

Influence of Renewable Energy Ratios and Electrolyzer Capacity Factor on Green Hydrogen Profitability

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Abstract—Green hydrogen, produced through water electrolysis powered by renewable energy, is a key technology in the transition toward a sustainable energy system. The profitability of green hydrogen projects depends on the ratio of renewable energy sources (RES), such as wind and solar, and the capacity factor of the electrolyzers.

This paper explores the techno-economic performance of green hydrogen production using a hybrid wind-solar power plant integrated with a Proton Exchange Membrane (PEM) electrolyzer, located at Korlat, Croatia. The main objective is to explore the impact of different wind/solar generation ratios as well as RES/PEM electrolyzer capacity ratios on the levelized cost of hydrogen (LCOH) and the overall system profitability indicators. The analysis compares two configurations: a grid-connected plant, which allows for the export of excess renewable energy, and an off-grid plant, which operates independently and relies solely on local renewable energy resources. Hourly time series data for a specific location are used to model RES production, taking into account the impact of RES variations, electrolyzer efficiency, and market prices on system performance. This analysis contributes to understanding the economic viability of green hydrogen and informs strategic decision-making for sustainable hydrogen production projects.

Index Terms—PEM electrolyzer, wind-solar hybrid plant, levelized cost of hydrogen, techno-economic analysis, profitability

I. INTRODUCTION

The production of green hydrogen—hydrogen derived from water electrolysis powered by renewable energy—is recognized as a sustainable solution for supporting the global energy transition. Therefore, green hydrogen is highly dependent on

This work was funded by the European Union NextGenerationEU through Croatia's National Recovery and Resilience Plan 2021-2026 under grant NPOO.C3.2.R3-11.04.0088 "Laboratory model and prototype of control and monitoring system for microgrids with renewable energy sources and hydrogen technologies".

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renewable forms of electricity generation, such as solar and wind. Combined hybrid wind-solar power plants offer a more reliable supply due to the complementary nature of the two individual power sources. This translates into an improvement in the reliability of electrolyzers' power supply, which depend on consistent electricity for their optimal performance. Also, a connection of hybrid wind-solar power plants over the common grid connection point, usually with a connection capacity below the total RES installed capacity together with an electrolyzer, allows a reduction of grid-connection costs.

The levelized cost of hydrogen (LCOH) accounts for all costs regarding hydrogen production, starting from capital expenditure (CAPEX) for electrolysis plants, operation, and maintenance costs, down to the cost of electricity generation from renewables. With continued declines in the costs of renewable energy technologies and electrolysis equipment, projections are that the LCOH of hydrogen produced by electrolysis will decrease significantly from about €5.3 per kg in 2020 to around €2.7 per kg by 2050 [1]. This study aims to assess the influence of varying wind/solar generation ratios on both the LCOH and the overall profitability of green hydrogen production projects. Furthermore, the study investigates the impact of the electrolyzer capacity factor on the overall economic feasibility, focusing on the relationship between system investment, operational costs, and revenue potential at various green hydrogen price levels. By identifying the financial implications of different renewable energy ratios and electrolyzer performance metrics, the study supports strategic decision-making in sustainable hydrogen project development.

Techno-economic assessment of various hybrid systems for producing green hydrogen was presented in [2]. The minimum LCOH of 3.1 €/kg was calculated for a combination of solar plant (with storage) and onshore wind turbines. Authors in [3] considered multi-MW water electrolysis plants that

