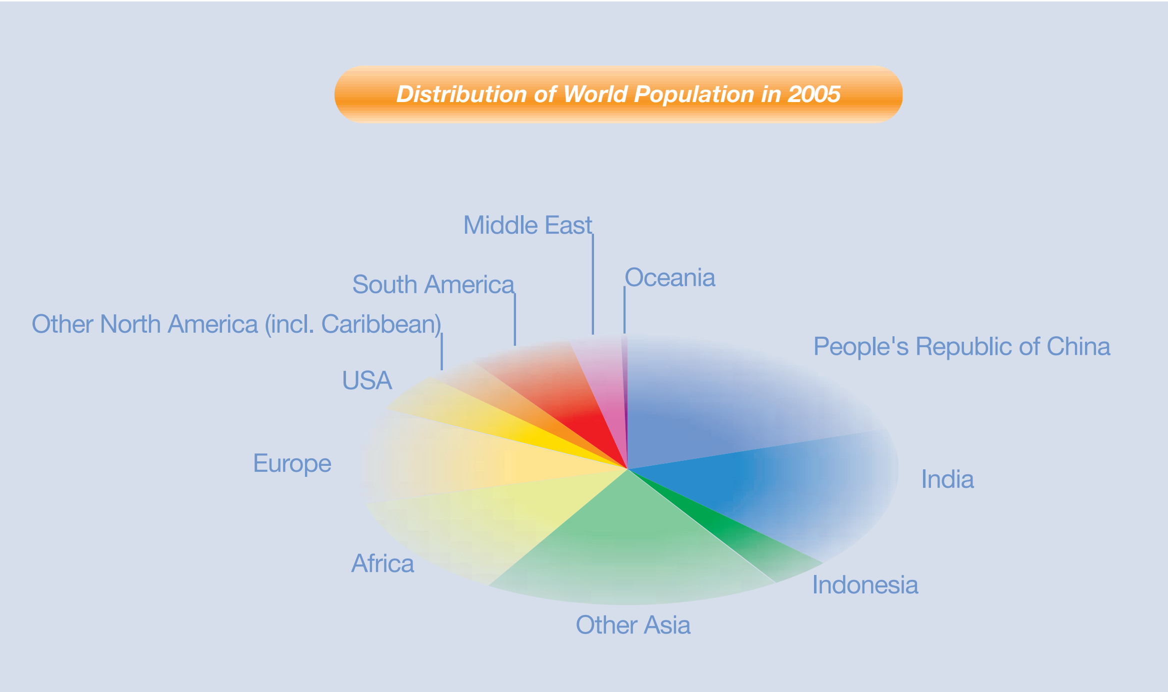


Fig. 1
Over 80 % of the people live in the developing countries. Total population about 6.5 billion in 2005 (UN 2004).

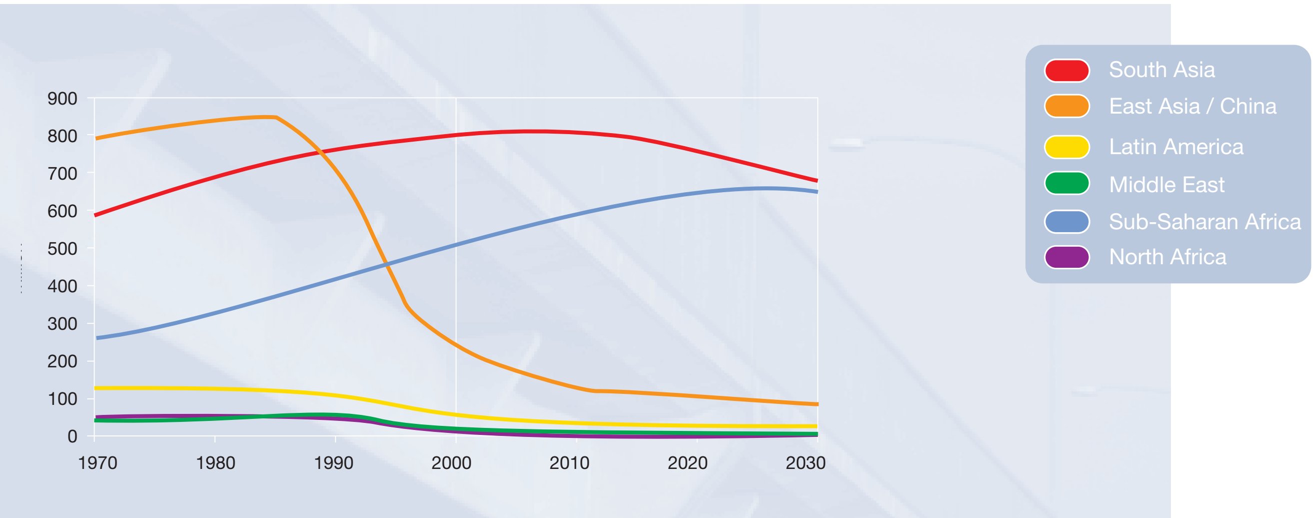


Fig. 2
Number of People without Electricity, 1970-2030 (IEA 2002).

