FLEXIBLE TECHNO-ECONOMIC ASSESSMENT TOOL FOR OPTIMAL ELECTROLYSIS-RES COUPLING

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ABSTRACT

The escalating urgency to address climate change has sparked unprecedented interest in hydrogen as a clean energy carrier. Green hydrogen, serving as an energy storage medium, adeptly accommodates the fluctuations and stochastic nature of Renewable Energy Sources (RES). Furthermore, it plays a pivotal role in decarbonizing hard-to-abate sectors and promoting sector coupling. This research article endeavors to delve into this the subject by developing a dynamic techno-economic assessment tool, capable of flexibly evaluating the optimal setup of an alkaline electrolyser coupled with intermittent RES within a specific region. The focus lies on achieving cost-effectiveness, efficiency, and sustainable production of green hydrogen. The tool utilizes a comprehensive dataset encompassing a full year of hourly data on renewable electricity production from RES, including solar, wind, and hybrid configurations. It sizes the RES-to-electrolyser capacity ratio to minimize the Levelized Cost of Hydrogen (LCOH) and surplus renewable electricity. Incorporating real electrolysis system operating maps from industrial manufacturers, the model considers the maximum and minimum alkaline electrolyser operating loads, degradation phenomena, and makes hourly decisions on the electrolyser's operating load, partial-load efficiency, and the amount of green H_2 produced. The tool assesses the impact on the electrolyser capacity factor, excess renewable electricity, and overall economic feasibility. The techno-economic assessment tool scrutinizes operational strategies of the electrolysis system when interfacing with stochastic RES, aiming to optimize economic and technical parameters.
Keywords: Electrolyser, RES, Green H_2, Techno-economic assessment, Dynamic Simulation, Parametric Optimisation, LCOH **Selected Conference Topic:** Hydrogen Energy (utilization, storage, production)

1 INTRODUCTION

The swift transition from fossil fuels to renewable energy alternatives, driven by climate change and geopolitical concerns, is accelerating (European Commission, 2019, 2020, 2021). Green hydrogen, derived from water electrolysis powered by renewable sources, has emerged as a versatile solution(Clean Hydrogen Partnership, 2022; IRENA, 2020; Hydrogen Europe, 2023), which can effectively decarbonize hard-to-abate sectors (transport, industry, energy) while enhancing system flexibility and security. Moreover, green H_2 ability to store surplus renewable electricity and release it during periods of high demand, addresses supply-demand imbalances(Skordoulias et al., 2022). However, a critical aspect that can hinder the kickstart of hydrogen economy is the high production cost. Exploiting cheap renewable electricity from RES for electrolytic hydrogen production can significantly lower down costs. However, supply stability challenges must be addressed due to the fluctuating nature of RES, with some fluctuations being predictable (e.g., solar radiation patterns) and others random (e.g., wind speed variations)(Egeland-Eriksen et al., 2023; Gunawan et al., 2020; Matute et al., 2023; Moran et al., 2023; Superchi et al., 2023). Ultimately, achieving price parity with fossil fuels hinges on optimally sizing and coupling RES and electrolysers to reduce costs, secure the renewable nature of hydrogen production, and ensure overall efficiency. This study introduces a novel approach through the creation of a flexible technoeconomic assessment tool. It combines actual

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historical data from intermittent RES with a comprehensive alkaline electrolyser mathematical model based on manufacturer specifications. By accounting for RES hourly availability, this tool accurately models the technoeconomics of hydrogen production and determines the optimal RES-to-Electrolyser (RES/Elec) installed capacity ratio to minimise LCOH. It can be adapted to various electricity procurement scenarios and seamlessly integrate multiple electricity sources to minimize costs and identify optimal RES/Elec configurations.

2 MATERIALS AND METHODS

2.1 Overall System Definition

The establishment of the TRIERES Hydrogen Valley marks a significant step towards fostering the hydrogen economy in Greece and potentially beyond. With its strategic location within Motor Oil's refinery at Ag. Theodoroi, Corinth, Greece, the project capitalizes on existing infrastructure while facilitating the production of renewable hydrogen on a considerable scale. The 30 MW electrolysis unit represents a substantial investment, capable of producing 4500 tons of renewable hydrogen annually. The annual hydrogen consumption within the TRIERES project would be equal to 2410 tons of H_2 holding promise for various end-use applications, spanning from road and maritime transport and industrial processes to the energy sector. In this context, a technoecnomomic assessment tool was developed to identify the cost-optimal RES/Elec coupling design for a hypothetical 30 MW alkaline electrolyser across three intermittent RES (wind, solar, hybrid) electricity procurement scenarios, as depicted in **Figure 1**.

This study introduces a novel approach by employing a technoeconomic assessment tool within a real-world application study. This application is pertinent for mitigating risks associated with future investments in the hydrogen economy, offering valuable insights to inform data-driven decision-making processes. Differently from other studies which use average aggregate data for solar and wind (namely wind distributions), here actual historic data from real utility-scale solar and wind farms in Greece were utilised as inputs to the model. These data are covering a full-year of operation (2023) with an hourly time granularity. The solar plant exhibits an annual CF of 20.14%, while the wind plant's CF is 37.36%. The model assumes that the electricity generated by the RES plants is supplied to the electrolyser at its LCOE. The LCOE for each RES installed capacity is computed using an internally developed discounted cash flow model. In this setup, the RES and electrolyser units are directly interconnected and under the same ownership. Alternatively, this connection could be established through a physical Power Purchase Agreement (PPA) with hourly temporal correlation and a "pay as produced" clause between the RES owner and the hydrogen production plant operator.

