Renewable Energy 34 (2009) 289–296

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Energy monitoring and conservation potential in school buildings in the C′ climatic zone of Greece

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ARTICLE INFO

Article history:
Received 12 January 2007
Accepted 4 April 2008
Available online 14 July 2008

Keywords:
School buildings
Energy monitoring
Energy conservation potential
Heating energy
Cooling energy

ABSTRACT

Energy efficiency is very important in school buildings as it is associated with comfort and air quality conditions in their interior and energy costs of these buildings are associated with their main operational costs. Moreover, school buildings differ from other types of buildings because they are the places where children are educated and have the opportunity to learn how to become environmentally-aware citizens. There is an increasing awareness throughout Europe for promotion of sustainable solutions in school buildings involving energy efficient technologies and measures. The aim of this article is to assess the energy performance, based on monitored data, of school buildings in the C′ climatic zone of Greece, a region with the lowest air temperature during winter period. It also demonstrates, through simulation studies, the potential for energy conservation of school buildings in this region.

1. Introduction

Energy efficiency is very important in school buildings as it is associated with comfort and air quality conditions in their interior, and energy costs of these buildings are associated with their main operational costs. Moreover, school buildings differ from other types of buildings because they are the places where children are educated and have the opportunity to learn how to become environmentally-aware citizens. Thus, it is essential that schools set a good example regarding users' comfort, efficient use of fossil energy, pollution control. There is an increasing awareness throughout Europe for promotion of sustainable solutions in school buildings involving energy efficient technologies and measures [1]. The energy profile of school buildings is of importance in different countries and stimulates national surveys for the investigation of most appropriate energy saving strategies to improve their energy performance [2–5]. In addition, various methods for evaluating and optimizing environmental comfort parameters of school buildings during the preliminary stages of design [6] and the environmental implications of applying different energy conservation technologies in school buildings [7] were investigated.

In Greek school buildings, energy is mainly consumed to cover heating and lighting needs, then for the operation of equipment, and only in a few cases for hot water. Energy for cooling purpose is consumed in limited cases. For most of the summer period schools are closed and thus, they are not equipped with A/C units apart from some personnel offices, where split A/C units are used.

According to a study carried out in 1995 in Greece [8], the mean annual energy consumption of school buildings, based on the measurements of buildings at different climatic regions and considering 65,000 school classes, is about 270,000 MWh. The mean annual energy consumption was estimated to be around 92 kWh/m^2 of heated space, but in many cases it reaches 100 and even up to 200 kWh/m^2 of heated space. Table 1 presents the estimated specific energy consumption per heated area of school classes in typical school buildings at different climatic regions. According to the existing 'thermal insulation regulation' [9], there are three climatic zones in Greece, where A′ climatic zone represents the high temperature areas and C′ climatic zone the colder areas. These estimates were based on simulation results, considering the existing condition of school buildings and assuming that optimal thermal comfort conditions are obtained at their interior.

The total annual energy of 270,000 MWh corresponds to a consumption of about 16,300 tonnes of oil diesel and an annual electricity consumption of 78,000 MWh. The resulted annual emissions of CO_2 (responsible for the greenhouse effect) and SO_2 were estimated to be around 150,000 and 1000 tonnes accordingly [8].

The energy consumption of school buildings in Greece was also monitored at the mid-90s [10]. According to a recent survey [11], the mean normalized annual energy consumption in school buildings is about 95 kWh/m^2, distributed to 68 kWh/m^2 for

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doi:10.1016/j.renene.2008.04.025

Table 1
Specific energy consumption for heating per heated area of school classes (kWh/m^2) [8]

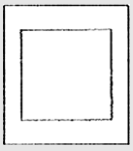
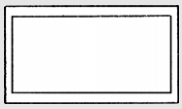
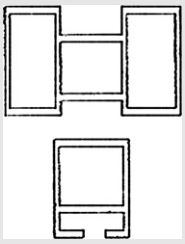
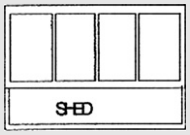
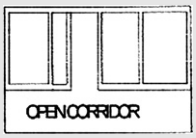
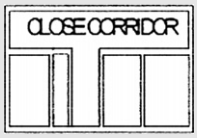
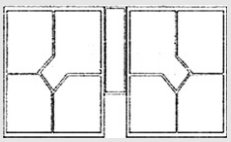
School type	Climatic zone A	Climatic zone B	Climatic zone C
Old stone building	10	48	146
Type with open corridor	15	46	122
Type with close corridor	12	41	115
Type ATHINA	5	27	86

heating and close to 27 kWh/m^2 for electricity. On the basis of the frequency distribution of the monitored buildings, the following energy benchmarks were proposed for school buildings in Greece [11]:

- *Typical school building* (50% of the stock): heating of 57 kW h/m^2 per year, electricity of 20 kW h/m^2 per year, with a total energy of 72 kW h/m^2 per year.
- *Best practice building* (top 25% of the stock): heating of 32 kW h/m^2 per year, electricity of 10 kW h/m^2 per year, with a total energy of 42 kW h/m^2 per year.

The aim of this article is to present the energy performance, based on monitored data, of school buildings in the C′ climatic zone of Greece, a region with the lowest air temperature during winter period. It also demonstrates, through simulation studies, the potential for energy conservation of school buildings in this region.

Table 2
Summary of time evolution of school buildings typologies

School type	Schematic plan	Construction period	Building materials	Surface/pupil (m^2/pupil)	Typologies	Classrooms orientation	Openings	Energy consumption (kWh/m^2)
		18th century	Stone structure		Rectangular plan, classrooms in one side			–
		1827–1831	Stone structure	0.56	Linear plan, classrooms in one side		Large/wooden frame	–
Neoclassic		1850–1900	Stone structure		Linear or rectangular plan	According to architectural style	Wooden frame/ according to architectural style	–
Type of 30's		1930–1960	Stone structure		Linear plan, classrooms in one side	Noon	Wooden frame	146
Type with open corridor		1960–1980	Concrete structure, non-insulated brick envelope	1.5–2.0	Linear plan, classrooms in one side	South	Large metallic frame	122
Type with close corridor		1960–1980	Concrete structure, non-insulated brick envelope	1.5–2.0	Linear plan, classrooms in one side	South	Large metallic frame	115
ATHINA		After 1980	Concrete structure, insulated brick envelope	1.5–2.0	Linear plan or type T or Cross type	South	Large (1.30 * 3.35)/ aluminum frame/ mainly South	88