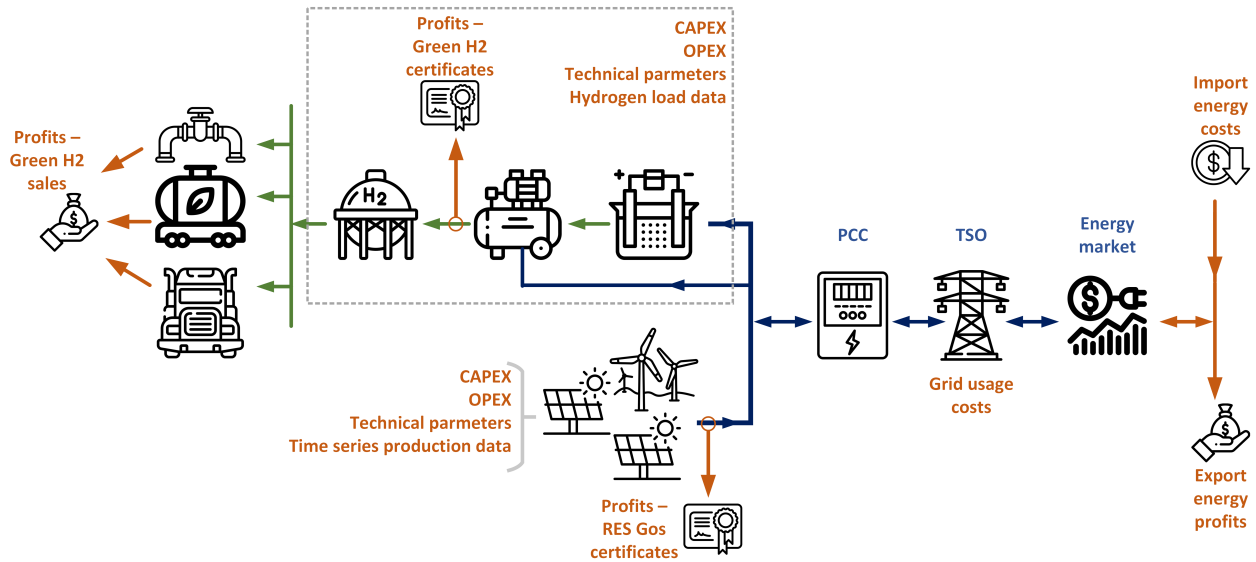


Fig. 1. Hybrid electricity-hydrogen production plant configuration diagram

can provide grid services while generating hydrogen. The calculated profit contribution from grid services provision was around 10%. A hybrid system for producing green hydrogen to be used in the steel industry was modeled in [4], with the goal of maximizing the use of renewable energy and minimizing the LCOH. Study showed that the implementation of a storage system, such as a BESS or a hydrogen tank, leads to lower LCOH and higher percentages of green hydrogen in the mix. Authors in [5] examine the economic viability of integrating wind-powered green hydrogen production systems in Finland, finding that strategic site selection is crucial, with the best wind farm location achieving 47% lower LCOH and 22% higher net present value (NPV). A techno-economic analysis of large-scale green hydrogen production in Poland to assess the LCOH in different NUTS-2 regions was delivered in [6]. Study showed that by 2050, the LCOH of a 20-MW PEM electrolyzer could fall to 1.95-2.03 €/kg for solar and 1.23-1.50 €/kg for onshore wind plants. An optimized system for the combined production of electricity and green hydrogen from a hybrid renewable energy system is presented in [7], with the goal of maintaining grid stability and minimizing the weighted average cost of energy generated. The optimized plant provided the grid with a quasi-steady capacity of 423 MW and produced hydrogen at the lowest cost of 1.9745 USD/kg. LCOH for hydrogen refueling stations in Sweden powered by solar PV and wind energy was investigated in [8], considering both off-grid and on-grid scenarios, finding that the on-grid option provides a good opportunity to further reduce LCOH. The influence of decreasing costs for electrolyzers on the optimal configuration and location of green hydrogen production plants in Europe was examined in [9]. A method to determine the optimal ratio of installed renewable power to electrolysis power in order to minimize LCOH was developed in [10]. The lowest hydrogen production costs of

2.53 €/kg were achieved with 50 MW of wind power and 72 MW of electrolysis capacity. A techno-economic model for optimizing the design and operating strategy of PEM water electrolyzers to achieve the lowest cost of hydrogen production was developed in [11], resulting in recommended annual operating times between 2000h and 8000h.

The rest of this paper is organized as follows: section II describes the hydrogen plant setup, located at Korlat Croatia, along with data used for calculations, results and conclusion are given in sections III and IV, respectively.

II. METHODOLOGY AND HYDROGEN PLANT DESCRIPTION

The methodology for calculating profitability of an electrolyzer plant supplied by a hybrid wind/solar power plant (Fig. 1) includes a comprehensive analysis using hourly data for each system component over the entire project lifetime. This profitability analysis takes into account electricity prices, renewable energy production, electrolyzer performance and system operational costs. There is a high level of uncertainty in the input data, such as day-ahead electricity prices, hydrogen prices, and renewable energy production that can significantly impact the accuracy of profitability predictions for the electrolyzer plant. Inherent variability of this input data due to market fluctuations, changes in weather patterns, and new technological advancements introduce certain risk that needs to be accounted for through sensitivity analysis and scenario modeling.

In order to model solar and wind power plant production, historical data for solar irradiance and wind speeds are used to estimate the hourly energy production of the hybrid power plant. Hourly day-ahead electricity market prices are considered to calculate the economic dynamics of selling excess power or purchasing grid electricity, depending on hybrid power plant electricity demand and RES generation. The day-ahead electricity market prices were modeled based on long-

term market projections from Brainpool [12], which provide detailed forecasts of future price trends. Fig. 2 shows a long term box plot of DA electricity prices that were considered in the analysis, indicating the trends of average DA market prices as well as the increase of price volatility in future electricity markets with higher shares of RES.

