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THE INTEGRATION OF THE REPUBLIC OF MOLDOVA INTO THE EU GREEN ENERGY SYSTEM THROUGH HYDROGEN PRODUCTION

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Abstract: *In the context of heightened regional instability and rising energy insecurity triggered by the Russia–Ukraine conflict, the Republic of Moldova faces severe challenges, including surging natural gas and electricity prices that have significantly constrained its economic resilience. As a candidate country for European Union (EU) membership, Moldova's strategic energy realignment aligns with the EU's "Energy Transition and Strategic Autonomy" agenda, which prioritizes the development of green electricity and green hydrogen to reduce dependency on imported fossil fuels. This paper conducts a comprehensive techno-economic assessment of Moldova's potential to participate in the EU green energy system by investing in green hydrogen production. Using the Levelized Cost of Hydrogen (LCOH) model, the study evaluates the financial and regulatory feasibility of constructing a 5 MW electrolysis facility under different technological and market scenarios. The findings suggest that Moldova possesses both economic and infrastructural conditions conducive to producing tradable renewable hydrogen, in accordance with EU standards. Furthermore, the development of a domestic hydrogen industry could stimulate demand for renewable electricity, catalyze investment in green infrastructure, and contribute to Moldova's long-term energy independence and economic diversification. This research offers both theoretical insight and policy guidance for small transitioning economies seeking to integrate into regional green energy markets.*

Keywords: *Hydrogen, EU, Republic of Moldova, European Integration, LCOH (Levelised Cost of Hydrogen)*

JEL Code: *Q42, Q48, Q56, O13, F15.*

UDC: 620.9(478):061.1EU

Introduction

Against the backdrop of the global push for sustainable energy transformation, the EU has consistently been at the forefront of green energy development, committed to building a low-carbon, environmentally friendly, and efficient energy system in alignment with the Paris Agreement (McCollum et al., 2018). Hydrogen, due to its versatile characteristics and its ability to be used directly or stored like natural gas, is regarded as one of the key contemporary solutions for decarbonizing the energy system. The EU's experience in this area has had a significant global impact (Pleshivtseva et al., 2023; Zhao & Wang, 2023).

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The Russia-Ukraine conflict has had a significant impact on the energy systems across Europe, particularly in Central and Eastern European countries (Sabbaghian & Rasooli, 2021; Liu et al., 2022). Against this backdrop, the EU proposed "Energy Transition and Strategic Autonomy" (European Economic and Social Committee, 2022), a core component of which is to reduce its dependence on Russian fossil fuels (Ryon, 2020). R. Moldova is one of the countries severely affected by the conflict. The disruption of the energy supply chain has led to a sharp increase in overall prices. The Government of the Republic of Moldova, with the support of the European Union, provides financial assistance to households across the country to mitigate the impact of rising electricity prices (Government of the Republic of Moldova, 2025). Financial support from the European Union has also deepened the cooperation between the two sides.

In the face of crisis, the reform of R. Moldova's energy sector, bolstered by financial support from the European Union (EEAS, 2024), demonstrates significant strategic synergy with the EU's "The REPowerEU Plan". This EU energy independence initiative aims to accelerate the green transition and reduce reliance on fossil fuels (European Commission, 2022). Such policy convergence has created a historic opportunity for R. Moldova to systematically integrate into the European Energy Union, particularly in renewable energy infrastructure development and cross-border energy market coordination (EFREMOV et al., 2022).

The successful implementation of this energy integration strategy may propel R. Moldova's transformation from an energy aid recipient to a renewable energy hub in Central Europe, especially regarding hydrogen exports to the Central and Eastern European market. This transformation not only aligns with the EU's strategic goal of energy diversification and autonomy but also resonates with R. Moldova's strategic aspiration to deepen European integration through functional cooperation mechanisms (European Commission, 2025; Sandu, 2022).

Current status of the hydrogen energy industry

Overview of EU hydrogen energy development

In terms of the development trend of the hydrogen energy market, the EU has clearly outlined in the REPowerEU Energy Plan that by 2030 the production and import of renewable hydrogen will each reach 10 million tons (European Commission Directorate-General for Energy, 2022). In 2020, Europe's hydrogen demand stood at 8.2 million tons. Driven by carbon tax policies, the demand for green hydrogen has shown an upward trend. However, at that time, the production capacity for hydrogen through water electrolysis was only 30,000 tons, resulting in a significant supply-demand gap. In terms of industrial layout, the European Hydrogen Bank (EHB) specifically aims to boost hydrogen production and transportation across Europe (H2InfraMap, 2024). Between 2024 and 2026, the EU plans to establish 21 "Hydrogen Valley" industrial cluster demonstration projects in fields such as oil refining and steelmaking. These projects will be operational, effectively advancing the industrialization process of green hydrogen (Yao 2024,). In 2024, Europe's investment in

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hydrogen energy was expected to increase by 140% (European Commission. 2024), with electrolyzer investment accounting for nearly one-third of the global total. Simultaneously, the EU is actively promoting the development of the hydrogen energy industry through various policy measures, including public funding assistance (IEA, 2024).

In terms of building standards and regulatory systems, the EU continues to enhance its hydrogen energy regulations and policy framework. The EU Hydrogen and Gas Decarbonization Plan, adopted in May 2024, comprises two regulations (EU, 2024/1788; EU, 2024/1789). The plan not only updates the EU's natural gas market rules and introduces a regulatory framework for hydrogen energy infrastructure but also revises the natural gas directive to establish a low-carbon hydrogen certification system. In terms of technical standards, the "Hydrogen Energy Standardization Roadmap" comprehensively addresses the standardization needs across the entire hydrogen energy value chain (European Commission, 2023).

Overview of R. Moldova's Energy Situation

For a long time, R. Moldova's energy supply has been heavily reliant on fossil fuels, particularly oil and natural gas imported from Russia. Over the past decade, R. Moldova has actively promoted the diversification of its natural gas supply by establishing interconnected pipelines with Romania, which has partially alleviated its energy challenges (Pamfile, 2024). Following the outbreak of the Russia-Ukraine conflict in 2022, R. Moldova accelerated its efforts to reduce dependence on Russian energy and vigorously pursued energy diversification and green production initiatives (Figure 1).

