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# Possibility of Seawater Desalination Using Reverse Osmosis Powered by Solar Photovoltaic Electricity on the Island of Crete, Greece

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**Abstract**
Water demand is rising globally, while water availability is declining due to factors such as pollution, climate change, and inefficient management. Among emerging clean water technologies, reverse osmosis stands out as a widely adopted, though energy-intensive, method. The island of Crete, Greece, hosts a thriving tourism industry that consumes substantial quantities of water. In regions with limited water resources, such as the Eastern Mediterranean, seawater desalination using reverse osmosis is expanding rapidly. This method is already broadly implemented in Mediterranean countries including Cyprus, Malta, Spain, and Israel. On Crete, seawater desalination via reverse osmosis can help increase potable water availability, with the required electricity supplied by solar photovoltaic (PV) systems. This study estimates that powering reverse osmosis plants to meet 20% of Crete's annual potable water demand would require solar PV systems with a total installed capacity of 76.56 $MW_p$, at an estimated installation cost of €84.22 million. The required system size is relatively modest, and the investment cost is considered affordable. This work may be of interest to policymakers, municipal authorities, water management agencies, and hotel operators, who all have a stake in securing sustainable water supplies for the island.

**Keywords:** Crete-Greece, Desalination, Photovoltaics, Reverse Osmosis, Solar Energy, Water

## 1. Introduction

The growing global demand for water necessitates the development of new methods for producing water for agricultural and domestic use [1, 2, 3]. On the island of Crete, Greece, water demand is increasing while available resources are decreasing, due to unsustainable management and the adverse effects of climate change [4, 5]. Among various desalination technologies, reverse osmosis (RO) is a well-established and commercially available method for producing potable water, though it requires considerable amounts of electricity [6, 7, 8, 9, 10, 11]. Fortunately, Crete benefits from abundant solar energy, which is increasingly harnessed through solar photovoltaic systems for electricity generation [12, 13].

*The aim of this study is to explore the feasibility of using solar PV electricity to power reverse osmosis desalination of seawater on the island of Crete.*

The paper is structured as follows: Following a literature review, the availability of water resources and solar PV electricity on Crete is assessed. Next, water desalination technologies are discussed, with a focus on the reverse osmosis process. Subsequently, the required capacity of the solar PV system needed to power the desalination plants is calculated. The paper concludes with a discussion of the findings, conclusions, and references.

This study is novel, as few previous works have examined the integration of seawater desalination via reverse osmosis with solar PV energy on Crete. It addresses a critical gap in research concerning the sustainable production of potable water on the island using membrane technologies and renewable energy. The results may be valuable to policymakers, municipalities, and private sector entities involved in desalination and solar PV projects.