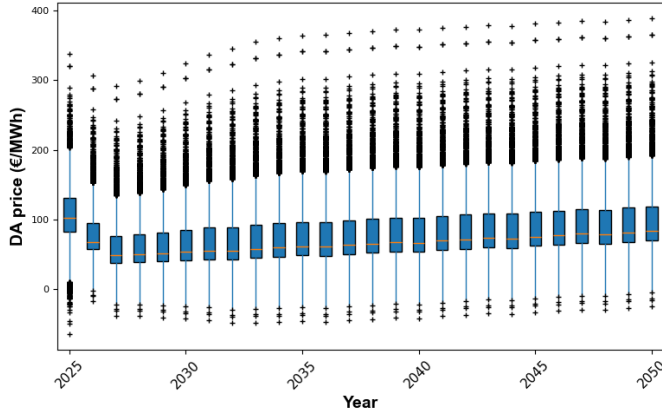


Fig. 2. Box plot of DA prices

A. PEM electrolyzer

Proton Exchange Membrane (PEM) electrolyzers are a key technology for producing green hydrogen. Their efficiency and performance have improved significantly in recent years, and further advancements are expected in the future. Modern PEM electrolyzers typically operate at an efficiency of 60-70%. Their efficiency depends on several factors, including the specific electrolyzer technology, the operating conditions, and whether the system includes balance-of-plant components (such as power supplies, cooling systems, etc.) [5]. Efficiency typically varies with the load or power level at which the electrolyzer operates.

When modeling the efficiency of an electrolyzer supplied by a PV or wind power plant, it is crucial to do so with precision due to the frequent fluctuations in the operating point of the electrolyzer. Both PV and wind energy sources are inherently intermittent, meaning that the power supplied to the electrolyzer can vary widely over time, causing shifts in its operating point. These fluctuations directly affect the electrolyzer's efficiency, as its performance is not linear across different loads. Therefore, an accurate model that captures these variations is necessary for optimizing the system's performance.

Fig. 3 illustrates the efficiency characteristics of the PEM electrolyzer, showing how efficiency varies with load. The efficiency curve is an approximation of the performance curve of a PEM electrolyzer currently in operation at Energiepark Mainz [13]. The curve is modeled using a polynomial function for the operating range between 0% and 16.66% of the PEM electrolyzer's rated capacity and a linear function for the range between 16.66% and 100% of the operating capacity, with expressions shown in Fig. 3.

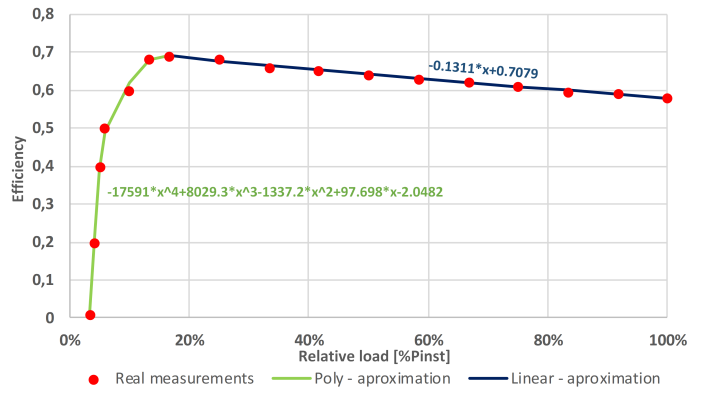


Fig. 3. Impact of PEM electrolyzer relative load on efficiency

For most modern PEM (Proton Exchange Membrane) electrolyzers, the minimum operating point is typically around 10-20% of their rated capacity, although the exact value can vary depending on the specific design and technology used. At this minimum operating point, the electrolyzer is still able to produce hydrogen, but its efficiency might drop significantly, and the system may not operate optimally. In the model, we assume that the PEM electrolyzer has a minimum operating point at 10% of its rated capacity. Therefore, when renewable energy generation (RES) is below 10% of the PEM electrolyzer's nominal power, we assume the RES power is exported to the grid and traded on the electricity market. Similarly, when RES production exceeds the rated capacity of the PEM electrolyzer, the surplus energy is also exported to the grid and traded on the electricity market.

TABLE I
FINANCIAL PARAMETERS

Parameter	Wind turbine	Solar	Electrolyzer	Grid
CAPEX (€/kW)	1200	800	1100	150
OPEX (% CAPEX/ann.)	3	2	2	
Replacement costs (%CAPEX)		20	30	
Replacement year		10	10	
Degradation (% per/ann)		0.4		

Capital expenditure (CAPEX) and operational expenditure (OPEX) are incorporated into the cost structure, which includes maintenance, labor, insurance, and other costs associated with running the plant. It is important to note that the CAPEX and OPEX costs considered in this model do not include additional expenses related to hydrogen transport and distribution (Table. I). Specifically, costs such as tube trailers for transporting hydrogen, infrastructure for tube trailer filling stations, connection fees to the gas network for relevant business models, gas network usage charges, etc., are not

accounted for in the analysis. These costs are external to the electrolyzer's operation but are essential for the overall hydrogen supply chain and would need to be considered separately for a complete financial analysis.

LCOH is used to compare options with different RES/electrolyzer power and wind/solar generation ratios. It is calculated by equation (1) taking into account total CAPEX, OPEX, replacement costs, electricity profits and annual production of hydrogen ($H2_y$) for each year y during project lifetime (Y) and discount rate (d).

$$\text{LCOH} = \frac{\text{CAPEX} + \sum_{y \in Y} \frac{\text{OPEX}_y + \text{REPLACEMENT}_y - \text{PROFITS}_y^{el}}{(1+d)^y}}{\sum_{y \in Y} \frac{H2_y}{(1+d)^y}} \quad (1)$$

To determine profitability, the system's annual revenue from hydrogen production and energy sales is compared with its total cost, including the fixed and variable costs over the lifetime of the project. Discounted cash flow (DCF) analysis is typically employed to assess the net present value (NPV), internal rate of return (IRR), and payback period of the investment.