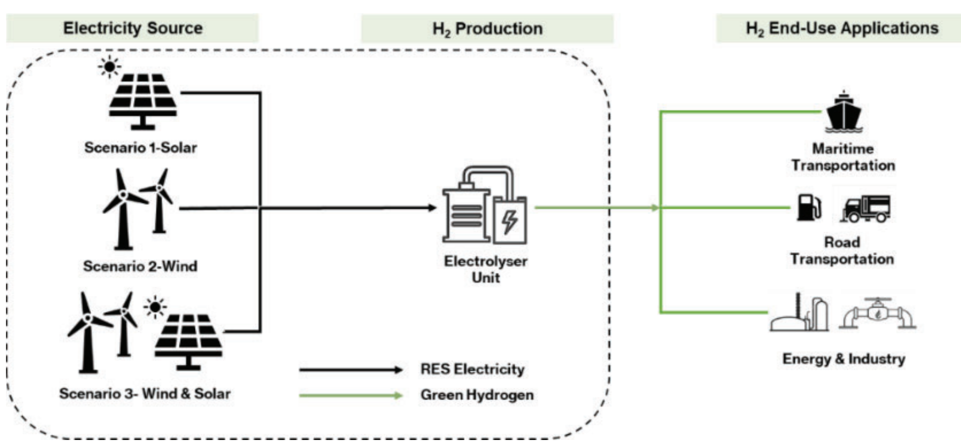

Figure 1: Techno-economic Assessment Tool system boundary.

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2.2 Control Strategy and Technoeconomic Parameters

The operation of the 30 MW electrolyser is governed by a power control algorithm, outlined in **Figure 2**. Hourly decisions are made based on the magnitude of the incoming RES power and the preset capacities of the various components. Initially, the algorithm takes inputs such as the renewable energy source type and location, along with hourly data spanning the entire year, to assess energy availability in the designated area. Based on hourly RES availability, the model makes an hourly decision on the electrolyser operation load. Then, considering technical limitations of the electrolysis technology (minimum and maximum operating power) and the performance curve at partial load, H_2 production is calculated on an hourly basis. At the end of the full-year simulation, the sum of the hourly H_2 production gives an accurate estimate of the system's annual hydrogen production capacity. Moreover, the model incorporates degradation phenomena to realistically simulate electrolyser performance across fluctuating energy supply profiles, identifying efficiency and hydrogen production rate impacts over time.

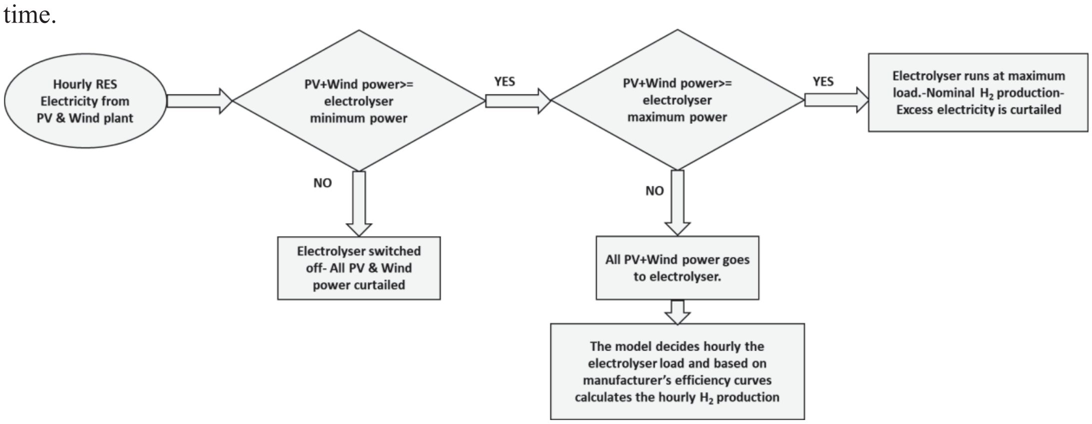

Figure 2: Hourly Power Control Strategy

LCOH is the key focus of the modelling, as it is used as the basis for component sizing. LCOH is calculated based on **Eq.1** and represents the total discounted present cost of producing hydrogen, over the lifetime of the system, in units of €/kgH_2. The costs for each aspect of the overall system and its components are broken down into initial capital expenditure (CAPEX), annual operational expenditure (OPEX) including operation and maintenance as well as electricity and water costs. For the purpose of this work, a discount rate of 5% is assumed as well as an economic lifetime of 20 years, similar to other studies(Egeland-Eriksen et al., 2023; Matute et al., 2023; Moran et al., 2023, 2024; Superchi et al., 2023). The cost of stack replacement of the electrolyser after 80.000 h of operation or maximum after 10 years is also considered in the calculation of LCOH, equal to 30% of CAPEX(Clean Hydrogen JU, 2022 ; Matute et al., 2023; Moran et al., 2023).

$$\mathrm{LCOH} = \frac{\mathrm{I_0} + \sum_0^t \frac{\mathrm{I_t} + \mathrm{E_t} + \mathrm{O_t} + \mathrm{W_t}}{(1+\mathrm{r})^t}}{\sum_0^t \frac{\mathrm{H_t}}{(1+\mathrm{r})^t}} \qquad \textbf{(1)}$$

Where, t: project lifetime; r: interest rate; I_0: CAPEX at year 0; I_t: electrolyser stack replacement cost at year t; E_t: electricity cost at year t; O_t: operation and maintenance costs at year t; W_t: water cost at year t; H_t: hydrogen production at year t. The main technoeconomic assumptions, based on literature(IRENA, 2019a, 2019b; Gunawan et al., 2020; Egeland-Eriksen et al., 2023; Matute, Yusta and Naval, 2023; Moran et al., 2023; Superchi et al., 2023) and electrolyser manufacturer's information are presented in **Table 1**.

