Comparative approach to energy behavior of contemporary urban buildings in Greece

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ABSTRACT: This study examines the particular characteristics that define the energy and environmental behavior of urban residential and commercial buildings in Greece, where both the climate and other factors that shape these characteristics are specific and well defined. Based on the available statistical data, the study evaluates the energy behavior of corresponding buildings and compares them with similar data of other countries, where prevail different climatic conditions. From this comparison, indications are obtained, and reflect the exploitation of the available energy potential in the country. Furthermore, this study examines the basic methods and practices, which are applied in the design and construction of urban buildings in Greece and contribute to their energy and environmental behavior.

1 INTRODUCTION

Greece, with an overall land area of approx. 132,000 km^2, consists, by the four-fifths of its mainland, of mountainous terrain. Greece is also a maritime country with numerous islands and a coastline of over 15,000 km in length. The bulk (i.e. about 59%) of the country's population according to the last census (2001), stands at about 11 million, lives in urban areas [4]. Most urban centres and the largest of them, including the conurbation of the capital, Athens, with its population of about 4 million, and the second largest city, Thessaloniki, with its population of about 1 million inhabitants, lie on the coast.

Greece has a Mediterranean climate [6]. According to the relevant climatic data, the annual cycle can be divided into a cold and rainy season (October to March) and a warm and dry season (April to September). Temperatures on the Greek mainland present intense contrasts mainly due to geographic factors. Greece is between the average annual isothermal of 14.5 and 19.5 °C. The extreme temperatures are close to -25 °C (during winter in the mountainous and northern regions) and +45 °C (during heatwaves on the mainland). The mean relative humidity ranges from 65% to 75%, according to location. It displays a simple annual fluctuation, with the maximum occurring during the winter months, and depends on the proximity of natural concentrations of water. In Greece, the general circulation of the atmosphere and the prevailing synoptic systems in the wider area contribute to the prevalence of western and northern wind components and fairly moderate speeds. However, in interaction with them, the complex relief of Greece plays an important role in determining the prevailing wind direction and speed in many regions. Greece is a very sunny country. The average annual rates of incoming solar radiation, moving from north to south, range from 5000 to 6100 MJ/m2/yr [3]. The climatic data above relate mainly to the countryside. In urban environments, in which the majority of buildings are situated, these data change as a result of the influence of the factors which make up the urban climate [9].

2 THE CONTEXT OF THE ENERGY BEHAVIOUR OF URBAN BUILDINGS IN GREECE

In Greece, the vast majority of buildings in urban environments, about 75%, are residential buildings. Second in terms of frequency comes the category of buildings housing productive activities, which are commonly known as commercial buildings (housing commercial operations, services, businesses etc.). In constructional and architectural terms, this category displays many similarities to the previous one. The smallest group includes buildings housing social services or functions (schools, hospitals, meeting halls etc.) and buildings serving special uses. In this category the greatest variety of architectural forms is to be found, despite the fact that the basic constructional characteristics of buildings in this category are the same as those in the other two categories.

An important piece of legislation with provisions relating to the health and comfort of occupants, the protection of the environment and energy saving in the building sector in Greece is the Construction Code for Buildings [13]. This Code deals specifically with the natural lighting, ventilation, damp protection, sound insulation and fire protection of buildings, amongst other things. In the recommendations that it contains, the Code uses mainly qualitative criteria; wherever quantitative criteria are used, these relate indirectly to the physical magnitudes of the phenomena being examined (e.g. the dimensions of openings for natural lighting or ventilation).

The EU Directive 2002/91 on the energy performance of buildings would have been transposed into Greek legislation by the end of 2006. The government had decided to launch a program to limit CO_2 emissions from the building sector by replacing existing regulations for the thermal insulation of buildings with more stringent ones. This would establish minimum energy standards for new and renovated buildings, energy audits, and energy labeling of buildings according to EU Directive 2002/91/EC. So far, no auditors have been trained [8]. This directive will replace the current legislation that concerns the energy behavior of buildings in Greece, the Thermal Insulation Code, which has been in force since 1979 [7].

