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The Nexus Among Energy, Water and Climate Change in the Island of Crete, Greece

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ABSTRACT: Water and energy consist of essential resources necessary for the prosperity of modern societies. Both of them affect and are affected by climate change. The island of Crete, Greece is located in eastern Mediterranean region which is adversely affected by climate change. The island faces water shortages which are exacerbated by climate change. The interrelation between water, energy and climate change in Crete has been investigated. The water-energy nexus, the water-climate change nexus and the energy-climate change nexus have been studied. Water management in Crete requires large quantities of energy while climate change has undesired impacts on its availability. Energy generation in Crete is currently based mainly on fossil fuels while the island has abundant solar and wind energy resources which should replace fossil fuels in the future. Our results, although qualitative, indicate that water, energy and climate change in Crete are interlinked and interdependent. The sustainable management of the water resources and the energy system in Crete and the need to mitigate and adapt to climate change should take into account these interrelations for improving the long-term efficiency of these basic resources. Our results could be useful to local authorities, to policy makers and to local residents who depend on these resources.

KEYWORDS: climate change, Crete-Greece, energy, interrelation, water resources

1. INTRODUCTION

Energy and water resources are essential for the prosperity of human societies [1], [2]. They are interdependent and interlinked while they both affect and are affected by climate change [3], [4], [5]. Many studies have been conducted focused on the investigation of the water-energy nexus and their linkage with climate change [6], [7], [8], [9]. The island of Crete, Greece is located in the eastern Mediterranean which is adversely affected by climate change while its energy economy is dominated by fossil fuels although it has abundant solar and wind energy resources [10], [11], [12], [13]. Crete as well as other islands in this territory are facing water shortages which are exacerbated by climate change [14].

The aim of the current work is to investigate the interlinkages and interdependences among water, energy and climate change in the island of Crete.

The text is structured as follows: After the literature survey the water resources, the energy system and the impacts of climate change on the island of Crete are analyzed. In the next sections the interdependence between energy and water, energy and climate change and water and climate change in Crete are explored. The text ends with discussion of the findings, the conclusions drawn and the citation of the references used.

The present work is innovative since there are not many studies so far regarding the nexus among water, energy and climate change in Crete while it fills a gap regarding the impacts of climate change on essential resources in Crete. The results of the current study could be useful to public authorities in Crete, to policy makers and to private and public organizations which depend on these basic resources in the island.

