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Carbon Neutral Campsites Due to Operational Energy Use in the Mediterranean Region: Are they Feasible?

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Abstract

Increase of energy efficiency and decrease of carbon emissions in the global tourism industry are necessary for the mitigation of climate change. Campsites, like other types of tourism accommodation, utilize mainly fossil fuels for covering their energy requirements. Use of renewable energy technologies for covering part or all of their energy needs is desirable since it would reduce their carbon footprint. Various renewable energy sources which are abundant in the Mediterranean region could be used for electricity, heat and cooling generation in campsites located in this area. These include solar energy, solid biomass, and wind energy combined with high efficiency heat pumps. Current advances in their technologies allow their commercial use in many daily applications since they are mature, reliable and cost-effective. Additionally, carbon emissions due to operational energy use in campsites could be offset with carbon sequestration from trees. Solar thermal energy combined with solar photovoltaic and heat pumps could cover all the operational energy use in campsites located in the Mediterranean region in a reliable and cost-effective way. It has been found that for a Mediterranean campsite hosting 150 guests, the total installation cost of a solar thermal system, a solar photovoltaic system and a high efficiency heat pump covering all its annual energy requirements is 122,884 €. It is concluded that there are no technical or economic barriers for reducing or even zeroing the carbon footprint due to energy use in campsites, allowing the increase of their sustainability and the promotion of eco-efficiency in the tourism industry.

Keywords: Sustainable tourism; campsite; energy; carbon emissions; Mediterranean region; renewable energies.

1. Introduction

Climate change is one of the most severe global environmental problems creating large environmental disasters worldwide and threatening with extinction many of the living organisms in the planet.

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Mitigation of climate change requires the sharp decrease of anthropogenic greenhouse gas emissions into the atmosphere including CO_2 emissions due to fossil fuels use. Fossil fuels are broadly used in the fast growing global tourism industry while air travel has the largest share in total carbon emissions in tourism. Reduction of the carbon footprint in the hospitality industry requires increasing use of renewable energies instead of fossil fuels which are currently the main energy sources used. Creation of net zero carbon tourism accommodations is going to improve the environmental performance of the tourism industry. Net zero emission campsites due to energy use have not been reported so far in the published literature. However current advances in various sustainable energy technologies allow their commercial use for heat, cooling and electricity generation. The Mediterranean region is abundant in various renewable energy sources, including solar energy, solid biomass and wind energy, which could be used with the existing mature, reliable and cost-effective technologies for covering all the annual energy requirements in campsites, zeroing their net carbon emissions due to energy use.

2. Literature survey

2.1 Tourism and climate change

A report on climate change and tourism has been released [1]. According to this report air transport causes 87% of total carbon emissions in international trips while average carbon emissions in accommodation is on average 15.6 $kgCO_2$/p.n.s. although it varies among different types of tourist residence. A study on the eco-efficiency of tourism has been reported [2]. The authors stated that a precondition for achieving sustainable tourism development is the decrease of fossil fuels use during the transportation of tourists. They mentioned that tourism is not necessarily environmentally more beneficial than other economic activities. According to various case studies implemented so far the authors concluded that great variations in eco-efficiencies existed in tourism dependent mainly on source and destination countries while air travel has the highest environmental impact of the tourism industry. Impacts of tourism on climate change have been investigated [3]. The authors mentioned that the impact of tourism on climate change, mainly through transport, is still an emerging concern for research. They stated that there is insufficient knowledge on the impacts of transport on climate while currently bunker fuel consumption in international travelling is not accounted for in national inventories. A report on the possibility of promoting tourism with low impacts on climate has been published [4]. The author stated that the greatest factor determining the CO_2 emissions of a trip is not the mode of transport selected but the distance travelled. He also mentioned that estimates regarding energy consumption and CO_2 emissions in tourist accommodation in New Zealand indicated carbon emissions in campsites at 4 $kgCO_2$/p.n.s.. A study on the ecological footprint of different kinds of tourism at the local level with reference to the Alpi Lepontine mountain community in Northern Italy has been released [5]. The authors compared the ecological footprint of seven different types of tourism accommodation including campsites. Their results indicated that campsites had high ecological footprint due to the land engaged for housing the campers which was no longer available for agriculture and pasture. A report on the de-carbonization of the hotel sector has been published [6]. The report suggested that in order to mitigate climate change, the hotel industry will need to be: a) more energy efficient, b) more renewable, and c) more electrified. A study on low carbon travel and tourism has been published [7]. It suggested various carbon emissions mitigation measures in the hotel industry including the increase of energy efficiency and the higher use of renewable energies in various accommodation facilities. A study on zero energy buildings has been published [8]. The authors stated that various definitions have been used to characterize zero