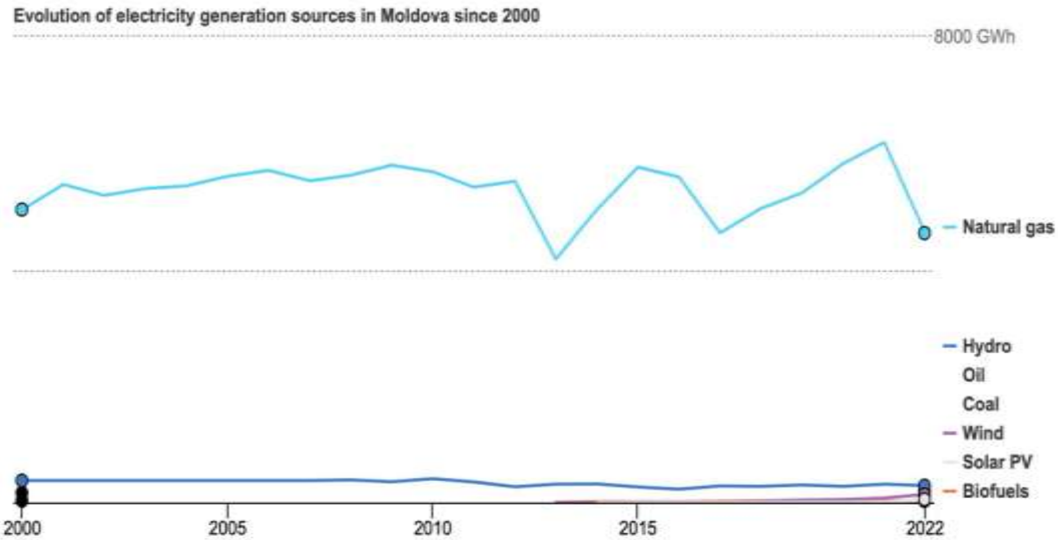

Figure 1: Evolution of R.Moldova's electricity sources (2000-2022)

Source: IEA (2022). https://www.iea.org/reports/moldova-2022, Licence: CC BY 4.0

However, in 2023 - 2024, its electricity consumption remained dominated by fossil fuels. Fossil energy, primarily natural gas, accounted for approximately 87.1% of electricity generation, while renewable and green energy sources represented only 5.6%. An additional 6.7% of electricity was net imports. Such an energy structure not only exacerbates climate change and air pollution but also hinders R. Moldova's integration into the European green energy system. Increasing the share of low-carbon energy and achieving a diversified power generation structure have become urgent priorities (National Bureau of Statistics of the Republic of Moldova, 2024). By January 2025, Moldova's energy crisis had intensified, with electricity price increased by 75% (consumers have to pay 4.10 MDL/KWh, price increase of 1.76 MDL), compared to the previous period (ANRE, 2025).

As a European country, R. Moldova's energy security is not only a concern for itself but also for the EU and the global community. International financial institutions such as the World Bank, the European Bank for Reconstruction and Development (EBRD), and the European Investment Bank (EIB) have all provided funding for its energy security projects. The United States Agency for International Development has also pledged $370 million in support (U.S. International Trade Administration, 2024). In recent years, R. Moldova has strategically utilized these funds to advance its energy transition. Externally, in collaboration with Romania, it has increased investment in upgraded energy infrastructure to facilitate integration into the European energy system and alleviate the energy crisis. Internally, it has supported large-scale renewable energy projects and promoted the diversification and greening of its energy structure. R. Moldova plans to increase the share of renewable energy in electricity consumption to 30% by 2030 and has approved the construction of a 105 MW wind farm and a 60 MW solar park project in 2025 (Ministry of Energy of the Republic of Moldova, 2025).

Additionally, the implementation of the third round of energy plans for R.Moldova's gas industry has created opportunities for natural gas supply and hydrogen trade. In July 2024, the "Moldova Hydrogen" conference was held, during which Ukraine Hydrogen Limited Liability Company (H2U) and Moldova Global Assistance Limited signed a memorandum of understanding to launch the Hydrogen Valley project (Hydrogen Ukraine LLC., 2023). This project aims to assess the potential of renewable energy, ensure compliance with European standards, confirm the availability of water resources for green hydrogen production, coordinate the use of infrastructure, learn from European best practices, promote the application of hydrogen energy, and facilitate the construction of "green hydrogen" facilities and transportation infrastructure.

Raise of the Question

Currently, R.Moldova has initiated the construction of photovoltaic and wind energy projects (Ministry of Energy of the Republic of Moldova, 2025). However, it cannot be overlooked that these types of renewable natural energy sources inherently exhibit instability in their production processes. On the one hand, exploring the use of electricity-to-hydrogen technology to achieve high-value energy conversion, storage, and sales holds significant research value and practical economic importance. On the other hand, whether the development of the hydrogen energy industry can drive investment in green energy power generation is also worthy of in-depth exploration. The ultimate goal of addressing these two issues is to alleviate R. Moldova's energy and financial pressures and to integrate the country into the EU's green energy system through measures such as hydrogen exports. These are critical directions that require thorough analysis and comprehensive demonstration.

Literature Review

European academic circles have conducted extensive research on R.Moldova's energy issues from multiple perspectives, including the feasibility of green energy development, integration into the EU market through energy trade, and the study of hydrogen valleys in neighboring countries. These studies provide valuable multi-dimensional references for R. Moldova's energy transition; however, many practical challenges remain unresolved.

C. Efremov, V. Arion and M. Sanduleac (2021) conducted a detailed analysis of hydrogen energy facility construction in R. Moldova. They explored the supply and demand dynamics within the framework of the Paris Agreement and provided an assessment. Their findings indicated that R. Moldova could only achieve energy system transformation if it reached a photovoltaic energy penetration rate of 30%–50%. While this assessment serves as a technical reference for R. Moldova's transition towards a carbon-neutral energy sector, the study also highlighted the country's extremely weak green power generation infrastructure. Three years later, the slow development of renewable energy in R. Moldova continues to hinder the large-scale adoption of hydrogen energy facilities. Expanding on this, Efremov C., Cernei M., and Leu V. (2022) pointed out that R. Moldova has taken key steps in energy transformation by designing an energy transition roadmap, including strengthening policy guidance and resource allocation. They has argued that R. Moldova possesses significant green energy potential, but as of now, several critical factors, the main being the insufficient development of renewable energy, remain obstacles to achieving energy transition goals. Regarding the economic feasibility of building hydrogen energy facilities, Comendant, I. Prepelita and L. Turcuman (2019) predicted how R. Moldova could achieve the basic requirements for 100% renewable energy transformation, the core issue was the constraints of technology and electricity prices.