During the last decade, the Greek energy system is undergoing significant changes. The penetration of natural gas, the construction of trans-European energy networks, the promotion of renewable energy and energy saving and the release of the electricity market are the new features.

In Greece almost all urban residential and commercial buildings take the form of multi-storey apartment blocks. The great majority of these buildings consist of a ground floor and a series of higher floors usually between three and five in number and very rarely more than seven. An analysis of building statistics for the period 2002-2006 reveals that the average volume of buildings in Greek towns is around 1500 m^3 [5]. This volume works out at about 120-200 m^2 per floor.

In Greek urban areas, buildings are constructed on site with a supporting structure of reinforced concrete and non-load bearing walls of perforated bricks. The external walls are built with a double row of bricks, each 9 cm wide, with internal insulation consisting of a 5 cm-thick layer of expanded or, at best, extruded polystyrene. Such a wall, if the layer of plaster on each side approx. 2 cm thick is included, is over 27 cm thick, while the mean thermal transmittance coefficient is approximately 0.45 W/m^2K. Thermal insulation is applied to the vertical elements in the envelope of the supporting structure by fastening 3 or 4 cm thick tiles of expanded or extruded polystyrene onto the external surfaces. In this case, the mean thermal transmittance coefficient of a typical wall 30 cm thick with a 3 cm-thick insulation layer is approx. 0.74 W/m^2K. Thermal insulation is also applied to the flat roof, as well as the floor of the first storey, if this lies above an open-sided parking area. The external openings in Greek buildings, i.e. windows and balcony doors, usually consist of two leaves, with each leaf consisting of a pane of glass set within a frame. In the past, frames used to be constructed of wood. In the 1970's wood began to be replaced by aluminium. Indeed, at that time aluminium frames used to be made to order by small cottage industries which could not guarantee good quality of construction or good behavior in their products. Typical aluminium frames consist of parallel sliding units. Nowadays, aluminium continues to be used as a construction material for external doors and windows, although at the same time greater use is being made of plastic. Typical modern synthetic door and window units consist of two leaves, with double glazing, which open or tilt around a horizontal axis in the bottom section of the frame [12].

In Greece, natural ventilation systems predominate as a result of the climatic conditions, which favour their use. All residential buildings in Greece are ventilated naturally. Mechanical ventilation systems can be found in other categories of buildings in cases where natural processes are unable to cover the increased or special ventilation requirements (e.g. meeting halls and conference rooms). As for the control of natural ventilation in internal areas, this can be achieved by using the doors and windows in the envelope, which in Greek buildings are generally sufficient in number and easy to use. As for infiltration, brick-and-concrete constructions generally imply airtight envelopes. Thus, most cases of infiltration appear to be related to external doors and windows, whose improvement in quality in recent years is leading, according to the current evidence, to even more airtight envelopes [10].

An important element that plays a decisive role in the interaction between buildings and their environment in Greece is the balcony. Balconies are an essential feature of all residential buildings. Apart from their functional role and their active contribution to the external appearance of the buildings to which they belong, balconies also play a dynamic role in shaping a series of environmental influences that are exerted on buildings. Such influences concern numerous aspects of building physics, like sun-control, day lighting, heat transfer, damp protection, sound insulation, wind-loading, natural ventilation etc [11]. These influences are essentially either directly or indirectly connected with the energy behavior of the building to which the balcony belongs.

All building interiors possess a heating system. In most apartment blocks this takes the form of a two-way oil-fired central heating system. The burner, distributor and fuel storage tank lie in the basement, whence a network of pipes, which are usually not insulated, carry the water to all floors and apartments.

