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### The Water-energy-tourism Nexus in the Island of Crete, Greece

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#### Abstract

Mediterranean islands are popular tourism destinations visited by millions of tourists every year while their natural resources are limited and often unable to support their growing tourism industry. The interrelation of tourism industry with energy and water resources in the island of Crete, Greece has been studied. The current status of tourism industry in Crete is reviewed as well as the availability of energy and water resources in the island. It has been estimated that the direct use of water in hotels is at 2.71 M<sup>3</sup> per tourist arrival while the energy consumption in hotels is at 124.55 KWh per tourist arrival. However, the indirect use of water by tourists is higher than the direct use while the energy consumption in tourists' transportation is significantly higher than the consumption in their

accommodation. Under normal hydrological conditions sufficient water resources can be supplied to local hotels and tourism accommodation facilities while adequate electricity can be also supplied to them. However, in order to avoid future water deficit in Crete which is going to adversely impact the local tourism industry several measures should be taken including: Water conservation measures in agriculture and in other sectors, water desalination, recycle of gray water and better management of the existing water resources. The abundant renewable energy resources of Crete should be used for heat and power generation in hotels. The results could be useful to stakeholders of the local tourism industry, to policy makers and to local authorities and residents.

**Keywords:** Crete-Greece, Energy, Interrelation, Sustainability, Tourism, Water

#### 1. Introduction

Tourism is the main industry in the island of Crete, Greece which is a popular tourism destination worldwide. Energy and water are fundamental resources in tourism industry. Solar and wind energy resources are abundant in Crete while they can be used for heat and power generation in a cost-effective way. However, the water resources are limited while future decrease in annual water precipitation could result in water deficit. Several studies have been implemented regarding the use of water in tourism industry (Gossling *et al*, 2012, Hadjikakou *et al*, 2013, Cole, 2012, *a pilot study on water and tourism*, 2009)<sup>[3, 5, 6, 20]</sup>. The water balance in the island of Crete has been also studied by various researchers (Baltas *et al*, 2013, Tzanakakis *et al*, 2020, Tzanakakis *et al*, 2022)<sup>[7, 8, 9]</sup>. Several studies have emphasized the importance of using RES in tourism industry (Asvanyi *et al*, 2017, Vourdoubas, 2018, Michalena, 2008)<sup>[2, 29, 34]</sup>. The use of renewable energies in water desalination plants has been investigated (Ghaffour *et al*, 2015, Mentis *et al*, 2016, Padron *et al*, 2019)<sup>[23, 21, 22]</sup>. The island of Crete is rich in RES while its water resources are rather limited. Both of them affect the local tourism industry which is foreseen to be adversely impacted in the future from climate change.

*The aim of the current research is to investigate the nexus between water, energy and tourism in the island of Crete, Greece.*

The structure of the text is as follows. After the literature review the impacts of tourism industry in Crete on the local water resources as well as on the production and consumption of energy are examined. Next, the impacts of energy on water resources and on tourism industry in the island are studied. After that, the impacts of water resources on the tourism industry and on energy in Crete are examined. The text ends with discussion of the findings, the conclusions drawn and the citation of the references used.

The current work fills the existing gap regarding the interrelation and the interconnections of water, energy and the tourism industry in the island of Crete, Greece. It is also innovative since there are not many similar studies published so far focusing on Mediterranean islands. It could be useful to policy makers, to several stakeholders of the local tourism industry as well as to local authorities and to citizens who are affected from the flourishing tourism industry in Crete which needs and consumes a significant share of the local natural resources.

