

Economic analysis of decarbonization in the Fuerteventura-Lanzarote system

Juan Manuel Roldan Fernandez, Javier Serrano Gonzalez, Olivia Mariela Domínguez Monge, Manuel Burgos Payan,
Universidad de Sevilla
Sevilla, Spain
jmroldan@us.es, javierserrano@us.es, olidommon@alum.us.es, mburgos@us.es

Abstract— This study assesses the economic feasibility of decarbonizing the isolated electrical systems of Fuerteventura and Lanzarote through increased renewable energy integration. Among five scenarios analyzed, the most profitable involved a 125% increase in wind and photovoltaic capacity compared to the baseline, requiring a €193.6 million investment. This scenario achieved annual fuel savings of €11.8 million. Hydrogen technologies, evaluated in later scenarios, showed limited short-term profitability due to high investment costs. In contrast, renewable energy alone delivered strong economic returns and substantial emissions reductions, particularly in fossil fuel-dependent island systems. The results emphasize the strategic role of renewables in enhancing energy independence and mitigating exposure to fossil fuel price volatility. While hydrogen integration is not yet cost-effective, it may support long-term system flexibility as technology costs decline. This study offers valuable insights for guiding investment decisions in island energy transitions under current and future market conditions.

Index Terms—Carbon emissions, green hydrogen, low carbon economy, renewable energy sources, sustainable development.

I. INTRODUCTION

The European Union (EU) has taken significant steps toward achieving climate neutrality by 2050, as outlined in the European Green Deal and associated policy instruments. Recent trends demonstrate encouraging progress: in 2023, the EU achieved an 8.3% reduction in net greenhouse gas (GHG) emissions compared to 2022, marking the largest annual decline in decades [1]. This was primarily due to a reduction in coal-based electricity generation and a surge in renewable energy production, particularly from wind and solar. The trend persisted into 2024, with emissions falling by 0.6% in Q3 year-on-year despite a 1.3% increase in GDP, further evidencing the decoupling of emissions from economic growth [1][2].

Despite these advances, the increasing penetration of variable renewable energy (VRE) sources such as wind and solar introduces operational and reliability challenges for power systems—especially in isolated or weakly interconnected networks. Maintaining supply-demand balance and ensuring system resilience in such contexts is critical. Green hydrogen, produced via electrolysis powered by renewable energy, has

emerged as a strategic energy carrier that offers long-term storage and multi-sector integration [3][4].

Hydrogen’s ability to store excess renewable energy and convert it back to electricity when needed makes it particularly attractive for systems facing renewable intermittency. Moreover, it can serve applications beyond power generation, including transportation, industrial processes, and heating [5]. As a zero-emission fuel, green hydrogen aligns with the EU’s climate strategy and sector coupling objectives, particularly in areas with limited grid flexibility or land availability.

Numerous studies have analyzed the role of hydrogen in future energy systems. Muthia et al. [4] examined green hydrogen production via floating solar PV for industrial decarbonization. Li and Zhang [5] assessed co-located wind and hydrogen systems, while Florez et al. [6] optimized off-grid hydrogen and ammonia production systems in desert environments. These contributions offer insights into the technical and economic dimensions of hydrogen integration. However, island systems remain underexplored in this literature. Islands often face specific constraints, such as land scarcity, limited interconnection, and high dependence on fossil fuel imports. As Handique et al. [3] emphasize, traditional energy modeling approaches are often unsuitable for these contexts due to oversimplified assumptions about infrastructure flexibility and energy demand patterns.

Furthermore, most techno-economic studies focus on large interconnected systems or export-oriented hydrogen production [7][8]. There is a clear need for localized, context-sensitive models that assess hydrogen’s role in balancing and decarbonizing island energy systems, particularly when considering the high costs of hydrogen infrastructure, land-use limitations, and sectoral integration.