2. LITERATURE SURVEY

The energy-for-water data in energy-water nexus publications have been reviewed [1]. The authors reviewed 170 published studies stating that the most prevalent geographic scale was at individual city scale, at 39%. They also mentioned that the energy for water studies reviewed are related with 34 different countries. The energy-water nexus has been studied [2]. The authors stated that in recent years the energy and water sectors have undergone rapid reform due to security of supply, sustainability and economic efficiency. They also stated that when water and energy rely on each other many complex challenges are posed for policy makers. A report on water-energy nexus in Europe has been published [3]. It is stated that the EU energy sector currently requires 74 billion M^3/year of freshwater similar to the water needs in agriculture. It is also mentioned that the energy consumed to collect, pump and treat this amount of water represents 2.6% of the EU electricity consumption. The water-energy nexus of Nisyros island has been studied [4]. Nisyros island is a small remote volcanic island located in the Greek island complex of Dodecanese with restricted water resources and abundant solar and wind energy resources. The authors proposed a solar PV-based power configuration to fuel a seawater desalination unit covering the water needs in the island. An overview of the water-energy nexus in USA has been reported [5]. It is stated that the energy and water systems are interdependent while a more integrated approach to address the challenges and opportunities of the water-energy nexus are needed. The water-energy-environment nexus has been examined [6]. The authors analyzed thirteen high quality paper concerning energy, water and environment systems. They stated that water, energy and environment have been closely interwoven among the natural, social and economic networks. The water-energy –greenhouse gas (GHG) nexus in urban water systems has been explored [7]. The authors stated that water supply and wastewater services require a large amount of energy and are related with GHG emissions. They mentioned that the link between water and energy is important as their availability and demand are closely interrelated. A report for climate change in the Mediterranean has been published by UN [8]. The report stated that the Mediterranean region is warming 20% faster than the global average. It is also mentioned that by 2050 the water demand is projected to double or even triple in this area while a 2ºC temperature increase will reduce precipitation in the region by about 10%-15%. Several case studies regarding the impacts of climate change on European islands have been published [9]. The report stated that Greece is expected to be hit hard economically by climate change. It is also mentioned that the main impacts of climate change on the Greek islands include decrease in water availability with lower precipitation rates, higher land and sea temperatures, sea level rise, reduced crop yields, increased risks of droughts and increased frequency and intensity of heat waves. The water-energy nexus in the island of Crete, Greece has been studied [10]. The author stated that the annual electricity consumption in Crete is at 4,793 kWh/ capita while the annual water consumption is in the range of 763.9 M^3/capita to 962.2 M^3/capita. The reshaping of the energy landscape of Crete through renewable energy valleys has been explored [11]. The authors stated that the concept of renewable energy valleys integrate advanced information and communication technologies, digital solutions, social innovation processes and economic viable business models for renewable energy systems. They also presented a case study of renewable energy valleys in Crete. The interconnection of the electric grid of Crete and its contribution to the clean energy transition has been investigated [12]. The author stated that the maximum power that can be transferred through the two undersea electric cables is higher than the maximum power demand in Crete which currently does not exceed 700 MW. He also mentioned that the green electricity generated by wind farms and solar-PV systems in Crete is higher than 20% of its annual electricity demand. The possibility of energy independence in Crete has been explored [13]. The authors stated that the use of renewable energy technologies combined with power storage systems such as pumped hydro storage can help Crete to become energy independent. The sustainable management of water resources on the island of Crete, Greece has been analyzed [14]. The authors stated that under average meteorological conditions the island is water-sufficient with average annual precipitation at 967 mm. They also mentioned that agriculture is the greatest user of water, with 78% of total water use, followed by domestic use at 21%. The water-energy nexus in China has been studied [15]. The authors stated that both resources are scarce in China while they focused on the energy implications of water use. They mentioned that the energy used both directly and indirectly in providing non-agricultural water supply currently represents only a small fraction of China's total energy consumption. The water-energy nexus in the island of Tenerife, Spain has been studied [16]. The authors stated that the water-energy nexus is strong which can be extended to similar insular systems with scarce energy and water resources. They also mentioned that as the availability of groundwater resources diminishes the energy cost of supplying the water demand from other sources will increase sharply. The climate change impacts on the water-energy-food-ecosystems nexus in Trentino region in the North-Eastern Italian Alps have been reviewed [17]. The authors stated that in Trentino most studies focus on ecosystems followed be water and food. Regarding the nexus, the water sector exhibits the majority of interconnections with other components. The inclusion of water quality in the management of the water-energy-food nexus in Caribbean small island states has been examined [18]. The authors mentioned that these islands have unstable water-energy-food nexus conditions while the stress is becoming more acute via climate change and the increasing tourism industry. They also stated that rainwater harvesting is an important alternative water source for individual households and small communities while water reuse from tourism entities has great potential in these islands. The climate change impacts on the frequency of hydrometeorological extremes in Crete have been studied [19]. The authors studied three temporal periods at 1985-2010, 2025-2050 and 2075-2100 stating that drought events, extreme precipitation and intense flow events will increase in the future in Crete. The water-climate nexus has been studied [20]. The authors stated that water security and climate change are important priorities for communities and regions worldwide. They studied the intersections between water and climate across drinking water, sanitation, food, agriculture and energy. The energy transition in Greek islands with the development of energy communities has been explored [21]. The authors stated that the legacy of lighthouse energy projects in small Greek islands such as Kythnos, Ikaria, Thilos et cetera combined with the movement of energy communities can facilitate the clean energy transition of the Greek islands. The climate change impacts on energy generation from renewable energies in the island of Crete, Greece has been studied [22]. The author stated that climate change during the 21st century is going to increase the solar energy potential in Crete by around 4% while the wind energy potential is going to decrease by 6-12%. A report regarding the climate change effect in the Mediterranean has been published [23]. It is stated that climate change has serious impacts on the ocean and a depleted ocean further exacerbates the effects of climate change. Therefore, the protection of ocean contributes to the fight against climate change. The water-energy nexus trends and future prospects have been reviewed [24]. The authors stated that understanding the nexus can help in achieving the sustainable development goals. They also mentioned that there is not a universal agreed methodology which could be used in studying the water-energy nexus. The methods and tools for assessing the water-energy nexus have been reviewed [25]. The authors stated that there are many approaches for understanding the water-energy nexus. They mentioned that there is a significant increase in analyzing the water-energy interdependencies while there is an increasing effort to assess the water and energy interlinkages. The strategic pillars to address the water-energy nexus are presented in table 1.