Country	Firewood	Gas, Kerosene	Charcoal	Electricity	Other
Central Africa Republic	100	0	0	0	0
Guinea	99	0	1	0	0
Gambia	97	1	1	0	1
Mali	97	0	0	0	2
Tanzania	96	0	3	0	0
Madagascar	94	0	5	0	0
Uganda	94	2	4	0	0
Kenya	93	2	4	0	0
Burkina Faso	91	1	1	0	7
Niger	90	1	0	0	9
Cote d'Ivoire	89	1	2	0	8
Zambia	89	0	9	1	1
Botswana	86	14	0	0	0
Senegal	84	2	12	0	2
South Africa	49	23	5	21	2
Djibouti	44	48	5	1	2

Fig. 3
Fuels used for cooking in rural households for selected African countries (% of fuel used). Source: World Bank, 2000 (Karekezi and Kithyoma 2004).

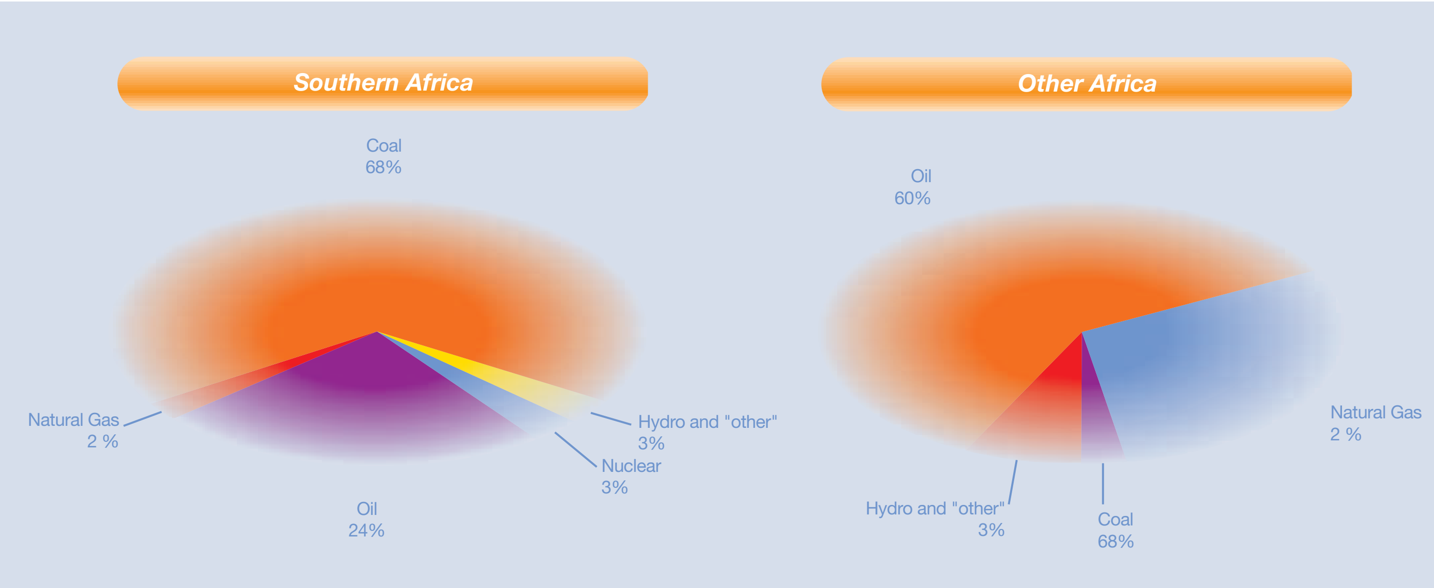


Fig. 4
Energy sources in Southern and other Africa in 1999. Energy in Africa. December 1999 (DoE 2006).

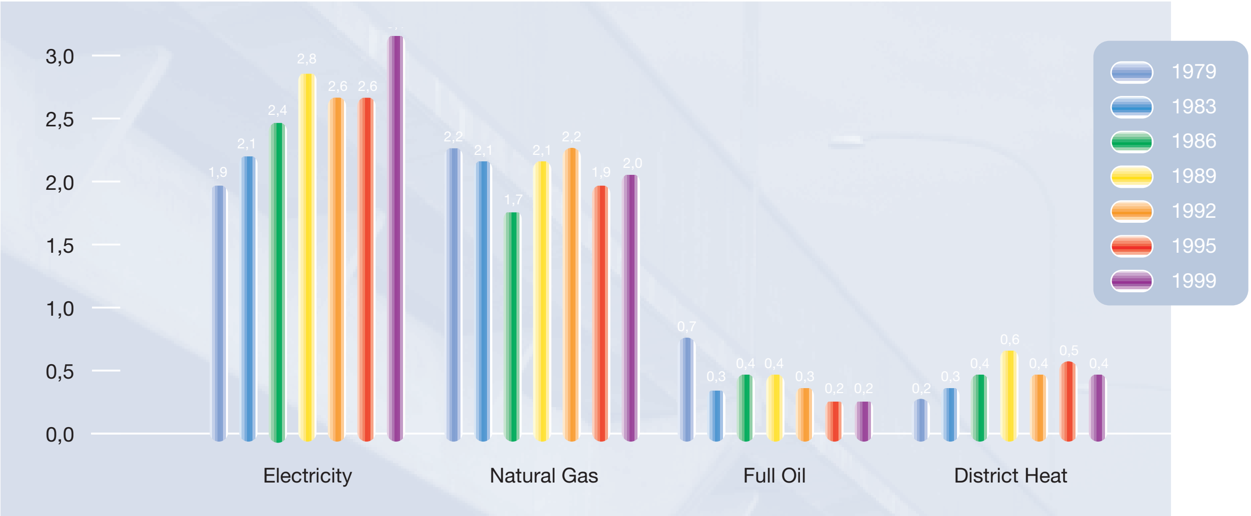


Fig. 5
Energy sources for commercial buildings in USA (Energy Information Administration / Annual Energy Review 2004).

