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STRATEGIC TRANSITION FROM HYDROCARBONS TO GREEN HYDROGEN: LONG-TERM PATHWAYS FOR AZERBAIJAN'S EXPORT DIVERSIFICATION**

Abstract. *As global demand for clean energy rises, green hydrogen is emerging as a critical driver of decarbonisation and sustainable economic growth. The study examines the production potential and export prospects of green hydrogen in Azerbaijan. Analysis focuses on an evaluation of Azerbaijan's technical capacity, the state of its infrastructure, policy framework, and investment climate for developing green hydrogen. The findings suggest that by leveraging its substantial wind and solar resources, Azerbaijan has the capacity to generate green hydrogen through electrolysis. The development of clean hydrogen and associated derivatives offers a strategic pathway for diversifying the national economy, attracting foreign investment in clean energy technologies, and fostering innovation-led long-term growth. The country's geostrategic position adds to its potential to be a pivotal hub for a green energy corridor between East and West, facilitating energy flows across Europe and Asia while strengthening regional energy security.*
Keywords: *Hydrogen energy, green energy exporter, energy security, net-zero energy systems, wind energy.*

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INTRODUCTION

The Republic of Azerbaijan is endowed with abundant oil and gas resources, and is proactive in safeguarding its role as a major energy exporter, even when oil production is anticipated to decline in the coming years. As part of this, Azerbaijan has set a target to in increase the electricity it generates from renewable energy sources (RES) to 30% by 2030, along with cutting carbon emissions by 40% by 2050. Emphasis is thus placed on the transition to renewable energy. Azerbaijan is not only prioritising the generation of green electricity, but is also actively exploring the possibility of producing and exporting green hydrogen. The country's technical potential for onshore solar and wind energy is currently assessed at 135 GW, with offshore wind potential in the Caspian Sea estimated at 157 GW, bringing a total technical potential amount of solar and wind energy of 292 GW. To exploit this capacity, Azerbaijan has already embarked on large-scale projects aimed at the production and export of green electricity that, among others, include the participation of leading global energy companies like Masdar (United Arab Emirates), ACWA Power (Saudi Arabia), China Energy (China) and BP (United Kingdom).

Parallel to this, Azerbaijan is making efforts to establish new international 'green energy corridors', such as the Caspian–Black Sea–Europe, Azerbaijan–Turkiye–Europe, Azerbaijan–Georgia–Turkiye–Europe, and Azerbaijan–Central Asia–Europe routes, to facilitate exports of green electricity (Shahbazov 2024; Gasimli 2025). Importantly, the country's commitment to renewable energy extends beyond the generation of electricity to also encompass the development of a green hydrogen sector. The relatively low cost and substantial potential availability of renewable electricity provide a strong foundation for the development of a low-carbon hydrogen economy in Azerbaijan.

To that end, in 2024 the Ministry of Energy of Azerbaijan (MoE) set up a dedicated working group tasked with preparing a strategic framework for low-carbon hydrogen production. Within the framework of a Memorandum of Understanding signed with the European Bank for Reconstruction and Development (EBRD), work has commenced on the project "Development of the Azerbaijan National Hydrogen Strategy and its Implementation Plan". On 13 November of that year, Azerbaijan presented its *National Strategic Overview Document on Hydrogen* at a COP29 event "Ensuring a Clean Hydrogen Economy and Developing New Supply Chains", co-organised by the Azerbaijan Renewable Energy Agency (AREA) and supported by the International Renewable Energy Agency (IRENA) and the Hydrogen Council (2023; 2024).

The production of green hydrogen is achieved with electrolysis of water using renewable energy sources (RES) like solar or wind power as the energy supply. This method produces no carbon emissions, making it one of the most environmentally friendly approaches to producing hydrogen (Hassan et al. 2024). One should also note that carbon dioxide, a significant contributor to the greenhouse gas effect, is also produced by non-renewable sources. Green hydrogen can accelerate the transition to energy sources that are clean and renewable, while improving the reliability and sustainability of energy systems (Risco-Bravo 2024). Green hydrogen is created in an electrolysis process that splits water into hydrogen (H2) and oxygen (O2) using RES and electricity. This process produces zero carbon emissions (Kumar and Lim 2022). The technology involved holds the potential to completely eliminate greenhouse gas emissions and play a crucial role in transforming global energy. The study presented in this article explores Azerbaijan's significant potential for green hydrogen production and its promising export opportunities. By thoroughly evaluating the country's strategic advantage in this emerging sector, we highlight its vital role in shaping the global energy market's future.