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Table 1: Main technoeconomic assumptions.

Parameter	Alkaline Electrolyser	Solar Plant	Wind Plant
Installed capacity (MW)	30	Varied	Varied
Electrolyser minimum load (%)	10	–	–
Electrolyser maximum load (%)	100	–	–
Electrolyser partial-load efficiency (kWh/kg)	46.95 – 60.97	–	–
Water requirements (kgH_2O/kgH_2)	14	–	–
Water Cost (€/m^3)	3.8	–	–
Electrolyser Stack Lifetime (h)	80000 (10 years max)	–	–
Degradation (%1000h)	0.15	–	–
CAPEX (€/kW)	1100	600	1400
OPEX (€/kW/year)	27.50	15	31
Stack Replacement Cost (% CAPEX)	30	–	–
Land Lease Cost (€/kW/year)	–	2.80	0.40
LCOE (€/MWh)[1]	–	35 – 45	40 – 50

3 RESULTS

In this section, the output results from the techno-economic assessment tool will be presented for the three electricity procurement scenarios (solar, wind, hybrid). The aim is to explore via parametric optimisation how the size of RES in each scenario affects electrolyser operation, surplus electricity and LCOH.

3.1 Scenario 1-Solar Plant

The results from the parametric optimisation for various Solar-to-Electrolyser (Solar/Elec) installed capacity ratios are presented in **Figure 3.** The blue and orange solid lines represent the surplus electricity (%) and electrolyser CF (%) respectively, while the grey bars represent the LCOH (€/kgH_2).

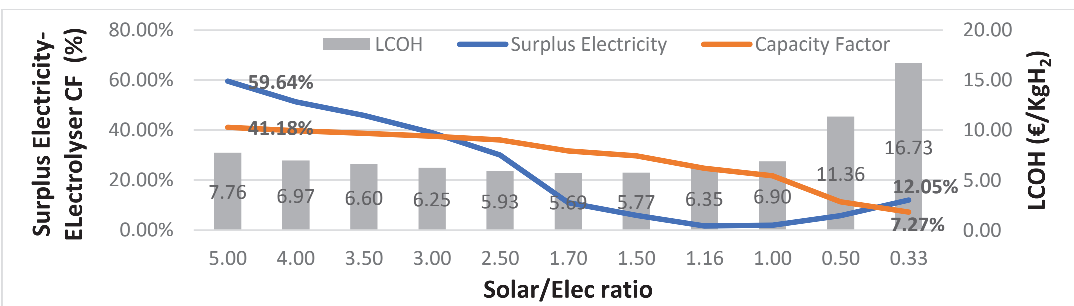

Figure 3: Scenario 1-30 MW Electrolyser Optimisation Results.

The results of yearlong simulations reveal an increase in electrolyser CF with higher Solar/Elec ratios. This trend is attributed to the increased availability of renewable energy that can be converted to H_2 due to the overdimensioning of the solar plant. For a highly overdimensioned solar plant, with a Solar/Elec ratio of 5, an electrolyser CF of 41.18% can be achieved, whereas for an underdimensioned solar plant with a Solar/Elec ratio of 0.33, the electrolyser CF can drop to values as low as 7.27%. Typically, higher CFs enable greater hydrogen production, thereby reducing the LCOH. However, results show that an optimal Solar/Elec ratio exists, that minimizes the LCOH, striking a balance between decreased capital expenditures, increased electricity costs, and enhanced electrolyser CF.

The optimal Solar/Elec ratio is found to be 1.70, leading to a minimum LCOH value of 5.69 €/kgH_2. Highly underdimensioned Solar/Elec configurations result in relatively high LCOH values, up to 16.73 €/kgH_2. Notably, the Solar/Elec ratio that minimizes the LCOH does not align with the ratio minimizing surplus electricity, i.e., the renewable electricity that cannot be converted to H_2 due to electrolyser

[1] Range of values calculated for the various Solar and Wind installed capacities based on discount cashflow model

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technical limitations. This energy is not sold to the energy market and it is penalized against LCOH, as operational cost. Thus, high Solar/Elec ratios lead to higher LCOH, as the increased CF cannot compensate for the increased electricity cost due to higher surplus energy. The key technoeconomic results for the minimum LCOH and minimum surplus electricity configurations are presented in **Table 2**.

Table 2: Main technoeconomic results for Scenario 1.