## 2. Literature survey

Wang et al, 2023<sup>[1]</sup> have studied the tourism development under the water and energy constraints with reference the Xinjiang, China. The authors stated that the total water supply and the water footprint should be taken into account for the estimation of tourism development. They also mentioned that the development of green tourism in a location should take into account the water conservation policy, the promotion of digital tourism and the organization of environmental monitoring mechanisms. Asvanyi et al, 2017<sup>[2]</sup> have reviewed the use of renewable energy sources (RES) in tourism industry. The authors stated that renewable energies play a significant role in tourism industry although the research in this field is so far limited. However, they mentioned the potential of using RES in tourism accommodations is enormous. Gosling et al, 2012<sup>[3]</sup> have studied the supply, demand and security of water supply in tourism. The authors stated that the direct tourism-related water use is considerably less than 1% of the global water consumption. However, they mentioned, in dry tourism destinations the water resources might be limited. They also stated that the indirect water requirements in tourism industry is likely to be higher than the direct requirements. Bojnec et al, 2009<sup>[4]</sup> have studied the green energy supply in the tourism sector and its sustainable development in Slovenia. The authors stated that in Bohinj, Slovenia the existing hydroelectricity plant is an attraction for tourists. They also mentioned that the water resources in Bohinj are used for domestic water use, irrigation, power generation, in local industries as well as for tourism development. Hadjikakou et al, 2013<sup>[5]</sup> have estimated the direct and indirect water use in tourism in the Eastern Mediterranean region. The authors evaluated the water use in semi-arid eastern Mediterranean tourism destinations including Cyprus, Greece, Turkey and Syria. They stated that the direct and indirect water footprint in tourism industry depends on the type of tourism travel as well as on tourism accommodations. Cole, 2012<sup>[6]</sup> has studied the relation between water and tourism in Bali, Indonesia. The author stated that 80% of the economy in Bali depends on the hospitality industry while tourism depends on adequate water supply. She also mentioned that the ancient water distribution system has been displaced due to tourism development and water mismanagement resulting in water inequity and local social conflicts threatening the sustainability of the local tourism industry. Baltas et al, 2013<sup>[7]</sup> have studied the management of water resources in the island of Crete. The authors stated that the mean annual precipitation in Crete is 934 mm while 72% of the water is subject to evapotranspiration. They also mentioned that 85% of the water resources in Crete are used in agriculture while the annual water deficit is estimated at 143 hm<sup>3</sup>. Tzanakakis et al, 2020<sup>[8]</sup> have studied the sustainable management of water resources in the island of Crete, Greece. The authors stated that under average meteorological conditions Crete is self-sufficient in water resources with mean annual precipitation at 967 mm. Agriculture is the largest user of water consuming 78% of the total resources followed by domestic water use at 21%. They also mentioned that the groundwater in the island is overexploited while the efficiency in water use is low and the use of unconventional water resources is limited. Tzanakakis et al, 2022<sup>[9]</sup> have studied the water balance in Crete. They authors stated that 27.50% of the water resources are stored underground while

72.50% of it are lost into the sea. They evaluated the theoretical total water potential in Crete at 3,425.89 hm<sup>3</sup> per year. Vourdoubas, 2021<sup>[10]</sup> has studied the water-energy nexus in the island of Crete. The author stated that the annual electricity consumption in Crete is 4,793 KWh/capita while the annual water consumption per capita is around 763.9 M<sup>3</sup> to 962.2 M<sup>3</sup> per capita. He also mentioned that the nexus between water and electricity in Crete is asymmetrical and uneven. Electricity generation is not significantly dependent on freshwater resources while water utilization is dependent on electricity. The Hellenic Electricity Distribution Network Operator, 2018 has analyzed the power system in Crete in 2018. It was stated that electricity generation in Crete in 2018 was 3,042.8 GWh while the share of renewable energy sources (RES) in the total energy mix was at 21.2 %. Data for the tourism industry in Crete have been published by the Hellenic Statistics Organization, 2023. It was stated that the domestic and foreigner tourist's arrivals in Crete in 2022 was 5.9 mils while the total overnight staying were 32 mils. It was also mentioned that the average tourist's staying in Crete was 6.42 days while the total arrivals of tourists in 2022 in the island were almost the same as in the pre-Covid-19 year, at 2019, indicating the recovery of the tourism industry in Crete. Vandarakis et al, 2023<sup>[13]</sup> have studied the carrying capacity of the tourism sector in the South Aegean region, Greece. The authors examined 17 appropriate variables categorizing them as: a) physical-ecological indexes, b) social-demographic indexes, and c) political-financial indexes for assessing the tourism sector in these islands. They stated that Mykonos and Santorini islands have high indexes facing over tourism. Haribudiman et al, 2023<sup>[14]</sup> have examined the role of the carrying capacity of tourism destinations in the promotion of their sustainability. The authors considered five sectors which affect the carrying capacity in tourism destinations including the territorial, governance, economic, social and environmental. Their analysis aimed to maintain the natural, economic, social and environmental balances in tourism destinations. Osorio-Molino, 2023<sup>[15]</sup> have studied the methodologies and perspectives on tourism, energy and sustainability. The authors stated that the high dependence of tourism activities on energy consumption and on non-renewable energy sources is a major barrier in building tourism sustainability. They also mentioned that during the last 20 years several researchers have studied the relationships among tourism development, economic growth, energy use and environmental degradation. Maggi et al, 2010<sup>[16]</sup> have studied the carrying capacity of a tourism destination with reference the small coastal Italian city Vieste in Apulia region. The authors stated that the "tourism carrying capacity has not a universal definition" while some researchers have defined it as "a certain threshold level of tourism activity beyond which damages in the environment will occur including natural habitats". They also mentioned that recreational activities can disturb the ecological and social system in Vieste in a variety of ways including natural resources, beaches and social services. Santiago, 2021<sup>[17]</sup> has evaluated the energy use in hotels with reference the Gran Canaria islands, Spain. The author studied six hotels stating that their mean energy consumption per night spent (p.n.s.) was in the range of 5.61 KWh/p.n.s. to 14.01 KWh/p.n.s. He also mentioned that electricity was the main energy source used in these hotels having a share at 55% to 100% in their total energy mix. He