B. Hybrid wind-solar plant

The modeling of the wind and PV plants is based on time series data for the Korlat location in Croatia, where a hybrid wind-PV plant is under construction (wind power plant in operation and PV plant under construction). The input data is sourced from Renewables.ninja, which provides detailed time series information for renewable energy production.

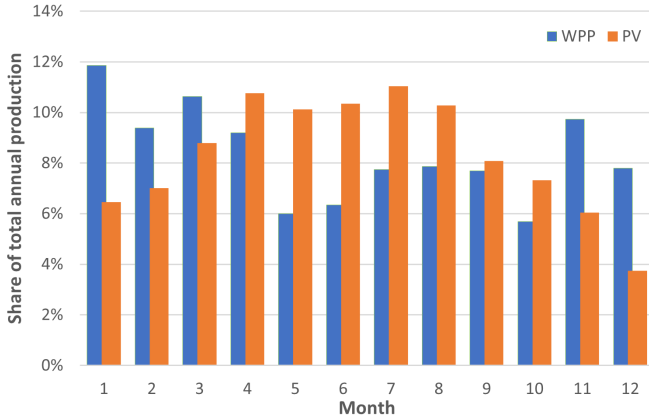


Fig. 4. Relative monthly production of WPP and PV plant

Fig. 4 shows the relative monthly production of the WPP and PV plant for location Korlat obtained using hourly dataset. In the simulation, relative hourly production is scaled proportionally to solar and wind installed power to accurately represent the RES/electrolyzer power ratio and wind/solar generation ratio. This approach allows for a more accurate reflection of the wind/solar plant's performance and its impact on the system's overall operation.

III. RESULTS

The results section focuses on the techno-economic performance of a hybrid wind/solar power plant integrated with a PEM electrolyzer. The study assesses the impact of different RES/electrolyzer power and wind/solar generation ratios on the LCOH, additionally exploring the economic feasibility of the green hydrogen production system under various market conditions. The analysis considers two cases:

- **CASE I - Grid connected hybrid electricity/hydrogen plant** - in this case, the hybrid plant is connected to the electricity grid, allowing the export of excess electricity from RES that can't be utilized by PEM electrolyzer and allowing participation in the electricity market. However, the investment costs are higher due to the additional expenses associated with grid connection.
- **CASE II - Off-grid hydrogen plant** - In contrast to the previous case, an off-grid hydrogen plant functions independently without a grid connection, relying solely on local renewable energy sources. In this case, the excess electricity from RES is either curtailed or can be stored in systems with integrated battery storage.

To identify the optimal RES capacity and wind/solar generation ratio for maximum profitability and the lowest LCOH, RES capacity was varied from 10 to 60 MW, while the PEM electrolyzer power was fixed at 20 MW, resulting in a RES/electrolyzer power ratio between 0.5 and 3. For each RES/electrolyzer power ratio, calculations were performed for wind/solar generation ratios ranging from 100% wind and 0% solar to 0% wind and 100% solar. The project lifetime is assumed to be 25 years, with a discount rate of 4%. Profits are generated by selling excess electricity at market prices and hydrogen at an initial price of 6 €/kg, which gradually decreases to 4 €/kg by the final year of the projected lifetime. In addition to this, we assume that the plant generates additional profit from selling guarantees of origin (GO) for excess energy exported to the grid and guarantees of origin for produced green hydrogen.

Table II and Table III (Appendix) give an overview of the results for different hybrid power plant power supply configurations, providing data related to net present value, internal rate of return, profitability index, payback time, LCOH, and electrolyzer utilization rate. The results for Case I showed that the configuration of a hybrid power plant that includes only a 60 MW wind plant, without any solar installed, proves to be the most profitable option. From the results provided, we can clearly see that an increase of PV plant install capacity in total RES capacity reduces total plant profitability. The WPP proves to be the more profitable option in this case due to its lower LCOE compared to the PV plant. Additionally, the excess electricity generated by the WPP is typically exported during periods of higher market prices, enhancing revenue potential. In contrast, PV plants often produce excess energy during midday hours when electricity prices tend to be lower, limiting profitability from surplus energy sales. This dynamic further strengthens the economic advantage of WPP for PEM

electrolyzer power supply under the assumptions associated with Case I.