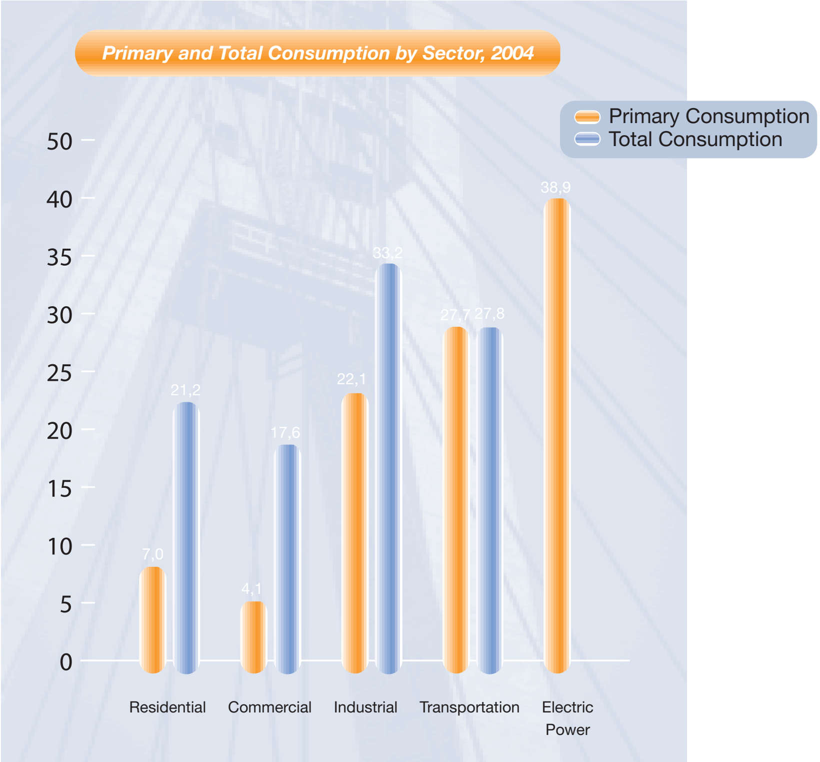


Fig. 6
Energy consumption by sector in USA (Energy Information Administration / Annual Energy Review 2004).

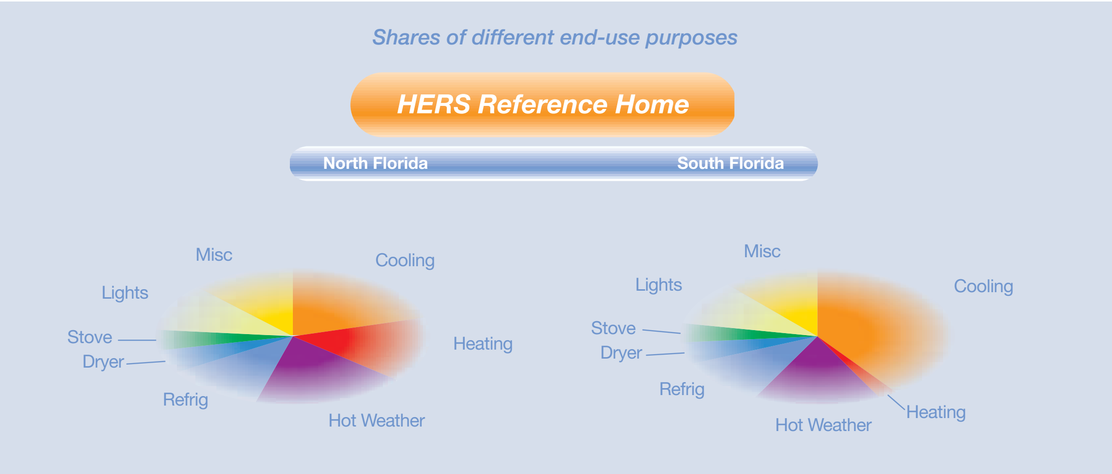


Fig. 7
The effect of climate to the shares of energy use. Calculated energy use of a reference house in southern and northern Florida (Energy Gauge).

Residential	23%
Commercial	11%
Public	8%

Table 2. Energy consumption in buildings by sector

Residential		
Refrigerating	32%	
Hot water	26%	
Lighting	23%	
TV	8%	
Other	10%	
Commercial and Public		
Lighting	44%	
HVAC	20%	
Refrigerating	17%	
Cooking	8%	
Other	11%	
Office		
HVAC	48%	
Lighting	24%	70%
Office equipments	15%	16%
Elevators and others	13%	14%

Fig. 8
Energy consumption in buildings in Brazil (Delbin et al. 2005).