This paper addresses this research gap by conducting a detailed techno-economic analysis of hydrogen integration in Lanzarote and Fuerteventura, two islands in the Canary archipelago with high renewable potential but limited capacity for conventional grid expansion.

This study presents a techno-economic assessment of integrating green hydrogen into the energy systems of Lanzarote and Fuerteventura, aiming to reduce reliance on

fossil-fuel-based thermal generation. By evaluating multiple renewable-hydrogen scenarios under current and projected cost conditions, the analysis identifies viable pathways to increase renewable energy penetration while ensuring system reliability.

The remainder of this paper is organized as follows. Section 2 describes the current energy system characteristics, constraints, and renewable potential of Lanzarote and Fuerteventura. Section 3 introduces the proposed energy model, including assumptions related to technology costs and investments. Section 4 presents and discusses the key results, with emphasis on cost-effectiveness potential. Finally, Section 5 concludes the paper, summarizing main findings and outlining recommendations for future research.

II. THE ELECTRICAL POWER SYSTEM FUERTENVENTURA-LANZAROTE

The system under study comprises the islands of Fuerteventura and Lanzarote, belonging to the Canary Islands archipelago located in the Atlantic Ocean off the coast of Africa. Unlike mainland Spain, which has an interconnected electrical grid, the Canary Islands' systems are isolated due to their distance from the mainland. These conditions give the islands unique characteristics compared to the rest of Spain, resulting in one of the lowest levels of renewable energy integration despite their geographical potential. This is because, as isolated systems, they rely on thermal power plants for grid stability. In a small territory, the intermittency of renewable energy sources can lead to grid instability when renewable resources are unavailable. Additionally, the separation of the islands by water hinders interconnection, as it would require extensive and expensive undersea power cables that are difficult to maintain. In the specific case of Fuerteventura and Lanzarote, both islands are interconnected, forming an isolated system [9]. The islands' power generation relies heavily on non-renewable sources, likely due to the challenge of balancing energy consumption and demand in a system with high renewable energy integration. This also makes the grid less reliable because the system is smaller, potentially leading to greater variability in consumption and a limited range of power generators.

Electricity demand is primarily met by thermal power generation plants, with two major power stations: Las Salinas in Fuerteventura and Punta Grande in Lanzarote. Each plant houses a number of generators utilizing two different technologies: reciprocating internal combustion engines (diesel) and gas turbines. Table I provides details of the breakdown of the power capacity:

TABLE I. SUMMARY OF FOSSIL FUEL POWER INSTALLED CAPACITY IN LANZAROTE AND FUERTEVENTURA

Location	Technology	Power capacity (MW)
Lanzarote	Diesel	121
Lanzarote	Gas Turbine	63
Fuerteventura	Diesel	115
Fuerteventura	Gas Turbine	80

The remaining energy is supplied by renewable sources. Unlike the rest of Spain, renewables do not have a significant contribution in the electrical power system. The Canary Islands' economy relies on its scenic landscapes, leading to a protective attitude among the population towards large-scale construction projects. This makes integrating renewable energy sources into the electrical system challenging, resulting in the Canary Islands having the sixth-lowest contribution of renewable energy among Spanish regions. Fuerteventura and Lanzarote have nine wind farms distributed across their territory, with a total installed capacity of 88.8 MW, as shown in Fig. 1 [10].



FIG. 1. LOCATION OF THE FUERTEVENTURA-LANZAROTE ISLANDS AND THEIR WINDFARMS

Solar PV plants have a limited contribution to the power system in these islands. Their presence is restricted to small, low-power installations, resulting in a total installed capacity of only 28.1 MW. FIG. 2 illustrates the share of energy production by technology in 2023. As shown, diesel dominates with 82%, followed by wind (11%), gas turbines (5%), and PV (2%). Therefore, there is significant potential for decarbonization.

