



Towards a Green, Low-Carbon Water Supply for Islands: Wind, Solar, and Energy and Water Management Strategy for Kos Island [†]

Maria Margarita Bertsiou ^{1,*} , Eftychia Papalexiou ² and Evangelos Baltas ¹

¹ Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, 5 Iroon Polytechniou, 157 80 Athens, Greece; baltas@chi.civil.ntua.gr

² Municipal Water Supply and Sewage Company of Kos, Skevou Zervou 40, 853 00 Kos, Greece; e_papalexiou@deyakos.gr

* Correspondence: mbertsiou@chi.civil.ntua.gr

[†] Presented at the 6th International Conference on Efficient Water Systems (EWaS6), Thessaloniki, Greece, 11–14 May 2026.

Abstract

Ensuring adequate water supply on islands is challenging due to high costs, limited resources, and energy constraints. This study examines the potential of meeting the water supply demands of the island of Kos through renewable-energy-powered desalination, supported by battery storage systems and the utilization of the under-construction Mia Dam. Energy management prioritizes domestic demand, with surplus energy stored or used for desalination, and deficits covered by battery storage and reservoirs. The results estimate water costs per cubic meter, allowing the assessment of the economic viability of the scenarios and the optimal strategic coverage of the island's water needs.

Keywords: renewable energy; sustainable development; desalination; water management; energy transition

1. Introduction

In recent years, as the effects of climate change have become increasingly apparent, extreme weather events have occurred, such as severe storms, higher-than-normal temperatures, and droughts [1]. As a result, significant water scarcity issues are being observed in many areas. This is particularly evident on islands, which have historically had issues with clean water supply. Even islands that have reservoirs for water storage are struggling to meet their water needs [2]. Many islands currently meet their needs through water transport or desalination. Both proposals face issues of high energy consumption, increased water costs [3], and large carbon footprints [4]. Another option involves the use of boreholes, which are, however, responsible for various environmental problems regarding groundwater quality due to over-pumping [5]. One proposal for a green, low-carbon water supply for islands is the integration of a desalination unit into a hybrid renewable energy system. In this way, desalination is powered by renewable energy sources (RESs), while any excess energy can be stored in a storage unit and used for different needs, such as electrical consumption.

There are many research papers combining RESs for water demand fulfillment or integrating storage technology, such as pumped storage, batteries, and hydrogen gas. Azinheira et al. [6] came to the conclusion that RES-powered seawater desalination could



Academic Editors: Vasilis Kanakoudis, Evangelos Keramaris, Francesco De Paola, Habib Muhammetoglu and Theodora Papamitsou

Published: 8 July 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

guarantee water security for the Portuguese Algarve region. Using an optimization model for minimizing electricity costs, the resulting cost of desalinated water is estimated at 0.73 EUR/m³. Papathanasiou et al. [7] calculated that the cost of desalinated water ranges from 0.48 to 0.91 EUR/m³ for different operational priorities of a hybrid system consisting of WTs and pumped hydro storage, succeeding full water coverage through an RES-based desalination system. In southern Italy, they face water scarcity, and thus, Palazzolo et al. [8] examined the possibility of filling existing reservoirs through wind energy-based desalination. The results show that up to 70,000 m³ of fresh water can be produced and stored. In [9], they found that replacing grid electricity with PV-powered desalination systems in Porto Santo and the Algarve reduced water production costs by about 33% using 2022 PV prices. With projected 2030 PV costs, the reduction increases to 40.5%, highlighting the major impact of energy costs on desalination.

This study evaluates three scenarios: (i) exploitation of wind energy, (ii) exploitation of solar energy, and (iii) combined use of wind and solar energy. Each scenario includes a desalination plant, the integration of batteries, and the exploitation of the under-construction Mia dam of the island. Energy management follows the priority of domestic water needs. In the case of surplus energy, the battery is charging, and any remaining energy is used for desalination and pumping water directed to the reservoir. In case of shortages, the battery is discharging, and the dam is used. The final proposal aims to support the green transition and to ensure a water-sufficient island, even during the summer months when demand increases due to tourism. The project's lifespan is 25 years through hourly time series of wind and solar speed from 2000 to 2024. The treatment of water scarcity on the island using green, low-carbon technology is the main purpose of this research study. The main contribution of this research is that it considers not only a hybrid renewable energy system (HRES) but also its coupling with existing water supply and management infrastructure. The proposed HRES includes battery storage as an energy storage component to support system operations and manage variability in renewable energy generation. In this way, the battery storage system remains relatively small and plays an auxiliary role, potentially allowing it to be relocated to other areas of the island if needed to cover possible shortages. In other words, it functions as a floating, easily transportable battery. The main unit for storing and utilizing wind and solar energy remains an under-construction reservoir. The research questions that need to be addressed focus on the extent to which the addition of RES can ensure water autonomy on a remote island and the extent to which the utilization of existing infrastructure can minimize both the economic and environmental costs associated with meeting water demand.