Another key pillar of R. Moldova's energy strategy is integrating into the EU market through green energy trade. Sandu, M. (2022) focused on analysis of the R. Moldova's energy security within the context of international economic relations. The study emphasized that R. Moldova should actively engage in energy cooperation with EU countries to enhance energy security and diversify its supply sources. By expanding energy trade, R. Moldova could leverage the EU's technical and financial support to accelerate its energy transition. However, the study did not detail specific implementation plans for hydrogen energy - particularly how hydrogen energy technology could be optimized within energy cooperation to improve the country's energy structure. This gap highlights the need for further research, and this paper will analyze the issue from a hydrogen energy perspective to refine the existing framework.

In the field of hydrogen energy applications, Stoicescu V., Vrabie C., and Bitoiu T. (2023) examined Romania's approach to industrial and value chain transformation toward sustainable practices. Their study proposed a conceptual framework for building a sustainable smart community through the "Hydrogen Valley" model. Romania's experience in utilizing regional resources to develop a hydrogen energy industry chain underscores the potential of hydrogen valleys in driving green economic growth and technological innovation. However, these studies do not address fiscal issues - such as how the construction of hydrogen plants could help alleviate financial pressures. R. Moldova lacks the necessary policy support to effectively promote its green energy transition.

Collectively, these studies explore R. Moldova's green energy development potential and strategic direction from multiple perspectives, yet they largely overlook the economic benefits associated with these transitions. One of R. Moldova's biggest challenges is the lack of national financial support and the long-term fiscal impact of such projects once they become operational. Additionally, the country's underdeveloped green energy infrastructure directly affects its power supply. Whether the construction of hydrogen energy plants can effectively stimulate demand for green energy remains an open question, highlighting significant research gaps in these two key areas.

Problem Discussion

Power-to-hydrogen (P2H) enables high-value energy conversion. Hydrogen energy trading is subject to EU regulations, which determine how R. Moldova produces hydrogen and whether it can participate in trading on the European Energy Exchange (EEX). If Moldova's hydrogen production does not comply with these regulations and cannot be traded, all investments and efforts will be ineffective.

The Key points to pay attention to: EU hydrogen energy trading regulations, technical methods for producing green hydrogen, electricity cost prices, hydrogen energy exchange prices and trends.

4.2 Can the hydrogen energy industry drive investment in green energy generation? To stimulate investment in green electricity through hydrogen energy, the first issue to address is the investment required for electrolysis plants - how much capital is needed, at what scale, and how long it will take to generate returns. These factors must be carefully calculated to ensure feasibility. Secondly, the amount of green electricity demand generated by hydrogen energy investments will determine how effectively private investment in green electricity can be encouraged and how much it can alleviate the financial burden on the Moldovan government.

The Key points to pay attention to: the scale of hydrogen energy plant investment, the profits generated by hydrogen energy investment, and how much green electricity demand is generated.

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Methodology

Regarding the above two issues, the study adopts an integrated techno-economic assessment that combines both **quantitative and qualitative methods** to evaluate the feasibility of the Republic of Moldova's integration into the EU green energy system through green hydrogen production. The core analytical tool is the Levelized Cost of Hydrogen (LCOH) model, which calculates the average lifecycle cost of hydrogen production per unit of energy (€/MWh). The model incorporates capital expenditures (CAPEX), operational expenditures (OPEX), and electricity costs, discounted over the expected lifespan of the electrolyzer system.

The analysis focuses on a comparative evaluation of two mainstream electrolysis technologies - Alkaline Water Electrolysis (AWE) and Proton Exchange Membrane Electrolysis (PEM) - assessed in terms of energy efficiency (ranging from 60% to 90%), energy consumption, and technological maturity. A standardized 5 MW hydrogen plant serves as the reference scenario, utilizing regionally relevant electricity price data from Moldova's domestic market and average rates under European Power Purchase Agreements (PPAs). In assessing market viability, the study incorporates real-time hydrogen trading prices from the European Energy Exchange (EEX) to establish a benchmark for potential returns on investment.

In addition to cost analysis, the methodological framework includes qualitative content analysis of EU policy documents, particularly a regulatory compliance review based on Directive (EU) 2023/2413. This directive outlines eligibility criteria for green hydrogen to be traded within the EU internal market. This dual-path approach - combining cost-effectiveness modeling with institutional and regulatory alignment - offers a multidimensional foundation for understanding Moldova's strategic potential to integrate into the EU hydrogen economy.

Problem Solving and Data Collection

EU Green Hydrogen Trading Regulations

The EU's Renewable Energy Directive-related bill, issued on February 13, 2023, clarifies the standards for tradable green hydrogen (EU, 2023/2413). In terms of production scenarios, it covers three modes: direct connection between renewable energy facilities and hydrogen production equipment, grid-powered production in areas with a high proportion of renewable energy, and grid-powered production after signing power purchase agreements in areas with low carbon dioxide emissions (Table 1). In terms of quantitative assessment, the renewable hydrogen fuel threshold must not exceed 28.2 grams of carbon dioxide equivalent per megajoule (3.4 kilograms of carbon dioxide equivalent per kilogram of hydrogen), and the calculation method for greenhouse gas emissions from co-production in fossil fuel facilities is specified.

R. Moldova currently meets the first and third requirements for the production of "renewable hydrogen." Specifically, hydrogen production is achieved by directly connecting renewable energy facilities with hydrogen production equipment. This means that wind and

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photovoltaic power generation facilities can be directly linked to water electrolysis equipment to produce green hydrogen. Although this method is technically feasible, Moldova's green power generation capacity is insufficient to meet domestic demand, let alone the electricity required for hydrogen production.

Table 1. EU regulation conceptualization of green hydrogen production scenario standards

Production scenario	**Regulation conceptualization**
Direct connection to new energy power generation facilities to produce hydrogen	Hydrogen produced by direct connection between renewable energy production facilities and hydrogen production equipment can be counted as "renewable hydrogen". For example, hydrogen produced by direct connection between wind power facilities and water electrolysis hydrogen production equipment.
Hydrogen production using power grid in areas with a high proportion of renewable energy	In areas where the proportion of renewable energy exceeds 90%, hydrogen produced using power grid power also meets the standards.
Signing an agreement for power supply and production in restricted emission areas	In areas with low CO2 emission restrictions, after signing a renewable energy power purchase agreement, using grid power to produce hydrogen can also be considered "renewable hydrogen"

Source: developed by the authors with accordance to regulations (EU, 2023/2413)

The gap in renewable energy generation significantly limits the possibility of large-scale adoption in the short term. However, hydrogen energy plants can create demand for green electricity and potentially stimulate private investment. The third method can be implemented through the European Green Power Purchase Agreement (PPA). Given its economic feasibility, this approach is preferred in the following discussion as a means of supplying green electricity.