evaluated that these six hotels could use solar-PV modules in their available space in their premises meeting 8% to 30% of their total electricity demand. *Vourdoubas, 2020*<sup>[18]</sup> has studied the over tourism in Crete, Greece. The author stated that Crete is categorized as an overcrowded tourism destination among EU regions while its tourism indexes are above the EU and global average. The impacts of over tourism on the fragile natural ecosystems of Crete are potentially catastrophic having also undesired social consequences. *Vourdoubas, 2020*<sup>[18]</sup> has studied the nexus between tourism and renewable energies in the island of Crete, Greece. The author stated that the development of renewable energies results in climate change mitigation while the promotion of green tourism reduces its ecological footprint. He also mentioned that the dual development of renewable energies and tourism industry has positive impacts on the island's economic growth. *A pilot study on water and tourism, 2009* stated that the management of water resources is becoming a major challenge in Mediterranean countries and the tourism sector. It is also mentioned that the share of water demand in tourism to the total water consumption in Malta and in Cyprus is around 4.5% while in Greece and Tunisia is at 2%. *Mentis et al, 2016*<sup>[21]</sup> have studied the water desalination using RES in arid islands of the South Aegean Sea. The authors stated that water supply in arid Greek islands is problematic regarding its quantity and quality. They also mentioned that the use of locally available RES for water desalination can provide potable water at relative low cost. *Padron et al, 2019*<sup>[22]</sup> have studied the use of hybrid renewable energy systems in water desalination in two islands in the Canary archipelago, Spain. The authors analyzed the feasibility of hybrid renewable energy systems using solar and water power for water desalination of up to 50 M<sup>3</sup> of water per day. They evaluated the cost of green electricity used in the desalination plants at 0.404 \$/KWh. *Ghaffour et al, 2015*<sup>[23]</sup> have reviewed the use of RES in water desalination technologies. The authors stated that several medium-size water desalination plants have been installed worldwide. They also mentioned that geothermal energy provides an attractive option for water desalination particularly when low-cost and low-enthalpy geothermal energy is available. *Yoon, 2018* has studied the water-energy nexus in the tourist area of Benidorm, Barcelona, Spain. The author evaluated the energy intensity in the hotel sector in Benidorm. He stated that the water-energy nexus is complex and is influenced by ecological, political and social processes. *Boemi et al, 2011*<sup>[25]</sup> have studied the energy performance of hotel buildings. The authors used the top-down and the bottom-up approach in order to determine the energy consumption of typical Hellenic hotels and developing a strategic plan for improving their energy and environmental performance. *An analysis on energy use in European hotels has been published, 2011*. It is stated that in EU hotels the energy use varies in the range of 200 KWh/m<sup>2</sup> year to 400 KWh/m<sup>2</sup> year while in most of them varies in the range of 305 KWh/m<sup>2</sup> year to 330 KWh/m<sup>2</sup> year. *Rodriguez-Urrego et al, 2022* have analyzed the water-energy nexus in Tenerife island, Spain. The authors investigated two scenarios for the future including the "business as usual" scenario and the "ecology-aware" scenario. They stated that in the "ecology-aware" scenario solar and wind energy were the only RES used for power generation. However, the