Table 1. Strategic pillars to address the water-energy nexus

1	Optimize the fresh water efficiency in energy generation
2	Optimize the energy efficiency in water management and treatment
3	Enhance the reliability and resilience of energy and water systems
4	Increase safe and productive use of non-traditional water sources
5	Exploit productive synergies among water and energy systems

Source: [5]

3. THE WATER RESOURCES IN CRETE

Crete, the largest island of Greece, faces unique challenges and opportunities in managing its water resources. The island's semi-arid climate, characterized by hot, dry summers and mild, rainy winters, creates strong seasonal variations in water availability. Although Crete receives a relatively high annual rainfall compared to other parts of Greece, the distribution is uneven—concentrated mostly in the mountainous western regions, while the eastern areas often face drought conditions.The island relies on a combination of surface water, groundwater, and small-scale reservoirs to meet the needs of its population, agriculture, and tourism sector. Mountain ranges such as the Lefka Ori and Psiloritis play a crucial role, capturing rainfall and snow that feed rivers, springs, and underground aquifers. However, many rivers are seasonal, flowing only during winter and spring, which limits their reliability as a consistent water source. Groundwater has historically been the most important supply, but over-extraction has led to problems such as falling water tables and seawater intrusion in coastal aquifers. These issues are particularly pressing in eastern Crete, where agriculture and tourism compete for limited resources. To address this, local authorities have invested in water storage projects, such as small dams and artificial lakes, which help regulate supply throughout the year. Tourism, a cornerstone of the island's economy, further intensifies water demand, especially during summer when natural resources are already strained. At the same time, agriculture—especially olive cultivation and greenhouse farming—consumes a significant share of available water. Modern irrigation techniques, such as drip systems, are increasingly promoted to improve efficiency and reduce waste.Therefore, while Crete is relatively rich in natural springs and rainfall compared to many Mediterranean islands, the pressures of climate change, overuse, and uneven distribution make water management a constant challenge. Sustainable practices, careful planning, and public awareness will be vital to secure Crete's water future. Table 2 indicates the water uses in Crete in 2016.

Table 2. Water uses in Crete (2016)

Sector	%, consumption
Domestic	20.89
Agriculture	78.30
Livestock	0.68
industry	0.12

Source: [14]

4. THE ENERGY SYSTEM IN CRETE

Crete, the largest island in Greece, has a unique and complex energy system shaped by its insular geography, high energy demands, and growing emphasis on sustainability. For decades, the island's electricity has been generated mainly from oil-fired power plants, making the energy system both costly and environmentally unsustainable. Due to its isolation from the mainland grid, Crete has relied heavily on imported fossil fuels, which contribute significantly to greenhouse gas emissions and expose the island to price fluctuations in global energy markets. In recent years, however, Crete has emerged as a key testing ground for Greece's transition to renewable energy. The island's natural conditions provide considerable potential for clean energy production. With abundant sunlight, strong winds, and significant geothermal and biomass prospects, Crete is well-positioned to reduce its reliance on fossil fuels. Already, solar and wind installations contribute a growing share to the energy mix, though intermittency remains a challenge. To address these issues, energy storage and grid modernization projects are underway. The interconnection of Crete with the Greek mainland's power grid, one of the largest infrastructure projects in the country, is expected to secure reliable electricity supply, reduce dependence on oil, and facilitate greater integration of renewable sources. The interconnection is consisted of: a) The small-scale interconnection between the prefecture of Chania and Peloponnesus 150 kW AC, 2X200 MVA. The project has been finalized one year ago, and b) The large-scale interconnection between the prefecture of Heraklion and Attica, DC interconnection, capability 2X350 MW. The project has been recently finalized and it is in the test phase. The interconnection project represents a turning point, enabling Crete not only to meet its own energy needs more sustainably but also to contribute to Greece's broader decarbonization goals. Energy efficiency is also a growing priority, particularly in the tourism sector, which drives high seasonal consumption. Hotels, resorts, and households are increasingly encouraged to adopt energy-saving technologies and renewable energy installations.Therefore, the energy system in Crete is undergoing a major transformation. From dependence on fossil fuels, the island is steadily moving toward a sustainable model based on renewable energies, innovation, and interconnection—offering a blueprint for other Mediterranean islands facing similar challenges. Table 3 indicates several characteristics of the electric system of Crete in 2018.

