23rd International Conference on Renewable Energies and Power Quality (ICREPQ'25)
Tenerife (Spain), 25th to 27th June 2025
ISBN-13: 978-84-09-66511-2

Decarbonizing an Offshore Microgrid with Green Hydrogen: The PLOCAN case study driven by the H2Verde Project

A. Romero-Filgueira[1,2], M.J. Pérez-Molina[1,2], J.A. Carta[2] , and P. Cabrera[2]

[1] Oceanic Platform of the Canary Islands (PLOCAN)
Telde, Spain
[2] Group for the Research on Renewable Energy Systems (GRRES), Department of Mechanical Engineering, Universidad de Las Palmas de Gran Canaria
Gran Canaria, Spain

Abstract. This paper presents the method used for designing the smart grid for PLOCAN's offshore platform, which aims to fully decarbonize the platform through a baseline renewable energy system, consisting of photovoltaic and wind power generation, along with electrical and chemical energy storage using renewable hydrogen. However, given PLOCAN's role as a testbed for the validation of marine technologies, the grid design must account for the integration of various marine-based power generation systems, thereby influencing the sizing of the installed equipment.

The electrical system has been modelled using HOMER software, which generated multiple scenarios. The selected scenario ensures the primary function of PLOCAN's Smart Grid: the integration of prototypes during their testing campaigns, in addition to minimizing pollutant emissions associated with the offshore platform's activities. The decarbonization and functional requirements impose constraints on decision-making, preventing certain optimizations that are typically applied to conventional self-consumption grids based solely on techno-economic criteria

Key words. Microgrid, green hydrogen, decarbonization.

1. Introduction

PLOCAN [1] supports the development of marine energy technologies by providing a unique infrastructure for validations in a real marine environment (Figure 1). Its offshore platform serves as an energy hub, managing power generated by prototypes deployed at its test site.

The H2Verde Project [3], funded under the Complementary Plan for R&D in Renewable Energy and Hydrogen, aims to transform the energy paradigm and reduce greenhouse gas emissions. As part of this initiative, PLOCAN's platform will integrate a green hydrogen power plant into its self-supply grid, enabling it to meet its energy needs while minimizing dependence on fossil fuels. This transformation will establish the platform as a self-sufficient, decarbonized system, serving as a model for island energy systems.

The green hydrogen plan will utilize energy from a Photovoltaic (PV) system and small wind turbines installed on the platform and deployed prototypes to produce hydrogen via Proton Exchange Membrane (PEM) electrolyzer. The hydrogen will be stored and later converted into electricity using a hydrogen fuel cell to meet the platform's energy demands. This paper offers a method to demonstrate the feasibility of generating green hydrogen in offshore environment and its application in isolated systems by modelling the system using HOMER software. The study assess the environmental impact of the measures designed for the offshore platform.

2. Material and methods

In this section we describe the current PLOCAN self-consumption electrical grid, and the target decarbonized electrical grid; as well as the equipment and software used. Finally, we outline the main criteria and assumptions used to to model the infrastructure according to its needs.

A. Current PLOCAN grid

PLOCAN's current self-consumption grid, or Smart Grid, is an intelligent system that efficiently manages the generation and consumption of electricity on its offshore platforms. The grid operates at a nominal three-phase voltage of 400 V with a nominal capacity of 1 MW. It includes:

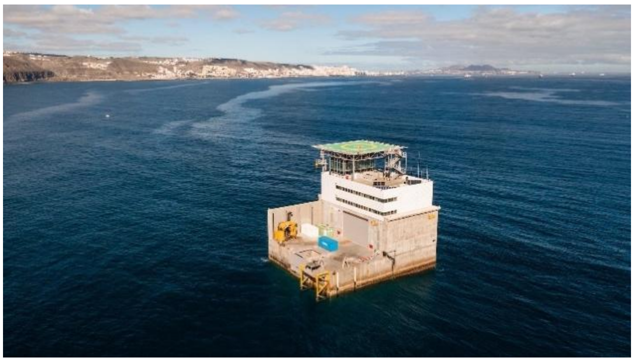

Figure 1. View of the PLOCAN platform's infrastructure.
Source: own-elaboration

- A 0,4/20 kV transformation center equipped with a 20 kV underwater cable for connecting an energy production prototype operating at this voltage level.
- Four generation feeders rated at 400 V and 250 kW each for prototypes connection. This generation capacity cannot be considered permanent since the prototypes are under validation and operate only during testing campaigns that may last for weeks or several months.
- Four consumption feeders rated at 400 V and 50 kW each for auxiliary services associated with the prototypes.
- The system also incorporates a resistive load bank position capable of consuming up to 1 MW of surplus energy,
- A 400 V panel dedicated to the offshore platform's general consumption.
- Two diesel baseline generators rated at 508 kW each. These serve as the synchronous reference for the isolated self-consumption grid, ensuring stability and reliability within the system.

B. *Target decarbonized PLOCAN grid*

A series of measures have been planned in order to reconfigure and enhance the Smart Grid with the objective of decarbonizing the energy management of the PLOCAN offshore platform; the electrical diagram is shown in Figure 2. These actions aim to ensure that diesel generation serves solely as backup or emergency power. In addition to the previously described components, the new elements to be integrated into the Smart Grid synchronization panel are as follows:

- Renewable Baseline Generation: A combination of a photovoltaic system and small wind turbines installed on the platform, with a capacity of 50 kW for the PV system and 12 kW for the wind turbines, comprising four 3 kW wind generators. The electrical grid also maintains the previously mentioned four 250 kW feeders for connecting marine energy prototypes under validation at PLOCAN's test site.
- Electrolyzer: A 100 kW PEM electrolyzer capable of producing up to 43 kg/day of renewable hydrogen at full power.
- Compressor: A pneumatic compressor that compresses renewable hydrogen produced at 30 bar to 200 bar.
- Hydrogen Storage: A system with a capacity of up to 9.600 liters.
- Fuel Cell: A 50 kW PEM fuel cell that will consume green hydrogen produced by the electrolyzer to generate electricity for the offshore platform's common services.
- Lithium-Ion Batteries: An energy storage system with a power input and output of 500 kW and 864 kWh of capacity. The system will stabilize the electrical grid, supply power to the electrolyzer, and support the 50 kW fuel cell, preventing fluctuations in these devices and ensuring overall grid stability.