The remainder of the article is structured as follows: section 2 reviews the relevant literature. Section 3 presents the data sources and outlines the research methodology. Section 4 reports and discusses the empirical results. Section 5 concludes the study and provides policy recommendations, while section 6 outlines the limitations and some suggested directions for future research.

GREEN HYDROGEN RESEARCH: CURRENT TRENDS AND KNOWLEDGE GAPS

In recent years, the growing global interest in clean hydrogen has been accompanied by a rapid expansion of research in this field. The role of hydrogen in the global energy transition is the subject of extensive scholarly analysis (Ahad et al. 2023; Vallejos-Romero et al. 2023; Dou et al. 2023; Jayachandran et al. 2024; IEA 2024a; IEA 2024c). Nonetheless, ongoing technological advances and evolving structural dynamics underscore the need for greater and more comprehensive research on green hydrogen. Empirical evidence already shows a steady rise in both the global production and utilisation of green hydrogen. At present, one of the central themes of international debate concerns the lowering of production costs, together with the possible challenges and risks associated with exports of green hydrogen.

Reports by esteemed international organisations like the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA) stress that green hydrogen has a crucial role to play in decarbonising energy systems.

The utilisation hydrogen as a primary energy source for various applications such as generating heat, producing electricity and serving as transportation fuel is referred to as the "hydrogen economy" where hydrogen is claimed to be a valuable part of the transition to a clean and sustainable energy sector (Dou et al. 2023).

Consequently, the current body of research and policy on hydrogen exports showcases the energy security concerns of those nations that depend significantly on energy imports (Curtis and McLellan 2023).

Gado (2024) made a comprehensive technical-economic-environmental assessment of green hydrogen production in several oil- and gas-rich Middle Eastern countries. The assessment included Iraq, Saudi Arabia, the United Arab

Emirates, Kuwait, Qatar and Bahrain, and evaluated major parameters like the levelised cost of hydrogen (LCOH), water requirements, carbon mitigation potential, and region-specific energy feasibility.

In research by D'Amore-Domenech et al. (2020), several methodologies (AHP, CBA, SAW, COPRAS, TOPSIS) were used to identify the most sustainable and economically viable electrolysis technologies for producing green hydrogen from seawater. The findings showed that PEME technology was the most effective, followed in ranking by AE, SOE and DES. Even though AE displays notable economic benefits, it is linked to substantial social and environmental risks. In contrast, PEME has a superior performance with regard to social and environmental criteria while maintaining a moderate level of economic efficiency.

Sadik-Zada (2021) argues that developing and transitioning economies rich in fossil fuels should create energy transition strategies distinct from those in countries which import oil and gas. In these fossil fuel-rich nations, establishing non-renewable hydrogen infrastructure alongside solar and wind energy parks can help expedite the transition to clean energy.

According to Panchenko et al. (2023), large-scale production of green hydrogen is still in its early stages compared to traditional energy sources like coal, gas and oil. Several factors contribute to this situation, including transport challenges, regulatory frameworks, economic inefficiencies, material limitations, technological hurdles, and the explosive nature of hydrogen.

In a study conducted by Hjeij et al. (2023), a composite index was developed to evaluate the competitive positions of nations in the production and export of hydrogen by the year 2050. The index reveals that the United States, Australia, Canada, the United Kingdom, China, Norway, India, Russia, the Netherlands and Germany will be the main players in this area. Specifically, with respect to the production of blue hydrogen, the United States, Australia, Norway, Qatar and the UAE emerge as the leading contenders. This index takes various factors into account, such as natural resources, economic and financial prospects, and the political and regulatory environment.