## 2. Literature Survey

A review of renewable energy-powered desalination systems [1] noted that RO accounts for about 62% of global desalination capacity, with specific energy consumption (SEC) ranging from 3 to 7 kWh/m³. Various desalination technologies using different energy sources were compared in [2]. The authors stated that, in addition to conventional energy sources, renewable energy options such as solar, wind, and geothermal power are viable alternatives. A review of renewable energy desalination in Greek island communities [3] emphasized water and energy security. Six islands had installed desalination systems with capacities between 3 m³/day and 3,360 m³/day, powered by solar PV, wind, and geothermal energy. Water resource management in Crete was discussed in [4], highlighting limited water availability, rising demand, and weak stakeholder coordination. The authors recommended adopting sustainable management practices. Challenges and opportunities for water management in Crete were further analyzed in [5]. Despite sufficient water under average conditions, agriculture consumes 78% of the island's water, followed by domestic use at 21%. Another study [6] emphasized that RO systems can serve as flexible loads within power systems. The authors noted that regulating the power consumption of large RO plants can help maintain voltage stability in electrical grids. In [7], theoretical models were used to evaluate the SEC of seawater RO systems integrated with membrane distillation and pressure-retarded osmosis. The SEC was estimated to range from 0.67 to 2.28 kWh/m³. Energy recovery in seawater RO was explored in [8]. The authors acknowledged that RO is the dominant large-scale desalination technology globally, yet its high energy consumption remains a concern. They discussed new methods to enhance energy recovery. In [9], authors concluded that SEC reductions could be achieved through improvements in membrane permeability, pump efficiency, and the use of energy recovery systems. The RO process was examined in [10], estimating an SEC of 3–6 kWh/m³ for seawater desalination, with water costs ranging from $0.45 to $1.72/m³. For brackish water RO, the SEC was 1.5–2.5 kWh/m³ and water costs between $0.26 and $1.33/m³. The desalination potential using renewable energy on Greek islands was assessed in [11]. The author noted the high cost of transporting potable water to remote islands and emphasized the potential for solar and wind-powered desalination. A comparison of two plants—one in Paros island using diesel and one in Milos island using wind—showed that the wind-powered plant had lower environmental impacts. Solar PV systems for meeting Crete's energy demands were studied in [12]. The author suggested rooftop, floating, and land-based installations, including agrivoltaics, to simultaneously produce food and electricity. Crete's existing PV capacity was estimated at around 100 $MW_p$ in [13]. The study noted that additional installations could offer a 7.5 $MW_p$ capacity credit to the local power grid. The energy consumption of reverse osmosis (RO) in seawater desalination has been widely studied. A recent study [14] highlighted that desalination is increasingly considered a potential solution to the global water crisis, estimating the lowest specific energy consumption for seawater desalination by RO at 3.65 kWh/m³. Potable water reuse systems were modeled in [15], where the authors estimated their typical energy consumption between 1.2–2.1 kWh/m³, compared to approximately 4 kWh/m³ for seawater desalination. Thermally assisted RO was examined in [16], which identified high energy consumption as a major barrier to wider adoption. The study showed that increasing the feedwater temperature from 25°C to 60°C reduced the energy required for desalination by about 40%. An analysis of desalination's energy footprint [17] found that membrane-based technologies generally consume less energy than thermal processes. The SEC for brackish water RO was around 1.9 kWh/m³, while for seawater RO it ranged from 4.3 to 4.4 kWh/m³. A novel desalination system powered by solar PV was introduced in [18]. In this study, water was used to cool PV panels, increasing their output. Simultaneously, the warmed water was fed into the RO unit. A 10°C increase in feedwater temperature reduced energy consumption by 28% and increased water output by 20%. Energy optimization in RO desalination was assessed in [19], where the author suggested that although RO has strong potential for global clean water production, limited economic incentives hinder the development of higher-permeability membranes. A comprehensive analysis of energy consumption, carbon emissions, and costs of desalination in China was conducted in [20]. The study found that seawater RO has an SEC of 5 kWh/m³, with carbon emissions ranging from 0.4 to 6.7 kg $CO_2$eq/m³. Energy accounted for 35% of the total operating cost. Further studies [21] reported that the SEC in brackish water RO ranges from 0.5 to 3 kWh/m³, and in seawater RO from 3 to 6 kWh/m³. An assessment of a medium-sized brackish water RO plant [22] reported energy use between 2–5 kWh/m³ for seawater and 1.5–2.5 kWh/m³ for brackish water. Supercritical water desalination was studied in [23], with energy consumption ranging from 0.28 to 0.42 kWh/m³ for different feed concentrations. The potential for fully meeting Crete's electricity demand with solar PV was examined in [24]. The study estimated a required PV capacity of 2.33 $GW_p$, with an installation cost of €2.33 billion and a land requirement of 4,660 hectares. In [25], solar PV installations and net metering in Greece were evaluated. The average household electricity consumption was 3,750 kWh/year, with thermal energy at 10,244 kWh/year. The payback period for a solar PV system in Heraklion, Crete, was found to be 9 years, with a net present value of €3,600. Climate change impacts on water resources in the Mediterranean, focusing on Catalonia, Spain, were studied in [26]. A significant reduction in precipitation, especially in summer and autumn, was predicted for the 21st century. Resource recovery in small-island desalination plants was explored in [27], focusing on Lampedusa, Italy. Although technically feasible, resource recovery was often not economically justified due to high investment costs. Wind-powered RO desalination systems were reviewed in [28], highlighting their increasing adoption. While grid-connected systems are preferred for large-scale use, off-grid hybrid systems are explored for remote locations.