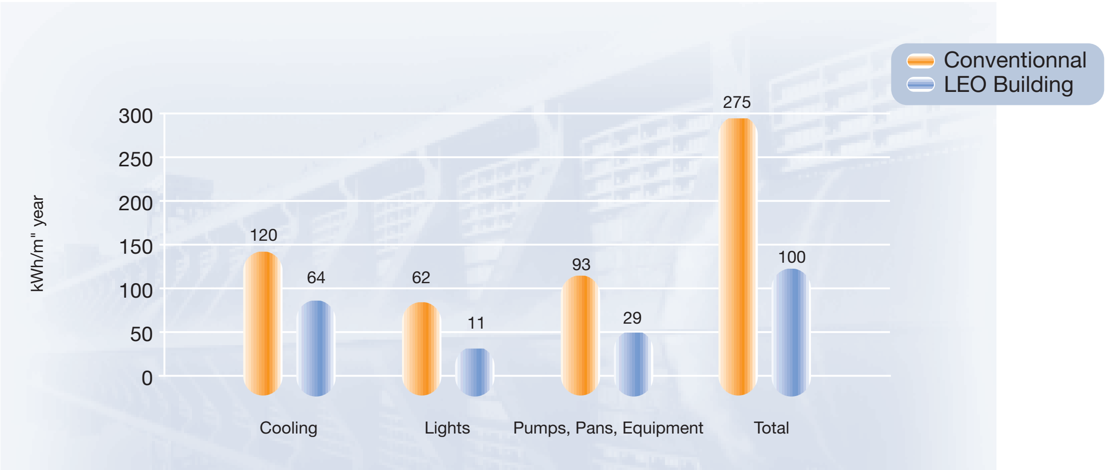
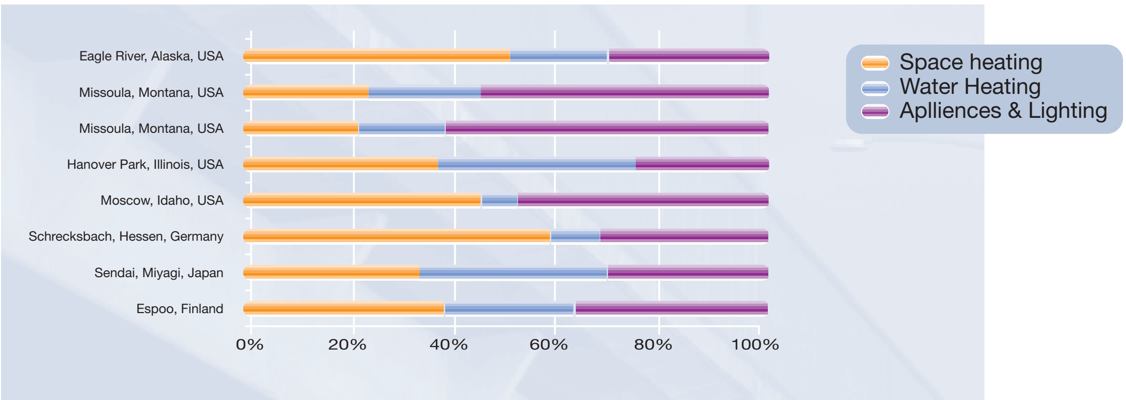


Fig. 9
Malaysian low-energy building compared to conventional building (Kumar et al. 2005).

Fig. 10
Shares of different energy uses in some low-energy houses (Meier et al. 1999). Distribution of the energy use over the life cycle