2. Materials and Methods

Kos is a Greek island in the Aegean Sea. It is the third largest island of the Dodecanese in area after Rhodes and Karpathos and the second most populous after Rhodes. The island has an area of 295.3 km² and a coastline of 112 km. The capital of the island is Kos, where the main port of the island is also located. It is 200 nautical miles from the port of Piraeus. The island also has an airport located 27 km southwest of the town of Kos, near the village of Antimachia.

The water needs of the island and its capital are mainly covered by boreholes. There are also natural springs, for which their water is considered to be of very good quality. Due to its high water demand, the tourism sector often competes with the agricultural sector for limited water resources. Several private boreholes are exploited for irrigation, while the island is also supported by the reservoirs in the Platy area and in the Messaria area. The first has a useful volume of 342,000 m³ and is used for both water supply and irrigation, and the second has a useful volume of 225,000 m³ and is used exclusively for

irrigation water. Finally, a reservoir is being constructed in the Mia area, with a useful volume of 630,000 m³, to exclusively cover the water supply needs of Kardamena, a coastal village of Kos located approximately 30 km from Kos town and a tourist attraction that entails increased water needs during the tourist months. In Figure 1, data concerning the population of Kardamena and their daily domestic and agricultural water demands are presented.

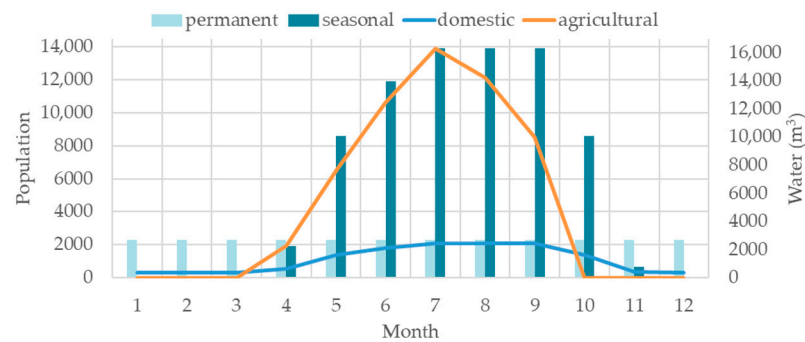


Figure 1. Population and water requirements data for Kardamena.

The visual crossing weather data [10] platform is used for meteorological data. Weather records are generated from surrounding meteorological stations. Historical datasets are compiled by analyzing stations within a maximum distance of 50 miles from the specified location. There are 2 stations on Kos Island: near the airport and in the principal town. Hourly data for temperature, precipitation, and wind and solar potential from 2000 to 2024 were extracted and used in the analysis. Figure 2 presents average wind speeds and solar radiation over the 25-year study period. For the years 2000 to 2009, there is no available data for solar radiation, and thus, average hourly values from 2010 to 2024 are obtained.

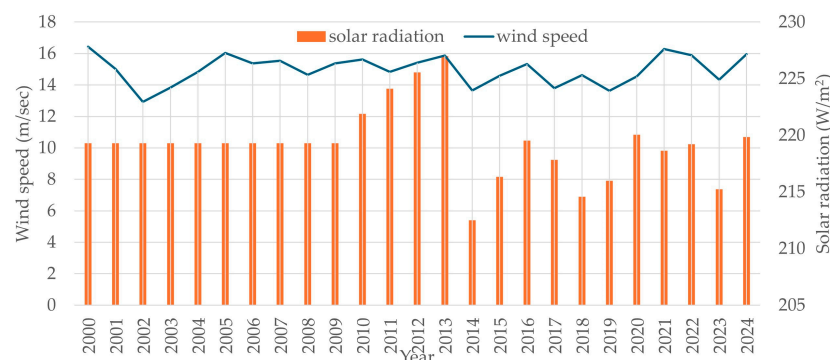


Figure 2. Wind speed and solar radiation over the 25-year study period.

This study assesses three scenarios: (i) the deployment of wind energy, (ii) the deployment of solar energy, and (iii) the integrated use of both wind and solar energy. The results provide an estimation of the final cost of water per cubic meter for each scenario, allowing the assessment of the economic viability of the scenarios and the optimal strategic coverage of the island's water needs. The flowchart of energy management is depicted in Figure 3.