## 3. Water resources in Crete

Despite its mountainous terrain and relatively high annual rainfall compared to other regions of Greece, Crete continues to face significant challenges in managing its water resources. The island's water supply is primarily sourced from rainfall, springs, rivers, and underground aquifers. The mountainous regions—including the Lefka Ori, Psiloritis, and Dikti ranges—play a vital role in capturing and storing rainwater, which replenishes rivers and underground reserves. Major rivers such as the Geropotamos, Anapodaris, and Koiliaris contribute to the island's freshwater system. Crete is also home to numerous karstic springs, especially in areas like Argyroupoli and Zaros, which provide high-quality drinking water to both local populations and agricultural regions. Agriculture is the dominant consumer of water in Crete, accounting for approximately 80–85% of total water use. The island is renowned for its olive groves, vineyards, and greenhouse farming, particularly in Ierapetra and the Messara plain. This high demand places immense pressure on available water resources, especially during the dry summer months when rainfall is minimal. Over-extraction of groundwater for irrigation has led to declining aquifer levels and salinization, particularly in coastal zones where seawater intrusion threatens freshwater reserves. Urban water consumption is also substantial, largely due to Crete's thriving tourism sector, which causes a significant seasonal population increase. Cities like Heraklion, Chania, Rethymno, and Agios Nikolaos face the dual challenge of supplying water to both residents and tourists while ensuring water quality and minimizing system losses. High leakage rates in urban distribution networks further exacerbate the strain on water supplies. Climate change compounds these challenges by making rainfall patterns more erratic and reducing total annual precipitation. Longer, hotter summers increase evaporation rates and irrigation needs, intensifying water stress across the island. In response, local and regional authorities have adopted various water management strategies. These include the construction of dams and reservoirs, such as the Potamon, Aposelemis, and Vrysses dams, which store water for use during dry periods. While still limited, desalination plants are being considered in areas with severe water scarcity. Promoting sustainable water use has become a growing priority. Modern irrigation techniques, such as drip irrigation, have proven effective in reducing agricultural water demand. Public awareness campaigns and educational initiatives encourage water conservation, and municipalities are increasingly investing in technologies to detect and reduce leaks in water distribution systems. Although Crete has a relatively rich endowment of natural water resources, it continues to face serious challenges due to overuse, climate variability, and infrastructure inefficiencies. Moreover, the distribution of water resources is uneven across the island—western Crete is better endowed, while the eastern region suffers from more acute water deficits. The rapid expansion of tourism has further increased demand for water, especially during the summer. According to climate projections, the eastern Mediterranean, including Crete, will likely experience reduced annual precipitation in the future, exacerbating water scarcity. Unlike other Eastern Mediterranean countries such as Cyprus and Israel, Crete has yet to fully develop the reuse of treated wastewater for agricultural irrigation, which remains an underutilized strategy for water conservation. The current use of water resources in Crete is summarized in Table 1.

**Table 1:** Use of water resources in Crete

| Sector | Annual water consumption (%) | Annual water consumption (mil. $M^3$) | Annual water consumption per capita ($M^3$ per capita) |
|---|---|---|---|
| Agriculture | 78.3 | 478.4 | 753.5 |
| Domestic uses | 20.9 | 127.6 | 201.0 |
| Others | 0.8 | 4.9 | 7.7 |
| Total | 100 | 610.9 | 962.2 |

