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Hotels with Net Zero Carbon Emissions in the Mediterranean Region: Are They Feasible?

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Abstract

Various, reliable, mature and cost-effective renewable energy technologies are broadly used today for heat, cooling and power generation. The Mediterranean basin is a well-developed tourism destination area with various abundant renewable energy sources. In the current era of sustainable development and climate change, the creation of net zero carbon emissions hotels is a challenge for improving overall sustainability. Low carbon emission hotels can be achieved with the combined use of various renewable energy technologies. Use of solar thermal energy, solar photovoltaic energy and high efficiency heat pumps generating heat, cooling and electricity in Mediterranean hotels could zero their carbon emissions due to energy use. Alternatively solid biomass, if available, could be used for heat production. Although these technologies are currently reliable and cost-effective, with many applications in all sectors, various barriers hinder their promotion in hotels in the Mediterranean area. Taking into account though the fact that many tourists prefer to stay in green hotels and that the use of these technologies results in many economic and environmental benefits, it is expected that in the future the use of renewable energy technologies will be promoted in Mediterranean hotels, reducing their carbon footprint.

Keywords: Carbon emissions, Electricity, Heat, Hotel, Mediterranean, Renewable energy

1. Introduction

Hotel buildings are considered among the most energy-consuming buildings after hospitals. They consume mainly electricity, natural gas and oil for space heating and cooling, lighting, hot water production and operation of various equipment. In the current era of sustainable development and climate change, efforts to promote sustainability in the hospitality sector are very important. However the fact that energy costs are only a small part of the total operation costs in the hotel industry does not encourage the adoption of sustainable energy technologies (SETs) in them. Current innovations and advances in SETs have increased their attractiveness in many applications including the tourism sector. Their reliability and their low cost results in low payback periods and positive net present values of sustainable energy investments. In regions like the Mediterranean basin the abundance of solar energy facilitates the use of various solar energy technologies, which are mature, reliable and cost-effective, for heat, cooling and power generation. The maturity and cost-effectiveness of various renewable energy technologies (RETs) offer the opportunity to improve the sustainability of the hotel industry, obtaining at the same time economic benefits to the owners.

1.1 Energy consumption in hotels

Moia-Pol et al, 2005 have reported on the energy consumption in Mediterranean island hotels with a case study in the Balearic islands. The authors stated that hotel buildings consume large amounts of energy while the average energy consumption in hotels in these islands is 15.4 KWh per night spent (p.n.s.). This is comparable with energy consumption in hotels in Greek islands which is 16.19 KWh/p.n.s..

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They also reported that with small investments in energy saving technologies more than 25% of the energy consumed in the hotels can be saved while the payback period of the energy investments could be less than 6 years. **Kyriaki et al, 2017** have reported on energy and environmental performance in hotel buildings. The authors examined the replacement of an oil boiler in a Greek hotel with a solar combi system including solar thermal panels and an air-water heat pump. They concluded that the combi system was cost-effective while it reduced CO_2 emissions in the hotel by 67%. **Yao et al, 2015** have studied the energy characteristics of hotel buildings in Shanghai, China. Implementing a survey in 45 hotels, the authors found that electricity is the main energy source used which accounts for 75% of their total energy consumption. They also mentioned that some hotels use solar collectors for hot water production. **Ramesh et al, 2010** have overviewed life cycle analysis in buildings. The authors analyzed 73 cases from 13 countries stating that operating energy in buildings corresponds to 80-90% of their life cycle energy consumption while the remaining 10-20% is their embodied energy. **Santamouris et al, 1996** have reported on the retrofitting potential of Hellenic hotels. Analyzing data from 158 Hellenic hotels, the authors concluded that the annual average total energy consumption was 273 KWh/m^2. They also mentioned that the results of several simulations in the hotels have indicated a 20% potential in energy savings.

Tsoutsos et al, 2013 have reported on nearly zero energy hotels in the Mediterranean area. The authors mentioned the implementation of the EU-funded project "Nearly zero-energy hotels" and various pilot projects realized in the participating countries. In the pilot studies they considered that 2/3 of the energy consumed is grid electricity and 1/3 heat provided by natural gas and oil. They have also assumed that 20% of the hotel's energy needs are covered by renewables, 50% for heating and 50% for electricity. An analysis on energy use by European hotels has been realized during the implementation of the EU-funded project **"Hotel energy solutions", 2011**. This analysis indicated that the average energy use by hotels is in the range of 305-330 KWh/m^2year while the average annual CO_2 emissions due to energy use were 160-200 kg CO_2 per m^2 of room floor area. According to the same report, the main RETs which could be used in hotels are solid biomass and solar energy.