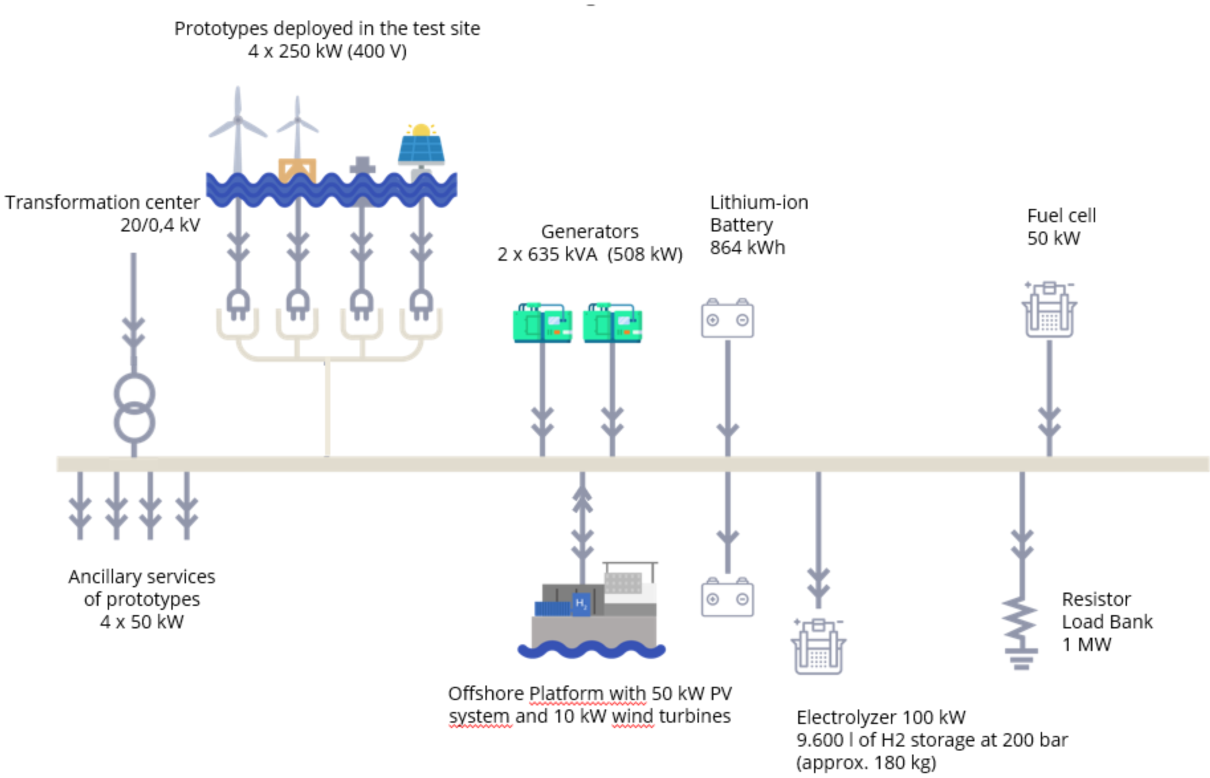

Figure 2. Electrical diagram of the target decarbonized PLOCAN grid.
Source: own elaboration

C. HOMER software [2]

HOMER software is a powerful tool for designing Hybrid Renewable Energy Systems (HRES), optimizing components through techno-economic analysis. It models various resources, including wind turbines, PV systems, fuel cells, batteries, generators and loads. For the calculation of solar-based generation, we will use the NASA Prediction of Worldwide Energy Resource database, which is directly loaded into the tool.

D. Lidar

A ZX300 LiDAR system has been deployed to generate a historical wind dataset for the designated wind turbine installation area. The LiDAR is mounted on the offshore platform building and has been continuously recording wind measurements since June 3, 2022. These data have been used for the precise modelling of the available wind resource and subsequently integrated into HOMER software for the energy system analysis.

E. Estimation of the consumer load

Currently, the offshore platform of PLOCAN shows an unusual consumption curve due to the fact that it remains unoccupied for a significant portion of the year. Access to the platform is only feasible if meteoceanic conditions allow, which occurs when the significant wave height does not exceed 1.2 meters. This happens on average for 120 days per year. On occupancy days, consumption is limited to 7-8 hours of activity. To model the current situation, a consumption of 25 kWh (calculated as the average of the consumptions measured over 14 days of access using an electrical analyzer) is distributed over 8 hours daily on access days. These days are distributed throughout the year according to the probability that meteoceanic conditions will permit access, using the historical series provided by the meteoceanic buoy of Puertos del Estado Las Palmas Este[1] (15,39º W. 28,05º N).

In the target infrastructure, modifications are proposed, as a baseline consumption of 5 kWh will be required for minimum services when the platform in unoccupied, and a consumption of 25 kWh during the occupancy hours. However, these will not be the only loads, as battery charging and the consumption of the electrolyzer and compressor will also come into play. These loads will be determined from simulations carried out using HOMER software.

F. Model

The implementation of the model in HOMER is based on initial information sources, technical specifications for designing the microgrid, the analysis requirements of the tool, automatically generated simulations, and the results obtained from the tool, classified according to resource optimization.

The system shown in Figure 2 has been modelled, incorporating economic data such as the cost and lifespan of each component, as well as certain operational parameters for the proper functioning of the energy system, such as the minimum battery charge. Figure 3 presents the model, which considers two diesel generators rated at 508 kW and a 50 kW fuel cell that will use green hydrogen as fuel and consequently produce zero pollutant gas emissions.

In order to meet the objective of decarbonization, the current PLOCAN grid has been modelled, where the only energy source are diesel generators, with the aim of comparing current pollutant gas emissions with those of the target PLOCAN grid.

It is important to highlight that the simulation was run for a period of one year, with the lithium-ion batteries fully discharged at the initial time of the simulation.

3. Results

One of the objectives of this study is to assess the environmental impact of the measures designed for the offshore platform. Consequently, we will present the emissions data obtained from the selected tool and compare them with those derived from the simulations of the target PLOCAN Grid. This analysis allows us to evaluate the effectiveness of the designed actions in advancing the decarbonization of the offshore platform.