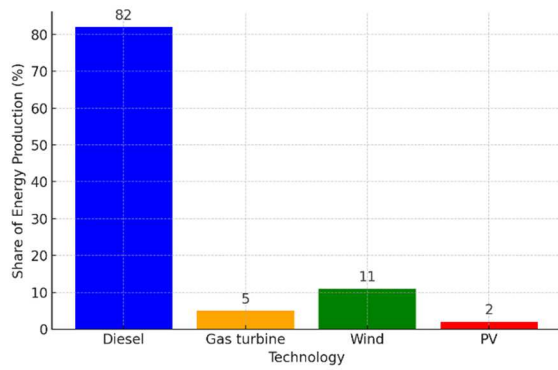


FIG. 2. ENERGY PRODUCTION DISTRIBUTION BY TECHNOLOGY

III. METHODOLOGY

The main objective of this work is to analyze medium- and long-term scenarios in which green hydrogen is used as a source for electricity production. Given that the Fuerteventura-Lanzarote island system is highly carbonized, it is proposed to increase the penetration of renewables in the system while using an electrolyzer to convert excess renewable energy into hydrogen, which can later be used for electricity generation.

The analysis is conducted using the EnergyPLAN software [11]. EnergyPLAN is a well-established and widely used energy system analysis tool, designed for modeling and simulating 100% renewable-based systems. It performs hourly simulations of the electricity, heating, cooling, and industrial sectors, making it a powerful tool for energy transition planning [12]. Fig. 3 illustrates the overall structure of the EnergyPLAN model, which consists of key components including Demand, Supply, Balancing and Storage, Cost, Simulation, and Output. Various energy sources, such as renewable electricity (RES), geothermal and solar heat, and fuel, are modeled within EnergyPLAN, feeding into different conversion and storage technologies, including power plants (PP), boilers, electrolyzers, hydrogen storage, and biomass conversion. The system is designed to balance energy supply and demand through electricity, heat, cooling, and transport sectors, incorporating hydro storage, gas storage, and electricity storage systems.

Furthermore, EnergyPLAN has been applied in various island systems worldwide, demonstrating its effectiveness in transitioning towards decarbonized energy. Recent studies highlight its application in small-scale, isolated grids, such as the Galápagos Islands, where renewable energy scenarios were explored to replace fossil fuel-based generation while ensuring system stability. EnergyPLAN is used to simulate the Fuerteventura-Lanzarote power system, incorporating electrolyzers and hydrogen fuel cells to evaluate future energy pathways. The results will help assess the impact of green hydrogen on system reliability, cost-effectiveness, and carbon emissions reduction, ultimately supporting the European Union's long-term energy goals.

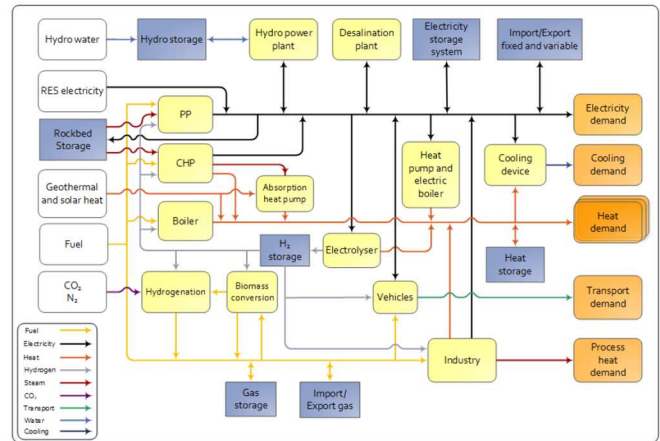


FIG. 3. ENERGY SYSTEM STRUCTURE IN THE ENERGYPLAN MODEL

Fig. 4 illustrates the Fuerteventura-Lanzarote energy system simulated with EnergyPLAN, focusing on the interaction between electricity demand and generation from different technologies. Wind and photovoltaic (PV) power generate electricity to meet demand while also supplying energy to an electrolyzer, which produces hydrogen (H_2). The hydrogen is stored and later converted back into electricity through a fuel cell or a hydrogen-based power plant, ensuring a stable energy supply for both residential and industrial consumers. This system enhances energy flexibility by enabling renewable energy storage, improving grid stability, and reducing dependence on fossil fuels.