Vourdoubas, 2016 has published an energy analysis of five summer operating hotels in Crete, Greece. The author estimated their annual energy consumption at 149 KWh/m^2 and 19.4 KWh/p.n.s. while their CO_2 emissions were 12.1 kg CO_2/p.n.s.. He also mentioned that the main renewable energy used in Cretan hotels is solar energy. **Placet et al, 2010** have studied the energy end-use patterns in large hotels in order to reduce the overall energy consumption by 30%. The authors stated that heating the guest rooms and the public areas accounts for almost 60% of total electricity consumption. They also mentioned that water heating accounts for 6% of total energy use, lighting at about 7% and operation of the kitchen at approximately 10%. **Bohdanowicz et al, 2001** have reported on increasing energy efficiency and use of renewables in hotels in order to promote sustainable tourism. The authors stated that on average heating and air-conditioning accounts for approximately 50% of total energy use, catering 25%, domestic hot water 12%, lighting 6% and other uses 7%. They also mentioned that maximizing energy efficiency as well as the use of renewable energy resources and technologies is a necessary step towards promoting sustainable tourism.

1.2 Use of renewable energy technologies in hotels

The possibility of reducing the carbon footprint in tourist accommodation has been studied in the EU funded project **RELACS, 2013**. The project's results have indicated that a 25% reduction in carbon emissions due to energy use can be achieved either by improving the energy efficiency or by using renewable energies. Renewable energy solutions for tourism have been reported by **Karabuga et al, 2015.** The authors proposed that various renewable energies can be used in hotels, depending on their availability, including solar energy, biomass, wind energy, heat pumps and geothermal energy. A case study regarding the use of renewable energies for electricity generation in a small grid-connected hotel in North America has been reported by **Robins, 2009**. The author mentioned that the use of solar and wind energy for electricity generation in the small hotel is not cost-efficient. This is partly due to the fact that the size of the hotel is small and the low cost of the grid electricity supplied.

Moia-Pol et al, 2014 have reported on renewable energy applications in Mediterranean hotels. Studying various hotels in the Balearic islands, the authors mentioned that a high amount of energy consumed in them is thermal energy. They proposed the use of solar energy as well as tri-generation systems which could reduce by 20-40% the conventional fuels used in them as well as their carbon footprint. Sustainability and energy use in small scale Greek hotels has been presented by **Parpairi, 2017**.

The author has proposed a list of energy strategies using cost-effective SETs which can be used in small-scale Greek hotels, reducing their energy consumption, their conventional fuels use and their carbon emissions. **Rezachek et al, 2001** have reported on the energy efficiency and renewable energy use in the hotel industry. The authors implemented two case studies in two hotels located in Hawaii and in Sweden.

They reported that energy conservation measures are cost-effective in both countries while in Hawaii solar energy, both thermal and PV, could provide more than 61% of the hotel's total energy requirements. Factors and initiatives affecting renewable energy use in the hotel industry have been reported in an EU funded project, **Hotel energy solutions, 2011**. According to this report the main factors influencing the use of RETs in hotels are: costs, quality of products and installations, ease of installation, geographic and climate conditions, user's distance from the manufacturer and optimal conditions for installations. **Henning et al, 2012** have reported on solar systems for heating and cooling buildings with reference to a case study for a hotel located in Malta. The authors concluded that solar heating and cooling in hotels can be obtained with solar energy particularly in areas with high solar irradiance. They also mentioned that in the future apart from solar thermal systems the use of solar photovoltaics (solar-PVs) combined with heat pumps could cover most of the energy requirements in hotels.

Good et al, 2015 have compared the use of various RETs in buildings in order to achieve a net zero energy building. Implementing a simulation study the authors compared solar thermal systems, solar-PV systems and hybrid PV/solar thermal systems. Their results indicated that the building with only efficient PV modulus achieves better results followed by the building using both solar thermal and solar-PV systems. **Kresteniti, 2017** has investigated the energy optimization of existing hotel buildings in Greece. The author studied interventions in the building envelope, in electro-mechanical systems and the application of solar energy technologies including solar-PVs and solar thermal systems. Her results indicated that an average reduction of 60% in the annual primary energy consumption could be achieved in the hotels. **Tselepis et al, 2002** have investigated the economics of hybrid photovoltaic/thermal (PV/T) systems which consist of PV modulus coupled with heat exchange devices. The authors compared the use of PV/T systems with simple solar-PV and solar thermal systems in Greece. Their results indicated that the use of hybrid PV/T systems has a payback time below 10 years which makes them attractive in various applications. A case study for a hotel with zero CO_2 emissions due to energy use in Crete, Greece has been presented by **Vourdoubas, 2015**. The author indicated that the combined use of solar thermal energy, solar-PV energy and high efficiency heat pumps could zero its carbon emissions due to operational energy use. He also estimated the installation cost of the required RETs at 2,254 € per bed and the annual CO_2 emission savings at 2,226 kgCO_2 per bed.