Annual and cumulative DCF for both CASE I and Case II are shown in Fig.5 and Fig.6. The figures show cash flow analysis for power supply combination with the highest profitability index and lowest LCOH. In order for excess electricity generated by RES to be sold at the actual market price in CASE I, the purchased grid connection capacity has to be equal to the excess RES power (40 MW). An initial CAPEX of 100 mil. € (72 % allocated to wind plant) allows profit realization by year 13. CAPEX for CASE II is notably lower at 63.6 mil. € compared to CASE I, primarily due to the exclusion of grid connection costs (6 mil. € in CASE I) and a reduced RES capacity (40 MW in CASE II versus 60 MW in CASE I). In CASE II, the hydrogen plant operates off-grid, with most profits coming from the sale of hydrogen, while hydrogen GO profits are minimal in comparison. As a result, CASE II has a significantly lower NPV (17.52 mil. €) compared to CASE I (65.08 mil. €) and a much higher LCOH of 4.41 €/kg compared to 2.75 €/kg in CASE I.

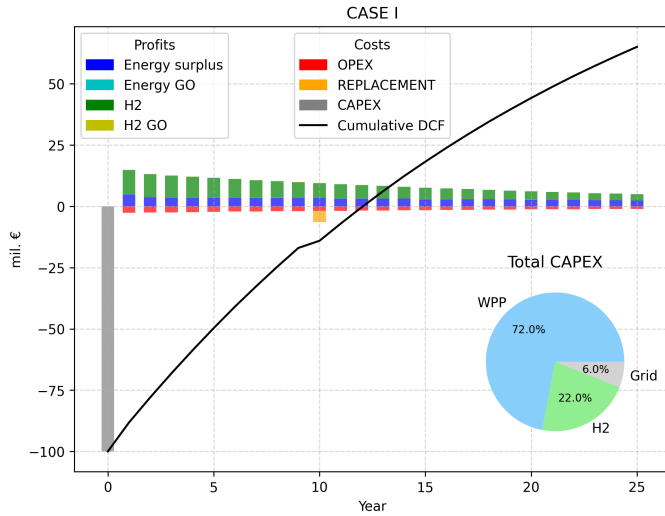


Fig. 5. Discounted cash flow CASE I - 60 MW WPP

The results of the simulation and financial analysis for Case II (Table III) highlight a fundamental difference from Case I, primarily due to the inability to sell surplus renewable energy. In this scenario, any excess electricity that cannot be utilized for hydrogen production is curtailed, eliminating the opportunity to generate additional revenue or offset costs through energy sales. This limitation significantly impacts the overall profitability and cost efficiency of the hydrogen production system.

Given these constraints, determining the optimal level of power supply is critical for minimizing curtailment while ensuring sufficient electricity for continuous hydrogen production. Oversizing the renewable energy power supply can lead to excessive energy curtailment, increasing the LCOH due to underutilized production capacity. On the other hand, undersizing the power RES supply might reduce curtailment

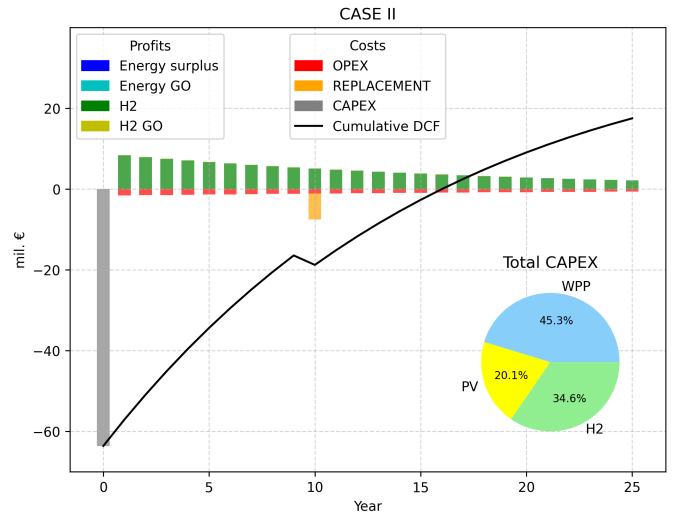


Fig. 6. Discounted cash flow CASE II - 40 MW RES, 40%/60% PV/WPP ratio

but could also limit hydrogen production capacity and reduce the electrolyzer utilization rate, reducing overall revenue potential. A well-balanced combination of wind and solar power can mitigate the variability of renewable energy generation, improving capacity utilization and reducing the risk of excessive curtailment. Since wind and solar have different production patterns, it is crucial to model their combined effect on hydrogen production efficiency. From the results shown in Table III, we can see that for Case II, the results follow the same pattern, indicating an increase in NPV with the increase of WPP in the electrolyzer power supply. However, the results follow this pattern only up to the point where the WPP installed capacity reaches the PEM electrolyzer installed capacity. Beyond this point, further increases in total RES capacity lead to energy curtailment, causing the results for Case II to diverge from those of Case I. The results for Case II show that after the total RES installed capacity exceeds the PEM electrolyzer installed capacity, it is more profitable to introduce PV production into the plant's power supply mix. In Case II, the highest profitability index is achieved for a total RES installed capacity of 40MW with a PV/WPP ratio of 40%/60%.

IV. CONCLUSION

This paper examines the techno-economic feasibility of producing green hydrogen using a PEM electrolyzer by a combined wind-solar power plant. The goal of this study was to evaluate the impact of different wind/solar power ratios as well as total RES/electrolyzer power ratios on the LCOH and other financial parameters. The analysis examines the relationship between renewable energy production, electrolyzer efficiency, and electricity market price dynamics, with a focus on identifying optimal configurations for maximizing profitability.