European Green Power Purchase Agreement (PPA)

As a key mechanism in Europe's renewable energy sector, the European Green Power Purchase Agreement (PPA) is of great significance to promoting energy transformation (Acer, 2024). It is defined as an agreement reached between the developer or operator of a renewable energy power generation project and the green power purchaser, under which the purchaser buys green power at a uniform price within a specified period. PPA is mainly divided into direct or physical power purchase agreement (DPPA) and virtual or financial power purchase agreement (VPPA). From the transaction process, it involves the power purchaser's request for proposal, the power seller's quotation, the drafting of the terms list, contract negotiation, signing and project implementation. The latest data shows that in the third quarter of 2024, the price of solar and wind power fell month-on-month to 63.64 euros/MWh and 88.7 euros/MWh, with an average of 76.17 euros/MWh (LevelTen Energy, 2024). It is expected that in the future, due to the grid connection of newly commissioned power generation units, prices will fall further (Figure 2).

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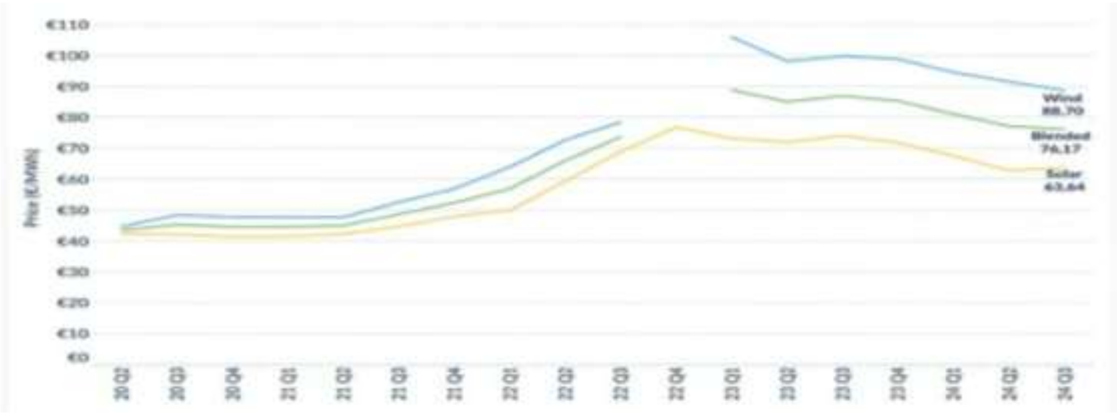

Figure 2. European green power purchase agreement prices (PPA) - Q3, 2024

Source: LevelTen Energy. (2024). https://www.leveltenenergy.com/post/levelten-u-q3-2024-ppi

Methods for producing green hydrogen

Hydrogen production technology includes three main methods: alkaline water electrolysis to produce hydrogen (AWE), using an electrolyzer to separate the positive and negative electrodes, with high maturity, low cost, and an efficiency of 60%-75%; proton exchange membrane water electrolysis (PEM) to produce hydrogen, using proton exchange membrane as electrolyte, with an efficiency of 70%-90%, high hydrogen purity, but high cost; solid oxide water electrolysis (SOEC) to produce hydrogen, using the oxygen ion conductivity characteristics at high temperatures of 700-1000℃, with a theoretical efficiency of more than 90%, but the technology is complex and is still in the laboratory stage (Table 2) (Ni 2022; Wang, 2023; Davies et al., 2021).

Table 2. Comparison of electrolysis hydrogen production technologies

	Alkaline (AWE)	**Proton exchange membrane (PEM)**	**Solid oxide (SOEC)**
Purit	≥99.8	≥99.999	Laboratory researching
Electrolyte	20%-30% (mass fraction) KOH/NaOH	PEM	Y2O3/ZrO2
Operating temperature	70-90 ℃	70-80℃	600-1000℃
Electrolysis efficiency	60-75 %	70-90 %	≥90 %
Energy consumption	4.5-5.5 kWh/Nm³	3.8-5.0 kWh/Nm³	2.6-3.6 kWh/Nm³
Operation characteristics	Quick start and stop	Quick start and stop	Difficulty in starting and stopping
Commercial features	Most mature, large-scale production, high degree of commercialization, no precious metal catalysts, low cost	High cost (proton exchange membrane, metal catalysts such as platinum and iridium), no pollution, low level of industrialization	R&D and demonstration phase

Source: developed by the authors based on Ni, Z. (2022, Wang, W. (2023), Davies, J., Dolci, F., & Weidner, E. (2021)

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Cost of producing green hydrogen

The cost assessment of European electrolyser technologies in 2023 shows distinct financial characteristics. The capital expenditure (CAPEX) of alkaline electrolysers is estimated at 1666 EUR/kW and the operating expenditure (OPEX) is 43 EUR/kW/year. In contrast, the cost structure of proton exchange membrane (PEM) electrolysers is relatively high, with capital expenditure (CAPEX) estimated at 1970 EUR/kW and operating expenditure (OPEX) at 64 EUR/kW/year (Figure 3).

Figure 3. Electrolyser maintenance costs and fixed costs in comparison, 2023

Source: European Hydrogen Observatory (2024).

The electrolyser capital expenditure (CAPEX) costs of both technologies are divided into three categories, including the electrolyser itself, auxiliary facilities (BoP) and other engineering, procurement and construction costs (Other EPC) (Figure 4).