installation of solar and wind energy systems requires large land areas which are limited in Tenerife island. *Albatayneh, 2023*<sup>[28]</sup> has studied the water-energy-food nexus to tackle climate change in Eastern Mediterranean region. The author stated that integrating water, energy and food systems can generate synergies to help Eastern Mediterranean countries to solve climate change related issues. He also mentioned that renewable energy is a critical component in assisting the water, energy and food nexus to cope with the problems faced by climate change. *Vourdoubas, 2018*<sup>[29]</sup> has investigated the possibility of achieving net-zero emission hotels in Mediterranean region. The author stated that the combined use of solar-thermal energy, solar photovoltaic energy and high efficiency heat pumps can meet all the energy needs in Mediterranean hotels achieving their net-carbon neutrality due to energy use. *Hoekstra et al, 2012*<sup>[30]</sup> have studied the water footprint of humanity. The authors stated that the annual average global water consumption was at 1,385 M<sup>3</sup>/capita during the period 1996-2005 while agriculture was the main water consumer having a share at 92% in the total water consumption. They also mentioned that the industrialized countries had annual water consumption in the range of 1,250 M<sup>3</sup>/capita to 2,850 M<sup>3</sup>/capita while 74% of the water used was rainwater, 11% ground and surface water while 15% was treated polluted water. *Feraso et al, 2021* have studied the water inequalities in EU countries. The authors stated that water scarcity is becoming a global concern for many reasons as water consumption increases. They also mentioned that Greece was among the EU countries with high quotient of fresh surface water withdrawal while it was ranked first regarding agricultural water withdrawal. *Vourdoubas, 2023*<sup>[32]</sup> has studied the interconnection of the electric grid of Crete with the grid of continental Greece. The author stated that after the interconnection of the electric grid of the island, which is foreseen to be finalized by 2025, its clean energy transition can be achieved. He also mentioned that the abundant solar and wind energy resources of Crete can be deployed for electricity generation over-meeting the annual power demand of the island. *Fernandez-Gil et al, 2019*<sup>[33]</sup> have studied the sustainable water generation in the Greek island Skyros. The authors stated that population growth, increasing droughts and high irrigation needs create deficit in fresh water. They proposed the construction of a water desalination plant powered by local RES and a system recycling the treated sewage for irrigation of crops. They evaluated the total water production cost at 2.49 €/M<sup>3</sup> which is lower than the current cost of water transportation from the mainland. *Michalena, 2008*<sup>[34]</sup> has studied the use of renewable energies in Mediterranean islands to promote sustainable tourism. The author stated that islands are highly vulnerable to climate change which should be mitigated by the use of RES instead of fossil fuels. She also mentioned that the promotion of RES for energy generation in islands is compatible with sustainable tourism development. The arrivals of tourists in Crete in 2022 are presented in Table 1.

**Table 1:** Arrival of tourists in Crete in 2022

Number of tourists	5,905,137
Nights spent in Crete	32,025,147
Average days of staying in Crete	6.42 days

**Source:** Greek Statistics Organization, 2023

### 3. Impact of tourism industry on water resources in Crete

Tourists utilize water during their vacations in their accommodation as well as in various activities. The water consumption in hotels and other tourism accommodations is high including the direct and the indirect water use, related with food preparation et cetera. The direct water use per tourist in several tourism destinations is presented in Table 2. Taking into account the water deficit in many popular tourism destinations in Mediterranean region the water requirements in tourism industry affects its availability in other uses including domestic water use, irrigation of crops, industrial use et cetera. Existing studies indicate that water consumption in tourism industry varies between 4.5% of the total water consumption in Malta and Cyprus to 2% in Greece and Tunisia (*Medstat II: "Water and Tourism", 2009*)<sup>[20]</sup>. Water precipitation in the western part of Crete is significantly higher than its eastern part while the direct water consumption in tourism accommodations consists only 0.48% of the total water consumption in the island

(Table 7). Higher-class hotels have higher water consumption than lower-class hotels while they also have higher water use index which varies in the range 3.3 M<sup>3</sup> of water per M<sup>2</sup> of covered surface (lower-class hotels) to 5.1 M<sup>3</sup> of water per M<sup>2</sup> of covered surface (higher-class hotels) (*Gossling et al, 2012*)<sup>[3]</sup>. The construction of new higher-class hotels during the last years in Crete results in higher water consumption. The direct water usage in hotel industry including the water consumption in accommodation and in several activities is lower than the indirect water consumption including the water used in food, transportation and in infrastructure (*Gossling et al, 2012*)<sup>[3]</sup>. When the food used in Cretan hotels is imported from other countries it includes the water consumption in other countries required for the production of the imported food. Tourism industry might pollute the fresh and sea water if the liquid wastes of several tourism accommodations are not properly treated. It could also damage several fragile coastal ecosystems when an excessive number of tourists visit areas of extreme natural beauty.