Table 3. Several characteristics of the electric system of Crete (2018)

Parameter	Value	%
Annual electricity generation	3,043 GWh	100%
Maximum power demand	684.6 MW	
Total installed power of thermo-electric plants	824.6 MW	73.56%
Total installed power of wind farms	200.3 MW	
Total installed power of solar-PV systems	95.5 MW	
Total installed power of hydroelectric plants	0.6 MW	
Total installed power of renewable energy systems	296.4 MW	26.44%
Annual electricity generation from thermo-electric plants	2,398 GWh	78.80%
Annual electricity generation from renewable energy systems	645 GWh	21.20%
Total installed power in Crete	1,121 MW	

Source: [12]

5. THE CLIMATE CHANGE IN CRETE

Crete, the largest island of Greece, is highly vulnerable to the impacts of climate change due to its geographical location in the eastern Mediterranean. The island already experiences a Mediterranean climate, with hot, dry summers and mild, wet winters, but recent decades have shown clear signs of climatic shifts. These changes threaten not only the island's natural environment but also its economy and society, which rely heavily on agriculture and tourism. One of the most evident effects of climate change in Crete is the increase in average temperatures. Heatwaves have become more frequent and intense, leading to higher risks of drought and wildfires. At the same time, rainfall patterns are changing. While the total annual rainfall is gradually decreasing, extreme weather events such as sudden storms and flash floods are becoming more common, causing soil erosion and damage to infrastructure. This irregular distribution of water resources poses a serious challenge for farmers and residents.Agriculture, one of Crete's main economic sectors, is particularly affected. Olive groves, vineyards, and greenhouses depend on stable weather conditions and adequate water supply. With climate change reducing rainfall and straining groundwater reserves, farmers face declining yields and higher costs for irrigation. Similarly, tourism, which thrives on the island's natural beauty and mild climate, is threatened by hotter summers, water shortages, and environmental degradation. Coastal areas of Crete are also at risk due to rising sea levels, which increase the likelihood of erosion and saltwater intrusion into freshwater reserves. Such impacts highlight the urgent need for adaptation strategies. Efforts are already being made to promote sustainable water management, renewable energy, and eco-friendly tourism. Therefore, climate change in Crete is not a distant concern but a present reality. Mitigation measures, combined with resilience planning, are essential to protect the island's environment, economy, and communities for future generations. Table 4 indicates some aspects of the climate change in the Mediterranean region.

Table 4. Some aspects of climate change in the Mediterranean region

1	The Mediterranean region is warming 20% faster than the global average
2	Coastal zones face heightened disaster risks, including flooding and erosion
3	By 2050 water demand is projected to double or triple

4	2°C global warming will reduce precipitation by around 10-15%
5	A temperature increase of 2°C to 4°C would reduce precipitation by up to 30% in Southern Europe

Source: [8]

6. THE IMPACTS OF THE ENERGYSYSTEM ON WATER RESOURCES IN CRETE

Crete's water infrastructure—from pumping and treatment to distribution—plays a pivotal role in the island's daily life and economic stability. Yet beneath these systems lie an intricate energy footprint that is both a challenge and an opportunity for sustainable management. A study of the water–energy nexus in Crete [10] reveals that electricity consumption per capita stands at approximately 4,793 kWh/year, while water usage ranges between 763.9 to 962.2 m³ per person annually. This electricity fuels nearly every stage of water handling: extraction from underground sources, pumping across diverse terrain, municipal treatment, distribution, desalination, irrigation operations, and wastewater processing. Energy is also used for hot water production in several applications. Crete relies predominantly on groundwater, given its unevenly distributed surface water and moderate overall resources. Extracting and distributing this water requires powerful electric pumps—a dependency that highlights how water systems in Crete are heavily reliant on consistent energy supply. Renewable integration offers promise: some pumping stations already incorporate solar-PV plants to partially offset grid electricity use. Sewage treatment plants in Crete use also energy in the treatment process. Furthermore, sea water desalination is an energy-intensive water supply method requiring electricity. Despite these advances, energy dependence remains pronounced: an estimated 80% of electricity used in water production, treatment and distribution in Crete still comes from fossil fuel–derived grid power. This underscores a structural asymmetry: water systems are energy-intensive, and energy for these systems still relies heavily on oil and diesel imports, even as renewable energies' share grows.Water systems—such as pumping, treatment, and sewage—are energy-intensive, often powered by fossil fuel–based grid electricity. Table 5 indicates the impacts of the energy system on water resources in Crete.