energy buildings including: a) net-zero site energy, b) net-zero source energy, c) net-zero energy costs, and d) net-zero energy emissions. Regarding the net-zero energy emissions buildings, they mentioned that there are various calculation difficulties. These are due to the uncertainty of determining the sources of grid electricity generation in different areas. Depending on the mix of the fuels used, the requirements for the necessary solar photovoltaic (solar-PV) system installed in a net-zero carbon emissions building are different. A report on Net Zero Carbon Buildings has been published [9]. The report was intended to act as guidance for the creation of net zero carbon buildings. It mentions two definitions for this type of buildings, one for its operational energy use and the other for its embodied energy use.

2.2 Energy consumption in campsites

A study on the energy consumption patterns in the accommodation sector in New Zealand has been released [10]. The authors stated that average energy consumption in hotels was 43 KWh/p.n.s., in bed and breakfast facilities 30.5 KWh/p.n.s, in motels 8.9 KWh/p.n.s and 6.9 KWh/p.n.s. in campsites. An investigation on the energy intensity of tourists in New Zealand according to their different travel choices, accommodation and activities has been implemented [11]. The authors studied seven different categories stating that campers' energy consumption was on average 86.1 KWh/day. They also mentioned that the share of travel in their overall energy consumption was 78%, 11.5% for accommodation and 10.5% for various activities. A report on campsite energy efficiency and renewable energy installations has been published [12]. The report mentioned that energy is used in campsites for heat, ventilation, air-conditioning (HVAC), hot water production, lighting and for cooking and the operation of various appliances in the kitchen. Among various renewable energy sources and technologies, solid biomass, solar thermal energy, solar-PV, heat pumps and small wind turbines could be used in them. The report also stated that electricity had a share of approximately 50% in their total energy consumption while, according to various studies, their total energy consumption varies between 8.1 KWh/p.n.s. and 16.5 KWh/p.n.s. This corresponds approximately to 20% of total energy consumption in mid-range hotels. The report proposes benchmarking values for total energy consumption in campsites at 2-3.4 KWh/p.n.s..

2.3 Use of renewable energies in various types of tourist accommodation including campsites

Research on the use of solar-PV systems for electricity generation in desert camping in Saudi Arabia has been made [13]. The authors compared the economic performance of a solar-PV system over a diesel generating electricity system. Their results indicated that due to high solar irradiance in the region the solar-PV system was preferable while electricity storage in a battery should be minimal. A report for a solar thermal action plan in the Mediterranean region has been published [14]. The report mentioned that the most established solar thermal technologies in the market are those requiring low to medium temperatures mostly used for domestic hot water (DHW) production. In 2010 China dominated the global market in these technologies with a share of 59%, Europe had a share of 13% while South East Mediterranean countries had a smaller share of just 9.3%. Use of a geothermal heat pump combined with a solar thermal system for heat generation at Knattholmen campsite, Norway has been reported [15]. The campsite hosted approximately 6,000 visitors annually. It installed, in 2016, a hybrid energy system consisting of solar collectors at 68 m^2 and three geothermal heat pumps at 12 KW each.

