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Energy Consumption and Use of Renewable Energy Sources in Hotels: A Case Study in Crete, Greece

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Abstract

The energy analysis of five summer operating hotels in Crete, Greece was implemented and their average annual energy consumption has been estimated at 149 KWh/m^2 and 19.4 KWh/p.n.s. Their average annual CO_2 emissions due to energy use have also been estimated at 12.1 kg CO_2/p.n.s.. Hotels in Crete utilize various renewable energy technologies with solar thermal energy being the most widely used. Apart from solar thermal energy, solar cooling, passive solar, solar-PV, solid biomass burning and low enthalpy geothermal energy with heat pumps have also been used in various cases. Since some of these technologies are currently cost effective having at the same time many environmental benefits , it is expected that in the future renewable energy technologies will have more applications in providing heat , cooling and electricity in hotels in Crete. Use of various renewable energy technologies in hotels could result in zeroing their CO_2 emissions due to the energy use in them. The Greek government currently subsidizes the use of energy saving and renewable energy technologies in hotels aiming in reducing their high energy consumption and the use of the polluting fossil fuels in them.

Keywords: CO_2 emissions, Crete, energy consumption, hotels, renewable energies

1. Introduction

1.1 Energy consumption in hotels: literature survey

Hotels consume energy for covering their needs in heating, cooling , lighting and the operation of various electric devices.

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Energy consumption in hotels depends on physical and operational factors including the climate in the location of the hotel the category of the hotel and the year of its construction.

An analysis on energy use in European hotels has been presented (hotel energy solutions ,IEE,2011) . According to their findings for most hotels energy use falls in the range of 200-400 KWh/m^2 yr with the average energy use in the range 305-330 KWh/m^2 yr. Analysis of the energy behavior of Greek hotels showed that 72-75 % of the total energy was consumed in space heating , hot water production and air conditioning. Fifteen percent was consumed in catering, 8-9 % for lighting and the rest for the operation of various machinery. Energy efficiency for the Antalya region hotels in Turkey has been reported by Onut et al, 2006. The authors analyzed 32 five-star hotels in the Antalya region evaluating their energy performance. They found that their energy consumption was diversified and that eight of them were energy efficient.

A method for energy classification of hotels with a case study in Greece has been presented by Farrou et al, 2012. The authors proposed their classification in clusters using the K-mean algorithm. Their results from the energy analysis of 90 Greek hotels have shown that for hotels with annual operation, the annual energy consumption was 290 KWh/m^2 and with seasonal operation it was 200 KWh/m^2. A simulation of energy consumption monitoring in Mediterranean hotels with application in Greece has been reported by Karagiorgas et al, 2007.

The authors evaluated the energy performance of ten hotels in Greece grouped in three categories: de luxe, A and B . According to their findings the average energy consumption in the de luxe hotels was 68.15 KWh per night spent (p.n.s), in the first category it was 41.54 KWh/p.n.s. and in the second category 17.59 KWh/p.n.s..They also found that electricity was the main energy source used in all the hotels. A study on the energy performance of 16 quality hotels in Hong-Kong has been reported by Deng et al , 2000. The authors stated that the average energy consumption was 564 KWh/m^2 per year and electricity was the main energy source used. According to them on average one third of the total energy consumption was used for air conditioning while the energy used was influenced by the year of construction and the category of the hotel. A study on energy performance of hotel buildings in Singapore has been reported by Priyadarsini et al , 2009.

Analysis of 29 quality hotels showed that the annual average energy consumption was 427 KWh/m^2. Electricity and gas were the main energy sources used while some hotels were also using diesel oil to power a standby generator and the hot water boiler. An assessment of practices and technologies of energy saving and renewable energy sources in Crete, Greece has been reported by Zografakis et al , 2011. Assessing 32 hotels in Crete the authors found that the mean annual electricity costs per bed were 112.17 € and that 87.5 % of the hotel managers agreed or fully agreed that efficient energy management can increase hotel profits. On the other hand , they stated ,that only 53.2 % agreed or fully agreed that tourists select their hotel accommodation based on its environmental image.