Parameter	Minimum LCOH Configuration	Minimum Surplus Electricity Configuration
Solar Installed Capacity (MW)	51.00	34.80
Solar/Elec ratio	1.70	1.16
Surplus Electricity (%)	11.02	1.74
Electrolyser Capacity Factor (%)	31.67	24.78
Electrolyser Average Efficiency (kWh/kg)	56.84	54.91
Annual H_2 Production (ton)	1365	1068
Year of stack replacement (years)	10	10
LCOH (€/kgH₂)	**5.69**	**6.35**

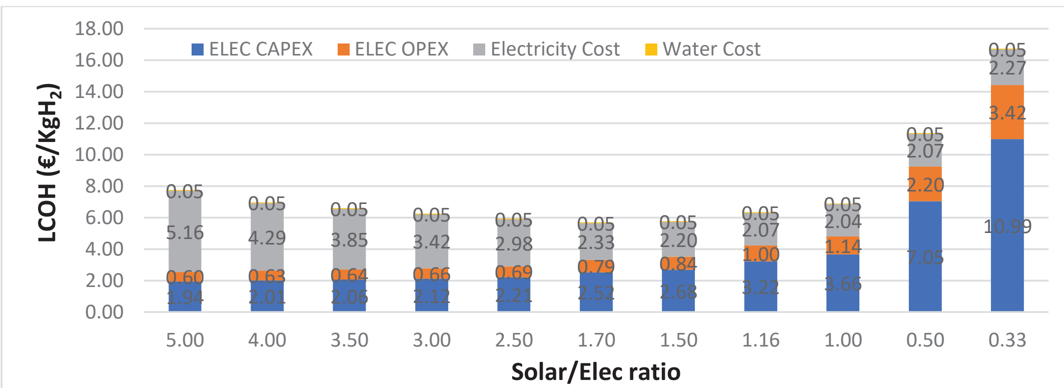

Figure 4: Scenario1-LCOH Breakdown for various Solar/Elec ratios.

As observed from **Figure 4**, for a larger solar plant size, surplus energy increases, resulting in higher electricity costs as the electrolyser buys more electricity that cannot be converted to hydrogen. Across the different Solar/Elec ratios, electrolyser capital expenditure contributes to the LCOH within a range of 25-66%, while electricity costs contribute within a range of 13-67%. The minimum LCOH is attained when contributions are nearly equal, with capital expenditure at 44% and electricity costs at 41%. Electrolyser operational expenditure contributes to the LCOH within a range of 8-20%, while water costs have almost negligible impact.

The operating profile of the electrolyser and available solar electricity are presented in **Figure 5** for the first two days and in **Figure 6** for 24 days within summer months, under the minimum LCOH configuration.

The 30 MW electrolyser operational strategy, as restricted by the power flow control algorithm, closely follows the intermittent operation of the solar plant, eventually leading to reduced annual CF. In time periods where the power generated from the solar plant is lower than the electrolyser minimum power requirements, the system is switched off and electricity is considered as curtailed. Conversely, during periods of high solar irradiation and subsequent high solar electricity production, typically occurring during midday, the electrolyser operates at its maximum load, producing hydrogen at nominal conditions. Any surplus energy that cannot be utilized by the electrolyser is deemed as curtailed.

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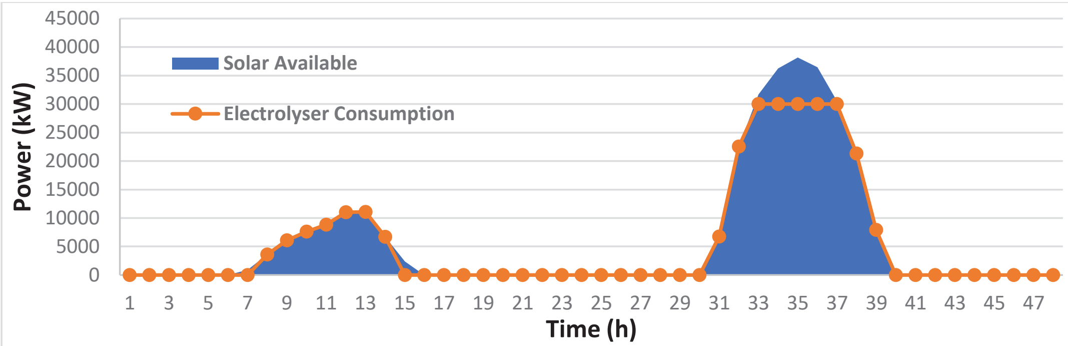

Figure 5: Scenario 1-Operating profile of 30 MW Electrolyser over a period of two days.

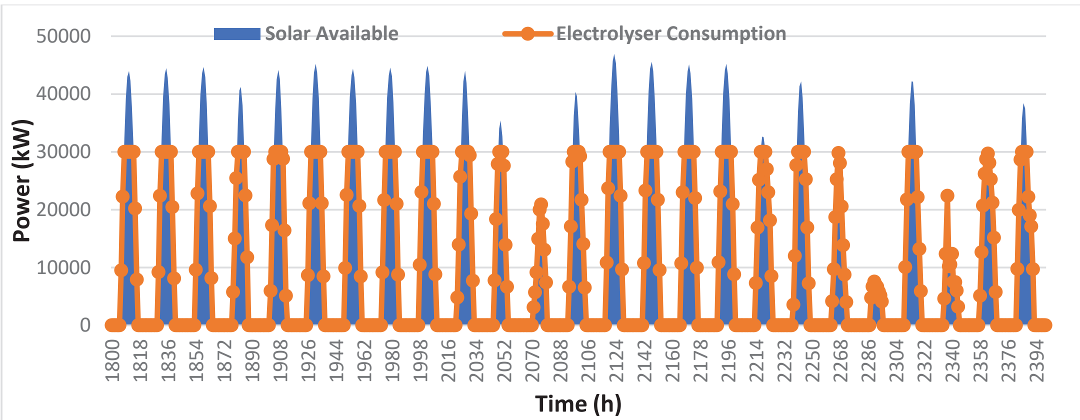

Figure 6: Scenario 1-Operating profile of 30 MW Electrolyser over a period of 24 days within summer months.

