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Improving energy efficiency through the design of the building envelope

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ABSTRACT

Buildings, their surroundings and related enterprises produce more CO_2, generate more pollution, consume more energy, and waste more natural resources than any other human enterprise or industry. Moreover, considerable parts of these environmental impacts are the results of the lodging industry [1].

Hotels are designed as multifunctional buildings to provide different comfort levels and services to guests. It is often desirous to pay for exclusive amenities. Resorts are often developed in untouched and very sensitive ecosystems with little or no consideration taken for the natural or cultural surroundings. Most strategies applied in design and many of the services offered by lodging establishments require the consumption of substantial quantities of energy, water and non-durable products.

The efficiency of the resource use starting from the building design to the end-users in hotel facilities is typically low, and the resulting environmental impacts are greater than those caused by other types of commercial buildings of similar size [2]. Decisions taken during the architectural building design play AS important A role in reducing these environmental impacts as DOES THE management of the building.

With a goal of enhancing the overall energy performance of hotel buildings, this paper represents a research-design project, located in İzmir-Turkey, based on the effect of passive solar design techniques for designing the building envelopes to develop and demonstrate high performance.

1. Introduction

Utility expenses represent the fastest-growing operating cost for hoteliers and have been increasing by an average of 12% per year from 2004 to 2006. There is a significant increase in energy use, cost, and an increase of greenhouse gas emissions through the hotel industry [3]. There is research on how, where, and when energy is used and the savings which are likely to occur from the standpoint of the management of the hotel facilities. However, a significant part of the hotel energy consumption can be reduced during the architectural design since this has a direct impact on choosing and sizing the mechanical system of the building which in turn affects the energy consumption of the building during its life time. Therefore identifying the energy consuming building components is critical from the perspective of the building designers, building owners and utilities to examine the possibilities of reducing building energy consumption, not only through efficient building systems and management, but also with building architectural characteristics.

The purpose of this study is to show how to reduce the energy demand by passive design. Properly designed buildings can significantly reduce energy consumption. Furthermore lower energy use reduces greenhouse gas emission (carbon dioxide, methane, nitrous oxide) and reduces operational costs [4].

Research that has been done on hotel energy efficiency gives a clear understanding about hotel energy consumption patterns. The average annual energy intensity for hotels is 87 kBtuh/ft^2 (274.8 kWh/m^2). 61% of this is from electricity and 39% is from natural gas and other fuels. This translates to 53.1 kBtuh/ft^2 (167.74 kWh/m^2) of electricity and 0.34 therms/sf (106.55 kWh/m^2) of natural gas as shown on Table 1, Figs. 1 and 2 [3].

When it is compared with other commercial buildings such as office and retail, the annual energy intensity of hotel's is higher. The average annual energy intensity for office buildings is 79.8 kBtuh/ft^2 (251,57 kWh/m^2) and 81.5 kBtuh/ft^2 (256,93 kWh/m^2) for retail properties [3]. Therefore evaluating the hotel buildings through energy efficient perspective has become more critical. Nevertheless none of the research gives any information about importance of the envelope of the hotel buildings in terms of the building energy consumption. Examples of these researches from literature are given below to prove that none of the research conducted so far has considered importance of the building envelope.

In the USA, the yearly average Energy Intensity for lodging buildings in 2007 ranged from 15 kBtuh/ft^2 (48 kwh/m^2) to 300 kBtuh/ft^2 (947 kwh/m^2). Typically, nearly 75 percent of a hotel's or motel's total energy use can be attributed to space

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Table 1
Annual energy consumption per square foot [3].

	Consumption per square foot (Billing units)	Energy use intensity (kBtu/sf)
Electric	15.6 kWh/sf	53.2
Natural Gas	0.34 therm/sf	33.8
Total		87.0

heating, water heating, lighting, and cooling combined [5]. The remaining 25% is for process, elevators, and kitchen.

These differ from the data on the energy performance of hotels in Ottawa, Canada. The yearly averaged energy intensity of 218 kBtuh/ft^2 (688.7 kwh/m^2) was reported, based on the survey results of 19 out of 44 hotels in the Ottawa area in 1991. The percentage breakdown of different energy types was also different from that of the US lodging buildings for which electricity, gas and steam account for 28.9%, 26.4% and 44.7% respectively. Space heating consumes 35%, while water heating, cooling and lighting constitute 15%, 33% and 8% respectively [6].

In the UK, several case studies on energy performance in hotel buildings have been reported. For example; in 1988 the yearly averaged energy consumption per floor area for hotels in London was 226.3 kBtuh/ft^2 (715 kwh/m^2), with approximately 74% of this from gas consumption [7].