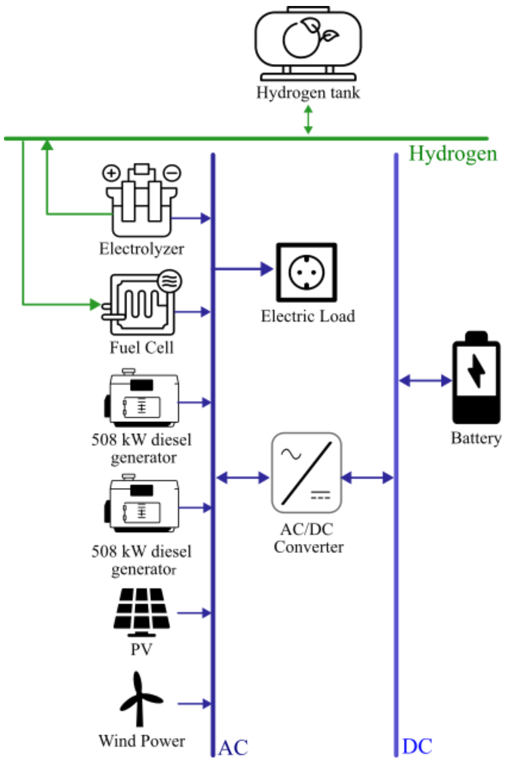

Figure 3. Target PLOCAN energy diagram implemented on HOMER software.
Source: own elaboration.

[1] https://portus.puertos.es/#/

A. Current PLOCAN Grid simulation

Three possible alternatives are offered by optimization and simulation results obtained from the model. From an economic standpoint, the optimized solution suggests using a single diesel generator. However, offshore regulatory requirements [4] mandate redundant backup generation. To meet this requirement while keeping both generator sets in operation, the costliest option is selected, which involves operating both generators, as this configuration more accurately reflects the actual conditions of plant operation. The simulation has estimated a fuel consumption of 11,616 L/year which is comparable to the current consumption of the platform under standard operating conditions.

Annual pollutant emissions associated with the current PLOCAN grid are shown in Table I.

Table I. – Annual pollutant emissions of the current PLOCAN Grid.

Quantify	Value (kg/yr)
Carbon Dioxide	30,460
Carbon Monoxide	158
Unburned Hydrocarbons	8.36
Particulate Matter	1.35
Sulfur Dioxide	74.5
Nitrogen Oxides	30.2

In addition to assessing of pollutant emissions, it is important to weight these emissions against the current operating hours of the offshore platform (960 hour corresponding to 120 days of access). Under the current conditions (24,000 kWh/year of electric production), there is neither generation nor consumption when the platform is unoccupied, which implies that the platform's monitoring systems are either out of service or in standby mode.

B. Target PLOCAN Grid simulation

In the simulations for the target PLOCAN Grid, HOMER determines that the optimal scenario requires the integration of the PV system, wind turbines, the electrolyzer (as a consumer), lithium-ion batteries, one of the two diesel generators and the fuel cell. The latter two play a minimal role, with the diesel generator operating for only 2 hours and producing 72.9 kWh, while the fuel cell operates for 11 hours, generating 235 kWh. In this scenario, the selected option involves only a single diesel generator, as the ultimate goal is the permanent shut-down of fossil fuel generators. A maintenance strategy will be necessary to ensure their reliability as an emergency backup system, which is common for this equipment. Figure 4 shows the charge status of the electricity batteries (in red), demonstrating that they achieve full charge in the optimized simulation of the target PLOCAN Grid. The green line in the same figure represents the state of the hydrogen storage (in kg), which reaches its maximum storage capacity early in March of a typical year. This also facilitates the integration of prototypes into the Smart Grid, as the fuel cell then has sufficient reserves to generate a synchronous reference voltage. At present, this synchronous reference is provided by diesel generators. The target PLOCAN Grid will incorporate a Grid-Forming Inverter system [5] [6]within the energy storage system, enabling island-mode operation.

Annual pollutant emissions associated with the target PLOCAN grid are shown in Table II.

