Green Energy and Technology

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Managing Indoor Environments and Energy in Buildings with Integrated Intelligent Systems

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Abbreviations

ACH	Air Changes per Hour
BEMS	Building Energy Management System
BEPR	Building Energy Performance Regulation
BESTEST	Building Energy Simulation TEST
BLC	Building Load Coefficient
CEN	Comitè Europèen De Normalization
CHP	Combined Heat and Power
COP	Coefficient Of Performance
CSI	Climate Severity Index
DD	Degree Day
EER	Energy Efficiency Ratio
EO	Emergency Ordinance
EPBD	Energy Performance of Building Directive
EPC	Energy Performance Certificate
EPI	Energy Performance Indicator
ERS	Energy Rating System
EU	European Union
EUI	Energy Use Intensity
FCU	Fan Coil Units
FTE	Full Time Equivalent
HVAC	Heating, Ventilating and Air-Conditioning
IEA	International Energy Agency
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
NPTR	National Program for Thermal Rehabilitation
PMV	Predicted Mean Vote
PPC	Public Power Corporation
PPD	Predicted Percentage of Dissatisfied Persons
PPM	Parts Per Million
RES	Renewable Energy Sources
SBS	Sick Building Syndrome

SEER	Seasonal Energy Efficiency Ratio
TMY	Typical Meteorological Year
VAM	Ventilation Air Mounted
VAV	Variable Air Volume
VBD	Virtual Building Dataset
VRV	Variable Refrigerant Volume

Contents

Chapter 1
Introduction

1.1 Energy and Building Sector

World energy crises, such as the 1979 oil shortage caused by the Iranian revolution or the drastic increase in the price of oil in the early 1990s due to the first Gulf War, raised governmental concerns over the supply of and access to worldwide energy resources. European nations, highly dependent on energy resources from politically unstable areas, were particularly affected.

The rapidly growing world energy use has already raised concerns over supply difficulties, exhaustion of energy resources, and heavy environmental impacts (ozone layer depletion, global warming, climate change, etc.). According to European Environmental Agency (EEA/ http://www.eea.europa.eu) survey published in 2015: "*Primary energy consumption in EU 28 in 2012 was almost the same as in 1990 and amounted to 1585 Mtoe. Between 2005 and 2012, primary energy consumption in the EU 28 decreased by 7.3 % particularly due to the economic recession and energy efficiency improvements. Primary energy consumption in the non-EU EEA countries doubled from 71 Mtoe in 1990 to 146 Mtoe in 2012. The main reason for the difference in the trend for this group of countries was the large increase in primary energy consumption in Turkey and, to a lesser extent, in Norway. Fossil fuels (including non-renewable waste) continued to dominate primary energy consumption in EU 28, but their share declined from 82.1 % in 1990 to 73.9 % in 2012. The share of renewable energy sources more than doubled over the period, from 4.5 % in 1990 to 11.6 % in 2012, increasing at an average annual rate of 4.4 %/year. The share of nuclear energy in gross inland energy consumption increased slightly from 13.1 % in 1990 to 14.4 % in 2012.*" (Fig. 1.1).

Regarding the total final energy consumption by sector and according to European Environmental Agency (EEA/ http://www.eea.europa.eu) survey

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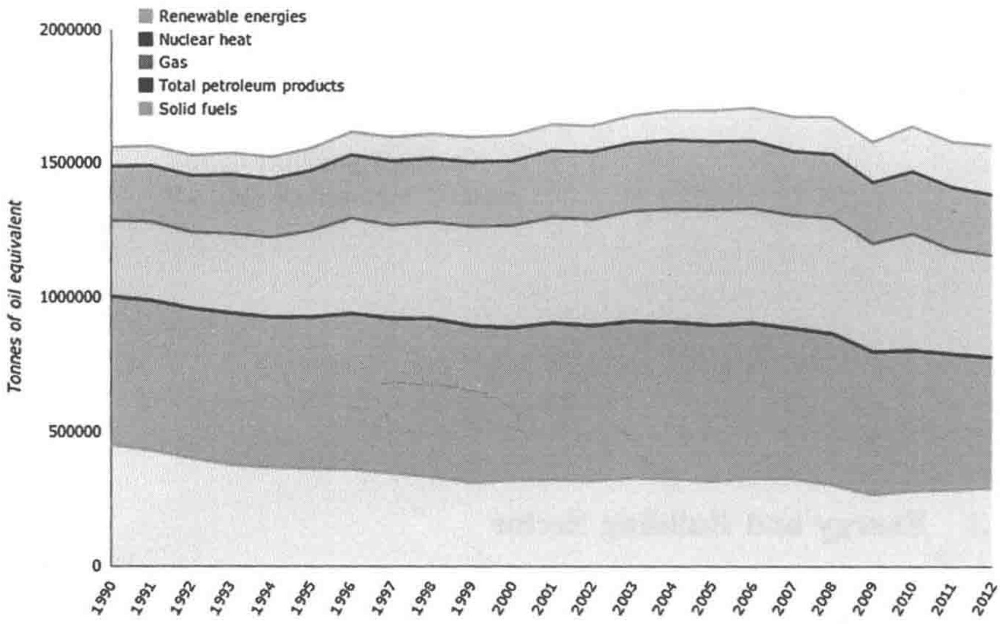