Bejcek et al, 2017 have reported on the optimization of a solar cooling system in a Greek hotel. The authors proposed that rejected heat from solar cooling systems in hotels could be recycled for hot water production and for pool heating. Implementing simulation studies in a Greek hotel, they concluded that recycling the rejected heat from solar cooling systems inside the hotel could achieve very high seasonal energy efficiency ratios at 7-7.5. **Kostakis et al, 2011** have investigated the willingness of tourists to pay for renewable energies used in hotels. Their empirical results indicated that middle-aged people and in general men are more likely to pay extra money for a green hotel using renewable energies. They concluded that environmental consciousness and adequately informed tourists are willing to pay more if renewable energies were used in hotels. A good example of a zero-energy balance hotel, the **Stadthalle,** exists in Vienna, Austria. It uses RETs to generate heat, cooling and electricity including solar thermal and solar-PV panels, ground water heat pumps and three wind turbines. RETs installed on-site generate annually the same amount of energy required for the hotel's operation.

The aims of the current work are:

a) *To investigate the possibility of using various renewable energy technologies available in the Mediterranean region in hotels zeroing their carbon footprint due to operational energy use, and*
a) *To indicate a combination of renewable energy technologies which could be used in hotels resulting in their net zero carbon emissions.*

1. Renewable energy technologies which can be used in hotels in the Mediterranean region

Various RETs, depending on the availability of the energy source, can be used in hotels in the Mediterranean region. Some of them are abundant like solar energy and others are site-dependent like wind energy and solid biomass. Their technologies are more or less mature, reliable and cost-effective. They can be used on site for heat, cooling and power generation. The combined use of energy saving technologies with RETs in hotels can minimize or zero the net energy consumption as well as the net carbon emissions due to the operational energy use in them.

2.1 Solar thermal energy

The high solar irradiance in the Mediterranean region facilitates the use of solar energy for heat generation in hotels. Hotels need hot water in the kitchen, the laundry, the client's rooms and occasionally for heating the swimming pool. Simple solar thermo-siphonic systems with flat plate collectors are broadly used today for hot water production in various buildings. They are technologically simple, mature, reliable and cost-effective systems producing hot water at 50-65^{o}C which is needed in hotels.

Solar collectors can be placed either on the roof terrace of the hotel's buildings or on the ground in a nearby area. Alternatively more technologically advanced solar systems with parabolic collectors or vacuum tubes can be used for hot water production.

2.2 Solar photovoltaic energy

Solar photovoltaic systems can generate electricity covering part or all of the hotel's electricity needs. The most commonly used systems include flat panels of mono-crystalline or poly-crystalline silicon. The sharp drop in their prices in the last years has made their use cost-effective and attractive particularly in areas with high solar irradiance like the Mediterranean basin. Solar-PV systems can be installed in grid-connected hotels and the electricity generated can be injected into the grid if not needed in the hotel. This is allowed in many countries with the net metering regulations, allowing the use of the grid as a battery and compensating the annual use of grid electricity in the hotel. Currently solar-PV technology is considered a reliable, mature and cost-effective technology which is increasingly used in households and in commercial applications. Efficiencies of solar-PV systems are below 20% and they are lower than the efficiencies of the solar thermal systems which are in the range of 30-35%. Current advances in semi-transparent solar-PVs allow their use in hotels although their prices are still higher than the prices of opaque modulus.

2.3 Solar cooling

Space cooling in hotels is needed when solar irradiance is high and this is a challenge for using solar cooling systems. Currently thermal driven solar cooling systems have been installed in various buildings, preferably in large buildings. These systems can recycle the rejected heat in the hotel obtaining high overall efficiencies. However many hotels prefer to use conventional cooling systems. Improvements of solar cooling technology in the future could increase its attractiveness in the Mediterranean tourism sector.

2.4 Hybrid solar systems

Hybrid heat and power co-generation systems using solar energy have been recently commercialized. However the experience from their use is limited and not enough yet for assessing their advantages, drawbacks and profitability. In one of them, solar-PV panels are combined with a heat exchanger which removes the excess heat of the panels during the summertime, producing hot water. At the same time the mean temperature of the panels is decreased, improving their efficiency in electricity generation. Their use could be ideal in the Mediterranean region during the summer when the hotels need both electricity and hot water. In a second system, a parabolic disc is used for heating a fluid at high temperatures followed by electricity generation with a Stirling engine. The parabolic disc has a sun tracker and apart from power it can also co-generate heat.