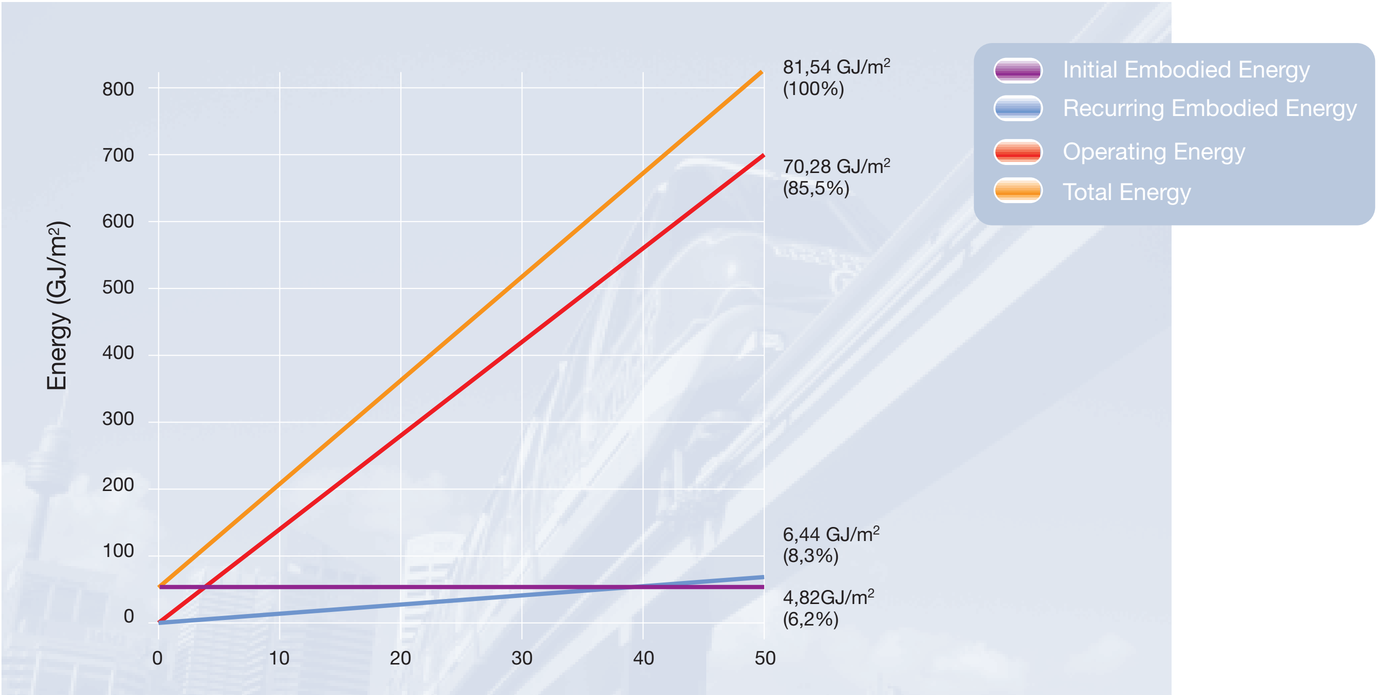


Fig. 11
Components of Energy Use During 50-Year Life Cycle of Typical Office Building with Underground Parking, Averaged Over Wood, Steel and Concrete Structures in Vancouver and Toronto. Source: Cole and Kernan, 1996 (Canadian Architects 2006).

Fig. 12
Greenhouse gas emissions over the life cycle of a house.
Option 1 Brick veneer/timber frame/concrete slab
Option 2 Brick veneer/steel frame/concrete slab
Option 3 Double brick/concrete slab
Option 4 Timber clad/steel frame/concrete slab
Option 5 Timber clad/timber frame/concrete slab

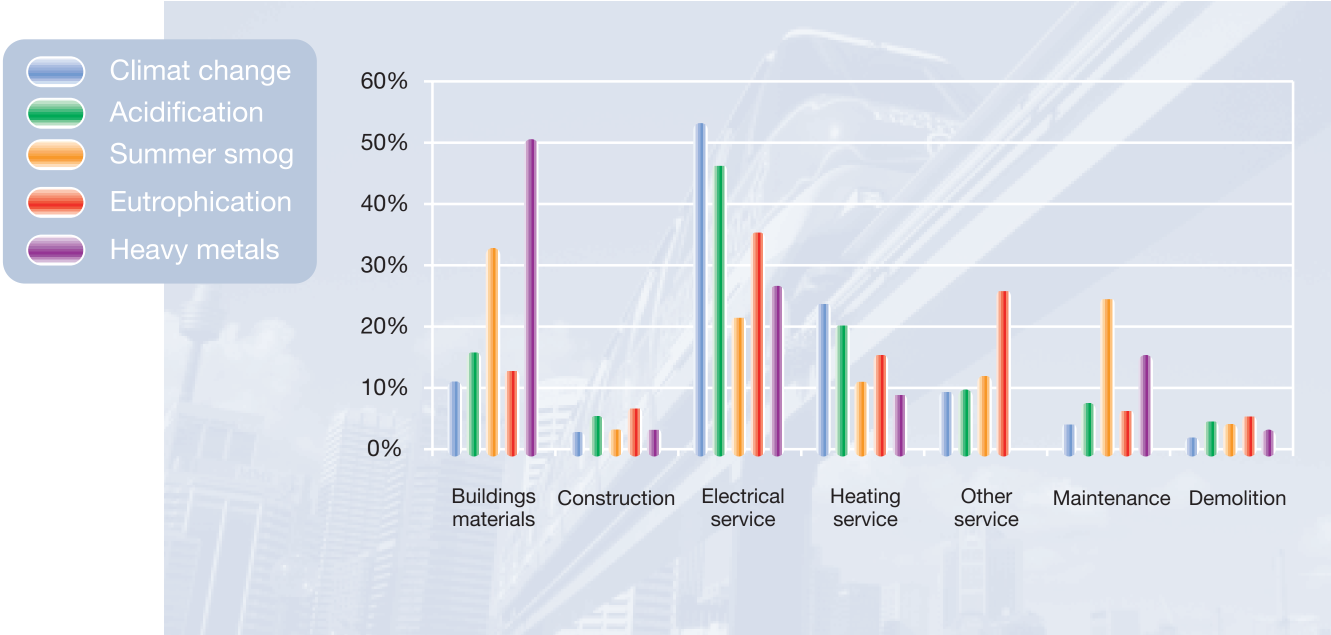


Fig. 13
Environmental impact of an office building by building life-cycle phases over 50 years of service life (Junnila 2004).