Table 5. The impacts of the energy system on water resources in Crete

1	Energy is required in pumping, purification and distribution of underground water in urban areas
2	Energy is required in pumping and distribution of underground water in irrigation
3	Energy is required in sewage treatment plants
4	Energy is required in sea water desalination plants
6	Energy is required for hot water production

Source: Own estimations

7. THE IMPACTS OF WATER RESOURCES ON THE ENERGY SYSTEM IN CRETE

While water often plays a supporting role in energy systems globally, Crete demonstrates an interesting dynamic where energy systems operate with minimal reliance on fresh water**,** especially compared to the reverse dependency seen in its water systems. According to comprehensive regional nexus studies, Crete's electricity generation—both conventional and renewable—exerts only a limited demand on freshwater resources. Fossil fuel-based plants, fueled by imported oil and diesel, primarily use brackish or desalinated water for cooling, minimizing freshwater use. Renewable energy dominates Crete's green electricity output—particularly solar-PV and wind power—and these technologies are remarkably water-light in operation. Solar-PV systems need only minimal water for periodic panel cleaning, while wind power consumes virtually none. Small hydroelectric and biogas systems likewise have negligible freshwater footprints. The sewage treatment plants in Chania and Heraklion utilize the sludge for biogas production and energy generation reducing their dependence on grid electricity. Water will be used for electricity storage in a pumped-hydro storage system which is going to be constructed in Crete. Innovative solutions further reduce water use in energy systems. For instance, in planned pumped hydro storage facilities, could host floating solar-PV installations on water reservoir surfaces—offering dual benefits of power generation and reduced water evaporation from dams. The green hydrogen production via water electrolysis requires also water resources. Energy systems, by contrast, are minimally water-dependent, especially when renewable energies dominate. Creative approaches like floating solar-PV on water reservoirs and interconnection with mainland grids bolster clean energy capacity while preserving precious water supplies. Table 6 indicates the impacts of water resources on the energy system in Crete.

Table 6. The impacts of water resources on the energy system in Crete

1	Cooling water is required in electricity generation from thermo-electric power stations
2	The water-sludge in the sewage treatment plants is used for biogas production and energy generation
3	Water is required in pumped-hydro systems for electricity storage
4	Water is required for installation of floating solar photovoltaics generating electricity
5	Small amounts of water are needed in solar-PV plants and in wind farms
6	Water is required for the production of green hydrogen with water electrolysis

Source: Own estimations

8. THE IMPACT OF CLIMATE CHANGE ON WATER RESOURCES IN CRETE

Crete, the largest island in Greece, sits at the crossroads of the Eastern Mediterranean—a region identified as one of the world’s climate change “hotspots” [8]. Water resources on the island are already under pressure due to uneven rainfall, high irrigation demand, and seasonal tourism. Climate change is expected to intensify these stresses, reshaping the hydrological balance and threatening the sustainability of ecosystems, agriculture, and communities. Climate projections consistently indicate that Crete will experience reduced annual rainfall alongside higher average temperatures throughout the 21st century. Studies suggest a possible 10–20% decrease in precipitation by 2100, coupled with average warming of around 2–3 °C. This dual effect reduces surface water availability and accelerates evaporation rates from reservoirs, rivers, and soils. In particular, winter rainfall, which traditionally recharges aquifers and surface flows, is expected to decline, leading to less reliable water storage. Groundwater currently supplies much of Crete’s domestic and agricultural water demand. However, lower recharge rates due to reduced rainfall and higher evapotranspiration threaten aquifer sustainability. Karstic springs, which provide vital flows in many regions, may see discharges decline by the end of the century. Over-extraction of groundwater in response to drought further risks salinization in coastal aquifers, reducing water quality and compounding scarcity problems. Climate change is not only reducing average rainfall but also altering its distribution. Rainfall is expected to arrive in fewer, more intense storms, separated by prolonged dry periods. This variability amplifies the frequency and severity of droughts, already evident in recent years when reservoirs such as the Aposelemis Dam reached critically low levels. Drought episodes disrupt agricultural production, constrain drinking water supply, and heighten competition between sectors such as farming and tourism. Agriculture, particularly olives, grapes, and citrus, consumes the majority of Crete’s water. With less reliable rainfall, irrigation demand is expected to increase even as supply shrinks. Farmers may face declining yields, rising costs, and greater vulnerability to crop failure. Tourism, a cornerstone of the Cretan economy, also intensifies seasonal water stress. Visitor arrivals peak in the dry summer months, increasing demand for water in hotels, swimming pools, and recreational facilities precisely when resources are scarcest. Freshwater ecosystems—rivers, wetlands, and lakes—are threatened by reduced inflows and increased evaporation. Loss of water flow can endanger biodiversity, disrupt fish habitats, and dry up wetlands critical for migratory birds. At the same time, water scarcity has social implications: rural communities dependent on farming may experience economic hardship, while competition for water between local residents and tourism infrastructure could spark social tensions.Table 7 indicates the impacts of climate change on water resources in Crete.