The main findings highlight the significant impact of renewable energy shares on electrolyzer usage rates, hydrogen costs and overall profitability. In situations involving grid-connected plants (Case I), the power supply option which only involves wind energy supply, has emerged as the more profitable option because of its reduced levelized cost of electricity (LCOE) and superior market price export possibilities in relation to solar. However, in case that considers off-grid operation (Case II), where surplus energy cannot be sold on the electricity market, energy curtailment becomes a key concern, significantly affecting the overall profitability and cost efficiency. The results show that the most profitable configurations in Case II occur when the renewable energy installed capacity is well balanced between the WPP and PV plant, avoiding excessive curtailment while maintaining significantly high electrolyzer utilization rates. Results for Case II indicate that a combination of wind and solar power can offer a more reliable and balanced energy supply, enhancing electrolyzer performance and minimizing curtailment losses.

Future research will focus on the incorporation of energy storage systems to address the curtailment problem and surplus energy utilization in on/off-grid plants. Also, additional investigation into local differences in renewable energy production and market dynamics would improve the capacity to create optimized hydrogen production systems suited to particular geographic areas.

REFERENCES

- [1] F. Frieden and J. Leker, "Future costs of hydrogen: a quantitative review," *Sustainable Energy Fuels*, vol. 8, no. 9, pp. 1806-1822, 2024. doi: 10.1039/D4SE00137K.
- [2] S. Baral and J. Šebo, "Techno-economic assessment of green hydrogen production integrated with hybrid and organic Rankine cycle (ORC) systems," *Heliyon*, vol. 10, no. 4, p. e25742, Feb. 29, 2024. doi: 10.1016/j.heliyon.2024.e25742.
- [3] G. Matute, J. M. Yusta, and L. C. Correas, "Techno-economic modelling of water electrolyzers in the range of several MW to provide grid services while generating hydrogen for different applications: A case study in Spain applied to mobility with FCEVs," *International Journal of Hydrogen Energy*, vol. 44, no. XX, pp. XXX-XXX, 2019. [Online]. Available: <https://api.semanticscholar.org/CorpusID:198353960>
- [4] F. Superchi, A. Mati, M. Pasqui, C. Carcasci, and A. Bianchini, "Techno-economic study on green hydrogen production and use in hard-to-abate industrial sectors," *Journal of Physics: Conference Series*, vol. 2385, 2022. [Online]. Available: <https://api.semanticscholar.org/CorpusID:254995915>.
- [5] N. Javanshir, S. Pekkinen, A. Santasalo-Aarnio, and S. Syri, "Green hydrogen and wind synergy: Assessing economic benefits and optimal operational strategies," *International Journal of Hydrogen Energy*, vol. XX, pp. XXX-XXX, 2024. [Online]. Available: <https://api.semanticscholar.org/CorpusID:271883015>.
- [6] P. Benalcazar and A. Komorowska, "Prospects of green hydrogen in Poland: A techno-economic analysis using a Monte Carlo approach," *International Journal of Hydrogen Energy*, vol. 47, no. 9, pp. 5779-5796, 2022. doi: 10.1016/j.ijhydene.2021.12.001.
- [7] R. Ragab, M. Hamdi, H. A. El Salmawy, and M. A. Ismail, "Optimized system for combined production of electricity/green hydrogen for multiple energy pathways: A case study of Egypt," *Clean Energy*, vol. XX, pp. XXX-XXX, 2024. [Online]. Available: <https://api.semanticscholar.org/CorpusID:270115905>.
- [8] O. Tang, J. Rehme, and P. Cerin, "Levelized cost of hydrogen for refueling stations with solar PV and wind in Sweden: On-grid or off-grid?," *Energy*, vol. XX, pp. XXX-XXX, 2021. [Online]. Available: <https://api.semanticscholar.org/CorpusID:245243639>.
- [9] R. Niepelt, M. Schlemminger, D. Bredemeier, F. Peterssen, C. Lohr, A. L. Bensmann, R. Hanke-Rauschenbach, and R. Brendel, "The influence of falling costs for electrolyzers on the location factors for green hydrogen production," *Solar RRL*, vol. 7, 2023. [Online]. Available: <https://api.semanticscholar.org/CorpusID:259682231>.
- [10] A. Hofrichter, D. Rank, M. Heberl, and M. Sterner, "Determination of the optimal power ratio between electrolysis and renewable energy to investigate the effects on the hydrogen production costs," *International Journal of Hydrogen Energy*, vol. XX, pp. XXX-XXX, 2022. [Online]. Available: <https://api.semanticscholar.org/CorpusID:253231546>.
- [11] F. Scheepers, M. Stähler, A. Stähler, M. Müller, and W. Lehnert, "Cost-optimized design point and operating strategy of polymer electrolyte membrane electrolyzers," *International Journal of Hydrogen Energy*, vol. XX, pp. XXX-XXX, 2023. [Online]. Available: <https://api.semanticscholar.org/CorpusID:255456074>.
- [12] Energy Brainpool, "Power price scenarios," Energy Brainpool GmbH & Co. KG, 2024. [Online]. Available: <https://www.energybrainpool.com/en/power-price-scenarios>. [Accessed: Feb. 7, 2025].
- [13] M. Kopp, D. Coleman, C. Stiller, K. Scheffer, J. Aichinger, and B. Scheppat, "Energiepark Mainz: Technical and economic analysis of the worldwide largest Power-to-Gas plant with PEM electrolysis," *International Journal of Hydrogen Energy*, vol. 42, no. 19, pp. 13311-13320, 2017. doi: 10.1016/j.ijhydene.2016.12.145.