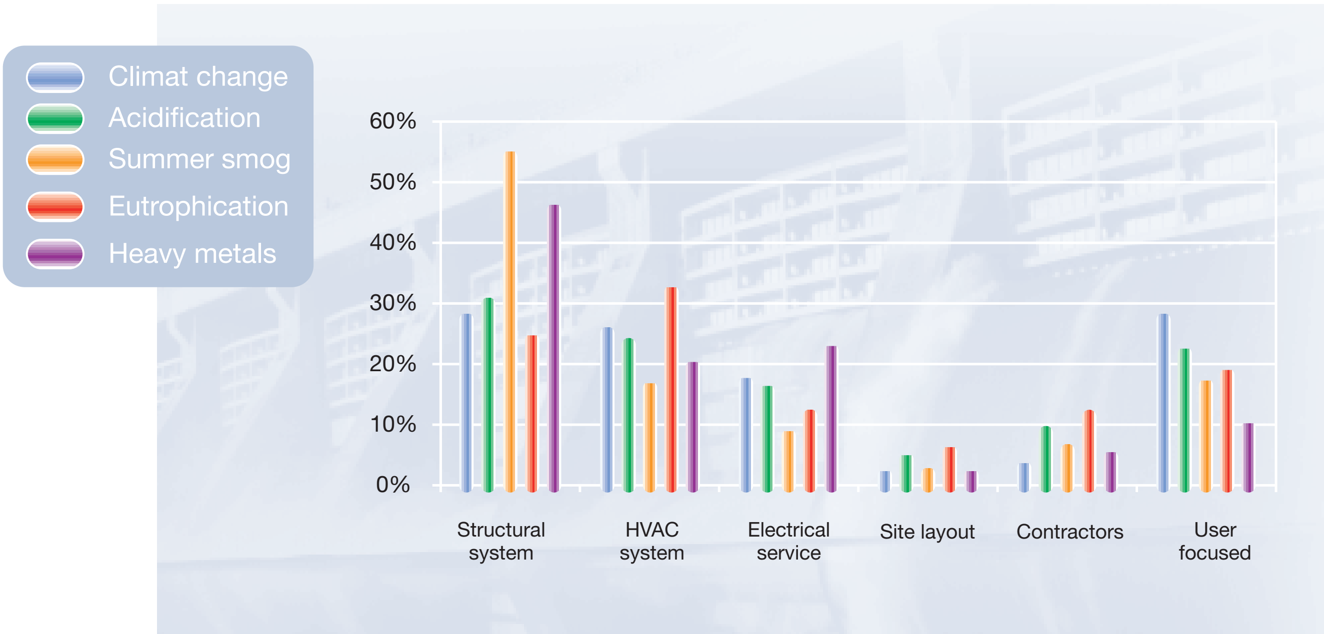


Fig. 12
Environmental impact of an office building by building systems over 50 years of service life (Junnila 2004).

Annex 2. Building Materials

Country	Steel MWh/t	Cement MWh/t	Steel GJ/t	Cement GJ/t
India	11.0	2.3	39.7	8.4
China	7.6 - 9.7	1.3	27.5 - 35.0	5.9
United States	7.1	1.1	25.4	4.0
Sweden	5.8	1.6	21.0	5.9
Japan	4.9	1.4	17.5	5.0

Table 1.
Final energy use in selected industries and countries, mid-1990's (gigajoules per tonne) (Jochem 2005).

MATERIAL	PER EMBODIED ENERGY kWh/KG	PER EMBODIED ENERGY MJ/KG
Kiln dried sawn softwood	0.9	3,4
Kiln dried sawn hardsoftwood	0.6	2,0
Air dried sawn hardwood	0.1	0,5
Hardboard	6.7	24,2
Particleboard	2.2	8,0
MDF	3.1	11,3
Plywood	2.9	10,4
Glue-laminated timber	3.1	11,0
Laminated veneer lumber	3.1	11,0
Plastics - general	25.0	90,0
PVC	22.2	80,0
Synthetic rubber	30.6	110,0
Acrylic paint	17.1	61,5
Stabilised earth	0.2	0,7
Imported dimension granite	3.9	13,9
Local dimension granite	1.6	5,9
Gypsum plaster	0.8	2,9
Plasterboard	1.2	4,4
Fibre cement	1.3	4,8
Cement	1.6	5,6
Insitu Concrete	0.5	1,9
Precast steam-cured concrete	0.6	2,0
Precast tilt-up concrete	0.5	1,9
Clay bricks	0.7	2,5
Concrete blocks	0.4	1,5
AAC	1.0	3,6
Glass	3.5	12,7
Aluminium	47.2	170,0
Clopper	27.8	100,0
Galvanised steel	10.6	38,0

Table 2.
Typical figures for some Australian materials (Lawson 1996).

Annex 3. Low-Energy Building IEA Task 13

	B	CDN-B	CDN-W	DK	FIN	D-R	D-B	I	J	NL	N	S	CH	US-GC	US-A
Super insulation	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
High-performance windows	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Transparent insulation											x				
Ventilation heat recovery systems	x			x	x	x	x	x	x	x	x	x	x		
Ground couple heat exchangers			x		x	x					x				
Sunspaces		x			x	x	x			x	x				
Thermal Storage (building mass)	x			i		l	x	i	x		x	x	i	x	l
Active Solar water systems			x	x	x		x	x		x		x			
Photovoltaic systems			l	l	x				x		x		x		
Integrated mechanical system		x	x								x			x	x
Home automation systems	x				x				x	x		x			
Evergy. efficient lights & appliences		x	x	x	x		x				x				x

Inherent in construction
Limited to active solar system pumping
Yes

Table 3.
Strategies and technologies used in the IEA task 13 low energy buildings. i=inherent in construction, l=limited to active solar system pumping, x=yes (IEA 1997).