Table 7. The impacts of climate change on water resources in Crete

1	Annual precipitation is going to be reduced.
2	Water evaporation is going to increase due to higher temperatures.
3	The frequency of droughts is going to increase.
4	Over-extraction of groundwater in response to droughts will increase water salinization in coastal aquifers.
5	Intense frequent storms will threaten the sustainability of aquifers.
6	Irrigation demand is expected to increase requiring more water in the crops.

Source: Own estimations

9. THE IMPACTS OF WATER RESOURCES ON CLIMATE CHANGE IN CRETE

While the effects of climate change on water resources are widely discussed, the reverse interaction—how the use of water resources contributes to climate change—is equally significant. In Crete, the way water is extracted, transported, consumed, and treated has a measurable impact on greenhouse gas emissions and local climate dynamics.The most direct link between water use and climate change lies in the energy required to manage water. Pumping groundwater from deep aquifers, transporting water over rugged terrain, treating it for consumption, and operating irrigation networks all demand electricity. Much of Crete’s electricity still comes from fossil fuel–based power plants. This means that every cubic meter of water extracted or delivered carries a carbon footprint. Desalination plants, which will be increasingly used to supplement supply in drought years, are particularly energy-intensive. Unless powered by renewable energies, their operation adds significantly to greenhouse gas emissions, reinforcing the very climate pressures that worsen water scarcity. Agriculture is the largest consumer of water on Crete, with olives, grapes, and citrus dominating production. Irrigation often relies on pumped groundwater or surface water stored behind dams. The energy consumed in irrigation translates directly into CO_2 emissions when powered by fossil fuels. In addition, inefficient irrigation practices—such as open-channel distribution and over-watering—result in wasted water, which indirectly means wasted energy and unnecessary emissions. Fertilizer and pesticide use, intensified by high irrigation levels, also contribute to nitrous oxide and methane emissions, further linking water management to climate impacts.The treatment of wastewater is another critical dimension. Wastewater plants consume energy but also produce emissions through the decomposition of organic matter. In some cases, untreated or partially treated wastewater releases methane and nitrous oxide into the atmosphere—gases far more potent than CO_2. While some Cretan wastewater plants have introduced biogas capture and cogeneration systems to offset emissions, coverage remains limited. Expanding these systems could turn a source of emissions into a renewable energy opportunity. Beyond direct emissions, the way water resources are used affects the land surface and its climate feedbacks. Over-extraction of groundwater can lower water tables, reduce soil moisture, and accelerate desertification in semi-arid parts of Crete. Drier soils release less moisture into the air, weakening evapotranspiration—a natural cooling process. The reduction of vegetative cover due to water stress also diminishes carbon sequestration capacity. Thus, unsustainable water use amplifies land degradation and undermines ecosystems' ability to buffer climate extremes.The use of water resources in Crete is not climate-neutral. From the electricity powering pumps and desalination plants to the emissions tied to irrigation and wastewater, water management is closely tied to greenhouse gas outputs. Table 8 indicates the impacts of water resources on climate change in Crete.