**Table 2:** Water use per tourist in several tourism destinations

Country/Region	Type of accommodation	Water use per tourist per day (Lit/tourist day)
Mediterranean region	All accommodation	440-880
Benidorm, Spain	4 stars hotels	361
Tunisia	Hotels	466
Morocco	5 stars hotels	500
Sharm El Skeikh, Egypt	Hotels	400
Philippines	4 stars hotels	1,802 (per room)
Melbourne, Australia	Various	227-435
Las Vegas, USA	Hotels	303
Germany		340
Scandinavia	Hotels	216-516
Normandy, France	Hotels	175

Source: Gossling et al, 2012<sup>[3]</sup>

### 4. Impact of tourism industry on energy production and consumption in Crete

The tourism industry in Crete consumes large amounts of energy including electricity and oil-based fuels during the transportation of visitors to Crete, their inland travelling, their staying in several accommodations and in during their activities. Tourists arriving to Crete from long distances consume large amounts of oil-based fuels in the incoming and outgoing flights. Significant amounts of oil-based fuels are also consumed during their inland travelling by buses or by cars. The energy consumption of tourists in hotels is presented in Table 3. Taken into account the average staying of tourists in Crete at 6.42 days and their daily energy consumption in hotels at 19.4 KWh/p.n.s. it is concluded that the energy consumption in Cretan hotels is at 124.55 KWh per tourist arrival. The total energy consumption in Cretan hotels at 621,285 MWh/year

corresponds at around 20% of the total electricity consumption in Crete in 2018 which was 3,043,000 MWh/year (Tables 5 and 7). Therefore, the tourism industry in Crete consuming large amounts of electricity has a high impact on the local electric grid particularly during the hot summer days. The quality and the reliability of the grid power in Crete is satisfactory while the interconnection of the Cretan grid and the continental grid in the coming years will improve its stability and reliability. According to the current policies hotel buildings should reduce their energy consumption becoming nearly-zero energy buildings. Tourism accommodations are currently incentivized to generate their own energy using RES in order to become carbon neutral. Their energy renovation will decrease the grid electricity usage and the carbon emissions in the hospitality sector in Crete.

**Table 3:** Energy consumption per tourist in hotels

Country/Region	Annual energy consumption per m <sup>2</sup> of covered surface in hotels (KWh/m <sup>2</sup> year)	Energy consumption per night spent (KWh/p.n.s.)	Sources
Europe	200-400		Hotel energy solution, 2011
Canary Islands, Spain		5.61-14.01	Santiago, 2021
Island of Crete, Greece	149	19.4	Vourdoubas, 2016

Source: Several references

**5. Impact of energy on water resources in Crete**

Production, processing, transportation and distribution of water requires significant amounts of electricity. Power is used for pumping water from underground reservoirs and surface water. Electricity is necessary in processing water for domestic and industrial use as well as for distributing it to the final users. Electricity is also required in sewage treatment plants as well as in water desalination plants. Therefore, energy is required in all stages of water production, processing, transportation and distribution in Crete. It is foreseen that due to climate change and to reduced water precipitation the island will face water deficit in the near future and the development of water desalination plants will be necessary. Water desalination is an energy intensive process while desalination plants in Crete can be powered by the solar and wind electricity which can be easily generated locally with wind turbines and solar-PV systems. Additionally, the effluents from the municipal sewage treatment plants should be recycled and used either for irrigation or for industrial water use reducing the need for fresh water resources.