Whenever surplus energy is available and the battery is fully charged, excess energy is utilized for seawater desalination and for pumping the produced freshwater to the dam at an elevation of 33.6 m. The specific energy consumption for desalination is assumed to be 5.5 kWh/m³. The sizing of the HRES components for each scenario, as well as the data required for the economic evaluation of each component of the hybrid system—namely wind turbines, photovoltaic modules, the desalination unit, battery storage system, and the dam—was obtained from [11]. For the dam, only costs for operation and maintenance have

been considered since its construction is independent of the implementation of the hybrid RES project.

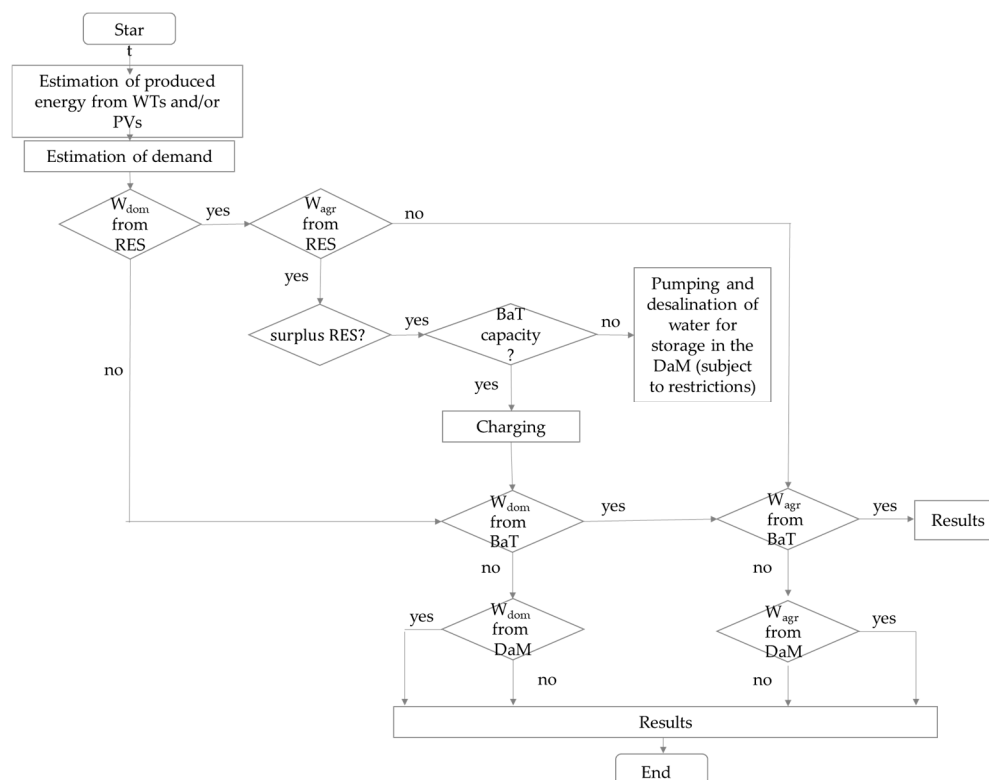


Figure 3. Flowchart of the methodology.

The first scenario consists of wind turbines with a total installed capacity of 5400 kW; the second scenario includes wind turbines with a total capacity of 4500 kW combined with 900 kW of photovoltaic systems; finally, the third scenario comprises photovoltaic systems with a total installed capacity of 9000 kW. The battery system is sized to ensure 5% of the average yearly energy requirements. At the beginning of each simulation year, the dam is assumed to be filled to 10% of its total storage capacity and the battery at its minimum state of charge. For the calculation of CO₂, the grid emission factor is equal to 264 g CO₂/kWh, which is the value for Greece and for the year 2024.

3. Results and Discussion

Figure 4a presents the variations in the final price of clean water resulting from the hybrid system in cooperation with the island's dam for the three different scenarios studied, over a 25-year time horizon, considering the island's varying meteorological data. A significant deviation in price is observed for the scenario that includes only photovoltaics compared with the other two scenarios, with an average price over 25 years of 0.196 EUR/m³. The first scenario, which includes only wind turbines, presents an average price of around 0.437 EUR/m³, while the second scenario, which is a combination of the two RESs, wind and solar, presents an average price of around 0.387 EUR/m³.