Table 8. The impacts of water resources on climate change in Crete

1	Pumping groundwater from deep aquifers, transporting, treating it for consumption, and operating irrigation networks all demand electricity. Much of Crete's electricity still comes from fossil fuel–based power plants emitting GHGs
2	Sea water desalination requires electricity
3	Sewage treatment requires electricity
4	Inefficient water use in irrigation wastes water and electricity results in unnecessary carbon emissions
5	Inefficient water use in agriculture can result in land desertification and lower carbon sequestration

Source: Own estimations

10. THE IMPACTS OF CLIMATE CHANGE ON THE ENERGY SYSTEM IN CRETE

Crete, the largest island in Greece, stands at the intersection of two major transitions: adapting to the impacts of climate change and moving toward a sustainable, renewable-based energy system. As part of the Mediterranean climate "hotspot," the island faces rising temperatures, prolonged droughts, shifting wind patterns, and extreme weather events. These changes are not only transforming water and agriculture but also reshaping how Crete generates, distributes, and consumes energy. One of the most immediate effects of climate change on energy in Crete is the increase in electricity demand for cooling. Hotter summers and more frequent heatwaves drive higher use of air conditioning in households, businesses, and the tourism sector, which peaks during the driest and hottest months. This seasonal surge in demand places stress on the electricity grid, historically reliant on imported oil and diesel. Without adequate renewable capacity or storage, such spikes could increase dependence on fossil fuels, undermining emissions targets and raising costs. Crete has made impressive progress in expanding renewable energy, especially wind and solar power. However, climate change introduces uncertainties to these resources.

a) Solar Energy: Higher average temperatures can slightly reduce the efficiency of photovoltaic panels, even if overall solar radiation increases. Dust from drought-driven desertification in North Africa may also affect panel performance.
b) Wind Energy**:** Changes in atmospheric circulation patterns may alter wind speeds and seasonal availability. A decline in consistent wind flows could reduce output from Crete's wind farms, though localized projections remain uncertain.
c) Hydropower: Although hydropower is limited on the island, reduced rainfall and shrinking spring discharges will further constrain potential generation. Pumped hydro storage, seen as a key solution for balancing renewables, may be challenged by declining water availability.

Climate change also poses risks to energy infrastructure. More frequent storms, floods, and wildfires threaten transmission lines, substations, and generation sites. Prolonged heat can also reduce the efficiency of thermal power plants and transformers, making the grid more unstable during periods of peak demand. Climate change is reshaping both the supply and demand sides of Crete's energy system. Rising temperatures and extreme events threaten infrastructure and drive up electricity use, while changing wind and rainfall patterns create uncertainty for renewable energy generation. Yet, these challenges also highlight the urgency of transitioning toward a resilient, renewable-based system that reduces dependence on fossil fuels. Table 9 indicates the impacts of climate change on the energy system in Crete.

Table 9. The impacts of climate change on the energy system in Crete

1	Rising temperatures increase the electricity demand for cooling
2	Rising temperatures can reduce the efficiency of solar-PV panels
3	Climate change is going to decrease the wind energy potential in Crete
4	Changing climate conditions will increase fires in rural and forest areas and will decrease the water availability which might decrease the solid biomass production for energy generation
5	Extreme weather events might harm the energy infrastructure in the island
6	Climate change is going to increase the solar energy potential in Crete