3.2 Scenario 2- Wind Plant

The parametric optimisation results for the various Wind-to-Electrolyser (Wind/Elec) installed capacity ratios are presented in **Figure 7**.

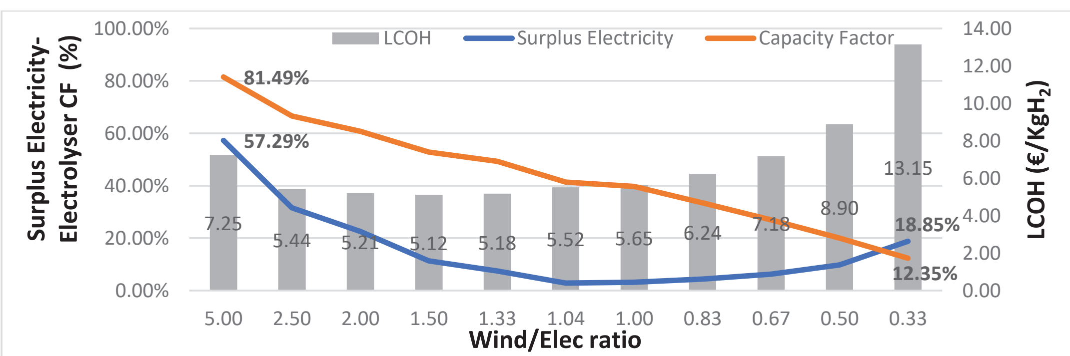

Figure 7: Scenario 2-30 MW Electrolyser Optimisation Results

The results of yearlong simulations indicate that for Scenario 2, the 30 MW electrolyser can achieve higher annual capacity factors (CFs) compared to Scenario 1, owing to increased electricity availability. This can be attributed to the higher annual capacity factor of the wind plant compared to the solar plant. For a highly overdimensioned wind plant, with a Wind/Elec ratio of 5, a high CF of 81.49% can be achieved, while for an underdimensioned plant (Wind/Elec ratio equal to 0.33), the CF can be as low as 12.35%. In Scenario 2, the minimum surplus electricity that can be achieved, as constrained by the hourly temporal correlation, is equal to 2.86% (2928.70 MWh), observed for a Wind/Elec ratio of 1.04.

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Due to the more unpredictable wind energy profile compared to solar energy, a closer match in the sizing of the two systems is required to minimize the electricity that cannot be utilized by the electrolyser.
The minimum LCOH is calculated equal to 5.12 €/kgH_2 and corresponds to a Wind/Elec ratio of 1.50. Among the various Wind/Elec ratios investigated, the highest LCOH is calculated to be 13.15 €/kgH_2 for an underdimensioned wind plant (Wind/Elec ratio of 0.33). The key technoeconomic results for the minimum LCOH and minimum surplus electricity configurations are presented in **Table 3**.

Table 3: Main technoeconomic results for Scenario 2.

Parameter	**Minimum LCOH Configuration**	**Minimum Surplus Electricity Configuration**
Wind Installed Capacity (MW)	45.00	31.30
Wind/Elec ratio	1.50	1.04
Surplus Electricity (%)	11.33	2.86
Electrolyser Capacity Factor (%)	52.84	41.37
Electrolyser Average Efficiency (kWh/kg)	54.87	53.50
Annual H_2 Production (ton)	2277	1783
Year of stack replacement (years)	10	10
LCOH (€/kgH_2)	**5.12**	**5.52**

The operating profile of the electrolyser and available wind electricity is presented in **Figure 8** for the first two days and in **Figure 9** for 24 days within summer months, under the minimum LCOH configuration.

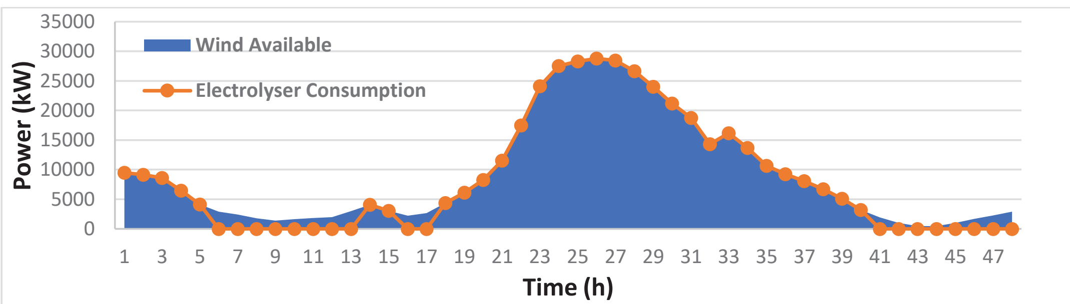

Figure 8: Scenario 2-Operating profile of 30 MW Electrolyser over a period of two days.

The operational strategy of the 30 MW electrolyser, as constrained by the power flow control algorithm, closely tracks the intermittent operation of the wind plant. Scenario 2 enable electrolyser to operate for more hours throughout the year at maximum load, thanks to the increased availability of renewable energy compared to Scenario 1. **Figure 9**, illustrates how the electrolyser operate for 6 consecutive days at maximum load, utilising the high wind energy production within this period. In time periods where the power generated from the wind plant is lower than the electrolyser minimum power requirements, the system is switched off and electricity is considered as curtailed.