Fig. 1.1 Primary energy consumption by fuel [*Data Source* Supply, transformation, consumption—all products—annual data provided by Statistical Office of the European Union (Eurostat)]

published in 2015: *"Over the period 1990 and 2012 final energy consumption in EU 28 increased by 2.3 % (6.5 % in EEA countries). Between 2005 and 2012 the final energy consumption in the EU 28 decreased by 7.1 % (5.0 % in EEA countries). The services sector is the only sector where the energy consumption increased by 3.5 % over the period 2005–2012. Between 2005 and 2012, the energy consumption dropped by 14 % in industry, 5.1 % in transport and 4 % in households. The implementation of energy efficiency policies and the economic recession played an important part in the reduction of energy consumption. On average, each person in the EEA countries used 2.1 tonnes of oil equivalent to meet their energy needs in 2012."* (Fig. 1.2).

Today, commercial and residential buildings are some of the largest energy consumers in the world, accounting for one-fourth to one-third of the total energy consumption and a similar amount of emissions (Lombard et al. 2008; Zgajewski 2015).

Energy is used in buildings for various purposes: the most important purposes being for, heating and cooling, ventilation, lighting, and the preparation of hot sanitary water. Moreover, residential and commercial buildings require additional energy for their installed equipment, appliances, and removable devices.

In order to tap the potential for energy savings and reduction of CO_2 emissions, the energy efficiency of buildings has to be improved as soon as possible. The basic principle of building energy efficiency is to use less energy for heating, cooling, and lighting, without affecting the comfort of those who use the building. High-performance buildings not only save on energy costs and natural resources, but also provide a higher quality indoor environment. The benefits of building energy efficiency include the following:

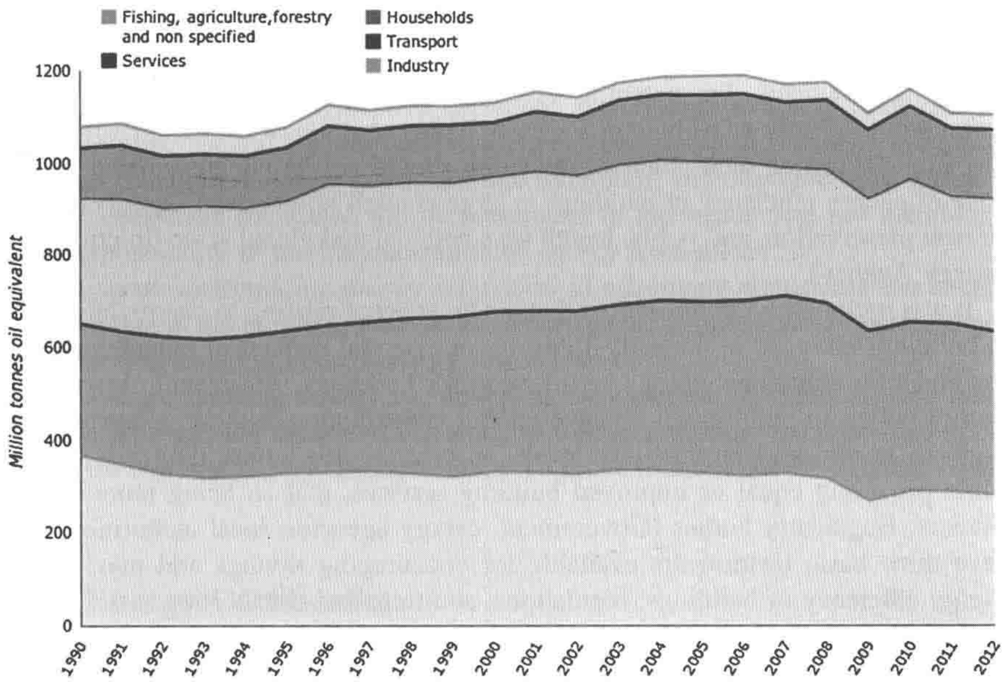

Fig. 1.2 Total final energy consumption by sector [*Data Source* Supply, transformation, consumption—all products—annual data provided by Statistical Office of the European Union (Eurostat)]