3 THE FACTS RELATING TO THE ENERGY BEHAVIOUR OF BUILDINGS IN GREECE

Buildings in Greece are wasteful in energy terms. According to statistics for 2007, the energy sector that they represent (Households and Services) consumes about 8.56 Mtoe or 39% of the total annual energy consumption [2], while, of this amount, the energy use for heating of buildings is estimated to be about 61%. In addition, it is characteristic that, apart from the increase in absolute values that the energy consumption sector for buildings understandably shows as a result of the increase in the number of buildings and the energy-consuming applications in them (66% between 1990 and 2000 and 13% between 2002 and 2007), in recent years, there has also been a sharp rise in the proportion of total energy consumption that it represents. Thus, this has increased by about 10% in 12 years and also by about 11% in the last six years (from 29% in 1990 to 39% in 2002, ending with 50% in 2007). This increase has been partly caused by the wide use in recent years of air conditioning systems in buildings [8].

These figures, although they are not directly comparable, appear to approach those of countries in central and northern Europe, where, however, the climatic conditions are clearly worse. Though in the last six years, for the majority of the European countries, the amount of energy consumed for residential needs has reduced in contrast with the Greek residences [2].

In Germany, the mean temperature is about 8.2 °C. The total energy consumption for Households and Services in 2007 is 90.53 Mtoe or 43% of the total annual energy consumption. While, of this amount, the energy use for heating of buildings is estimated to be about 74%. This amount of energy has decreased by about 10% during the last six years [2].

In Switzerland, the mean temperature is about 4 °C. The total energy consumption of the buildings in 2007 is 9.77 Mtoe or 46% of the total annual energy consumption, while, of this amount, the energy use for heating of buildings is estimated to be about 69%. This amount of energy is decreased by about 13% from 2004 to 2007. Finally, in another Mediterranean country, Spain where the climate appears similar to Greece, the mean temperatures in winter is about 2 °C and in summer 35 °C. The total energy consumption for Households and Services in Spain is 29.90 Mtoe or 30% of the total annual energy consumption, while, of this amount, the energy use for heating of buildings is estimated to be about 80%. The amount of energy consumed for residential need from 2004 to 2007 appears also in Spain slightly decreased of 0.3% [12].

As can be assumed with this comparison with the other European countries, in all the analyzed countries (Germany, Switzerland and Spain) during the last three years, the total energy consumption for buildings has reduced regardless to the new buildings that are constructed. This reduction rate in some appears to be quite weak and in some it is more evident (Figure 1). Greece not only has not improved the total amount of energy consumed for residential uses but also the total percentage of energy consumed from the building sector appears similar with countries with much more severe climates such as Germany and Switzerland.

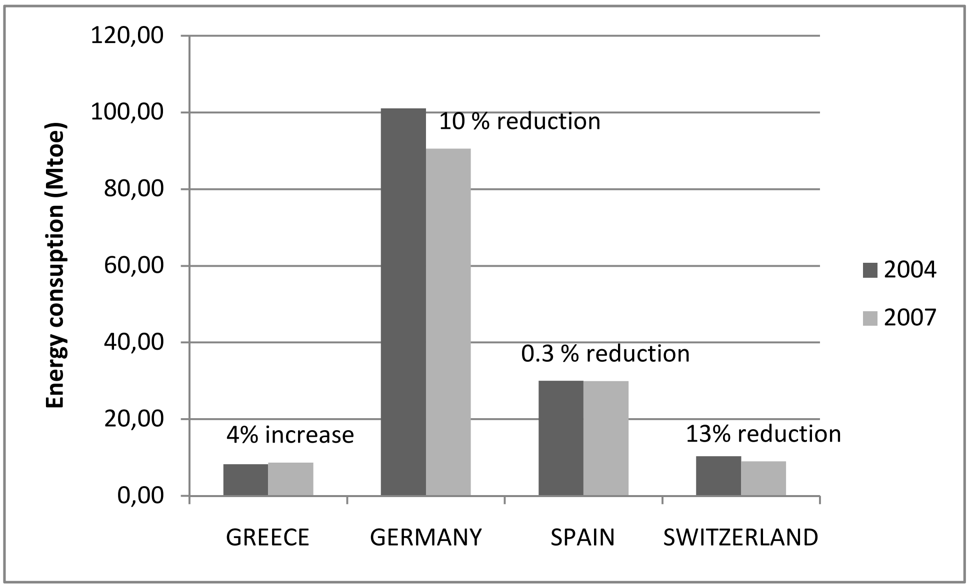

Figure 1: Energy consumption in Mtoe in 2004 and in 2007

The main factors responsible for the low performance of buildings with regard to energy behavior may be the following, in no particular order of importance:

a. A large proportion of these buildings were built before the Thermal Insulation Code (1979) came into effect and do not possess thermal insulation of any kind. In this respect, it has been estimated that the average annual heating energy demand of Greek apartment buildings built before 1980 is about 96 kWh/m^2, while for those built after 1980 the demand is estimated to be between 75-94 kWh/m^2 [1].

b. On the basis of modern scientific approaches, the present Thermal Insulation Code does not successfully deal with the matter of energy losses in buildings. On the contrary, in a dubious attempt to simplify matters, it excludes or reduces the significance of parameters that play an important role in them. As an example, it does not take account of infiltration losses or losses from thermal bridges in its calculations.

c. The practices followed in the implementation of thermal insulation studies are not always suitable. It is quite usual for inferior, and therefore cheaper, thermal insulation materials to be used, just as it is fairly common to see poor workmanship in their application, the most characteristic example of this being the laying of such materials on broken surfaces.

d. Energy design is ignored. The number of urban buildings in Greece in which serious attempts at energy design have been made is small, just as there is only a small number of design teams that possess the experience to undertake and carry out such works.

Apart from these factors, a significant share of the responsibility for the high consumption of energy in buildings in Greece belongs to the residents, with their generally low sensitivity to energy-saving matters [14].

On the basis of 2007 statistics, oil (which is used as a fuel for heating buildings), accounts for 43.2% of the total amount of energy consumed in the buildings sector in Greece [2]. Electricity, with 39.7% of the total, represents the second most used energy form. It is used for lighting and the operation of domestic appliances (including air conditioning systems) and, more rarely, for heating buildings (electric fires and storage heaters). Natural Gas began to be used in buildings in 1998, mainly as a fuel in central heating systems. Despite its rapid spread, it accounts for just 3.3% of the total amount of energy consumed in the buildings sector throughout the country. This percentage is larger in urban buildings, since only these are supplied by the existing network. In contrast, renewable forms of energy, which account for 11.0% of the total amount of energy consumed in the buildings sector in Greece, represent a smaller proportion of the energy used in urban buildings, since most of this category consists of the burning of wood and wood-waste in order to heat buildings in agricultural areas. In urban buildings, this proportion of energy use relates mainly to the exploitation of solar energy through glazed solar collectors, which are placed on the flat roofs of apartment blocks in order to heat water for domestic use.

Although in 2002 the total consumption of renewable sourced energy in the building sector was relatively high compared with other countries in Europe, in 2007 some countries seem to have adopted a large variety of measures for energy efficiency in buildings even though their energy potential is poorer compared with Greece. For example in Switzerland renewable forms of energy account for 11.7% of the total amount of energy consumed for buildings. In addition, Greece owns this high percentage more in heating from biomass and lacks of the ability to exploit other sources which are equally beneficial judging from the region's available potential. Whereas countries like Spain, where almost all the percentage of the renewable energy consumed by the building sector (7.6%) comes from the exploitation of the solar energy and the implementation of PV panels on residences.