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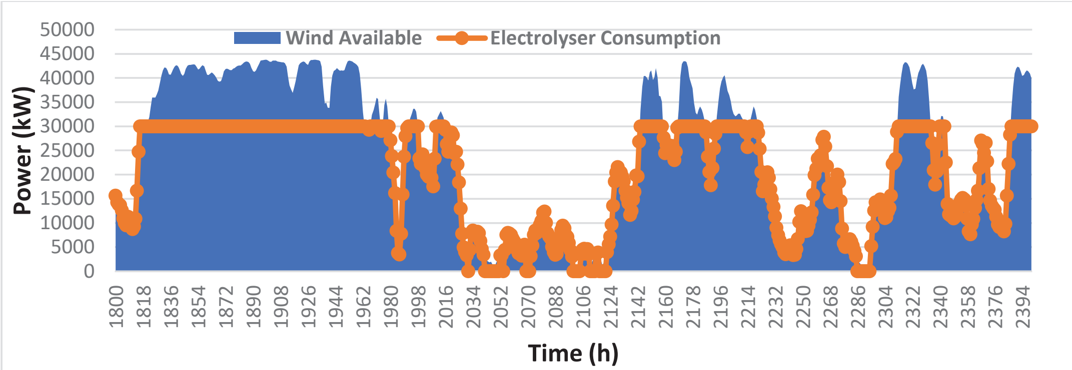

Figure 9: Scenario 2-Operating profile of 30 MW Electrolyser over a period of 24 days within summer months.

3.3 Scenario 3 – Hybrid Wind and Solar plant

Initially, the installed capacity of each technology, i.e., wind and solar, was considered equal to facilitate the simulations. Following an analysis of the results and identification of the installed capacity range that minimizes the LCOH value, the Wind-to-Solar (Wind/Solar) installed capacity ratio was varied to determine the global minimum design in terms of LCOH. The results from the parametric analysis for various Wind and Solar plant installed capacities, assuming a Wind/Solar ratio equal to 1 are presented in **Figure 10**.

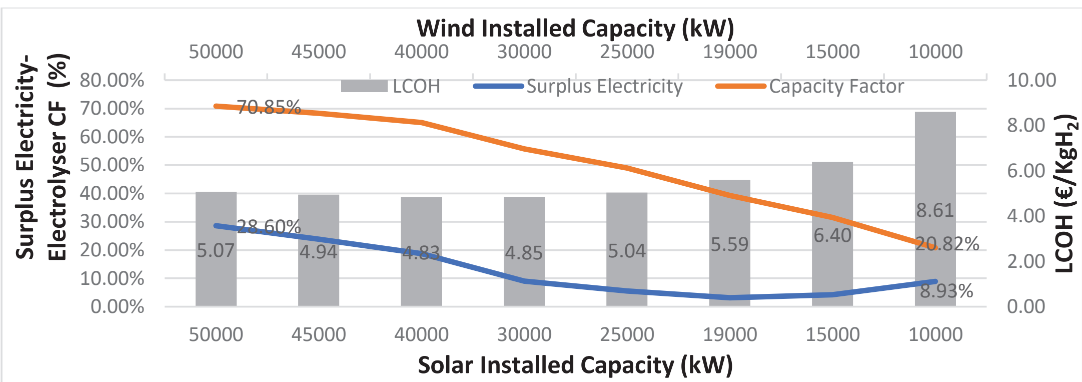

Figure 10: Scenario 3-30 MW Electrolyser Optimisation Results, Wind/Solar ratio equal to 1.

Based on the results shown in **Figure 10** and assuming an equal Wind/Solar plant ratio, it is evident that as the size of the hybrid unit increases, there is a corresponding increase in electrolyser capacity factor (CF) and surplus electricity. After simulating various combinations, the minimum levelized cost of hydrogen (LCOH) of 4.83 €/kgH_2 is achieved for a combination of a 40 MW Wind and 40 MW Solar hybrid plant. For this optimal size, the electrolyser CF and surplus electricity are equal to 65.08% and 15.71%, respectively. The minimum surplus electricity value, equal to 3.15% (3015.78 MWh), is achieved for a smaller size of the hybrid unit, comprising 19 MW Wind and 19 MW Solar. However, this leads to a higher LCOH value of 5.59 €/kgH_2. After identifying the installed capacity range that minimizes the LCOH, the Wind/Solar ratio was varied to find the global minimum design in terms of LCOH. The results of the optimisation are presented in **Figure 11** for a fixed 40 MW wind plant.

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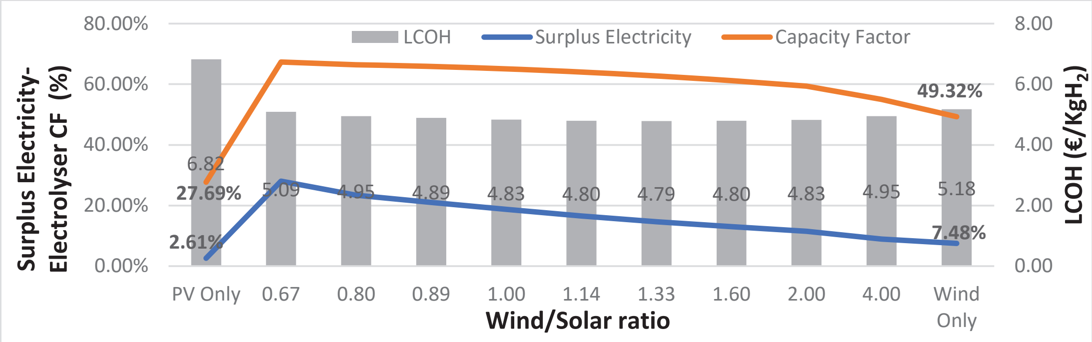

Figure 11: Scenario 3-30 MW Electrolyser Optimisation Results, varied Wind/Solar ratio.