**6. Impact of energy on tourism industry in Crete**

Energy is a fundamental resource in tourism industry. Tourists utilize energy during the transportation to and from Crete, during their staying in tourism accommodations, during the inland travelling and in several activities during

their vacations. They arrive in Crete either by airplanes or by boats while air- and sea transportation utilizes large amounts of energy. Estimations regarding the energy use in different sectors of tourism industry in Crete have indicated that energy consumption in Cretan tourism industry is dominated by the consumption during the arrivals and departures of the visitors in the island. Hotel buildings are energy intensive buildings consuming large amounts of energy compared with other public and private buildings while only hospitals have higher energy intensity than hotels. The majority of hotels in Crete are summer operating hotels utilizing mainly grid electricity while the use of oil-based fuels and solar energy is rather limited. Electricity is mainly produced in Crete with oil-based fuels while solar and wind energy have a share in the total electricity mix slightly higher than 20% as is presented in Table 5. Renewable energies are currently used in several hotels and tourism accommodations in Crete for heat, cooling and power generation as is presented in Table 4. Solar energy is the most popular benign energy source used in Cretan hotels for domestic hot water production and for electricity generation. However, the available space in hotels for the installation of solar energy systems is often limited particularly in city hotels. Geothermal and energy efficient heat pumps are also extensively used for heat and cooling production. Solid biomass and passive solar systems including green roofs are also used in several hotels.

**Table 4:** Use of renewable energy systems in hotels in Crete

Energy source/technology	Electricity	Heat-space heating	Heat-hot water	Cooling-space cooling
Passive solar		Yes		Yes
Solar thermal			Yes	
Solar-PV	Yes			
Solid biomass burning		Yes	Yes	
Geothermal heat pumps		Yes	Yes	Yes

Source: Vourdoubas, 2020

**Table 5:** Electricity consumption in Crete in 2018

Electricity consumption	3,043 GWh
Residents in Crete	670,000
Electricity consumption per capita	4,542 KWh/year
Share of RES in the electricity mix	21.20 %

Source: The energy system of Crete, 2018

The “energy tourism”, targeting a specific segment of visitors, which is based on guided tours of tourists in existing renewable energy installations in the island will probably grow in the near future.

**7. Impact of water resources on tourism industry in Crete**

Water like energy is a basic resource in tourism accommodations. The island of Crete is currently considered as self-sufficient in water resources assuming the rational management of the available resources (8, 9). Climate change though is foreseen to have negative impacts in water precipitation in many tourism destinations, including Crete, resulting in future water deficit. The water usage in various sectors in the island in 2016 is presented in Table 6. Crete has unequal water availability in the Western and the East part of the island while crops’ irrigation consumed in 2016 around 80% of the total water resources in the island. The deficit of water resources in the future in Crete might result in conflicts among various users and social protests regarding its use for domestic purposes, in agriculture and in

tourism industry. However, tourism destinations in Mediterranean region, like Crete, have abundant solar and wind energy resources. This fact facilitates the desalination of sea water using locally available renewable energies like solar and wind energy while their technologies for power generation are mature, reliable and cost-efficient. The use of low-cost solar and wind electricity, generated by wind farms and solar photovoltaic systems, in desalination plants can produce potable water at affordable cost which can be used in tourism industry. The recycle of the treated effluents in various hotels irrigating their gardens consists of a good practice for the efficient utilization of the limited water resources in the island. In order to cope with the expected future water shortages in Crete, due to climate change, hotels should be focused in water conservation, in recycling grey water and in the increased use of desalinated water in their facilities which should be produced in local communities. Additionally, the development of appropriate policies from local authorities in Crete, regarding water saving in agriculture, which consumes large quantities of water, is required.

**Table 6:** Water use in Crete in 2016 (hm<sup>3</sup>/year)

Source	Domestic	Agriculture	Livestock	Industry	Total	Total per capita (M <sup>3</sup> )
Surface water	39.40	34.60	2.10	0.27	76.37	100.49
Sub-surface water	88.21	443.81	2.08	0.48	534.58	131.66
Total	127.65	478.39	4.16	0.75	610.94	189.55
Consumption rate (%)	20.89	78.30	0.68	0.12		

Source: Tzanakakis *et al.*, 2020<sup>[9]</sup>, Own estimations

## 8. Impact of water resources on energy production and consumption in Crete

Electricity is mainly generated in Crete by thermo-electric power plants using fuel oil and diesel oil while its generation cost is high. The share of solar and wind electricity in the energy mix is currently low at around 21%. After the interconnection of the electric grid of the island, in the next 1-2 years, it is foreseen that power generation in Crete will be based on local RES and on imported low-cost electricity from the mainland. The use of water in the operation of wind farms and solar photovoltaic systems is limited. Heat is currently generated in Crete using oil-based

fuels, solid biomass and solar thermal energy. The water use during heat production is also limited. Therefore, generation of heat and electricity in Crete does not require significant amounts of water resources. Hydroelectricity is not currently generated in Crete and water resources are not used for power generation. Probably water is going to be used in pumped water storage systems which are going to be developed in the future in the island. Heat or/and power generation in Cretan hotels using mainly RES does not require water resources. The energy and water consumption in hotels in Crete are presented in Table 7.