CONCLUSIONS

The basic factors that determine the energy behavior of buildings in Greece can be briefly divided into three categories:

- The most important and obvious category is the local climate. The mild characteristics of this climate, combined with the way in which these characteristics fluctuate widely during the climatic cycle, create a complex set of conditions and also challenges which the concerced buildings have to meet.
- The second most important category is the building construction methods. The concrete, perforated bricks and other building materials, as well as the building practices that prevail in the construction of urban buildings in Greece, have a direct impact on their energy behavior. Thus, the great heat capacity of the building materials, the low air permeability of the envelopes, the presence of thermal bridges, the high levels of fire resistance and mechanical resistance, as some of the typical properties of the particular construction model used, of course play a role in shaping important parameters in the behavior of the buildings concerned. So, too, do those properties relating to thermal conductivity, moisture permeability, sound-insulating power and other parameters of the construction elements.
- The quality of construction of buildings in Greece, at least during the last few decades, has, by and large, been average. The building materials that are used and the practices that are applied, with regard mainly the invisible surfaces of buildings (such as layers of insulation) are often governed by a rationale of low cost and ease of application. The underlying causes of this reality can be sought in different areas. Its consequences, however, are reflected in building pathology issues and of course in the low performances of the buildings in terms of their energy behavior.
- The last category concerns the Greek people. In particular, it concerns the way they behave in the buildings in which they live or work. One aspect of this behavior includes the attempt by constructors to exploit the weaknesses of the existing system of building construction in order to make financial gains at the expense of the quality of construction. Another very important aspect of the user's behavior concerns his active intervention in processes that influence the behavior of the buildings they live in. In this area, although no available data exists, it can be assumed that the Greeks are by and large insufficiently sensitized. The way in which they face their role in the energy behavior of buildings is rather superficial and their conduct in this respect could be described as being based on reflex actions. For example, the actions they take to control the parameters of the internal environments of their buildings rarely go beyond using the available electro-mechanical installations.

The similarities in the energy behavior of different urban buildings in Greece allow us to form an overall picture of this behavior. This picture is also improved by the comparison of the data that represent it with similar data from countries in different climatic zones. According to what has been stated above, this behavior presents certain weaknesses, various causative factors of which have already been identified. One of the main reasons that could explain these weaknesses is the fact that many of the crucial choices that play a part in forming the overall picture are determined by other parameters and priorities. This finding, insofar as it reveals a wrong approach, indicates how useful it would be to encourage attempts to give greater emphasis to energy parameters in the design, construction and use of buildings.

REFERENCES

1. Balaras, C.A. & Daskalaki, E. & Droutsa, K. & Kontoyannidis, S. 2005, Heating Energy Consumption and Resulting Environmental Impact of European Apartment Buildings. Energy and Buildings, Vol. 37 (5), 429-442.
2. EUROSTAT, 2009, Energy: Yearly statistics - Data 2007, Office for Official Publications of the European Communities, Luxembourg, p. 476.
3. Flocas, A.A. 1980, Estimation and Prediction of Global Solar Radiation over Greece. Solar Energy Journal, Vol. 24 (1), 63-70
4. General Secretariat of National Statistical Service of Greece, 2005, Greece in Numbers, Athens, p. 29.
5. General Secretariat of National Statistical Service of Greece, 1996, Construction Activity Statistics, Athens
6. Hellenic National Meteorological Service, 2006, The climate of Greece.
7. Hellenic Ministry of Environment, Planning and Public Works, 1979, Thermal Insulation Code for Buildings, Decree-Law 1/6/1979, The Hellenic Official Gazette, 362D,.
8. International Energy Agency, Energy Policies of IEA Countries, 2006, Review, OECD/IEA, p. 117, Greece,
9. Landsberg, H.E. 1981, The Urban Climate. Academic Press, London.
10. Papamanolis, N. 1988, Experimental Approach to Natural Ventilation Conditions in Buildings in Greece. Technika Chronika, Scientific Journal of the TCG, II. Vol 18 (1,2), 7-19
11. Papamanolis, N. 2004, An Overview of the Balcony's Contribution to the Environmental Behaviour of Buildings. Proceedings of PLEA 2004, Eindhoven, The Netherlands.
12. Papamanolis, N. 2005, The Main Constructional Characteristics of Contemporary Urban Residential Buildings in Greece. Building and Environment, Vol. 40 (3), 389-396.
13. Technical Chamber of Greece, 1989, Hellenic Construction Code for Buildings, Weekly Information Bulletin 1557a, Special edition, p. 112.