The hybrid energy system was operating successfully, with an overall seasonal coefficient of performance (SCOP) for heating and hot water production at 5.2, covering a large part of the annual heating requirements in the campsite. Energy consumption and use of RES in hotels located in Crete, Greece has been reported [16]. The author mentioned that the average annual energy consumption in five summer operating hotels in Crete was at 19.4 KWh/p.n.s while the most often renewable energy used in them was solar energy. A study on the possibility of using solar energy for the creation of carbon neutral hotels in Mediterranean countries has been implemented [17]. The author mentioned that solar thermal energy and solar-PV energy combined with high efficiency heat pumps can cover all the energy requirements of summer-operating hotels in Mediterranean countries. The use of these technologies, he added, is technically feasible, economically profitable and environmentally desirable. A report on the solar-PV market development in Greece with the net-metering initiative has been released [18]. The author has presented two case studies regarding the viability of the PV net-metering program for a household and a commercial enterprise. His results indicated that the solar-PV investments were in both cases profitable, having low payback periods, below 12 years for the household and below 8 years for the commercial enterprise.

2.4 Offsetting carbon emissions in tourism accommodation

An investigation on energy efficiency and reduction of CO_2 emissions from campsites located in protected areas in Tuscany, Italy has been realized [19]. The authors mentioned that a part of the CO_2 emissions due to energy use in campsites is counterbalanced from carbon sequestration due to existing tree plantations in the campsites located in naturalistic parks. Analyzing data from six campsites in Italy with sizes between 4-10 hectares (ha), they found that carbon sequestration corresponds to 20-60% of their energy-related CO_2 emissions. A study on CO_2 removal rates from forest restoration activities has been implemented [20]. The authors stated that planted forests had the highest annual CO_2 removal rates, ranging from 4.5 to 40.7 tCO_2 per ha. They also mentioned that mangrove tree restoration was the second more efficient with annual CO_2 removal rates up to 23.1 tCO_2 per ha while annual CO_2 removal rates in natural regeneration varied between 9.1 and 18.8 tCO_2 per ha. A report on using forest carbon credits to offset emissions in the downstream business has been published [21]**.** The report stated that prices for forest carbon credits vary on average from US$ 4 to US$ 10 per tCO_2 while afforestation and reforestation projects average at US$ 8 per tCO_2. It also mentioned that carbon credits from wind energy are cheaper than forest carbon credits. A study on carbon sequestration by forests has been realized [22]. The Kyoto protocol in 1979 stated the need for terrestrial ecosystems, especially growing trees, to sequester carbon. The author mentioned that forests are cost-effective as CO_2 absorbers while tropical forests may absorb more CO_2. He also stated that maple-beech-birch forests could absorb annually 1.973-4.382 tCO_2 per ha while white and red pine forests absorb 8.425-11.015 tCO_2 per ha.

The aims of the current work are:

a) *To investigate the possibility of zeroing net CO_2 emissions in campsites due to operational energy use, and*
b) *To investigate the viability of using various renewable energy technologies in campsites located in the Mediterranean region covering all their annual energy requirements.*

The approach followed included the investigation of energy consumption in campsites as well as the commercially used renewable energy sources and technologies which could be used for energy generation in them. Taking into account the requirements for net zero carbon emissions campsites, calculations regarding the size and the cost of appropriate RETs which could cover all the annual energy requirements in a pilot campsite located in Mediterranean region have been made.

3. Energy consumption in campsites

Energy is used in campsites for covering their requirements for lighting, operation of various appliances, air conditioning and hot water production. According to existing studies [12] energy consumption in 55 campsites was distributed as follows: 40% natural gas, 30% electricity, 18% liquefied gas, and 12% heating oil. Energy efficiency in campsites can be increased with relatively simple actions like:

a) Improvement of the thermal insulation of the accommodation's building envelope including walls, windows, doors and roofs,
b) Reduction of hot water demand with insulation of boilers and pipes and with the installation of efficient fittings and control mechanisms,
c) Use of energy-efficient heat pumps for HVAC using electricity more efficiently,
d) Use of low energy consumption lighting systems, and
e) Monitoring energy consumption.

4. Renewable energy technologies which can be used in campsites

Various renewable energy sources and technologies can be used in campsites for generation of electricity, heat and cooling, like:

a) Solar thermal energy for hot water production,
b) Solid biomass burning for space heating and hot water production,
c) Solar photovoltaic energy for electricity generation,
d) Geothermal heat pumps or other types of energy-efficient heat pumps for air conditioning and hot water production, and
e) Small or medium size wind turbines, located on-site or off-site, for electricity generation.