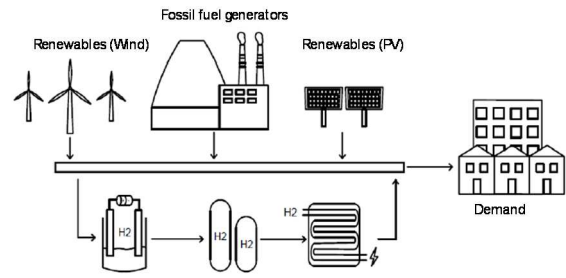


FIG. 4. HYDROGEN-BASED ENERGY SYSTEM WITH RENEWABLE INTEGRATION

The analysis follows a structured approach. First, the current system (2023) is modeled, and its operational costs are calculated. A base model is established, reflecting the 2023 energy generation and demand, which amounts to 1.57 TWh annually. The generation mix includes 28.1 MW of photovoltaic power, 88.8 MW of wind power, and thermal generation from gas and diesel. The system is simulated using EnergyPLAN, which allows for a detailed definition of demand and generation. The operational costs are then determined based on fuel consumption and thermal generation expenses.

Next, renewables and/or hydrogen are integrated, and their impact on costs is analyzed. Renewable scenarios are developed, increasing renewable capacity by 25% in each iteration. Hydrogen technology is introduced as both a storage solution and a secondary energy source, utilizing electrolyzers to convert excess renewable energy into hydrogen. The analysis

evaluates how these changes reduce fossil fuel consumption and overall system operating costs. Finally, Net Present Value (NPV) analysis is conducted to assess investment profitability. The savings in fossil fuel consumption obtained in each scenario are considered financial benefits.

IV. RESULTS

Using the previous methodology a baseline scenario was established along with five additional scenarios where renewable energy capacity was progressively increased. Table 2 summarizes the installed capacities of wind, photovoltaic (PV), and hydrogen systems across these scenarios, illustrating the structural transformation of the energy system.

TABLE 2. SCENARIO ANALYSIS AND INSTALLED CAPACITY

Scenario	Wind (MW)	PV (MW)	Hydrogen (MW)
Baseline Case	88.8	28.1	0
Scenario 1: 25% Increase	111	35.1	0
Scenario 2: 75% Increase	155.4	49.2	0
Scenario 3: 125% Increase	199.8	63.2	0
Scenario 4: 175% Increase	244.2	77.3	20
Scenario 5: 225% Increase	288.6	91.3	60

It is important to highlight that the increase in renewables gradually replaces the contribution of thermal generation, as their production costs are lower. Hydrogen generation becomes feasible when there is a surplus of renewable energy, which occurs when the installed renewable capacity nearly doubles (Scenario 4). Until Scenario 4, there was not enough renewable energy to fully meet demand and generate surplus energy, resulting in zero hydrogen production in the previous scenarios.

The transition toward decarbonization necessitates substantial investments in renewable energy and emerging technologies, such as hydrogen production and electricity generation. However, the profitability of these investments is not always guaranteed, much like the early stages of wind and photovoltaic energy, which initially faced economic and technological challenges before becoming cost-effective solutions.

This work aims to assess the profitability of new energy investments using an approximate yet insightful approach. By quantifying fuel savings resulting from increased renewable energy integration, we establish a measure of profitability through the Net Present Value (NPV), a widely used financial metric for evaluating the long-term viability of capital-intensive projects. Increasing the installed capacity of a specific technology involves an initial investment cost, which includes construction, maintenance, and implementation expenses. This value encompasses all additional costs associated with expanding wind, photovoltaic, and hydrogen system capacity. The cash flow are derived from fuel (diesel and gas) savings resulting from the increased share of renewable energy in the system. As the production of electricity from thermal power

plants decreases, fossil fuel consumption is reduced, generating economic savings compared to the baseline scenario, which is considered a financial gain.