V. APPENDIX

TABLE II
RESULTS OF ECONOMIC ANALYSIS FOR DIFFERENT ELECTROLYZER/RES RATIOS AND DIFFERENT WPP/PV RATIOS - CASE I

NPV		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
NPV [mil. €]	10	-13,75	-14,58	-15,31	-15,82	-16,56	-17,48	-18,49	-19,40	-20,30	-21,10	-21,88
Total RES install capacity [MW]	20	3,44	2,69	1,92	0,76	-0,63	-2,25	-4,01	-6,00	-8,30	-10,46	-12,35
	30	18,28	16,90	15,26	13,52	11,71	9,60	7,04	4,07	0,64	-3,28	-6,76
	40	33,58	31,18	28,42	25,63	22,71	19,71	16,41	12,42	7,88	2,66	-2,20
	50	49,35	45,94	42,01	37,85	33,56	29,14	24,72	20,12	14,77	8,58	2,36
	60	65,08	60,70	55,65	50,14	44,29	38,47	32,87	27,50	21,55	14,47	6,90

IRR		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
IRR [%]	10	-0,6%	-0,9%	-1,3%	-1,6%	-2,0%	-2,5%	-3,1%	-3,6%	-4,1%	-4,9%	-5,8%
Total RES install capacity [MW]	20	4,8%	4,6%	4,4%	4,2%	3,8%	3,4%	3,0%	2,4%	1,7%	1,0%	0,3%
	30	7,0%	6,8%	6,6%	6,4%	6,2%	5,8%	5,4%	4,8%	4,1%	3,3%	2,5%
	40	8,2%	8,1%	7,9%	7,6%	7,3%	7,0%	6,6%	6,0%	5,3%	4,5%	3,6%
	50	9,1%	8,9%	8,7%	8,4%	8,1%	7,7%	7,2%	6,7%	6,1%	5,2%	4,4%
	60	9,6%	9,5%	9,2%	8,9%	8,5%	8,1%	7,6%	7,2%	6,5%	5,8%	4,9%

Payback		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
Payback [year]	10	-	-	-	-	-	-	-	-	-	-	-
Total RES install capacity [MW]	20	22	23	23	25	-	-	-	-	-	-	-
	30	16	16	17	17	18	19	20	22	25	-	-
	40	14	14	15	15	16	16	17	18	20	23	-
	50	13	13	14	14	14	15	16	17	19	21	24
	60	13	13	13	13	14	14	15	16	18	20	22

LCOH		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
LCOH [€/kg]	10	7,38	7,65	7,88	8,04	8,31	8,68	9,16	9,77	10,46	10,49	10,47
Total RES install capacity [MW]	20	4,97	5,02	5,08	5,17	5,29	5,44	5,62	5,85	6,16	6,53	6,72
	30	4,24	4,32	4,39	4,47	4,55	4,65	4,78	4,96	5,19	5,52	5,84
	40	3,70	3,83	3,95	4,07	4,18	4,28	4,40	4,55	4,76	5,07	5,43
	50	3,20	3,39	3,56	3,73	3,88	4,02	4,14	4,27	4,45	4,73	5,11
	60	2,75	2,98	3,20	3,42	3,61	3,78	3,92	4,04	4,19	4,44	4,82

Profitability index		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
Profitability index	10	0,60	0,57	0,54	0,52	0,49	0,46	0,42	0,38	0,35	0,31	0,28
Total RES install capacity [MW]	20	1,07	1,06	1,04	1,02	0,99	0,95	0,90	0,85	0,79	0,73	0,68
	30	1,31	1,29	1,27	1,24	1,21	1,18	1,13	1,08	1,01	0,93	0,86
	40	1,46	1,44	1,41	1,38	1,34	1,30	1,26	1,20	1,13	1,05	0,96
	50	1,57	1,54	1,51	1,47	1,43	1,38	1,33	1,28	1,21	1,13	1,04
	60	1,65	1,62	1,59	1,54	1,49	1,44	1,39	1,33	1,27	1,18	1,09