Table II. – Annually pollutant emissions of target PLOCAN Grid

Quantify	Value (kg/yr)
Carbon Dioxide	285
Carbon Monoxide	1.48
Unburned Hydrocarbons	0.0783
Particulate Matter	0.0126
Sulfur Dioxide	0.697
Nitrogen Oxides	0.283

In this scenario, in addition to the evident reduction in pollutant gas emissions, the offshore platform remains in operation 365 days a year (88,531 kWh/year of electric production, 95,784 kWh if we add production of fuel cell and batteries), even in the absence of operational and maintenance personnel. Consequently, all ocean observation and monitoring equipment installed in the platform remains continuously active without interruption.

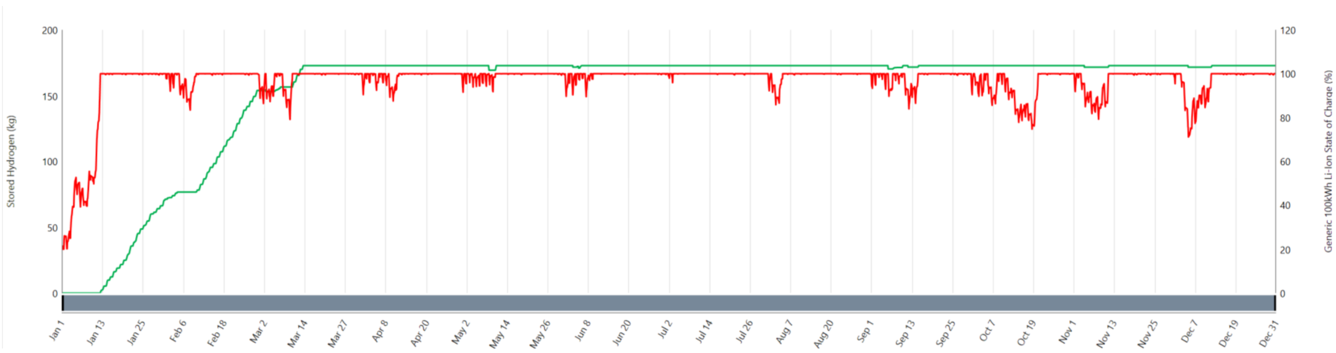

Figure 4. Annual energy storage charge status of the electricity batteries (in red) and the hydrogen storage system (in green). Source: own elaboration.

4. Conclusion

The comparison of the energy mix in both scenarios is shown in Table III and Figure 5, diesel generation in the target PLOCAN Grid is close to zero and consequently imperceptible in the bar chart.

Table III. – Comparison of the Energy Mix.

	Current PLOCAN Grid (kWh/year)	Target PLOCAN Grid (kWh/year)
Diesel	24,000.00	72.94
PV panels	-	49,114.76
Wind Turbines	-	33,343.97
Fuel Cell	-	235.23
Lithium-Ion batteries	-	7,017.32
Total	24,000.00	95,784.21

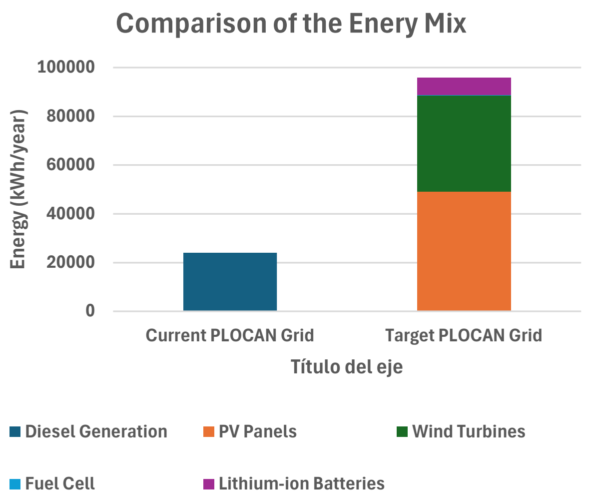

Figure 5. Comparison of the Energy Mix.
Source: own elaboration.

The first evident benefit of the implemented actions is the significant reduction in pollutant gas emissions, as observed in Tables I and II. It is important to note that the analysis is conducted over a one-year period, assuming the batteries start fully discharged. In a multi-year analysis, the batteries would retain charge at the end of the previous year, eliminating even the minimal two-hour operation of the diesel generator. This would result in the complete elimination of pollutant emissions, thereby achieving full decarbonization.