**Source:** Tzanakakis *et al*, 2000

## 4. Electricity generation using solar photovoltaics in Crete

Crete enjoys over 300 days of sunshine annually, making it an ideal location for the development of solar photovoltaic (PV) energy. As the world shifts toward renewable energy to combat climate change and reduce reliance on fossil fuels, Crete's abundant solar potential positions it as a promising hub for clean energy. Historically, the island's energy needs have been met by oil-based power plants—an approach that is costly, polluting, and reliant on imported fuels. The current electricity demand in Crete is approximately 3,000 GWh per year. However, recent years have seen a growing transition toward renewables, with solar PV playing a leading role. Crete boasts some of the highest solar irradiance levels in Europe, allowing PV systems to operate efficiently throughout most of the year. Annual electricity generation per kilowatt peak ($kW_p$) of installed PV capacity typically ranges from 1,500 to 1,600 kWh. Solar panels are increasingly being installed on residential, commercial, and industrial rooftops, contributing to decentralized energy production. As of the mid-2020s, installed solar PV systems on Crete, both on rooftops and in solar fields, exceed a nominal capacity of 100 $MW_p$, generating around 150 GWh per year. Following the recent grid interconnection with mainland Greece, installations are expected to increase significantly, potentially surpassing 1,000 MW. Several medium-sized solar parks have already been established, and many households and businesses have adopted rooftop systems—often supported by government incentives or EU funding. Net metering and, more recently, net billing schemes have further encouraged private investment by allowing users to offset or sell surplus electricity. Despite this progress, several challenges limit the full potential of solar PV on the island. One key issue is Crete's limited grid infrastructure. Until recently, Crete was not connected to the mainland grid, meaning electricity had to be produced and consumed locally. During periods of high solar output and low demand, surplus energy was often wasted due to insufficient storage or transmission capacity. The new undersea grid interconnection is expected to enhance grid stability, facilitate energy exports, and attract further renewable energy investments. Energy storage remains a critical challenge. Solar energy is intermittent and unavailable at night, necessitating the use of battery storage systems at both household and utility scales to balance supply and demand. Large-scale battery projects and hybrid systems combining solar with other renewables are currently under development. Looking ahead, Crete has the potential to become a model of sustainable energy in the Mediterranean. Continued investment in PV technology, grid modernization, and energy storage will be essential. Additionally, solar energy can support applications beyond electricity generation, such as solar water heating and solar-powered desalination, contributing to both energy and water security. Harnessing its rich solar potential will help Crete reduce environmental impacts, create economic opportunities, and strengthen its energy independence.

## 5. Water Desalination Technologies

As global freshwater sources decline due to population growth, industrialization, and climate change, desalination is becoming an increasingly vital solution for providing clean, safe water. Desalination refers to the process of removing salts and other impurities from saline or brackish water to produce potable water. While Reverse Osmosis is currently the dominant desalination technology, several other methods also play important roles. The main desalination technologies include:

a) Reverse Osmosis (RO)
b) Multi-Stage Flash Distillation (MSF)
c) Multi-Effect Distillation (MED)
d) Electrodialysis (ED)
e) Vapor Compression Distillation (VCD)

### 5.1 Reverse Osmosis (RO)

RO is the most widely used and commercially successful desalination technology. It employs a semipermeable membrane to separate salts and impurities from water. By applying high pressure (typically 55–70 bars for seawater), water is forced through the membrane, leaving salts behind.

*Advantages:*

- **Highly efficient:** Removes up to 99% of dissolved salts and contaminants
- **Scalable and modular:** Suitable for household units and large municipal plants
- Constantly improving with advances in membrane technology and energy recovery systems.

*Disadvantages:*

- High energy consumption
- Membrane fouling from biological or chemical substances
- Disposal of concentrated brine can harm marine environments.

RO is especially common in water-scarce regions such as the Middle East, North Africa, and parts of the United States.

### 5.2 Multi-Stage Flash Distillation (MSF)

MSF is a thermal desalination process that has been widely used for decades. It involves heating seawater until it "flashes" into vapor in a series of low-pressure chambers. The vapor condenses into freshwater, while the remaining brine is discharged.

*Advantages:*

- Very reliable for large-scale operations
- Can utilize waste heat or be integrated with power plants
- Resistant to biological fouling due to thermal processing.

*Disadvantages:*

- Highly energy-intensive
- High capital and operational costs
- Unsuitable for small-scale systems.

MSF is primarily used in energy-rich countries like Saudi Arabia and the UAE.

### 5.3 Multi-Effect Distillation (MED)

MED is a more energy-efficient thermal desalination method than MSF. It uses multiple stages where seawater is evaporated and condensed at progressively lower pressures, reusing heat in each stage.

*Advantages:*

- Lower energy consumption than MSF
- Better suited for small and medium-scale operations
- Can use low-grade or solar thermal energy.

*Disadvantages:*

- More energy-intensive than membrane-based methods
- Requires durable construction to resist scaling and corrosion.

MED is often integrated with renewable heat sources and hybrid systems.

### 5.4 Electrodialysis (ED)

ED uses electrically charged membranes and electrodes to move salt ions out of water.

*Advantages:*

- Very efficient for desalinating brackish water
- Lower energy use than RO for low-salinity water
- Reversible polarity extends membrane life.

*Disadvantages:*

- Not suitable for high-salinity seawater
- Requires complex controls and pre-treatment
- Less effective at removing non-ionic contaminants.

ED is commonly used in agriculture and industrial applications, especially in inland areas.