Annex 4. Energy in Building Rating and CSR Reporting Systems

GRI Sustainability Reporting Guidelines
Energy
EN3 Direct energy consumption broken down by primary energy source
EN4 Indirect energy consumption broken down by primary energy source
EN5 Percentage of total energy consumption met by renewable sources
EN6 Total energy saved due to conservation and efficiency improvements
EN7 Initiatives to provide energy-efficient products and services
EN8 Initiatives to reduce indirect energy consumption.
Emissions, Effluents, and waste
EN17 Greenhouse gas emissions
EN18 Emissions of ozone-depleting substances
EN19 NOx, SOx, and other significant air emissions by weight

Green Building Challenge
B ENERGY AND RESOURCE CONSUMPTION
B1 Total Life Cycle Non-Renewable Energy
B1.1 Predicted non-renewable primary energy embodied in construction materials
B1.2 Predicted non-renewable primary energy used for building operations
B2 Predicted electrical peak demand for building operations
B3 Renewable Energy
B3.1 Plans for use of off-site energy that is generated from renewable sources
B3.2 Plans for use of on-site renewable energy systems
C ENVIRONMENTAL LOADINGS
C1 Greenhouse Gas Emissions
C1.1 GHG emissions embodied in construction materials
C1.2 Predicted GHG emissions from all energy used for annual building operations
C2 Other Atmospheric Emissions
C2.1 Design features to minimize emissions of ozone-depleting substances during building operations
C2.2 Design features to minimize emissions of acidifying emissions during building operations
C2.3 Design features to minimize emissions leading to photo-oxidants during building operations

Leed for Homes
Indoor Environmental Quality (IEQ)
Energy STAR with Indoor Air Package
Energy and Atmosphere (EA)
Energy STAR Home

EcoHomes
Energy
Ene 1 Carbon Dioxide
Ene 2 Building Fabric
Ene 3 Drying Space
Ene 4 EcoLabelled Goods
Ene 5 External Lighting
Pollution
Pol 1 Insulant ODP and GWP
Pol 2 NOx Emissions
Pol 3 Reduction of Surface Runoff
Pol 4 Zero Emission Energy Source

PromisE environmental rating system for new housing projects
Energy consumption 40 %
Setting requirements for energy consumption 15 %
Heat consumption 40 %
Use of real estate energy 20 %
Energy consumption management 15 %
Quality of acceptance inspection 10 %

Annex 5. Summary of Implemented and Planned EU Policies and Measures on Building Sector

Policies and measures 'energy demand'	Description /Emission reduction potential in the EU-15 by 2010	Stage of implementation
'ALTENER' component of 'Intelligent Energy - Europe' funding programme (Decision 1230/2003/EC)	The 'Intelligent Energy - Europe' programme is a funding scheme with a budget of € 250 million for 2003-2006 to promote intelligent energy use and more renewables. It is not technology-related, but co-finances the start-up of local or regional agencies as well as international projects & events aimed at spreading best practise and building capacity. Ninety projects had been selected by October 2005. There are four areas of activity. 'ALTENER' supports the use of renewable energy sources. The other three fields deal with energy efficiency, sustainable transport and the use of renewables in developing countries.	2003-2006 Commission proposal to continue the IEE programme during the 2007-2013 budgetary period and almost double its budget to € 780 million
Energy performance of buildings (Directive 2002/91/EC)	Buildings account for around 40 % of EU energy demand. Based on an EU-wide common methodology to measure the energy performance of buildings, EU governments have set minimum performance standards. These will apply to all new constructions and large old buildings undergoing major refurbishment from January 2006. Sellers and landlords will have to provide prospective buyers and tenants with energy performance certificates. Emission reduction potential in the EU-15 Member States by 2010: 20 Mt CO_2 eq	Implementation by Member States was due by 4 January 2006
Energy labelling of domestic household appliances (package of Directives relating to specific appliances with Directive 92/75/EEC from 1992 providing for the framework)	Domestic household appliances sold in the EU must carry a label grading them according to their energy efficiency, with the grades running from A (high energy efficiency) to G (low efficiency). This allows consumers to choose the most efficient ones and has stimulated producers to improve the energy efficiency of their products. Emission reduction potential in the EU-15 Member States by 2010: 31 Mt CO_2 eq. (existing labels) 23 Mt CO_2 eq. (planned new labels and tightening of requirements for existing labels)	First labels, for washing machines, mandatory since 1 January 1996, others thereafter
Framework for setting eco-design requirements for energy-using products (Directive 2005/32/EC)	This initiative aims at improving the environmental performance, including energy efficiency, of products during their entire life cycle. It requires systematic integration of environmental aspects at the earliest stage of their design. The Directive makes it possible to adopt binding measures (based on common conditions and criteria defined in the Directive) or to conclude voluntary agreements with manufacturers. The European Commission is investigating groups of products that have the potential to generate significant energy savings.	To be implemented in Member States by 11 August 2007