Another key benefit is the continuous availability of energy on the offshore platform. As an ocean observatory, it is essential to maintain uninterrupted historical data series of oceanic parameters and ensure their real-time visualization from land. The designed actions not only achieve the decarbonization of the offshore platform but also provide an uninterrupted power supply.

The offshore platform of PLOCAN, and more specifically its Smart Grid, is designed to serve as a testing site for marine energy prototypes. These prototypes feed the generation energy into the Smart Grid, which integrates it into the platform's energy balance, where it is either consumed by the platform, used for green hydrogen production, or stored in lithium-ion batteries. However, as prototypes, these generators often exhibit intermittent operation and efficiency levels significantly lower that commercially available solutions.

Since these are typically asynchronous generators, they require a synchronous reference within the grid to which they are connected. Initially, they consume a considerable amount of synchronous power from the Smart Grid until they achieve grid synchronization. At present, this synchronous reference is provided by diesel generators. The target PLOCAN Grid will incorporate a Grid-Forming Inverter system within the energy storage system, enabling island-mode operation.

Given this context, it is crucial to keep the ion-lithium batteries at full charge for as long as possible. In line with the optimized simulation results obtained, the batteries quickly reach full charge and hydrogen storage achieves its maximum capacity early in the year, ensuring that the fuel cell has sufficient reserves to generate a synchronous reference voltage for prototype integration.

5. Further research

Once the first decarbonization goal of an isolated grid has been achieved, future studies will focus on modelling prototypes connected to the Smart Grid, characterizing different technologies such as floating PV system, wave energy, or offshore wind power, and their integration into the offshore platform's energy balance.

Similarly, different uses for the generated hydrogen, beyond the power-to-grid approach analyzed in this study, can be explored, increasing the energy input required to produce more hydrogen. In this way, the offshore platform of PLOCAN could serve as a testing ground for the decarbonization strategies based on green hydrogen proposed in [7]

In this study, the technical evaluation and pollutant gas emissions analysis provided by HOMER have been used. A separate study will address the economic analysis, which would allow us to assess the actual cost of producing offshore green hydrogen from marine energy sources.

Acknowledgement

This research has been carried out the Complementary R&D&I Plan in the Area of "Renewable Energy and Hydrogen", cofounded by the EU Next Generation programme thought the Spanish Recovery, Transformation, and Resilience Plan and Canary Islands funds.

References

[1] Oceanic Platform of the Canary Islands, “Offshore Ocean Platform,” https://plocan.eu/en/installations/offshore-ocean-platform. Accessed: May 20, 2024. [Online]. Available: https://plocan.eu/en/installations/offshore-ocean-platform

[2] “HOMER Software.” Accessed: Feb. 03, 2025. [Online]. Available: https://homerenergy.com/

[3] “H2 Verde Project.” Accessed: Feb. 03, 2025. [Online]. Available: https://h2verde.plocan.eu/en/

[4] IMO, “SOLAS Regulations, Chapter II-1 - Electrical installations,” 1974. Accessed: Feb. 03, 2025. [Online]. Available: https://www.boe.es/buscar/doc.php?id=BOE-A-1985-1455

[5] J. Hernandez-Alvidrez, R. Darbali-Zamora, J. D. Flicker, M. Shirazi, J. VanderMeer, and W. Thomson, “Using Energy Storage-Based Grid Forming Inverters for Operational Reserve in Hybrid Diesel Microgrids,” *Energies (Basel)*, vol. 15, no. 7, p. 2456, Mar. 2022, doi: 10.3390/en15072456.

[6] R. H. Lasseter, Z. Chen, and D. Pattabiraman, “Grid-Forming Inverters: A Critical Asset for the Power Grid,” *IEEE J Emerg Sel Top Power Electron*, vol. 8, no. 2, pp. 925–935, Jun. 2020, doi: 10.1109/JESTPE.2019.2959271.

[7] D. Pivetta, C. Dall’Armi, P. Sandrin, M. Bogar, and R. Taccani, “The role of hydrogen as enabler of industrial port area decarbonization,” *Renewable and Sustainable Energy Reviews*, vol. 189, p. 113912, Jan. 2024, doi: 10.1016/j.rser.2023.113912.