The Wind/Solar ratio that results in the global minimum LCOH value of 4.79 €/kgH_2 is equal to 1.33, corresponding to a hybrid unit with an installed capacity of 40 MW Wind and 30 MW Solar. For this global minimum configuration, the electrolyser capacity factor (CF) and surplus electricity are calculated to be 62.76% and 14.66%, respectively. The main technoeconomic results for the minimum LCOH and minimum surplus electricity configurations are presented in **Table 4**.

Table 4: Main technoeconomic results for Scenario 3.

Parameter	Minimum LCOH Configuration	Minimum Surplus Electricity Configuration
Wind Installed Capacity (MW)	40	19
Solar Installed Capacity (MW)	30	19
Wind/Solar ratio	1.33	1
RES/Elec ratio	2.33	1.27
Surplus Electricity (%)	14.66	2.67
Electrolyser Capacity Factor (%)	62.76	39.33
Electrolyser Average Efficiency (kWh/kg)	55.97	52.92
Annual H_2 Production (ton)	2704	1695
Year of stack replacement (years)	9	10
LCOH (€/kgH_2)	**4.79**	**5.59**

The operating profile of the electrolyser and available wind and solar electricity is presented in **Figure 12** for the first two days and in **Figure 13** for 24 days within the summer months, under the minimum LCOH configuration. The operational strategy of the 30 MW electrolyser closely tracks the intermittent operation of both the solar and wind plants. This enables the system to operate for more hours throughout the year at maximum load, thanks to the increased availability of renewable energy compared to Scenarios 1 and 2. **Figure 13**, illustrates how the electrolyser operates for more hours during the year at maximum load, utilising the wind and solar complimentary generation profiles.

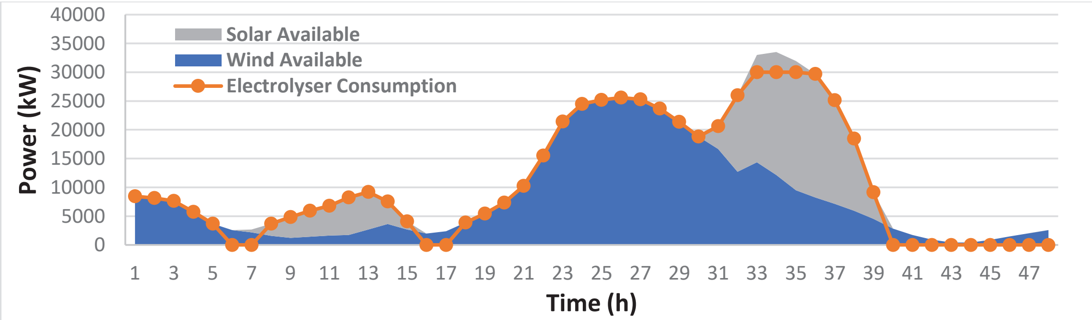

Figure 12: Scenario 3-Operating profile of 30 MW Electrolyser over a period of two days.

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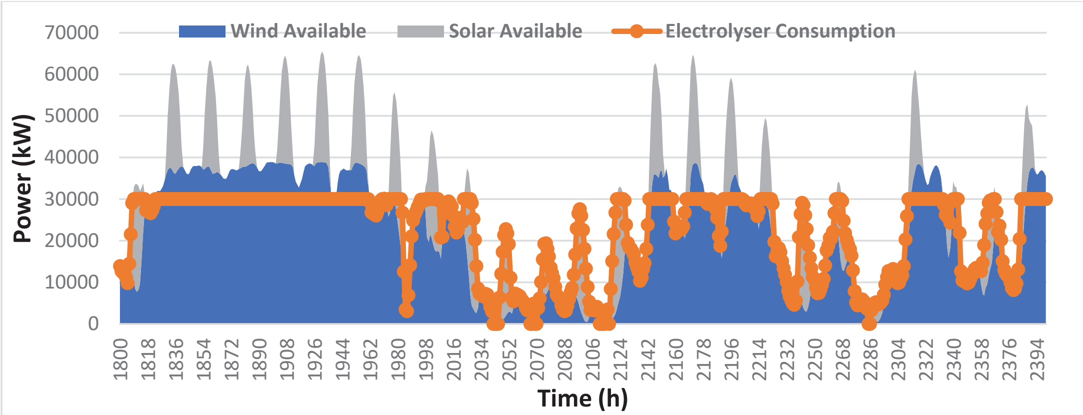

Figure 13: Scenario 3-Operating profile of 30 MW Electrolyser over a period of 24 days within summer months.

4 Discussion and Conclusion

This research article developed a technoeconomic assessment tool, able to utilise hourly renewable energy availability over a full-year, simulate in detail the operation of the 30 MW electrolyser via a novel control algorithm and optimise system design and RES utilisation by minimising the LCOH. Three different electricity procurement strategies based on intermittent RES were analysed (wind, solar, hybrid) with the aim to find the most cost-efficient RES/Electrolyser coupling design. In order to compare the annual operation of the 30 MW electrolyser for the different electricity procurement scenarios investigated, the percentages of the total time the electrolyser operated in each power interval within a full-year (%) are presented in **Figure 14.**

The 30 MW electrolyser demonstrates significantly reduced switched-off intervals, accounting for only 7.36% in Scenario 3, in contrast to Scenario 1 (56.84%) and Scenario 2 (12.84%). Typically, the electrolyser is turned off during periods of low solar power or when wind power experiences rapid fluctuations around the cut-in speed. These results underscore the strategic advantage of combining wind and solar energy, ensuring a more reliable and stable energy supply for the electrolyser. Wind and solar energy exhibit complementary generation patterns: while wind energy maintains consistency during certain periods, solar energy production peaks at different times. By harnessing both sources, enhanced operational hours for the electrolyser and consequently increased hydrogen production can be achieved through a more stable operation.