### 5.5 Vapor Compression Distillation (VCD)

VCD uses mechanical or thermal compressors to condense vaporized water. The released heat is recycled to evaporate more water, making it efficient for small-scale use.

*Advantages:*

- Highly energy-efficient at small scale
- Compact and straightforward design
- Handles varying water qualities well.

*Disadvantages:*

- Not ideal for large-scale applications
- Mechanical parts require regular maintenance
- High initial setup costs for remote or isolated locations.

VCD is often used in remote installations, such as offshore platforms, small resorts, and islands.

Table 2 provides the main water desalination technologies while table 3 the energy consumption and the cost of clean water in several water desalination processes.

**Table 2:** The main water desalination Technologies

| S. No. | Technology | Energy use in water desalination |
|---|---|---|
| 1 | Reverse osmosis | Electricity |
| 2 | Multi-Stage Flash Distillation | Heat |
| 3 | Multi-Effect Distillation | Heat |
| 4 | Electrodialysis | Electricity |
| 5 | Vapor Compression Distillation | Heat or electricity |

**Source:** Own estimations

**Table 3:** Energy consumption and clean water cost in several water desalination processes

| Desalination process | Electricity consumption (kWh/m$^3$) | Thermal energy consumption (MJ/m$^3$) | Potable water cost (\$/m$^3$) |
|---|---|---|---|
| Mechanical vapor compression | 6-12 | 0 | 2.00-2.60 |
| Multi-stages flash evaporation | 4-6 | 190-390 | 0.56-1.75 |
| Thermal vapor compression | 1.5-2.5 | 145-390 | 0.87-0.95 |
| Multi-effect distillation | 1.5-2.5 | 230-390 | 0.52-1.50 |
| Electrodialysis | 2.64-5.50 | 0 | 0.60-1.05 |
| Reverse osmosis of brackish water | 1.5-2.5 | 0 | 0.26-1.33 |
| Reverse osmosis of sea water | 3-6 | 0 | 0.45-1.72 |

**Source:** Curto *et al*, 2021

The energy requirements of the main water desalination processes are presented in table 4 while the percentage of renewable enargies used in several water desalination processes worldwide in table 5.

**Table 4:** Energy requirements of the main water desalination processes

| Desalination process | Plant capacity (m$^3$/day) | Total energy heat and electricity consumption (kWh/m$^3$) |
|---|---|---|
| Mechanical vapor compression | 100-2,500 | 7-12 |
| Multi-effect distillation - Thermal vapor compression | 10,000-35,000 | 11-28 |
| Multi-effect distillation | 5,000-15,000 | 6.5-11 |
| Reverse osmosis | 24,000 | 3-7 |
| Electrodialysis | 145,000 | 2.6-5.5 |
| Multi-stages flash evaporation | 50,000-70,000 | 13.5-25.5 |

**Source:** Alkaisi *et al*, 2021

**Table 5:** Percentage of renewable energies used in several water desalination processes worldwide

| Renewable energy source | Share of renewable energy to energy mix (%) |
|---|---|
| Solar electric energy | 43 |
| Solar thermal energy | 27 |
| Wind energy | 20 |
| Other | 10 |

**Source:** Alkaisi *et al*, 2021

The typical cost of several renewable energy desalination systems is presented in table 6.

**Table 6:** Typical cost of several renewable energy desalination systems

| Process | Renewable energy used | Plant capacity (m$^3$/day) | Cost of clean water (\$/m$^3$) |
|---|---|---|---|
| Multi-effect distillation | Solar thermal energy | >5,000 | 2.5-3.0 |
| Electrodialysis | Solar electricity | >100 | 11.2-12.6 |
| Reverse osmosis | Solar electricity | >100 | 12.5-16.8 |
| Mechanical vapor compression | Wind energy | >100 | 5.6-8.4 |
| Reverse osmosis | Wind energy | >50 | 7.0-9.8 |
| Reverse osmosis | Wind energy | >1,000 | 2.1-5.6 |