Figure 4b depicts the reliability of each scenario for the 25-year time horizon in covering the total volume of water needs, both for domestic water and for irrigation needs. First, all scenarios over the 25-year horizon show high reliability, while the third scenario has a smoother "behavior". On the other hand, the first two scenarios show a greater variation over the years while maintaining reliability within acceptable limits. The results of the

first two scenarios are explained by the greater variation in wind speeds over the years compared to solar potential.

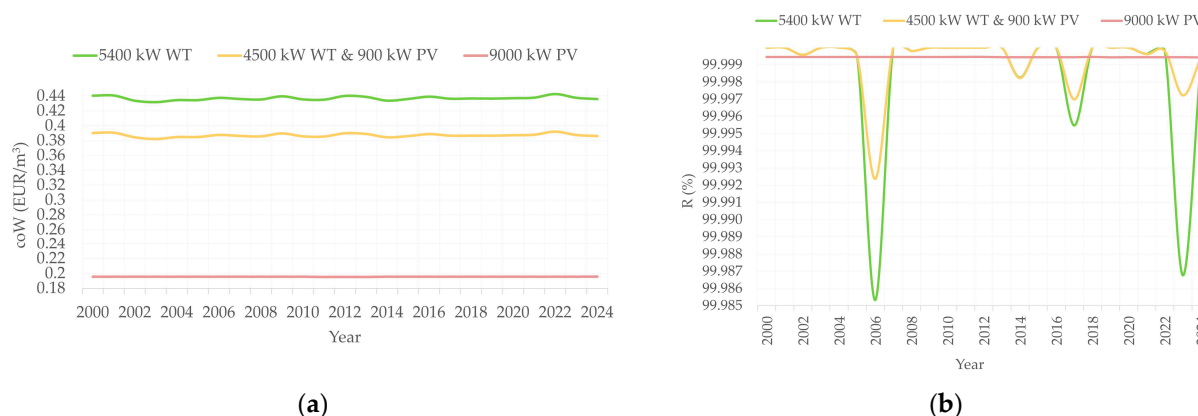


Figure 4. Comparison of (a) water cost and (b) reliability over a 25-year period for each scenario.

Figure 5 illustrates the monthly distribution of the coverage of water supply and irrigation needs from the three available sources—RES, battery, and the dam—based on meteorological data for the year 2024. In the figure, the solid blue bars represent water supplied from the reservoir for domestic water supply, while the patterned blue bars represent water supplied from the reservoir for irrigation. For each month, the percentage of participation of each source in the total coverage of water demand is presented, highlighting their role in ensuring the adequacy of water resources. The dam is exclusively used during the period from April to September, a period that corresponds to the irrigation season, during which water demand increases significantly. This fact highlights the contribution of the hybrid system to covering increased seasonal needs while utilizing clean and sustainable energy resources.

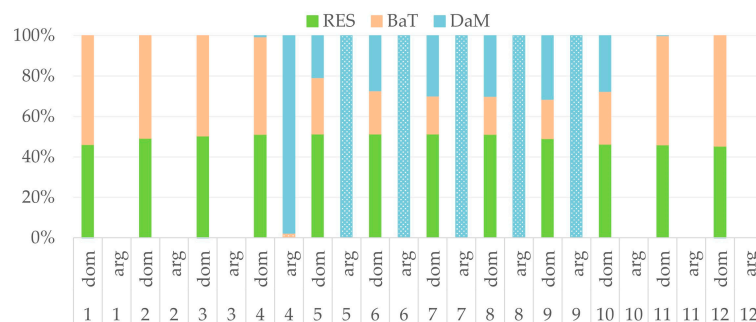


Figure 5. Monthly share of water supply and irrigation demand met by RES, battery storage, and the dam.

The proposed systems aim both to ensure water sufficiency and to significantly reduce the environmental footprint. Emphasis is placed on the reduction in CO₂ emissions, highlighting the role of hybrid energy solutions as sustainable and low-carbon options. Figure 6 presents the results of the reduction in CO₂ emissions for three different scenarios over a 25-year time horizon. A greater reduction in emissions is observed in the scenarios that also contain wind turbines, and in each case, the tons per year shows the viability of the proposal.

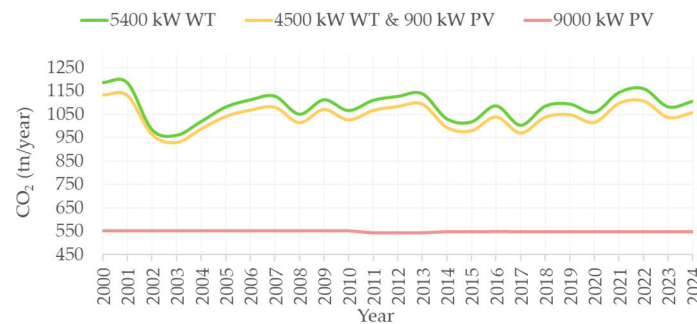


Figure 6. Reduced CO₂ emissions resulting from the implementation of the hybrid system across different scenarios over 25 years.