A review of CO_2 emissions generated by energy consumption in hotels and home-stay facilities in Taiwan has been reported by Tsai et al , 2014. The authors found that depending on the category of the accommodation CO_2 emissions varied between 28.9 and 6.3 kg CO_2 per person and night spent. Hotels with higher service levels had higher CO_2 emissions. Benchmarking of resource consumption in hotels with reference to Hilton International and Scandic in Europe has been presented by Bohdanowich et al , 2007. The authors reported that the mean energy consumption was 364.3 KWh/m^2 per year for Hilton International and 285 KWh/m^2 per year for Scandic. The corresponding mean energy consumption per night spent was for Hilton 89.5 KWh/p.n.s. and for Scandic 47.8 KWh/p.n.s.. A case study on the improvement of energy efficiency in the Tunisian hotel sector has been presented by Khemiri et al , 2005. The authors estimated the energy consumption of a hotel located in the center of Tunis after two energy conservation measures during 1987, 1996 and 2002.

The results showed that the energy saving potential can be as high as 50 %. Energy conservation and retrofitting potential in Hellenic hotels has been reported by Santamouris et al , 1996. The authors analyzed data from 158 Hellenic hotels and they found a mean annual energy consumption of 273 KWh/m^2. They also reported that energy consumption in the hotel sector in Greece can be reduced up to 20 %. Analysis of energy consumption patterns in the accommodation sector in New Zealand has been reported by Becken et al , 2001. The authors found a mean annual energy consumption in hotels at 144 KWh/m^2 which corresponds to 43 KWh/p.n.s.. These values are lower than in other countries due to the mild climate of New Zealand. Energy efficiency and conservation in hotels has been reported by Bohdanowicz et al , 2001.

The authors reported that for standard 3-star hotels in Southern Europe , having 120 rooms , the annual energy consumption varied between 128 KWh/m^2 and 171 KWh/m^2 , depending on the availability of air conditioning and on the operation of restaurants inside the hotels. Energy use ,CO_2 emissions and waste throughout the life cycle of a sample of hotels in the Balearic islands have been reported by Rosselo-Batle et al , 2010. The authors reported that approximately 70-80 % of the total energy used in those hotels for a lifetime of 50 years is due to the operation phase. The rest is mainly due to the construction phase and small amounts of energy have been used during refurbishment and demolition phases.

The total energy used over 50 years in two hotels studied varies between 7417 KWh/m^2 and 10315 KWh/m^2 while CO_2 emissions vary between 4809 kg CO_2/m^2 and 6289 kg CO_2/m^2. A review of the carbon footprint analysis of hotels has been presented by Filimonau et al , 2011. The authors used life cycle energy analysis in two 3-star hotels in the UK in order to quantify their CO_2 emissions. Annual electricity consumption was estimated at 25.5 KWh/p.n.s. and 20.9 KWh/p.n.s. and greenhouse gas emissions at 11.65 kg CO_2/p.n.s. and 8.25 kg CO_2/p.n.s.

The authors also stated that energy consumption in breakfast and laundry services is significant and it cannot be ignored. Evaluation of energy consumption in Mediterranean island hotels with reference to Balearic islands has been reported by Moia-Pol et al , 2005. The authors report that the annual energy consumption in Balearic hotels varies from 7 up to 77 KWh/p.n.s. with an average of 15.4 KWh/p.n.s. which matches the Greek conditions. Annual energy consumption in Greek island hotels , in the B category , varies from 5 up to 25 KWh/p.n.s. with an average of 16.19 KWh/p.n.s..They also report that for old hotels built during the 70s and 80s there is a big potential of energy saving up to 25 % with a low capital investment.

The average annual energy consumption and CO_2 emissions in various hotels included in the literature surveyed are presented in Table 1.