2.5 Solid biomass

Solid biomass, if available, can be used for heat generation in hotels. Biomass burning is an old, well known and cost-effective technology for heat generation. However solid biomass is not always available while its use results in carbon emissions with the exit gases. Although solid biomass fuel is not zero-cost like solar energy it can be used for space heating and hot water production in hotels. In modern solid biomass burning systems high efficiencies at 70-80 % are usually obtained.

2.6 Ground source heat pumps

Heat pumps are very energy-efficient devices producing heat and cooling. They use the low enthalpy energy of the environment, including the heat of the ground at low depths, and electricity to produce useful energy. In modern heat pumps, including ground source heat pumps, very high coefficients of performance in the range of 200-500% can be achieved. They are able to cover all the heating and cooling needs of a modern tourism facility and they are currently used in many hotels due to their advantages.

Their operation is not related with the emission of pollutants in the hotels like the use of heating oil or solid biomass. However they have a high initial investment cost but they are profitable in the long run.

2.7 Wind turbines

Wind turbines can generate electricity like solar-PVs and if the mean annual wind velocity in the hotel site is satisfactory their use could be profitable. Wind turbines like solar-PVs are reliable and mature renewable energy systems generating electricity in a cost-effective way.

They can cover part or all of the hotel electricity needs provided that their use is allowed and the electricity generated, if it is not needed in the hotel, could be stored into the grid and used later when needed. Characteristics of various RETs used in hotels in the Mediterranean region are presented in table 1.

Table 1. Characteristics of renewable energy technologies which can be used in hotels in the Mediterranean region

Renewable energy technology	Energy generated	Main advantages	Main drawbacks
Solar thermal with flat plate collectors	Heat	- Low cost - Well known and cost-effective technology	- Require large surfaces for installation
Solar-PV	Electricity	- cost-effective technology	- Require large surfaces for installation
Solid biomass burning	Heat	- Low cost - Well known and cost-effective technology	- Emits pollutants in the atmosphere - Fuel cost
Ground source heat pumps	Heat and cooling	- It can cover all the heating and cooling needs - Very high efficiency	- Initial installation cost is high
Wind turbines	Electricity		- Require high wind speed - Profitability in small size wind turbines is uncertain
Hybrid solar systems	Heat and electricity	- Co-generate heat and power with the same system	- Lack of experience to assess the technology in hotels
Solar cooling	Cooling	- Produces cooling during the summer when it is needed and the solar irradiance is high	- High maintenance cost - Not appropriate in small size hotels

3. Requirements for a net zero carbon emissions hotel due to operational energy use

In order to achieve a net zero carbon emissions grid-connected hotel due to operational energy use the following two requirements must be fulfilled

a) The heating needs of the hotel must be covered by renewable energies instead of fossil fuels, and
a) All the grid electricity used in the hotel for lighting and operation of various devices and machinery must be offset annually with electricity generated by renewable energies like solar-PV energy. This should be allowed by the existing legal framework including the net metering regulations.

Fulfillment of the second criterion assumes that all the grid electricity used in the hotel is generated by fossil fuels which is not always true since usually part of the grid electricity is generated by renewable energies. It should be noted though that fulfillment of the two criteria does not imply zeroing the embodied energy in the hotel but only its operational energy. Renewable energy technologies which can be used for zeroing net carbon emissions in hotels in the Mediterranean region are presented in table 2.

Table 2. Renewable energy technologies which could be used for zeroing the carbon footprint in hotels in the Mediterranean region

Energy required	Energy form	Renewable energy technology
Space heating	heat	1. Ground source heat pumps 2. Solid biomass 3. Hybrid solar systems
Space cooling	cooling	1. Ground source heat pumps 2. Solar cooling
Hot water	heat	1. Solar thermal system 2. Ground source heat pumps 3. Solid biomass 4. Hybrid solar systems
Lighting	electricity	1. Solar-PV 2. Wind energy 3. Hybrid solar systems
Operation of various devices and machinery including heat pumps	electricity	1. Solar-PV 2. Wind energy 3. Hybrid solar systems