NPV requires two additional parameters to be defined: the number of years (n) and the discount rate (k). The investment payback period has been set at 20 years, which corresponds approximately to the expected lifespan of the implemented technologies. The discount rate adjusts the value of future earnings to their present-day equivalent, considering that future money holds less value than money today. As previously mentioned, the discount rate is set at 7%, aligning with the value used by the International Renewable Energy Agency (IRENA) for assessing future energy investments [12].

TABLE 3 presents the economic evaluation of various renewable energy investment scenarios, detailing the costs associated with wind, photovoltaic (PV), and hydrogen technologies alongside their respective fuel savings and Net Present Value (NPV). The results indicate that increasing investments in wind and PV alone initially yields strong financial returns, with NPVs remaining positive and increasing significantly in Scenarios 1 to 3. In Scenario 3, an investment of 162.3 M€ in wind and 31.3 M€ in PV leads to 11.8 M€ in fuel savings and the highest NPV of 125.3 M€, demonstrating strong profitability. However, as hydrogen infrastructure is introduced in Scenario 4 along with increased wind and PV investments, the NPV drops to 99.9 M€, suggesting that the high upfront cost of hydrogen impacts short-term economic viability despite achieving higher fuel savings (16.4 M€).

A more aggressive hydrogen investment strategy in Scenario 5 leads to further cost increases, even though wind and PV investments are at their peak. While fuel savings reach 21.0 M€, the NPV turns negative (5.9 M€), indicating that the investment cost outweighs the economic benefits in the current market conditions. This suggests that while hydrogen can contribute to long-term energy system flexibility and decarbonization, its high infrastructure costs currently reduce overall profitability. To maximize economic returns, a balanced integration of renewables and hydrogen is essential, alongside further reductions in hydrogen technology costs.

Moreover, these results reflect broader patterns observed historically in energy transitions. Early-stage investments in wind and PV also faced economic and technological barriers but became cost-effective over time due to sustained policy support, innovation, and economies of scale. Hydrogen may follow a similar trajectory, but it will require strategic planning, phased implementation, and substantial cost reductions to reach economic maturity.

Beyond the financial results, this study also points to several strategic and systemic implications. Increasing renewable penetration not only yields economic benefits but also enhances energy security by reducing reliance on imported fossil fuels, an especially relevant factor in the context of recent geopolitical instability and fuel price volatility. For island systems, which are typically more vulnerable to external energy shocks, this transition represents an opportunity to reinforce local resilience and sovereignty.

Nonetheless, challenges remain that merit further exploration. The environmental impact of renewable infrastructure expansion, including land use, effects on tourism, biodiversity, and lifecycle emissions, was not addressed in this analysis but is crucial for evaluating the overall sustainability of decarbonization strategies. Additionally, higher shares of variable renewables may introduce grid stability concerns, potentially requiring complementary technologies such as battery storage or demand-side flexibility.

TABLE 3. ECONOMIC EVALUATION OF RENEWABLE ENERGY AND HYDROGEN INVESTMENT SCENARIOS

Scenario	Investment (M€)			Savings (M€)	NPV (M €)
	Wind	PV	Hydrogen		
1	32.5	6.3	0	2.3	24.3
2	97.4	18.8	0	7.3	76.8
3	162.3	31.3	0	11.8	125.3
4	227.2	43.8	73.9	16.4	99.9
5	292.1	56.3	228.1	21.0	-5.9

V. CONCLUSIONS

This study presents a techno-economic assessment of integrating renewables and green hydrogen into the energy systems of Lanzarote and Fuerteventura, two islands currently dependent on fossil-fuel-based generation. The analysis confirms that increasing renewable energy capacity, particularly through wind and photovoltaic systems, leads to significant fuel savings and strong financial returns. These investments demonstrate high profitability, especially in early scenarios without hydrogen infrastructure.