Policies and measures 'energy demand'	Description /Emission reduction potential in the EU-15 by 2010	Stage of implementation
Proposal on the promotion of end use efficiency and energy services (Commission proposal COM (2003) 739)	The new Directive envisages a 9 % cut in energy consumption over business-as-usual in the nine years 2008-2017. Member States will have to prepare first energy efficiency plans by 30 June 2007. Energy companies will be required to offer energy services (services that combine the sale of energy with energy-efficient end-use technology, e.g. lighting equipment). Emission reduction potential in the EU-15 Member States by 2010: 40-55 Mt CO2 eq.	Adoption to be finalised in early 2006
Action plan on energy efficiency (Green Paper on Energy Efficiency COM (2005) 265)	The action plan will encompass a variety of actions and measures to be taken by governments at all levels, industry and consumers. It will harness cost-effective energy savings equivalent to 20 % of the EU's current energy use by 2020.	To be presented in March 2006
Inclusion of energy efficiency requirements in the permit system for industrial and agricultural installations (Directive 96/61/EC)	Under the 1996 Directive on Integrated Pollution Prevention and Control (IPPC), major polluting industrial and agricultural installations in the EU (45,000 installations in the EU-15) must obtain a permit from their national authorities to be allowed to operate. The permits are based on the concept of Best Available Techniques (BAT) to prevent and reduce emissions, and to use energy efficiently. BAT is provided in sectoral BAT reference documents, which are agreed in a process involving all stakeholders, and then adopted by the Commission. In order to further improve energy efficiency, a 'horizontal' BAT reference document on energy efficiency is in preparation.	New installations have been obliged to comply with IPPC permits since 30 October 1999; existing installations must be brought into conformity by 30 October 2007
'SAVE' component of 'Intelligent Energy - Europe' funding programme (Decision 1230/2003/EC)	The 'SAVE' component of 'Intelligent Energy - Europe' funding programme (see item 8) supports energy efficiency, in particular in industry and buildings. The other three components of the programme deal with renewable energy sources, sustainable transport and the use of renewables in developing countries.	2003-2006 Commission proposal to continue the IEE programme during the 2007-2013 budgetary period and almost double its budget to € 780 million

Annex 6. IEA undergoing tasks

The IEA has an implementing agreement – ECBCS (Energy Conservation in Buildings and Community Systems) – and several ongoing projects regarding energy efficiency:

> Air Infiltration and Ventilation Centre;
> Whole Building Heat, Air and Moisture Response (MOIST-EN);
> The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (COGEN-SIM);
> Testing and Validation of Building Energy Simulation Tools;
> Integrating Environmentally Responsive Elements in Buildings;
> Energy-Efficient Future Electric Lighting for Buildings;
> Holistic Assessment Tool-kit on Energy-efficient Retrofit Measures for Government Buildings (EnERGo);
> Cost Effective Commissioning of Existing and Low Energy Buildings;
> Heat Pumping and Reversible Air Conditioning;
> Low Exergy Systems for High Performance Built Environments and Communities;
> Prefabricated Systems for Low Energy / High Comfort Building Renewal.

The IEA also has a Solar Heating and Cooling programme, including the following tasks at the moment:

> Task 27 - Performance of Solar Facade Components;
> Task 31 - Daylighting Buildings in the 21st Century;
> Task 32 - Advanced Storage Concepts for Solar Thermal Systems in Low Energy Buildings;
> Task 34 - Testing and Validation of Building Energy Simulation Tools;
> Task 35 - PV/Thermal Solar System.

As part of this programme, the following tasks have already been completed:

> Task 28 - Solar Sustainable Housing (2005);
> Task 26 - Solar Combisystems (2003);
> Task 25 - Solar Assisted Air Conditioning of Buildings;
> Task 24 - Active Solar Procurement (2003);
> Task 23 - Optimization of Solar Energy Use in Large Buildings (2003);
> Task 22 - Building Energy Analysis Tools (2003);
> Task 21 - Daylight in Buildings (2002);
> Task 20 - Solar Energy in Building Renovation.

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

> sustainable consumption and production,
> the efficient use of renewable energy,
> adequate management of chemicals,
> the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

> **The International Environmental Technology Centre** - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
> **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
> **Chemicals** (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
> **Energy** (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
> **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
> **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information,
see **www.unep.fr**

The building sector contributes up to 40% of greenhouse gas emissions, mostly from energy use during the life time of buildings. Identifying opportunities to reduce these emissions has become a priority in the global effort to reduce climate change. "Buildings and Climate Change" provides an overview of current knowledge about greenhouse gas emissions from buildings, and presents opportunities for their minimisation.

The report describes sources and distribution of greenhouse gas emissions across different stages and functions of buildings, and the technical measures available for their reduction. Examples of policies and tools applied in different countries to improve energy efficiency in buildings are presented, as are selected case studies on initiatives to reduce energy use in buildings. This report also reviews the relevance of some regional and international agreements to the building sector to curb greenhouse gas emissions, in particular the Kyoto Protocol. A number of recommendations on how to progress the knowledge and understanding of this issue, and how to encourage action to reduce greenhouse gas emissions from buildings are also proposed.

This report is a product of the UNEP Sustainable Buildings and Construction Initiative – SBCI.

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