**Source:** Alkaisi *et al*, 2021

## 6. Sea Water Desalination Using Reverse Osmosis

Among various desalination methods, reverse osmosis has become the most widely adopted due to its relative efficiency, scalability, and technological maturity. RO is a water purification process that employs a semipermeable membrane to remove salts and impurities from water. Naturally, osmosis causes water to move from a region of low solute concentration to one of higher concentration through a membrane. Reverse osmosis reverses this process by applying pressure to saline water, forcing water molecules through the membrane while retaining dissolved salts, microbes, and other contaminants. In a typical seawater reverse osmosis (SWRO) system, seawater is first pre-treated to remove large particles, bacteria, and organic matter that could damage the membranes. After pre-treatment, high pressure—usually between 55 and 70 bars—is applied to push the seawater through the RO membranes. This produces two streams: Permeate (freshwater) and brine (highly concentrated saline water). The permeate is then post-treated to stabilize its chemical composition, making it suitable for drinking or agricultural use.

### 6.1 Advantages of Reverse Osmosis Desalination

A key advantage of reverse osmosis is its high efficiency in salt removal. RO membranes can eliminate up to 99% of dissolved salts and impurities, producing water that meets or exceeds drinking water standards. Additionally, RO systems are modular and scalable, suitable for applications ranging from small community units to large municipal plants. Energy efficiency has improved significantly with advancements such as energy recovery devices—like pressure exchangers—that recycle pressure from the brine stream, reducing overall energy consumption. Modern SWRO plants typically use between 3 and 4 kWh per cubic meter of produced freshwater, a substantial improvement over older systems. Unlike thermal desalination processes (e.g., multi-stage flash or multi-effect distillation), RO does not require phase changes like boiling or condensation, making it more energy-efficient, especially in regions without access to low-cost thermal energy.

### 6.2 Challenges and Environmental Concerns

Despite its advantages, reverse osmosis faces technical and environmental challenges. Brine disposal is a major concern: For every liter of freshwater produced, an almost equal volume of highly concentrated brine is generated. Improper discharge can harm marine ecosystems due to its high salinity and chemical additives from pre-treatment. Membrane fouling—caused by biofouling, scaling, and clogging from organic matter or minerals—reduces membrane efficiency, necessitating frequent cleaning or replacement. This increases operational costs and environmental impact due to chemical use and membrane waste. Energy consumption remains an issue, particularly in regions reliant on fossil fuels. The carbon footprint of RO plants is closely tied to their energy sources. Therefore, integrating renewable energy—such as solar or wind power—is essential for sustainable expansion. Furthermore, infrastructure and maintenance costs can be prohibitive, especially for developing countries. The construction of intake systems, pre-treatment facilities, and pipelines demands significant capital, while operational expenses including energy, chemicals, and skilled labor add to the financial burden.

### 6.3 Global Adoption and Case Studies

RO desalination is widely adopted in water-scarce regions. The Middle East and North Africa, notably Saudi Arabia and the United Arab Emirates, have heavily invested in large-scale SWRO plants. In Israel, advanced RO membranes provide up to 20% of the country's drinking water, highlighting desalination's strategic role in national water planning. In California, USA, desalination is considered a supplementary source during prolonged droughts, though regulatory and environmental concerns have slowed its broader implementation.

### 6.4 Innovations and the Future of Reverse Osmosis

The future of RO desalination depends on technological innovation and sustainability. Research focuses on developing more resilient, fouling-resistant membranes to reduce cleaning frequency and extend membrane lifespan. Another promising direction is renewable-powered desalination: Integrating solar photovoltaic (PV) or wind energy with RO plants not only reduces carbon emissions but also enables desalination in remote or off-grid locations. Pilot projects on islands are already demonstrating the feasibility of these systems. RO desalination offers a powerful and increasingly vital solution to the global freshwater crisis by transforming abundant seawater into potable water. While challenges related to energy consumption, environmental impact, and cost remain, ongoing innovation and strategic planning can mitigate these issues. Table7 provides the advantages and drawbacks of reverse osmosis water desalination plants.