Additionally fried vegetable oils from the restaurants in the campsites could be used for the production of bio-diesel. The abovementioned renewable energies are currently mature, reliable and cost-effective. They are used in various daily commercial applications. Generation of solar or wind electricity is facilitated with the net-metering initiative which allows its storage into the grid, when it is not needed. The characteristics of various renewable energies which can be used in campsites are presented in Table 1.

Table 1: Energy generation by various renewable energies and technologies which can be used in campsites

Renewable energy	Electricity generation	Space heating	Space cooling	Hot water production	Are they currently used commercially?
Solar thermal				+	Yes
Solar-PV	+				Yes
Solid biomass		+		+	Yes
Wind turbines	+				Yes, occasionally
High efficiency heat pumps		+	+	+	Yes

On-site wind turbines could be used only if the wind characteristics and the average annual velocity on the campsite are satisfactory. Alternatively, if allowed, off-ste wind turbines could be used. Offsetting annual grid electricity use with solar-PV electricity is usually allowed in many countries with the net-metering regulations. Solar-PV systems could be installed either on-site or off-site (virtual net-metering).

5. Requirements for net zero CO_2 emissions campsites

In order to achieve net zero CO_2 emissions campsites due to operational energy use, the following requirements must be fulfilled:

a) All the fossil fuels used should be replaced by renewable energies,
b) All the annual grid electricity consumed should be generated (on-site or off-site) by renewable energy sources preferably by solar-PV electricity, and
c) Any remaining carbon emissions should be offset annually by carbon sequestration by tree plantations.

Increase of energy efficiency in campsites is not a prerequisite but it is recommended since it would facilitate the elimination of their carbon emissions, lowering their energy consumption and the size of various renewable energy technology systems required for electricity, heat and cooling generation. Replacement of the old cooking apparatus in the kitchen, using LPG or LNG, with electric apparatus would help in using solar electricity in the kitchen instead of fossil fuels. In the Mediterranean region, the required conditions for net zero carbon emissions campsites can be fulfilled with the use of: a) solar thermal energy for hot water production, b) high efficiency heat pumps for air-conditioning, and c) solar-PV electricity for lighting and operation of various electric devices including heat pumps and apparatus used in the kitchen.

6. A net zero carbon emissions campsite due to operational energy use

A conceptual design of a campsite which could cover all its operational energy requirements with renewable energy sources available in the Mediterranean basin is followed. In order to calculate the size of the required renewable energy systems, the following assumptions have been made:

1. Capacity of the campsite, 150 guests,
2. Annual operation, 180 days
3. Annual occupancy rate, 70%
4. Energy consumption, 10 KWh/p.n.s.

5. Share of electricity used in lighting, 12%,
6. Share of electricity used in the operation of various electric devices, 25%,
7. Share of energy used in space heating and cooling, 45%,
8. Share of energy used for hot water production, 18%,

It will be considered that in the campsite, there will be used: a) a solar thermal system for hot water production, b) a high efficiency heat pump for HVAC and c) a solar-PV system for generation of the electricity required. The campsite is grid-connected and the generated electricity with the solar-PV will be stored into the grid when it is not needed, according to the net-metering regulations. Additionally, it has been assumed that:

9. Annual electricity generation by the solar-PV is 1,500 KWh/KW_p,
10. SCOP of the heat pump is 3.5, and it will operate 12 hours daily for 6 months, in total 2,190 hours annually,
11. Annual heat generation by a solar thermo-siphonic system with flat plate collectors is 400 KWh_{th}/m^2
12. Cost of solar-PV system is 1,200 €/KW_p
13. Cost of heat pump is 2,000 €/KW
14. Cost of solar thermo-siphonic system is 300 €/m^2

Results from the calculation of the annual electricity and heating needs in the campsite are presented in Table 2.