4. Conclusions

The HRES, combined with the island's dam, provides a reliable supply of clean water over the 25-year horizon. Among the three scenarios, photovoltaics results in the lowest average water price of 0.196 EUR/m³, while wind turbines result in the highest price of 0.437 EUR/m³. The combined scenario yields an intermediate price of 0.387 EUR/m³. The system effectively meets seasonal peaks in water demand, with the dam being used primarily during the irrigation period, highlighting the role of each source of the HRES in maintaining water adequacy. All scenarios contribute to a substantial reduction in CO₂ emissions, with the greatest reductions observed in scenarios including wind turbines. Overall, integrating multiple RESs with existing water infrastructure reduces prices and ensures a consistent water supply for the island.

Author Contributions: Conceptualization, E.B. and M.M.B.; methodology, M.M.B.; software, M.M.B.; validation, E.B. and M.M.B.; formal analysis, M.M.B.; investigation, M.M.B.; resources, M.M.B. and E.P.; data curation, M.M.B. and E.P.; writing—original draft preparation, M.M.B. and E.B.; writing—review and editing, M.M.B. and E.B.; visualization, M.M.B.; supervision, E.B.; project administration, E.B. and E.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded within the framework of a research project supported by the Municipality of Kos, Greece.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is available from the authors upon reasonable request.

Conflicts of Interest: Author Eftychia Papalexiou was employed by the company Municipal Water Supply and Sewage Company of Kos. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors declare that this study received funding from Municipality of Kos. The funder had the following involvement with the study: resources, data curation, project administration.

References

1. Espinosa, L.A.; Portela, M.M.; Matos, J.P.; Gharbia, S. Climate Change Trends in a European Coastal Metropolitan Area: Rainfall, Temperature, and Extreme Events (1864–2021). *Atmosphere* **2022**, *13*, 1995. [CrossRef]
2. Bertsiou, M.M.; Baltas, E. Sustainable energy and water resources management to address water scarcity. *Water Util. J.* **2025**, *34*, 1–11.
3. Papathanasiou, A.-F.; Ntemiri, K.; Baltas, E. Sustainable Water Resources Management and Energy Production in Small Mediterranean Islands. *Environ. Process.* **2025**, *12*, 19. [CrossRef]
4. Dhakal, N.; Salinas-Rodriguez, S.G.; Hamdani, J.; Abushaban, A.; Sawalha, H.; Schippers, J.C.; Kennedy, M.D. Is Desalination a Solution to Freshwater Scarcity in Developing Countries? *Membranes* **2022**, *12*, 381. [CrossRef] [PubMed]

5. Tabari, M.M.R.; Eilbeigi, M. Evaluating and determining the mechanism of land subsidence susceptibility under excessive overexploitation of groundwater and problematic sediments. *Environ. Dev. Sustain.* **2025**. [[CrossRef](#)]
6. Azinheira, G.; Segurado, R.; Costa, M. Use of RES-powered desalination in water-stressed regions. A case study in Algarve, Portugal. In *Energy Storage for Multigeneration*; Elsevier: Amsterdam, The Netherlands, 2023; pp. 93–124. [[CrossRef](#)]
7. Papathanasiou, A.-F.; Platanitis, I.; Baltas, E. Investigation of Water Supply Through Renewable Energy During the Peak Tourist Season on Mykonos Island. *Water* **2026**, *18*, 259. [[CrossRef](#)]
8. Palazzolo, G.; Martorana, P.; Mantegna, M.; Milone, D.; Franzitta, V. The Role of RES and Desalination Plants. A Case Study. In *OCEANS 2024—Halifax*; IEEE: New York, NY, USA, 2024; pp. 1–5. [[CrossRef](#)]
9. Apolinário, R.; Castro, R. Solar-Powered Desalination as a Sustainable Long-Term Solution for the Water Scarcity Problem: Case Studies in Portugal. *Water* **2024**, *16*, 2140. [[CrossRef](#)]
10. Visual Crossing Weather, “Weather Data & API”. Available online: <https://www.visualcrossing.com> (accessed on 20 September 2024).
11. Bertsiou, M.M.; Baltas, E. Integration of Different Storage Technologies towards Sustainable Development—A Case Study in a Greek Island. *Wind* **2024**, *4*, 68–89. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.