3. Creation of net zero carbon emissions hotels due to energy use in the Mediterranean region

Net zero carbon emissions hotels can be achieved with the combined use of various RETs covering their energy requirements. The use of RETs should be combined with the use of energy saving technologies in order to reduce the overall energy consumption in the hotel. Solar energy is the primary energy source which can be used in hotels due to its abundance in the Mediterranean region and the fact that many solar energy technologies are currently cost-effective. The existing legal framework must allow the use of solar-PVs for electricity generation injected into the grid when it is not needed in the hotel. This is already allowed in many countries with the net-metering regulations. Various RETs can be used for space heating and hot water production. For space cooling the most broadly used technology is related with high efficiency heat pumps. For electricity generation solar-PV systems are increasingly used in buildings due to their economic attractiveness. Therefore the following combination of RETs used in hotels could result in generating all the annually required energy and zeroing their net carbon emissions.

a) Solar thermal energy for hot water production assisted, if needed, with ground source heat pumps,
a) Ground source heat pumps for space heating and cooling, and
b) Solar-PVs for electricity generation equal with the total annual electricity requirements in the hotels.

The proposed technologies for the creation of net zero carbon emissions hotels due to operational energy use in the Mediterranean region are presented in table 3.

Table3. Proposed technologies for the creation of net zero carbon emissions hotels due to operational energy use in the Mediterranean region[1]

Hotel requirements	Renewable energy source	Energy technology	Is it already used in hotels ?	Is it cost-effective ?
Space heating	Ground heat	Ground source heat pumps	Yes	Yes
Hot water production	Solar energy	Solar thermal systems	Yes	Yes
Hot water production	Ground heat	Ground source heat pumps	Yes	Yes
Space cooling-air conditioning	Ground heat	Ground source heat pumps	Yes	Yes
Electricity for lighting and operation of various machinery including heat pumps	Solar energy	Solar-PVs	Yes	Yes

It is assumed that the use of solar-PVs in grid-connected hotels is allowed with the net metering regulations
The above-mentioned technologies are not the only technologies which could be used in hotels for zeroing their carbon footprint. Solid biomass burning, solar cooling, other types of high efficiency heat pumps and wind turbine technologies could also be used if the energy sources are available and if they are more attractive than the technologies presented in table 3.

3. Discussion

The energy cost in hotels is only a small part of their operation cost which does not prioritize the promotion of energy sustainability in them. However there are many opportunities for using renewable energies in hotels for heat and electricity generation, reducing their environmental impacts and also offering a profit to the owners. Net metering regulations are a prerequisite in achieving net zero carbon emissions hotels since it allows the on-site electricity generation and the use of the grid as a battery. Although many RETs are currently mature, reliable and cost-effective, there are various barriers hindering their promotion in hotels. The lack of awareness among hotel owners and managers regarding the benefits of using RETs in them does not facilitate their promotion. The lack of capital availability in various Mediterranean countries, like in Greece, necessary for RETs installation, results in limited energy investments in hotels. However in some EU countries the promotion of green energy hotels is supported with economic incentives through EU structural funds. In many hotels there is limited space availability on the roof terrace required for solar thermal and solar-PV installations.

Other hotels do not accept the installation of solar energy systems in the building due to changes in their architecture landscape. The maintenance costs of solar thermal systems, solar-PVs and heat pumps are not high compared with the maintenance costs of oil or gas boilers. Future increases in grid electricity costs combined with a further drop in the cost of solar-PV panels will increase their attractiveness.

Since many environmentally conscious visitors are willing to pay more for staying in a green hotel zeroing their net carbon emissions with the use of benign energy sources, could be a marketing tool for attracting more high-income tourists.

3. Conclusions

Hotel buildings are among the most energy-intensive buildings consuming large amounts of energy per unit surface. Most of their energy consumption is derived from fossil fuels. Use of RETs in Mediterranean hotels is rather limited although this region has abundant renewable energy resources. Currently many RETs are mature, reliable and cost-effective. Therefore they can be used in hotels for heat and power generation, replacing fossil fuels and offering a profit to the owner. At the same time the reduction of carbon emissions will result in environmental benefits mitigating climate change. It has been indicated that the combined use of various RETs, using renewable energy resources, abundant in the Mediterranean region, could generate all the heat, cooling and electricity needed annually in a grid-connected hotel, zeroing its carbon footprint due to operational energy use. However in order to increase the use of RETs in Mediterranean hotels, various existing barriers should be removed. Combined use of solar energy technologies and high efficiency heat pumps could result in net carbon emissions hotels. Zeroing net carbon emissions due to energy use in Mediterranean hotels is technically feasible, economically profitable, and environmentally desirable while it meets the expectations of environmentally conscious tourists who wish to spend their holidays in green hotels. Further research should be focused on zeroing carbon emissions in hotels due to the use of vehicles additionally to heat and electricity consumption. If electric vehicles with batteries are used in the hotel the possibility of installing solar-PVs in-situ for re-charging their batteries should be investigated.

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