Table 2: Annual electricity and heat requirements in the abovementioned campsite

Parameter	Value
Annual number of guest-nights	18,900
Total annual energy consumption	189,000KWh,
Annual electricity consumption for lighting	22,680 KWh,
Annual electricity consumption for the operation of electric devices without the heat pump	47,250 KWh,
Annual heating/cooling energy required for HVAC	85,050 KWh
Annual electricity consumption for the operation of heat pump used for HVAC	24,300 KWh
Annual heat requirements for hot water production	34,020KWh_{th}
Total annual electricity requirements for lighting, operation of electric devices and the heat pump in the campsite	94,230 KWh

Results from calculations regarding the size and the cost of the proposed sustainable energy technologies (SETs) for covering all the annual energy needs in the above-mentioned campsite are presented in Table 3.

Table 3: Size and cost of the sustainable energy technologies required for covering all the annual energy needs in the above-mentioned campsite

Sustainable energy system	Size	Energy generation (KWh)	Energy consumption (KWh_{el})	Capital Cost (€)
Solar-PV	62.82 KW_p	94,230 KWh_{el}		75,384
Solar thermal	85 m^2	34,020 KWh_{th}		25,500
Heat pump	11 KW	85,050 KWh_{th}	24,300 KWh_{el}	22,000
Total		213,300 KWh_{el+th}	24,300 KWh_{el}	122,884

The total installation cost of the required SETs per guest-site in the campsite is 819.23 € corresponding to 0.65 € per total KWh consumed annually in it. In the above-mentioned analysis, the fact that the existing trees in the campsite sequester atmospheric carbon has not be taken into account. If the sustainable energy systems installed in the campsite cannot generate the required energy for covering all its annual energy needs, then some quantities of fossil fuels would be used, resulting in carbon emissions. These carbon emissions could be offset with carbon sequestration from the existing trees in the campsite.

7. Discussion

The current study indicates that by using existing SETs in campsites located in the Mediterranean region, electricity, heat and cooling could be provided to them. Campsites according to the existing literature annually consume less energy compared with other types of tourism accommodation like hotels, apartments and bed and breakfast motels. The proposed zero carbon emissions energy technologies are mature, reliable, cost-effective and already used in many daily commercial applications. Their use can contribute towards the decrease of carbon emissions in tourism, attributed to accommodation, increasing the eco-efficiency of the hospitality industry. Solar energy which can provide heat and electricity in campsites is abundant in the Mediterranean basin, while the use of low carbon energy sources instead of fossil fuels is promoted by EU policies since their use contributes in climate change mitigation. The same methodology for the creation of zero carbon emissions campsites, due to operational energy use, can be applied in campsites located in other territories. If the availability of solar energy there is low, then other renewable energy sources like biomass, wind energy or geothermal energy could be used, combined with low carbon emission energy technologies. Our findings can assist owners and managers in campsites, as well as engineers, to design and implement energy renovation in their enterprises, increasing their energy efficiency and lowering the fossil fuels use and their carbon emissions. Since the technical and economic viability of many renewable energy technologies has been proved so far, their broad use in the future requires the removal of various barriers which already exist, combined with sensitization of the campsite's owners and travelers regarding the benefits of using the above-mentioned benign energy sources.

8. Conclusions

Decreasing or zeroing the net carbon emissions due to energy use in the tourism industry is assisting the mitigation of climate change. SETs could generate all the energy required in campsites covering all their energy needs, avoiding the use of fossil fuels in them. Various renewable energy sources which are abundant in the Mediterranean region could be used for heat and electricity generation in campsites. In the current study it has been indicated that the combined use of solar energy and high efficiency heat pumps could cover all the annual electricity, heat and cooling requirements in campsites located in the Mediterranean region. Their technical and economic viability has already been established since they are used in many daily commercial applications. In a campsite allowing the hosting of 150 guests, its annual total energy consumption has been estimated at 189,000 KWh while the total investment cost in various renewable energy technologies covering all its annual energy needs has been estimated at 122,884 €. It is concluded that there are no technical or economic barriers hindering the broad use of various renewable energy technologies in campsites in the Mediterranean region. The combined

use of these benign SETs could decrease or totally eliminate their annual carbon footprint due to operational energy use.

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