Table 1: Average annual energy consumption and CO_2 emissions in various hotels according to the literature surveyed

Source	Country-Area	Annual energy consumption KWh/m^2	Annual energy consumption KWh/p.n.s.	Annual CO_2 emissions KgCO_2/p.n.s.
IEE	Europe	305-330		
Farrou	Greece	200-290		
Karagiorgas	Greece		17.59-68.15	
Deng	Hong-Kong	564		
Priyadarsini	Singapore	427		
Tsai	Taiwan			6.3-28.9
Bohdanowich	Europe	285-364.3	47.8-89.5	
Santamouris	Greece	273		
Becken	New Zealand	144	43	
Bohdanowich	Southern Europe	128-171		
Filomonau	U.K.		20.9-25.5	8.25-11.65
Moia-Pol	Spain-Balearic islands		7-77	
Moia-Pol	Greek islands		5-25	

1.1 Use of renewable energy sources in hotels : literature survey

The use of renewable energies in hotels has been reported by Karagiorgas et al , 2006. The authors stated that during the implementation of the project HOTRES they investigated the use of five renewable energy technologies including solar thermal, solar passive, solar PV, biomass and geothermal energy in hotels. They found that three out of five renewable energy technologies have been promoted including solar thermal, grid connected PVs and geothermal energy.

A survey of tourist attitudes to renewable energy supply in Australian hotel accommodation has been reported by Dalton et al , 2008. More than 50 % of the tourists responded positively regarding the use of renewable energies in hotel accommodation despite the fact that only 12 % of the respondents had renewable energy systems in their homes.

While 51 % of the respondents surveyed indicated that they were not willing to pay extra costs for the renewable energy systems, 92 % of the remainder indicated that they were willing to pay 1-5 % extra for that. A case study feasibility analysis of renewable energy supply options for small and medium size tourist accommodations has been presented by Dalton et al, 2009. According to their analysis in three hotels in Australia using wind energy and solar-PV hybrid systems the supplied power had an affordable price and the payback time of the investments varied between 3 and 7 years. Feasibility analysis of renewable energy supply options for a grid-connected large hotel has been presented by Dalton et al, 2009. The authors studied various hybrid power supply configurations for a large-scale grid connected hotel with over 100 beds in Australia. They found that large scale wind turbines (over 1,000 KW) are more economical than small scale wind turbines and photovoltaics.

A feasibility analysis of stand-alone renewable energy supply options for a large hotel has been reported by Dalton et al, 2008. The authors used RES assessment software programs regarding power generation, and they concluded that the most profitable configuration consisted of a large wind turbine and a back up diesel generator. The possibility of creating zero CO_2 emission hotels in Crete, Greece due to energy use has been reported by Vourdoubas, 2006. The author proposed the combination of solar thermal energy, solar-PV, solid biomass and low enthalpy geothermal energy with heat pumps for covering all the energy needs of a typical hotel in Crete. He also estimated the required size of the renewable energy systems stating that the use of these technologies in hotels in Crete, Greece is cost effective resulting in economic and environmental benefits.

The factors which affect the willingness of tourists to pay for renewable energy has been investigated by Kostakis et al , 2012.The authors stated that empirical results suggest that middle-aged people and men are more likely to pay a premium for accommodation in a hotel with renewable energy practices. Their research also indicated the importance of information dissemination and awareness rising in the willingness to pay for renewable energy sources. An investigation of the energy behavior of five summer operating hotels in Crete has been reported by Vourdoubas , 2012. He stated that their annual energy consumption is relatively low and that three of them used solar energy for hot water production. According to the current literature survey renewable energy sources are not used extensively in hotels worldwide.

Applications of solar thermal energy, solar–PV energy and geothermal energy exist while the use of large wind turbines in them, according to the existing studies , is profitable. However their use in hotels is rather rare.

The purpose of this study was

a) To estimate the energy consumption and the CO_2 emissions due to energy use in hotels in Crete, Greece by analyzing the existing energy data in five hotels and
b) To present the existing applications of various renewable energy technologies in hotels in Crete highlighting the possibility of creating zero CO_2 emissions hotels due to energy use in them.

2. Energy consumption in hotels in Crete, Greece

Analysis of the energy data in five summer-operating hotels of a small and medium size (15-360 beds) in Crete-Greece has been implemented. The energy sources used in these hotels were

a) Electricity for lighting, cooling, heating and operation of various electric devices.
b) Diesel oil for space heating and hot water production
c) LPG for heating and cooking and
d) Solar energy for hot water production

The percentage of energy sources in the annual energy balance of each hotel is presented in Table 2.