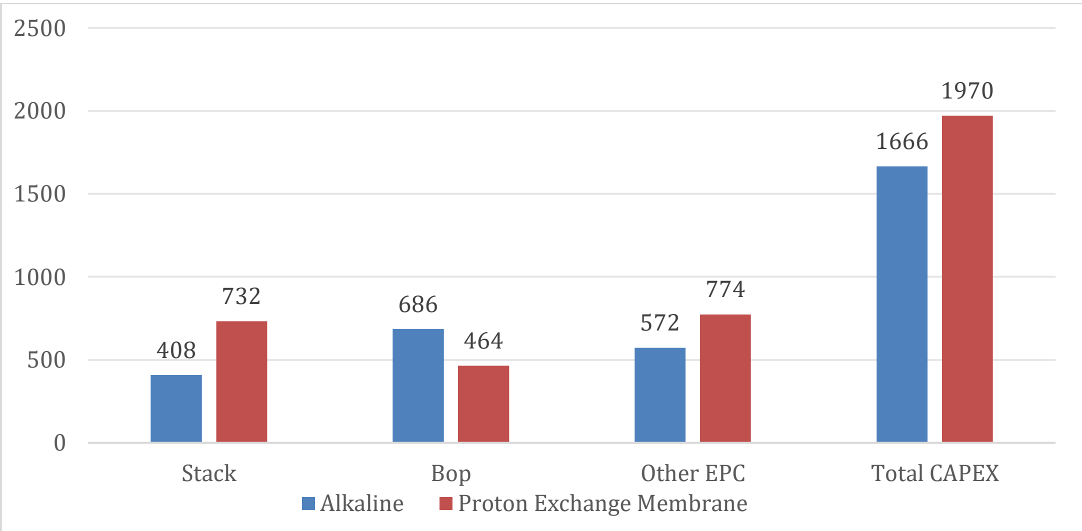

Figure 4. Capital expenditure costs of electrolyzers in 2023, €/kw

Source: European Hydrogen Observatory (2024).

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Hydrogen Energy Exchange

Founded in 2002 and headquartered in Leipzig, Germany, the European Energy Exchange (EEX) is one of the leading energy trading platforms in Europe and even the world. The EEX provides trading services for a variety of contracts such as electricity, natural gas, carbon emission rights, freight and agricultural products for the international commodity market. As part of the EEX Group, EEX is committed to building a safe, successful and sustainable global green energy commodity market. In the field of hydrogen energy, EEX is the first exchange in the world to launch hydrogen commodities to promote competition among enterprises, reduce the cost of hydrogen energy manufacturing, and popularize the use of hydrogen energy. The hydrogen trading market is operated by Hintco (market maker), which consists of more than 50 European companies, including ArcelorMittal and BNP Paribas. The EEX is expected to provide operating system support, which will strongly promote the green energy transformation in Europe (Hintco, 2024).

The EEX Hydrogen Index is based on a supply and demand model. Since the launch of the index, price volatility has increased, and as of January 24, 2025, the price has reached 286 euros/MWh (Figure 5).

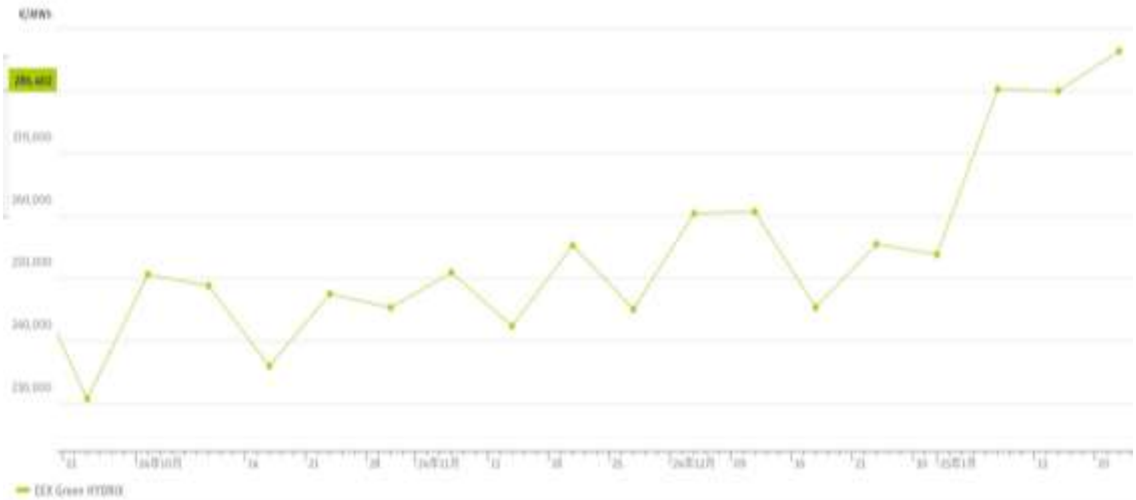

Figure 5. EEX - Hydrogen Energy Trading Price, January 24, 2025 (Euro/MWh)

Source: EEX Exchange. (2025).

It is expected that as the hydrogen energy gap continues to expand in the future, prices will rise further (Figure 6).

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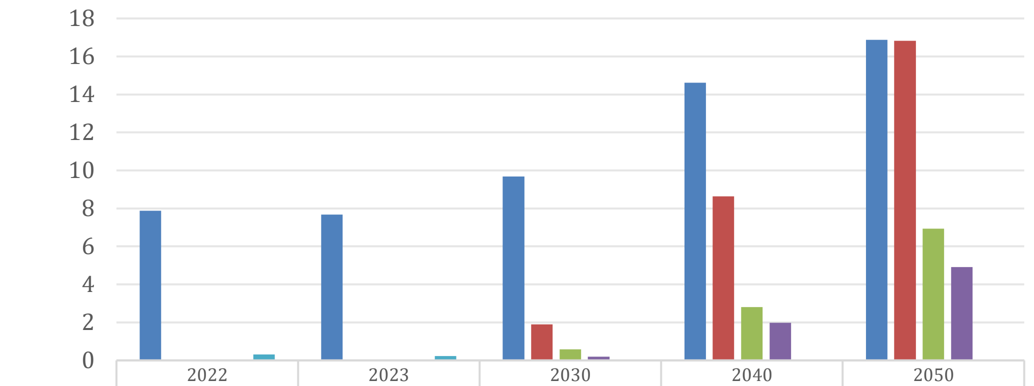

	2022	2023	2030	2040	2050
Industy	7.87	7.68	9.68	14.62	16.88
Transport		0.01	1.9	8.63	16.83
Buiding			0.58	2.8	6.93
Power			0.2	1.98	4.91
Other	0.31	0.23			

Figure 6. Average projected hydrogen demand by industry in 2030, 2040 and 2050 under different scenarios, Mt/year

Source: European Hydrogen Observatory (2024).

Global electrolysis plant installed capacity

Across Europe, water electrolysis projects are of different sizes. It is worth noting that there are 3 projects with a capacity of 10 MW or more, which together account for 21% of the total water electrolysis capacity, totaling 50 MW. In addition, there are 12 projects with an electrolysis capacity of 5-10 MW, which together account for 33% of the total electrolysis capacity in the region, with a cumulative capacity of 77.8 MW (European Hydrogen Observatory, 2024). In addition, there are 51 projects with an installed capacity of 1-5 MW, which contribute significantly to the total installed capacity, accounting for 40% (95.19 MW), so 1-5 MW is the mainstream (Figure 7).