Source: own estimations

11. THE IMPACTS OF ENERGY SYSTEMON CLIMATE CHANGE IN CRETE

Crete, the largest island in Greece, is both a regional hub for tourism and agriculture and a testing ground for the country's energy transition. The island's energy consumption patterns have far-reaching implications for greenhouse gas emissions and, therefore, for climate change. While Crete is rich in renewable energy potential—particularly solar and wind energy—its historical and current reliance on fossil fuels means that energy use remains a major driver of climate pressures in the region. For decades, Crete has depended on oil-fired power plants to supply its electricity. Heavy fuel oil and diesel imports have powered thermal stations near major urban centers such as Heraklion and Chania. These plants emit large quantities of carbon dioxide (CO_2), sulfur dioxide, and particulate matter. Energy consumption in Crete extends beyond electricity for households and tourism infrastructure. Water systems—including groundwater pumping, irrigation, and desalination—are among the island's most energy-intensive operations. Since agriculture is a cornerstone of Crete's economy, vast amounts of energy are consumed in irrigating olive groves, vineyards, and citrus plantations. Heating buildings and industrial heat production in Crete utilize heating oil and grid electricity resulting in GHG emissions. Tourism, a critical sector for Crete, compounds the problem. Hotels, resorts, swimming pools, and transport services demand huge amounts of electricity and fuel. Air conditioning use peaks during heatwaves—events that are themselves intensified by climate change. The seasonal nature of this demand places additional stress on the energy grid, forcing greater reliance on oil-fired stations at precisely the moments when renewable generation cannot always fully compensate. Thus, tourism's heavy energy footprint directly fuels climate pressures that, paradoxically, threaten the long-term attractiveness of Crete as a destination. Energy infrastructure itself is a source of climate impact. Outdated power stations operate with relatively low efficiency, consuming more fuel per unit of electricity produced. Energy losses in transmission and distribution systems also inflate emissions. In the transport sector, road vehicles powered by gasoline and diesel remain dominant, contributing to local air pollution and CO_2 output. Shipping, critical for connecting Crete with the mainland and other islands, relies heavily on heavy fuel oil, further extending the island's climate impact. Energy use in Crete is a significant contributor to climate change, largely because of the island's dependence on imported oil and fossil fuels to power homes, agriculture, tourism, and water infrastructure. The resulting greenhouse gas emissions exacerbate global warming, which in turn magnifies local climate risks such as heatwaves, droughts, and wildfires. Table 10 indicates the impacts of the energy system on climate change in Crete.

Table 10. The impacts of the energy system on climate change in Crete

1	The energy system of Crete is based in fossil fuels resulting in GHG emissions. However there is a shift nowadays towards renewable energies
2	Energy infrastructure itself is a source of climate impact. Outdated power stations operate with relatively low efficiency, consuming more fuel per unit of electricity produced
3	Vast amounts of energy are consumed in irrigating olive groves, vineyards, and citrus plantations
4	Hotels, resorts, swimming pools and transport services demand huge amounts of electricity and fuel
5	Fossil fuels are mainly used in transportation by vehicles, ships and aircrafts resulting in GHG emissions
6	Fossil fuels and grid electricity are mainly used in heat production resulting in GHG emissions

Source: Own estimations

12. DISCUSSION

The interdependence among water, energy and climate change in the island of Crete, Greece has been studied. It has been indicated that climate change has harmful impacts on the availability of the limited water resources in the island. Pumping, distributing and treating freshwater in Crete requires large amounts of energy while energy production in Crete does not require significant quantities of water resources. The management of water resources in the future in Crete should take into consideration the undesired effect of climate change on their availability while fossil fuels should be replaced in energy generation with the abundant solar and wind energy resources in the island. Our study is qualitative without presenting quantitative estimations regarding the energy use in the water sector and the water consumption in energy generation. According to a EU report [3] the water consumption in the energy sector in EU is equal to water consumption in agriculture. On the contrary, the water consumption in the energy sector in Crete is insignificant. It is also stated that the energy consumed to collect, pump and treat water in EU represents 2.6% of the EU electricity consumption. Using this figure in Crete and taking into account that the annual electricity consumption in the island is around 3,000 GWh/year it is concluded that the electricity consumption in the water sector in Crete will be at around 78 GWh/year. Future work should be focused on quantitative estimations regarding the water consumption in the energy sector and the energy consumption in the water sector in Crete. It should be also focused on quantitate estimations regarding the GHG emissions from the energy and water sectors in the island.

13. CONCLUSIONS

The nexus among water, energy and climate change in the island of Crete, Greece has been explored. It has been found that the water resources, the energy system and climate crisis in Crete are interlinked and interdependent. Climate crisis has harmful impacts in the limited water resources and in the energy system of the island. Energy generation and water consumption in Crete affect climate change. Energy is required in the production, treatment and transport of water resources while the water use in energy generation in Crete is insignificant. Although the current work follows a qualitative approach without quantitative estimations there are several key points which should be considered by the local stakeholders including: a) sustainable and rational management of the water resources is necessary in the future in Crete to avoid water shortages, b) fossil fuels which are currently used for energy generation should be replaced by solar and wind energy resources which are abundant in Crete, c) the water and energy infrastructure in the island should become more resilient and adaptive to climate change, and d) agriculture and tourism industry which are the main sectors of island's economy should try to improve their energy and water efficiency in order to mitigate their impacts to climate change. However, a quantitative approach of the water-energy-climate change nexus in Crete could reveal more clearly their interlinkages and interconnections facilitating the sustainable management of the abovementioned essential resources in the current era of climate change.

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