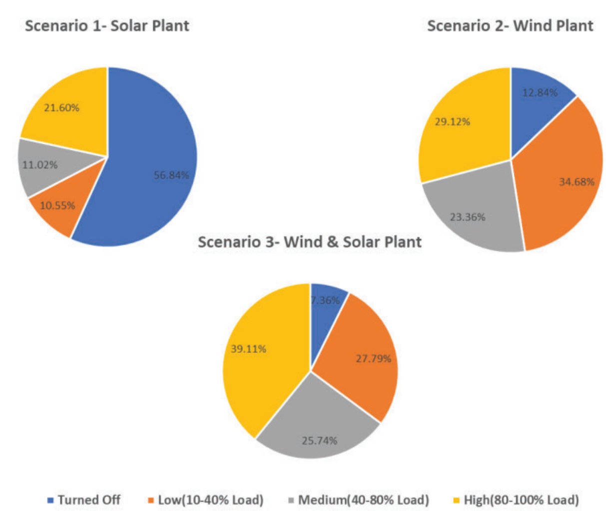

Figure 14: Percentage of total time in each power interval for the 30 MW electrolyser.

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In terms of cost-effectiveness, the combination of both solar and wind energy (Scenario 3) emerges as the most efficient strategy for procuring electricity for the 30 MW electrolyser, achieving a global minimum LCOH value of 4.79 €/kgH_2. Compared to Scenario 2 and Scenario 1, the LCOH for Scenario 3 is lower by 0.33 €/kgH_2 and 0.99 €/kgH_2 respectively.
Putting also into perspective the annual hydrogen demand of the TRIERES valley end-use applications, which stands at 2410 tonH_2/year, results show that only Scenario 2 and Scenario 3 are capable of meeting this demand. The key results of the analysis for the minimum LCOH configurations of each electricity procurement scenario are summarised in **Table 5**.

Table 5: Key Results of Technoeconomic Assessment Tool for various scenarios.

Parameter	Annual Hydrogen Production (tonH_2)	Annual Hydrogen Demand (tonH_2)	Annual Hydrogen Deficit/Surplus (tonH_2)	LCOH (€/kgH_2)
Scenario 1- Solar Plant	1365	2410	−1045	5.69
Scenario 2-Wind Plant	2277	2410	−133	5.12
Scenario 3- Solar & Wind Plant	2705	2410	295	4.79

In Scenario 1, relying solely on an intermittent Solar plant, proves to be technically and economically unviable for meeting the annual hydrogen demand of the valley, even for an extensively oversized solar capacities (i.e. 3GW). The limited renewable energy availability, constrained by the low solar plant capacity factor, prevents adequate electricity supply to the 30 MW electrolyser. In Scenario 2, adhering to the minimum LCOH configuration results in an annual hydrogen deficit of 133 tons of H_2. To bridge this gap, a marginally oversized wind plant is necessary to meet the annual hydrogen demand. This adjustment leads to a Wind/Elec ratio of 2 and requires a wind plant installed capacity of 60 MW. Consequently, the annual production of 2410 tons of H_2 becomes feasible, albeit at a higher LCOH of 5.21 €/kgH_2. Scenario 3 ensures that the valley's annual hydrogen demand will be covered in the most cost-effective way (4.79 €/kgH_2).
The findings can be universally applied regardless of the size of the electrolyzer, when coupling with solar or wind installations either via direct coupling or via PPA with hourly match and a "pay as produced" clause. Achieving a RES-to-electrolyser ratio of 1.70 and 1.50 for solar and wind respectively would result in the lowest LCOH, achieving the optimal trade-off between CF and surplus electricity cost penalty. When coupling to a hybrid unit, a RES-to-electrolyzer ratio of 2.33 and a wind-to-solar ratio of 1.33 would yield the most favorable LCOH.
An area for future research involves integrating the 30 MW electrolyser plant with the electricity grid to enhance flexibility, minimize frequent on/off cycles, and decrease electricity costs by procuring grid electricity during periods of wholesale prices below RES LCOE. However, since grid electricity is not entirely renewable, ensuring compliance with the requirements of renewable hydrogen production, as outlined in the RED II policy framework, is critical. Additionally, exploring the impact of hydrogen storage and hourly hydrogen demand on the technoeconomics of the H_2 value chain and electrolyser operational strategy presents another area for future investigation. Overall, further research is needed to understand how electrolysers leveraging both intermittent RES and grid support can effectively utilize renewable energy, secure electricity system stability, and contribute to the decarbonization of hard-to-abate end-use applications.

NOMENCLATURE

CAPEX	Capital Expenditure	(€/kW)
CF	Capacity Factor	(%)
LCOE	Levelised Cost of Electricity	(€/MWh)
LCOH	Levelised Cost of Hydrogen	(€/kgH_2)
OPEX	Operational Expenditure	(€/kW/year)
PPA	Power Purchase Agreement	
RES	Renewable Energy Sources	

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