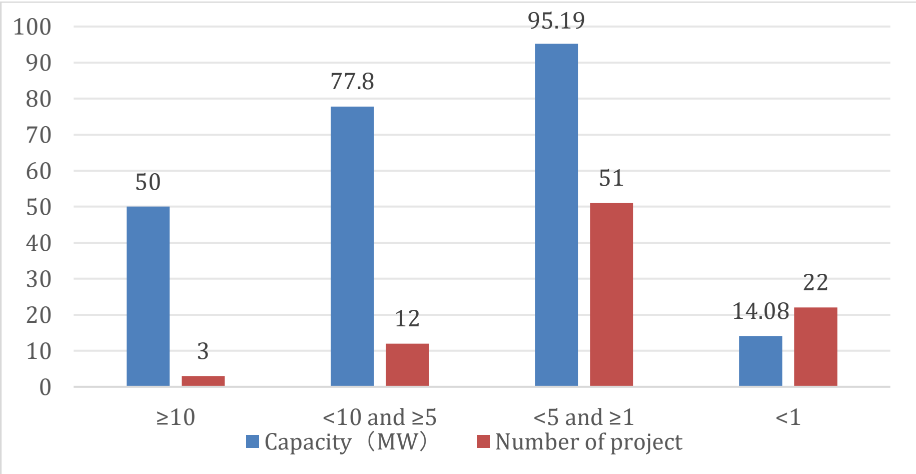

Figure 7. Electrolyser capacity and number of projects, *MW-Number of Project*

Source: European Hydrogen Observatory (2024).

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However, as the gap between hydrogen demand and supply in Europe widens, hydrogen energy plants with an installed capacity of 100MW and above are being planned and started, such as the Reni Hydrogen Valley in Odessa, Ukraine. Because it is close to R. Moldova, it has important reference significance (Figure 8). Therefore, according to the trend, it is planned to be more than 100MW in the future.

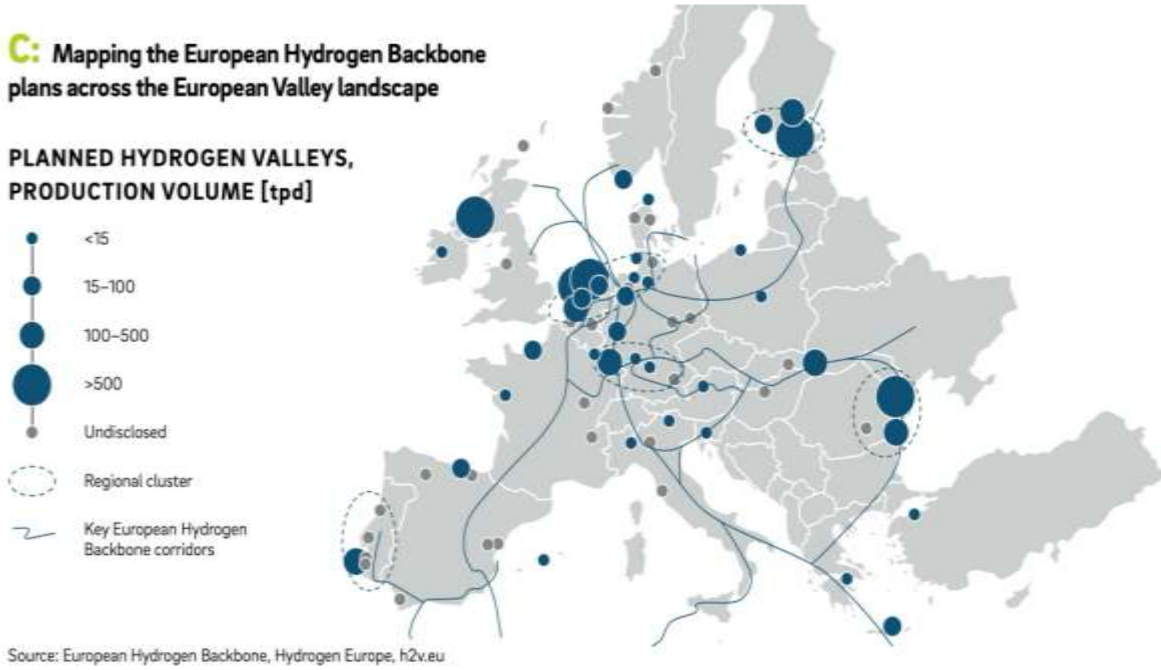

Figure 8. European Hydrogen Backbone Map

Source: Weichenhain et al (2024)

The significance and enlightenment of Ukraine's Reni H_2 Valley

H2U Hydrogen Valley - Reni is a strategically important hydrogen energy project in Odessa, Ukraine, located around the city of Reni in the Odessa region. It was supported by the Ukrainian Ministry of Energy. The project has joined hands with Bilfinger Tebodin and other professional institutions to conduct feasibility studies on hydrogen production, hydrogen transmission pipelines, and wind and solar farm construction (Hydrogen Ukraine LLC, 2023).

The project plans to build a renewable hydrogen plant with an initial electrolysis capacity of 100 MW and an output of 210 tons/year. The long-term goal is to increase the production capacity to 3 GW, when the annual hydrogen production is expected to reach 210,000 tons. In terms of industrial chain layout, hydrogen is produced through proton exchange membrane electrolyzers (PEM), involving multiple storage and transportation methods. At present, the project has completed technical and economic calculations and front-end engineering design, and is currently conducting feasibility studies. The Odessa Reni Hydrogen Valley project has a far-reaching impact on Ukraine's energy transformation, economic development, energy security and environmental protection, and is a key measure to promote regional sustainable development (Hydrogen Ukraine LLC, 2023). Because of many similarities such as Odessa's geographical location, it provides a reference for Moldova's hydrogen energy construction.

Data collection and calculation

The difference between high calorific value and low calorific value of hydrogen is mainly due to the different states of the generated product water. In the case of high calorific value, the combustion product water is liquid, while in the case of low calorific value, the water is gaseous. It takes heat to change from liquid water to gaseous water, so the high calorific value is bigger than the low calorific value. High calorific value (liquid water) is 142 kJ/g, low calorific value (gaseous water) is 120 kJ/g (Aravindan et al., 2023).

$$2H_2 + O2 \rightarrow 2H_2O \quad (1)$$

In actual application, 1 kg of hydrogen is often taken as equivalent to 33.33 kWh, which is a more practical approximate value obtained after comprehensive consideration of various practical factors (Singh et al., 2021). The following table is obtained by sorting out the above text and related data. (Table 3).