**Table 7:** Advantages and drawbacks of reverse osmosis water desalination plants

| Advantages | Drawbacks |
|---|---|
| Significantly lower cost when treating brackish water | Requires preheating of saline water |
| Easy adaptation to local conditions | Possibility of membrane fouling |
| Plant size can be adjusted to meet increasing water demand in the future | Requires skilled personnel |
| The capital cost of RO is 25% lower than the thermal processes | Complex process configuration |

**Source:** Alkaisi *et al*, 2017

## 7. Sea Water Desalination Using Reverse Osmosis Powered by Solar Photovoltaic Electricity in Crete

The increasing demand for water resources in Crete, combined with limited availability due to the climate crisis, necessitates the integration of seawater desalination technology to produce potable water on the island. This analysis assumes that 20% of the current domestic water demand can be met through seawater desalination using RO. The desalinated water demand is estimated at:

$$127.6 \text{ million } m^3/\text{year} \times 0.20 = 25.52 \text{ million } m^3/\text{year}.$$

Assuming an energy consumption of 4.5 kWh per cubic meter for seawater RO desalination, the total electricity demand for this process is approximately 114.84 GWh/year. Given that solar photovoltaic panels in Crete generate 1,500 kWh per $kW_p$ annually, the nominal power capacity required for the PV system to generate 114.84 GWh/year is estimated at 76.56 $MW_p$. Assuming an installation cost of €1,100 per $kW_p$ for solar PV systems in Crete, the total installation cost for a 76.56 $MW_p$ system would be approximately €84.22 million.

Table 8 presents the detailed estimation of the nominal power of solar PV systems required to generate the electricity needed for seawater desalination via RO in Crete.

**Table 8:** Estimation of the nominal power of solar-PV systems generating the required electricity in the sea water desalination systems with RO in Crete

| | Production of 20% of the total water demand in the domestic sector in Crete | Production of 50% of the total water demand in the domestic sector in Crete | Production of 100% of the total water demand in the domestic sector in Crete |
|---|---|---|---|
| Potable water demand | 25.52 mil $m^3$ per year | 63.8 mil $m^3$ per year | 127.6 mil $m^3$ per year |
| Electricity demand for sea water desalination with RO | 114.84 GWh/year | 287.1 GWh/year | 574.20 GWh/year |
| Nominal power of solar-PV systems generating the required electricity in sea water desalination with RO in Crete | 76.56 $MW_p$ | 191.4 $MW_p$ | 382.8 $MW_p$ |
| Installation cost of solar-PV systems generating the required electricity in sea water desalination with RO | 84.22 mil € | 210.55 mil € | 421.1 mil € |

**Source:** Own estimations

## 8. Discussion

This study explores the desalination of seawater using reverse osmosis powered by solar photovoltaic (PV) electricity on the island of Crete. Water and energy are vital resources for human well-being. Due to rising water consumption in Crete and the adverse effects of climate change in the eastern Mediterranean basin, the island's water deficit is expected to increase in the future. Reverse osmosis desalination is an energy-intensive process, but solar PV systems can provide the necessary power sustainably. Solar photovoltaic technology is currently mature, reliable, and cost-effective. Similarly, seawater desalination via reverse osmosis is a well-established method with many global applications. Our evaluation shows that the nominal power capacity of the solar PV systems needed to produce 20% of Crete's potable water demand is less than the total nominal power of solar PV systems already installed on the island, and the associated costs are affordable. These findings suggest that Crete can produce potable water through seawater desalination powered by solar PV electricity, thereby avoiding fossil fuel consumption and greenhouse gas emissions. This approach aligns with national and European Union targets for achieving a net-zero carbon society by 2050. However, the accuracy of our results regarding the size and cost of the solar PV systems depends on assumptions about domestic water consumption and electricity use in reverse osmosis desalination plants. Future research should investigate the potential of wind farms and hybrid solar-wind energy systems to provide power for reverse osmosis desalination plants in Crete.

## 9. Conclusions

This study investigated the feasibility of seawater desalination using reverse osmosis powered by solar PV electricity on the island of Crete, Greece. Water demand on the island is increasing, while current water management practices are inefficient. Furthermore, climate change is expected to reduce annual precipitation in the region. Reverse osmosis desalination is a mature, reliable, and energy-intensive technology. Crete has abundant solar energy, which is currently harnessed for electricity generation through solar PV systems. Using data from existing literature, we estimated Crete's potable water demand and the electricity required for seawater desalination via reverse osmosis. Our results show that solar PV systems with a nominal power of 76.56 $MW_p$ can generate the electricity needed to desalinate 20% of Crete's annual potable water demand. The installation cost of these solar PV systems is estimated at €84.22 million. This study indicates that the size and cost of the solar PV plants required to meet 20% of Crete's potable water demand using sea water desalination with RO are both reasonable and affordable.

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