Utilization rate		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
Utilization rate	10	14%	13%	12%	12%	11%	11%	10%	9%	8%	9%	9%
Total RES install capacity [MW]	20	31%	29%	28%	27%	26%	24%	23%	22%	20%	18%	19%
	30	43%	43%	42%	41%	39%	37%	35%	33%	31%	28%	27%
	40	51%	52%	52%	51%	50%	48%	45%	42%	38%	34%	31%
	50	57%	59%	59%	59%	59%	57%	53%	49%	43%	38%	34%
	60	62%	64%	65%	65%	65%	63%	59%	54%	48%	41%	36%

TABLE III
RESULTS OF ECONOMIC ANALYSIS FOR DIFFERENT ELECTROLYZER/RES RATIOS AND DIFFERENT WPP/PV RATIOS - CASE II

NPV		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
NPV [mil. €]	10	-17,58	-18,81	-19,47	-19,67	-20,39	-21,40	-22,64	-24,29	-25,72	-24,46	-23,01
Total RES install capacity [MW]	20	0,96	0,34	-0,14	-1,31	-2,77	-4,49	-6,37	-8,71	-11,68	-15,15	-12,90
	30	9,44	11,42	12,15	11,78	10,23	8,02	5,41	2,30	-1,81	-7,77	-8,79
	40	8,58	12,89	15,78	17,40	17,52	15,86	12,15	6,92	0,40	-7,93	-12,41
	50	2,91	9,20	13,97	17,44	19,03	18,09	13,74	6,71	-1,60	-11,65	-18,96
	60	-5,43	2,49	8,80	13,56	16,02	15,32	11,55	4,15	-5,67	-17,21	-26,82

IRR		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
IRR [%]	10	-2,4%	-3,0%	-3,5%	-3,7%	-4,2%	-4,9%	-5,9%	-7,2%	-8,7%	-7,8%	-6,9%
Total RES install capacity [MW]	20	4,2%	4,1%	4,0%	3,7%	3,3%	2,8%	2,3%	1,6%	0,6%	-0,6%	0,0%
	30	5,7%	6,0%	6,2%	6,2%	6,0%	5,6%	5,1%	4,5%	3,6%	2,2%	1,9%
	40	5,3%	5,9%	6,4%	6,7%	6,8%	6,6%	6,0%	5,2%	4,1%	2,4%	1,4%
	50	4,4%	5,2%	5,8%	6,3%	6,6%	6,5%	6,0%	5,0%	3,7%	2,0%	0,5%
	60	3,4%	4,3%	5,0%	5,6%	5,9%	5,9%	5,5%	4,6%	3,2%	1,4%	-0,4%

Payback		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
Payback [year]	10	-	-	-	-	-	-	-	-	-	-	-
Total RES install capacity [MW]	20	24	25	-	-	-	-	-	-	-	-	-
	30	19	18	18	18	18	19	21	23	-	-	-
	40	20	18	17	17	17	17	18	21	25	-	-
	50	24	20	19	17	17	17	18	21	-	-	-
	60	-	24	21	19	18	18	20	23	-	-	-

LCOH		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
LCOH [€/kg]	10	7,97	8,33	8,58	8,71	9,01	9,44	10,02	10,89	11,82	11,31	10,73
Total RES install capacity [MW]	20	5,15	5,20	5,24	5,34	5,47	5,64	5,84	6,12	6,53	7,10	6,79
	30	4,71	4,61	4,56	4,57	4,63	4,74	4,88	5,08	5,37	5,89	6,01
	40	4,83	4,64	4,51	4,43	4,41	4,46	4,61	4,85	5,21	5,79	6,19
	50	5,10	4,85	4,67	4,53	4,46	4,47	4,62	4,90	5,32	5,96	6,60
	60	5,44	5,13	4,90	4,73	4,64	4,64	4,76	5,05	5,51	6,23	7,07

Profitability index		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
Profitability index	10	0,48	0,44	0,41	0,40	0,37	0,33	0,28	0,22	0,16	0,20	0,23
Total RES install capacity [MW]	20	1,02	1,01	1,00	0,97	0,94	0,89	0,85	0,78	0,71	0,61	0,66
	30	1,16	1,20	1,22	1,22	1,19	1,15	1,11	1,05	0,96	0,84	0,81
	40	1,12	1,19	1,24	1,27	1,28	1,26	1,20	1,12	1,01	0,86	0,77
	50	1,04	1,11	1,18	1,23	1,26	1,25	1,20	1,10	0,98	0,82	0,69
	60	0,94	1,03	1,10	1,16	1,19	1,19	1,15	1,05	0,92	0,76	0,62

Utilization rate		PV/WPP install power ratio [%]										
		0/100	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10	100/0
Utilization rate	10	14%	13%	12%	12%	11%	11%	10%	9%	8%	9%	9%
Total RES install capacity [MW]	20	31%	29%	28%	27%	26%	24%	23%	22%	20%	18%	19%
	30	43%	43%	42%	41%	39%	37%	35%	33%	31%	28%	27%
	40	51%	52%	52%	51%	50%	48%	45%	42%	38%	34%	31%
	50	57%	59%	59%	59%	59%	57%	53%	49%	43%	38%	34%
	60	62%	64%	65%	65%	65%	63%	59%	54%	48%	41%	36%