**Table 7:** Energy and water consumption by tourists in hotels in Crete (2022)

Number of tourist arrivals in Crete	5,905,137
Number of tourist nights spent in Crete	32,025,147
Energy consumption of tourists in hotels	19.4 KWh/p.n.s.
Total energy consumption of tourists in hotels	621,285 MWh/year
Total energy consumption in hotels per tourist arrival	124.55 KWh per tourist arrival
Water consumption of tourists in hotels	500 lit per tourist per day
Water consumption in hotels per tourist arrival	2.71 M <sup>3</sup>
Total water consumption of tourists in hotels in Crete	2.95 hm <sup>3</sup> /year
Water consumption by tourists in hotels to total water consumption in Crete	0.48%
Water consumption by tourists in hotels to total water consumption in domestic uses in Crete	2.31%

Source: Own estimations, Vourdoubas, 2021

## 9. Discussion

The nexus between water resources, energy and the tourism industry in Crete has been studied. Water and energy are indispensable resources in tourism industry which is flourishing in Crete. Water, energy and tourism in the island are interlinked and interconnected affecting each other. Crete, like other Mediterranean islands, has limited water resources but it is rich in renewable energy resources. Direct water consumption by tourists in Crete has a share at around 0.48% in the total water consumption in the island while agriculture is the main water consumer having a share at around 70% in the total water consumption. The energy consumption in hotel buildings is high while the direct energy use in hotels and other tourism accommodations in the island corresponds at around 20% of the total electricity consumption in Crete. Water resources are unevenly distributed between the west and the east part of Crete which is self-sufficient in water resources under normal hydrological conditions. However, in order to avoid future water shortages in the island water conservation in tourism industry and in agriculture is required as well as desalination of sea water, recycle of grey water and better management of the existing water resources. Crete has abundant renewable energy resources particularly solar and wind energy which can be used for heat and power generation in hotels as well as in other sectors minimizing the use of fossil fuels in the island. Solar and wind energy can be used in a cost-effective way for water desalination meeting the water demand in the future. Water and energy are basic resources in tourism industry which is growing rapidly in Crete. Water

shortages might be faced in the future resulting in local social conflicts. However, current advances in water and energy technologies combined with better regional policies can minimize the conflicts related with the efficient supply of these fundamental resources in various sectors in Crete. Future research should be focused on the optimum use of water and energy resources in Crete for achieving the sustainability in the local tourism industry. Additionally, on the impacts of climate change on water availability in the island which affects the future of the local tourism industry.

## 10. Conclusions

The nexus between tourism industry, water resources and energy in the island of Crete, Greece has been investigated. The findings of the present work can be summarized as follows:

1. The island of Crete is a popular global tourism destination while the local tourism industry is flourishing,
2. Water and energy are basic resources in tourism industry which depends on the smooth supply of them,
3. Crete is self-sufficient in water resources under normal hydrological conditions which though are unevenly distributed between the western and the eastern part of the island,
4. The water consumption in Cretan hotels has a small share, at 0.48%, to the total water consumption in the island,
5. Coping with the higher demand of water resources in the future in Crete might require the recycle of grey

water, use of desalinated water and improving the water conservation techniques,

6. The abundant solar and wind energy resources in Crete can be used in a cost-effective way for water desalination meeting the future water demand,
7. Hotel buildings consume high amounts of energy compared to other private and public buildings while Cretan hotels currently utilize mainly grid electricity,
8. Electricity supply to hotels is sufficient while electricity generation in Crete is currently related with oil- based fuels,
9. Solar energy can be used in Cretan hotels to meet a significant amount of their heat and power needs, and
10. Crete has abundant solar and wind energy resources which can be used in the future for heat and power generation providing green electricity to hotels and eliminating the use of fossil fuels in the island.

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