The results also show that while hydrogen offers long-term flexibility and decarbonization potential, its current high investment costs limit its short-term economic viability. A balanced strategy that prioritizes renewable deployment while preparing for cost reductions in hydrogen technologies is essential for future implementation.

Future research should explore complementary storage solutions such as battery systems, assess grid stability impacts under high renewable penetration, and evaluate environmental and socio-economic implications. A multidimensional approach incorporating technical, financial, and sustainability metrics will be key to supporting a successful and just energy transition in isolated power systems.

ACKNOWLEDGMENT

This work was supported by the Andalusian Government under a grant PROYEXCEL_00588.

REFERENCES

[1] European Environment Agency, "Trends and projections in Europe 2024", <https://www.eea.europa.eu/en/analysis/publications/trends-and-projections-in-europe-2024>.

[2] European Commission, "Report from the commission to the European Parliament and the Council", EU Climate Action Progress Report, 2024. https://climate.ec.europa.eu/document/download/d0671350-37f2-4bc4-88e8-088d0508fb03_en

[3] Handique, A.J., Peer, R.A.M. & Haas, J. Understanding the Challenges for Modelling Islands' Energy Systems and How to Solve Them. *Curr Sustainable Renewable Energy Rep* 11, 95–104 (2024). <https://doi.org/10.1007/s40518-024-00243-8>

[4] Rahma Muthia, Anastasia Segari Putri Pramudya, Mochamad Rafly Maulana, Widodo Wahyu Purwanto, "Techno-economic analysis of green hydrogen production by a floating solar photovoltaic system for industrial decarbonization", *Clean Energy*, Volume 8, Issue 4, August 2024, Pages 1–14, <https://doi.org/10.1093/ce/zkae032>.

[5] Li, H., and Zhang, J. (December 18, 2023). "Towards Sustainable Integration: Techno-Economic Analysis and Future Perspectives of Co-Located Wind and Hydrogen Energy Systems." *ASME. J. Mech. Des.* February 2024; 146(2): 020903. <https://doi.org/10.1115/1.4063971>

[6] Julian Florez, Mohammed AlAbbad, Holkan Vazquez-Sanchez, Miguel Gonzalez Morales, S. Mani Sarathy, Optimizing islanded green ammonia and hydrogen production and export from Saudi Arabia, *International Journal of Hydrogen Energy*, Volume 56, 2024, Pages 959-972, ISSN 0360-3199, <https://doi.org/10.1016/j.ijhydene.2023.12.075>.

[7] Staffell, I., et al. "The role of hydrogen and fuel cells in the global energy system." *Energy & Environmental Science*, 12(2), 2019. <https://doi.org/10.1039/C8EE01157E>

[8] Parra, D., Patel, M., & Bauer, C. "Hydrogen as a renewable energy carrier: a review." *Renewable and Sustainable Energy Reviews*, 60, 2016. <https://doi.org/10.1016/j.rser.2016.01.036>

[9] System Operator, Red Eléctrica Española, "EL SISTEMA ELÉCTRICO CANARIO" (The Canarian electrical power system), 2016.

[10] System Operator, Red Eléctrica Española, "Mapas de Generación en España," ESIOS, 2022.

[11] EnergyPLAN (n.d.), <https://www.energyplan.eu/>.

[12] Icaza-Alvarez, D., Jurado, F., Tostado-Vélez, M., & Arevalo, P. (2022). Decarbonization of the Galápagos Islands: Proposal to transform the energy system into 100% renewable by 2050. *Renewable Energy*, 189, 199-220. DOI: 10.1016/j.renene.2022.03.008.

[13] Renewable Energy Agency, *Global Energy Transformation: A Roadmap to 2050*. 2018. [Online]. Available: www.irena.org