In Hong Kong, there have been earlier studies of electrical energy requirement for hotels, with average electricity consumption intensities of 81.6 kBtuh/ft^2 (257.8 kwh/m^2) [8] and 115.9 kBtuh/ft^2 (366 kwh/m^2) [9] being reported. However, these studies in Hong Kong have focused on the electrical energy use only.

There are also some studies on Mediterranean type climate hotels. Energy consumption at 158 Hellenic hotels' averaged 86.4 kBtuh/ft^2 (273 kwh/m^2) [10]. The annual average total energy consumption of the Tunisian hotel sector ranged between 54.1 and 117.8 kBtuh/ft^2 (170.9–372 kwh/m^2.) [11]. The Antalya region hotels in Turkey were analyzed and energy consumption was measured between 40.8 and 204.6 kBtuh/ft^2 (129–646.3 kwh/m^2) [12].

This research paper will take the above mentioned research findings further to emphasize the importance of the energy efficiency of the building envelop. It is critical to realize that improvement of the energy efficiency in the big scale buildings cannot be only by application of advanced mechanical systems and advanced technologies, but also by the design decisions that affect operation and management. These decisions have to be taken at the beginning of the building design process when its impact on energy efficiency would be most significant as this paper emphasizes. This is a multidisciplinary problem and requires integrated work that involves engineering, architecture, environmental management, design, and public policy. Every new structure that is constructed without sustainable principles is a lost opportunity for the life time of that building. Design decisions determine how a building will perform throughout its operational life from a resource consumption and waste generation standpoint. It impacts annual operating costs.

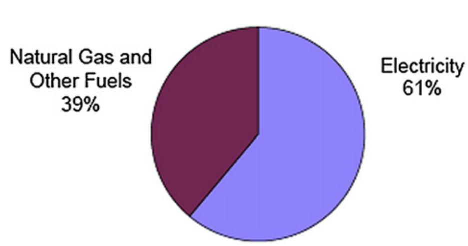

Fig. 1. Energy consumption by fuel type.

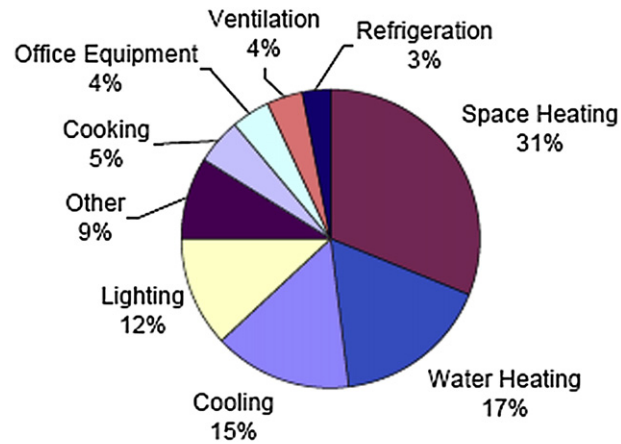

Fig. 2. Total energy consumption by end use adapted from E source, 2006.

Energy consumed for space conditioning especially for cooling is the primary concern in Mediterranean countries. During the past decade, the use of mechanical air conditioners in southern European countries has increased dramatically [13] not only for the lodging but also other building industries. This is primarily due to an increase in the living standards and the cost of air conditioner units. There is a clear trend of increasing sales with gross national product in EU member states [13]. The impact on the electric energy consumption has been alarming. Peak electric energy loads have started to occur during summers in most southern regions in Europe [14].

This research shows the advantage of natural energy flow to reduce heating and cooling load even when it is used at an existing large scale building such as a hotel, that is passively designed. Reduction in energy consumption is given by percentage. In this specific case study, emphasis was made on not only for cooling but also for heating load because the hotel is used the most during the summer tourist season but it is also open during the winter.

2. Modeling the hotel building for energy consumptions

e-QUEST (based on the DOE2.2 program by USDOE) energy analysis program was used to model the hotel building, located at Izmir, Turkey. This city is the third most populous city and the country's popular tourist area, located along the Aegean Sea. It has the **geographic coordinates of** 38°25′N latitude, 27°08′E longitude [15]. Izmir is characterized by long, hot summers and mild, rainy winters, a typical hot Mediterranean climate. The climate allows for a long tourism season with sunshine for 300 days of the year. Summers are dry; the summer months (June through September) are characterized by scarcity of water, and average daytime temperatures of 82.4 °F (28 °C) or higher [16]. Winter, on the other hand, is mild with occasional snow and average rainfall. In fact, 77% of the total precipitation occurs in the winter months from November through March. The average maximum temperatures during the winter months vary between 48 and 55 °F (8.8 and 13 °C) [16] as shown on Figs. 3 and 4.

Since 8760 h of weather data suitable for use with the DOE2 energy program was not available for Izmir, the weather for Palermo, Italy was used as the nearest equivalent. January and July temperature profiles and dry-wet bulb temps shown on shown on Figs. 3–5.