Table 3. Hydrogen physical data, Production technology and cost, Electricity price

Average calorific value of hydrogen	120MJ/KG (approximate value for general engineering)	
H2 Numeric conversion	1 MWh =30 Nm3	
	Alkaline (AWE)	Proton exchange membrane (PEM)
Fixed costs (CAPEAX)	1666 € / KW	1970 € / KW
Maintenance cost (OPEX)	43 € / KW / Year	64 € / KW / Year
Electricity costs	Electricity price in R. Moldova: 3.29 MDL / KWh ≈ 167€/MWh European PPA price: 76 € / MWh	
Technology life	About 10 Years (Approximately 90,000 hours at full load)	
Construction scale	5 MW (Authors' selection: current global average)	
Electrolyzer efficiency	60-75%	70-90%
Energy consumption (kWh·Nm3)	4.5-5.5 (Authors' selection: 5)	3.8-5.0 (Authors' selection: 4.5)
Hydrogen price (EEX)	286 € / MWh	

Source: composed by the authors based on references from Figure 3, Figure 7; Singh et al.(2021), Wei et al. (2024); Gerloff. (2021), Smolinka et al. (2022), Gao et al (2021); Monitorul Oficial al Republicii Moldova. (2025);AVIC Securities Research Institute (2024).

The levelized cost of hydrogen (LCOH) is an economic indicator that measures the average cost of hydrogen production over the entire life cycle, covering initial investment, operation and maintenance, fuel, depreciation and other costs, and helps compare the economic feasibility of different hydrogen production technologies. LCOH is obtained by dividing the total cost by the total hydrogen production after discount (see the formulas (2) and (3) (Clean Hydrogen Observatory, 2024; China Industrial Development Promotion Association, 2021). In Table 4, there is the analysis and calculation results of AWE and PEM by the LCOH method with the formulas, in comparison.

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$$\text{LCO (Levelized cost of hydrogen)} = \frac{\text{Fixed costs (CAPEX)}}{H_2 \text{ (capacity)} \times \text{Lifetime}} + \text{Maintenance cost (OPEX)} \quad (2)$$

$$\text{Maintenance cost (OPEX)} = \text{Energy consumption (KWh} \cdot \text{Nm}^3\text{)} \times \text{Price} + \text{Other cost} \quad (3)$$

Table 4. Levelized cost analysis LCOH - life 87,600 hours (10 years)

	Alkaline (AWE)		**Proton Exchange Membrane (PEM)**	
Power Consumption	4,380,000 MWh			
Electricity costs (76 € / MWh)	76 € / MWh 33,288,000 €			
Fixed costs (CAPEAX)	8,330,000 €		9,850,000 €	
Maintenance cost (OPEX)	2,150,000 €		3,200,000 €	
Total Cost	43,768,000 €		46,338,000 €	
	η=60%	η=75%	η=70%	η=90%
Hydrogen production	1,752,000 MWh	2,190,000 MWh	2,271,888 MWh	2,920,988 MWh
LCOH	24.98 € / MWh	19.99 € / MWh	20.40 € / MWh	15.88 € / MWh

Source: Authors' calculation

The levelized production cost of hydrogen energy is compared with other energy costs (Table 5) to estimate the range of construction costs (X) that need to be controlled. Finally, the cost-effectiveness of Moldova's entry into the European market through hydrogen energy and the possibility of replacing other energy sources are predicted.

Table 5. Comparison of the hydrogen LCOH with other fuel costs (1€ = 0.924 $)

Energy Name	**Unit conversion**	**Price fluctuation range in 2024**	**Average price**
Alkaline - LCOH		19.99-24.98 € / MWh	22.49 € / MWh
PEM – LCOH		15.88-20.40 € / MWh	18.14 € / MWh
Construction costs (land, plant)		X € / MWh	
International Energy Agency : 3.0 - 4.3 $ / Kg		96.5-138.3 € / MWh	117.4€ / MWh
EEX Hydrogen Price		230-286 € / MWh	258 € / MWh
Average green electricity prices under European Power Purchase Agreements (PPA)		76-82 € / MWh	79 € / MWh
Brent Crude Oil Average Price: 68 - 93 $ / B	≈ 1.7 MWh / B	43.28-59.22 € / MWh	51.25 €/ MWh
ICE Newcastle Coal Price: 127-140 $ / T	≈ 6.7 MWh / T	20.54-22.65 € / MWh	21.60 €/ MWh
Natural gas main prices: 7.5-16 $ / MMbtu	≈ 0.293 MWh / MMBtu	27.7-59.1 € / MWh	43.4 €/ MWh

Source: Authors' calculation based on IEA (2022), MacroMicro. (2024), Revolut Ltd. (2025).

Compared with other energy sources, it can be seen that the production cost of hydrogen has a huge cost advantage, but the construction cost X (land cost, plant cost, etc.) directly affects the total cost of hydrogen, and further affects the sales profit of hydrogen. On this basis, the formulas (4) and (5) for building hydrogen costs (Y) and profits (Z) are:

$$\text{Total Cost: } Y = \text{LCOH } H_2 \text{ (AWE or PEM)} + X \text{ (Construction cost)} \quad (4)$$

$$\text{Total Profit: } Z = \text{Line } (\text{EEX-}H_2) - Y \quad (5)$$

Note: The X-axis is the construction cost (X) . The Y-axis is the price (€), (Figure 9).