Table 2: Percentage of energy sources used in five summer-operating hotels in Crete, Greece.

Energy sourc	Hotel 1	Hotel 2	Hotel 3	Hotel 4	Hotel 5
Electricity	65.88 %	68.37 %	84.05 %	73.06 %	62.90 %
Diesel oil	18.82 %	26.87 %	0 %	12.48 %	29.10 %
LPG	6.02 %	4.76 %	0 %	6.54 %	8.00 %
Solar energy	9.28 %	0 %	15.95 %	7.92 %	0 %
Total	100 %	100 %	100 %	100 %	100 %

The average energy consumption and the CO_2 emissions in the five summer operating hotels in Crete, Greece are presented in table 3. It can be concluded from Table 2 that the main energy source used in these hotels was electricity and that the only renewable energy source used in three out of five hotels was solar energy for hot water production. It can also be seen that diesel oil was used more than LPG in these hotels.

Table 3: Average energy consumption and CO_2 emissions in five summer-operating hotels in Crete, Greece

Occupancy rate	65.20 %
Annual energy consumption	149 KWh/m^2
Annual energy consumption	2,371 KWh/bed
Annual energy consumption	19.4 KWh/p.n.s.
Annual CO_2 emissions	93.2 Kg CO_2/ m^2
Annual CO_2 emissions	1,485 kg CO_2/ bed
Annual CO_2 emissions	12.1 kg CO_2/p.n.s.

Energy consumption in hotels constructed during the 70s and 80s is higher than recently constructed hotels due to the fact that energy saving was not important then as it is today. Therefore there is a high energy saving potential in old constructed hotels using simple energy saving techniques and technologies. Their applications are very profitable with low payback periods for the capital invested.

3. Use of renewable energy sources in hotels

Renewable energy sources can be used in hotels for electricity, heat and cooling generation. Solar-PV technology can be used for power generation which can be fed into the grid offsetting the grid electricity consumption. The decrease in the price of PV panels in the last few years has increased their attractiveness. Solar thermal energy is broadly used for hot water production and to a smaller extent for space heating and cooling. Solid biomass like wood pellets and wood chips can be used for space heating and hot water production.

Low enthalpy geothermal energy with high efficiency heat pumps can provide space heating and air conditioning for hotels. Large hotels with restaurants can recycle their fried vegetable oils in order to be used for biodiesel production.

Therefore, various renewable energy technologies which are currently mature and cost effective can be used in hotels. The cost effectiveness of the renewable energy technologies depends on the location and the availability of the energy source. Their use decreases CO_2 emissions due to energy use in the hotels and increases their sustainability. Therefore their use is desirable and various renewable energy technologies are currently subsidized in many countries.

3.1 Use of renewable energy sources in hotels in Crete, Greece

The most commonly used renewable energy source in Cretan hotels is solar thermal energy for hot water production. It is used in many summer operating hotels since it is cost effective due to the high solar irradiance during the summer. The hot water produced is used in the showers, catering, laundry and swimming pools. Flat plate collectors are mainly used for the water heating. In order to promote its use in hotels the government offers capital subsidies for the installed systems through European structural funds. Solar thermal energy is also used for solar cooling with absorption systems and flat plate collectors. Two solar cooling systems have been installed so far in Cretan hotels but this technology has not been propagated in Crete in the last 15 years.

Passive solar systems have also been used so far in a few hotels in Crete reducing the energy consumption. At the end of 2014 the Greek government launched the net-metering initiative permitting the installation of solar-PV systems in buildings, including hotels in order to offset the grid electricity consumed on an annual basis with solar electricity. The installation of these systems in hotels is currently profitable and there is an expressed interest from hotel owners who are in the license approval stage.