- Reduced Resource Consumption: Improving building energy efficiency with renewable energy sources significantly reduces demand for new oil supplies and new power plant investment.
- Minimized Life-cycle Costs: High levels of building energy efficiency reduce the amount of energy required to operate a building, and reduce costs for the occupants of the building.
- Reduced Environmental Impact: Buildings contribute to the discharge of four primary pollutants which are mono-nitrogen oxides (NO_x), sulfur oxide (SO_x), carbon dioxide (CO_2), and particulates. The improvement of building energy efficiency reduces the need for fossil fuels and reduces greenhouse gas emissions.
- Healthier Indoor Environment: Efficient buildings also mean a healthier indoor environment for the people who live and work in them. Comfortable temperatures and a quiet work environment are some key features of high-performance buildings.
- Increased Employee Productivity: Improved comfort of building occupants contributes to increased employee productivity. Recent studies have shown an increase in employee productivity when buildings have features such as natural light, better control of temperature, and a more intelligent use of space (Papadimitriou 2009).

As it is mentioned above, buildings account for close to 40 % of the total energy used globally. Given the many possibilities to substantially reduce buildings' energy requirements, the potential savings of energy efficiency in the building sector would greatly contribute to a society wide reduction of energy consumption. The implications of such potential reduction should not be underestimated, as the scale of energy efficiency in buildings is large enough to influence security policy, climate preservation, and public health on a national and global scale (International Energy Agency).

It was under such circumstances that a new concept relating to energy efficiency in buildings emerged in the early 1990s as an essential method of reducing energy use and CO_2 emissions: energy certification for buildings. An overall objective of energy policy in buildings is to save energy consumption without compromising comfort, health, and productivity levels. In other words, consuming less energy while providing equal or improved building services, that is, being more energy efficient. Regulatory bodies (Government, energy agencies, local authorities, etc.) have three basic instruments available for encouraging savings and maximizing energy efficiency in buildings: regulations, auditing, and certification.

Building energy regulations, also referred to as building energy codes, establish minimum requirements to achieve energy efficient design in new buildings. The primary aim is saving final energy or any related parameter (primary energy, CO_2 emissions, or energy costs) without compromising thermal comfort (Lombard et al. 2009).

The ASHRAE Standard 55 (ASHRAE 1992) describes thermal comfort as "the condition of mind which expresses satisfaction with the thermal environment." The environmental variables that influence thermal comfort are the air temperature, the mean radiant temperature, the air velocity, and the water vapor pressure in ambient air. Two other important variables are the person's activity level and clothing. The heat balance of the body provides a basis for the development of an equation for the thermal comfort. The equation provides a means of determining all possible acceptable ranges of the environmental variables for given values of activity level and clothing (Kolokotsa 2001).

While the comfort equation shows how the environmental variables are combined to obtain optimal thermal comfort, it does not indicate the preferred comfort conditions for persons. This is a function of the Predicted Mean Vote (PMV), which provides information on the degree of discomfort experienced in a thermal environment (EN ISO 7730 2005),(Kolokotsa 2001).

The PMV (see ANNEX A for details) is a seven-point scale from –3 (cold) to +3 (hot) with 0 as the neutral level. A last indicator of the degree of satisfaction with the thermal environment is the Percentage of People Dissatisfied (PPD).

1.2 Energy Regulation

Energy regulation has a perceptive character, and its objective is to establish and limit the upper bound for the buildings energy consumption. With its normative character, energy regulation establishes the minimum, and often the only, building energy assessment tools that will be introduced in the sector, and has therefore a high responsibility in the internalization of energy assessment.

The success of building energy regulation in effectively controlling the energy consumption in the building sector is associated to the adopted energy performance indicator and to the promoted energy assessment tools.

Nowadays, building energy regulation in the different countries is very inhomogeneous regarding these two elements, as well as regarding the pretended upper bound for building energy requirements, even in the frame of the EU (Casals 2006).

1.3 Energy Certification

Energy certification is a mechanism whose main objective is to promote higher energy performance standards than the regulated ones (Lewandowska et al. 2015). To reach this objective, energy certification must provide a clear and detailed information about the building's energy performance (energy labeling), allowing for the straight comparison between different buildings. As well as with energy regulation, the indicators implemented in the energy certification will condition its capability to reach the objective. The indicator implemented in the energy regulation should be included among the indicators provided by the energy certification in order to clearly situate the certification on the reference regulated level of energy performance. The energy assessment methods, upon which energy certification is based, are key elements for its success.

A well-implemented energy certification scheme must allow for, and promote, a clear quantification of design concepts with potential for building energy consumption reduction, such as bioclimatic architecture, passive solar heating, passive cooling, passive ventilation, and integration of renewable energies, always guaranteeing some given comfort levels.

Energy certification may have a compulsory or voluntary character. Compulsory energy certification schemes may introduce some additional burdens on the administration, while voluntary ones do not. However, only through a compulsory energy certification scheme can this mechanism develop all its potential for energy improvement in the building sector. Voluntary energy certification schemes have a limited scope and not always succeed to send the appropriate signals to the building market (Casals 2006).