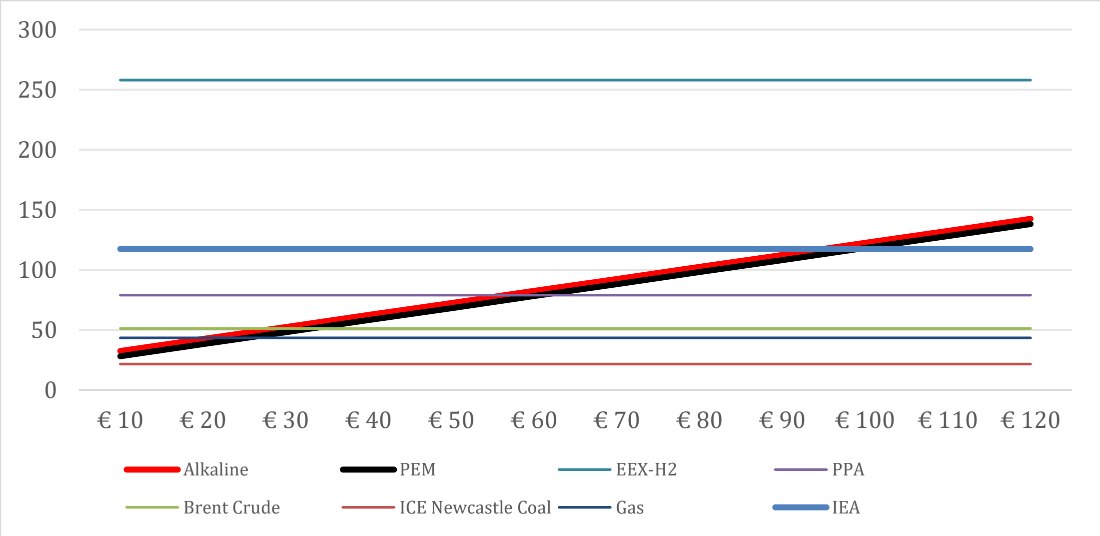

Figure 9. Impact of hydrogen plant construction costs (X)

Source: created by the authors

Based on Moldova's superior geographical endowment (dense rivers and flat terrain), its renewable energy infrastructure construction has significant cost advantages. This geographical feature not only improves the economic feasibility of the hydrogen energy industry by reducing the fixed cost investment threshold, but also strengthens the competitiveness of green hydrogen compared to traditional energy, providing key economic support for the transformation of the energy structure.

Conclusion

Under the global energy transition framework, R. Moldova is confronting severe energy shortages, with soaring prices of natural gas and electricity exerting significant pressure on its national economy. However, the EU’s "Energy Transition and Strategic Autonomy", which drives member states to strengthen energy infrastructure development and accelerate energy transition while actively pursuing international cooperation to reduce dependence on Russian fossil fuels, has created strategic opportunities for R. Moldova. The EU's provision of financial assistance for green energy development offers R. Moldova a crucial pathway to align with the EU's green energy system. By advancing hydrogen energy technologies, expanding hydrogen production facilities, and engaging in the EU's green energy market through hydrogen fuel exports, R. Moldova could potentially achieve dual objectives of energy self-sufficiency and economic stabilization. The following four considerations are the basis for achieving the goal of energy independence:

1. Economic feasibility and feasibility of hydrogen energy technology: By analyzing the costs in the production process through LCOH (levelized cost of hydrogen), R. Moldova has a certain degree of economic feasibility when using alkaline electrolyzer (AWE) and proton exchange membrane electrolyzer (PEM) technology to produce green hydrogen. However, fixed capital (X) investment directly affects the economic benefits of hydrogen energy. Therefore, the site selection and plant construction of hydrogen energy plants need to be considered, and reference can be made to the construction of different hydrogen valleys around the world to select reasonable standards. At the same time, reasonable maintenance can also increase the life of the electrolyzer and reduce depreciation costs.

2. The driving effect of hydrogen energy on the demand for green electricity: The demand for green electricity from hydrogen energy plants is huge. The construction of plants can not only directly produce green hydrogen, but also create demand for green electricity, thereby driving investment in renewable energy in R. Moldova. Through the electrolysis of water to produce hydrogen, R. Moldova can convert unstable wind and solar energy into storable hydrogen, thereby achieving efficient utilization and storage of energy. This will not only help alleviate the problem of energy shortage, but also promote the development of the domestic green energy industry and reduce dependence on imported fossil energy.

3. Potential for integration into the EU green energy system: R. Moldova can gradually integrate into the EU green energy system by developing hydrogen energy, especially green hydrogen production. The EU's demand for green hydrogen is growing, and its hydrogen energy trading market (such as EEX) provides R. Moldova with the opportunity to export hydrogen. At the same time, it makes profits for the Moldovan government and alleviates fiscal and energy pressures. Although Moldova's green power infrastructure is currently weak, through the construction of hydrogen energy plants, its green energy production capacity can be gradually improved, thereby meeting the EU's demand for green hydrogen.

4. R. Moldova will face the challenge of high requirements of hydrogen regulations: The EU has strict regulations on hydrogen energy trading. R. Moldova can only meet the requirement of directly connecting renewable energy production facilities with hydrogen production equipment to qualify as producing "renewable hydrogen." However, due to the low proportion of renewable energy in its power grid, it fails to meet the other two criteria. If the hydrogen produced does not comply with EU standards, it will be ineligible for trading on the European Energy Exchange (EEX), rendering the initial investment futile.

Suggestion

Based on the above four considerations, strong policy support and international cooperation are essential for R. Moldova's hydrogen energy development. The EU's "Energy Independence Plan REPowerEU" and "European Hydrogen Bank Plan" offer financial and technical support opportunities. Additionally, by strengthening energy infrastructure and collaborating with neighboring countries such as Romania, R. Moldova can accelerate the development and utilization of green energy. Based on the author's thinking, the development of hydrogen energy in the Republic of Moldova should consider the long-term timeline, so the author makes the following suggestions:

Short-Term Recommendations:

- Launch a 5MW hydrogen demonstration project through fiscal subsidies and competitive public tenders;
- Introduce Green Power Purchase Agreements (PPAs) to ensure a stable electricity supply for hydrogen production;
- Upgrade renewable energy infrastructure to increase the share of green electricity in the national energy mix.

Long-Term Strategies:

- Promote domestic development of hydrogen technologies by encouraging R&D activities in universities and industrial enterprises;
- Align national hydrogen production and regulation frameworks with the EU's hydrogen trading standards, particularly those outlined in Directive (EU) 2023/2413;
- Develop an export-oriented hydrogen economy by enabling participation in the European Energy Exchange (EEX), thereby establishing Moldova as a regional green fuel supplier.

Thus, with the growing global demand for green energy, hydrogen - as a clean and efficient energy carrier - is expected to play a crucial role in the future energy system. By developing hydrogen energy technology, R. Moldova can not only mitigate its current energy crisis but also lay the foundation for a long-term green energy transition, securing a place in Europe's green energy landscape. The construction of hydrogen production facilities in R. Moldova will drive demand for green electricity, stimulate domestic renewable energy investment, and accelerate Moldova's integration into the EU's green energy system. Despite technical and financial challenges, with policy support, international cooperation, and technological innovation, R. Moldova has the potential to establish a significant presence in the future green energy market while achieving energy independence and sustainable economic growth.

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