However due to technical reasons the installation of such systems in Cretan hotels has not started yet but it is expected that their operation will start soon. Space heating and hot water production in hotels in Crete using local biomass sources, instead of diesel oil or LPG, such as olive kernel wood is profitable. There are currently some yearly operating hotels in Crete using olive kernel wood for heat generation. The use of low enthalpy geothermal energy with heat pumps mainly in large Cretan hotels is increasing. Ground or water source heat pumps are used for that covering the heat and cooling needs of the hotels.

The high efficiency of the pumps, the absence of any pollution during their operation and their cost effectiveness over the long run make their use attractive and desirable. The renewable energy technologies currently used in Cretan hotels are presented in Table 4.

Table 4: Renewable energy technologies currently used in Cretan hotels

	Renewable energy technology	Useful energy	Applications
1.	Solar thermal	Hot water	Many
2.	Solar passive	Space heating and cooling	Few
3.	Solar cooling - Absorption systems	Space cooling	Few
4.	Solar-PV (operation has not started yet , only the licenses have been approved)	Electricity	Few but there is an increasing interest
5.	Burning of solid biomass (olive kernel wood)	Hot water and space heating	Few
6.	Low enthalpy geothermal energy with heat pumps	Heating and cooling	Few but there is an increasing interest

3.2 Towards the zero CO_2 emission hotel due to energy use

The combination of energy saving technologies and the use of renewable energies for covering the energy needs of hotels could result in zeroing their CO2 emissions due to energy use during their operation. Renewable energy technologies which are reliable, cost effective and could be used on the hotel site in Crete, Greece are:

a) Solar thermal energy for hot water production,
b) Solar-PV electricity which can be fed into the grid offsetting the grid electricity used through net-metering,
c) Solid biomass for heat generation, and
d) Low enthalpy geothermal energy with heat pumps for the production of heat and cooling

The use of some or all of the abovementioned sustainable energy technologies could result in a hotel which could cover directly or indirectly all its energy needs without using fossil fuels and without emitting greenhouse gases. A successful example of a city hotel with zero energy balance has been reported in Vienna, Austria. A hotel in Crete without CO_2 emissions due to energy use could be environmentally friendly and could be attractive to environmentally conscious tourists. At the same time investment in renewable energy technologies in a hotel could be profitable offering additional economic benefits apart from environmental.

3.3 Subsidies in energy investments in hotels in Greece

Energy investments in hotels are currently subsidized by the Greek government through the European structural funds. Both energy saving and renewable energy investments are supported. Subsidies are either direct or indirect. Direct subsidies include return of the capital invested in various energy saving and renewable energy technologies which can be as high as 40 % or tax allowances. Indirect investments include feed-in tariffs and net-metering for the solar electricity generated. Many hotels in Crete have in the past utilized the governmental subsidies for the energy refurbishment of their buildings.

4. Discussion and conclusions

The energy analysis in five summer operating hotels in Crete, Greece has shown that their average annual energy consumption was 149 KWh/m^2 or 19.4 KWh/p.n.s which matches with the values reported in the literature for Greece and southern European countries. However this value is significantly lower than the average value of 273 KWh/m^2 yr reported by Santamouris et al, 1996 for Greek hotels. Three of those hotels were using solar energy for hot water production which corresponded from 7.92 % up to 15.95 % to their total energy consumption. Average annual CO_2 emissions of the five hotels studied was estimated at 12.1 kg CO_2 /p.n.s..

Hotels in Crete use various renewable energy sources for covering part of their energy needs including solar energy, solid biomass and low enthalpy geothermal energy. Solar thermal energy is the most widely used renewable energy in hotels in Crete, Greece, particularly in summer operating hotels.

However solar-PV and geothermal energy are currently cost effective and they are expected to have more applications in the hotel sector in the future in Crete. Passive solar, solar cooling and solid biomass burning have also been used for heat and cooling applications in a few cases. Proper use of various reliable and cost effective renewable energy technologies in hotels in Crete could result in zero CO_2 emission hotels due to energy use contributing in the mitigation of the greenhouse effect. This would be attractive to environmentally conscious tourists and economically profitable for hotel owners. Further research should be oriented in the creation of a zero CO_2 emissions hotel in Crete using various renewable energy technologies in order to study its behavior and to investigate its cost effectiveness.

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