A study by Dokhani et al. (2023) found that the cost of the water purification process is relatively low, representing just 1% of total energy consumption in the overall cost of hydrogen production. With the current grid connection, the estimated cost of producing 1 kg of hydrogen is USD 3.51. The mentioned figure includes the energy costs associated with both seawater electrolysis and the water purification process (Dokhani et al. 2023).

Guliyev (2024) established a positive correlation between renewable energy growth and the effectiveness of a legal framework, with this relationship being a factor that strongly influences both the scale and speed of the energy transition.

Melnikov (2024) examined Russia's ambitions to enter the global hydrogen market and the strategies this would entail. The growth of Russia's hydrogen market chiefly hinges on its export capacity and technological advances. However, regulatory challenges, energy policies and geopolitical factors complicate this process. In the context of hydrogen exports, Russia could both compete against and collaborate with Saudi Arabia. Despite the two countries having abundant natural resources and the potential to produce low-carbon hydrogen, they are also susceptible to financial and technological risks.

Research by Tunn et al. (2024) demonstrates how the transition to green hydrogen in the Global South could exacerbate socio-ecological injustices. Producing hydrogen could worsen water scarcity, trigger land conflicts, and increase energy poverty.

Sadik-Zada et al. (2025) state that the expansion of green hydrogen production across the African continent holds substantial economic potential. In their projections, this sector's development could be responsible for around USD 126 billion in extra GDP and facilitate the creation of up to 13 million new jobs. Nevertheless, the authors caution that if the sector's development does not proceed according to equitable and inclusive frameworks it might inadvertently cause new forms of energy dependency and reinforce the traditional extractivist paradigm in economics, characterised by unregulated, destructive extraction and the exporting of raw materials with limited value-added processing.

While research on Azerbaijan's renewable energy potential is limited, green hydrogen exports hold considerable promise. Expanding the use of wind and solar energy in the country and developing the necessary infrastructure for hydrogen energy are essential. This makes it important to review existing research on this topic.

A collaborative study by Hamidova and Samadova (2024) shows Azerbaijan has substantial potential for hydrogen production. The country can increase both blue and green hydrogen production by leveraging its existing oil and gas infrastructure, together with its expertise in ammonia and methanol markets.

As is clear from the studies discussed above, the production and export of green hydrogen is a relatively new subject, with research in this field having only just commenced in Azerbaijan. Still, given the sector's significant development potential, the number of studies in this area is expected to rise in the coming years.

DATA AND METHODOLOGY

Data

Data were obtained from reliable sources, including the State Statistics Committee of Azerbaijan (SSC), thereby assuring a solid empirical foundation. Recent academic publications, government reports and market analyses were comprehensively reviewed to identify the principal barriers hindering the adoption of green hydrogen.

In May 2025, the authors made site visits to the solar and wind power plants operated by Masdar and ACWA Power in Azerbaijan. During these visits, discussions also focused on the companies' potential capacities to produce green hydrogen.

Methods

Due to the complex and multidimensional nature of the research, a mixed-methods approach was employed. The approach integrates the strengths of both qualitative and quantitative research methods, permitting an in-depth and systematic examination of various aspects of the topic under study.

The research analysed partnerships, investment initiatives and policy directions currently in place or planned for Azerbaijan's green hydrogen sector. As part of this analysis, we explored the potential for Azerbaijan's global and regional cooperation in green hydrogen development. In addition, we examined central aspects of the partnerships established with the European Union and other significant stakeholders.

The study examined the main directions for forming and developing the green hydrogen value chain, coupled with their possible impacts on the global hydrogen market's structure. In this analytical process, it became clear that the literature contains some gaps. The research also assessed Azerbaijan's potential to turn these gaps into strategic advantages. The aims of the multidimensional, mixed-methods research was to provide both theoretical insights and practical contributions to a deeper and more systematic understanding of the country's green hydrogen production and exports. It concentrates on identifying possible strategic development pathways and formulating effective policy and investment decisions in this field.

a) Levelised Cost of Hydrogen (LCOH)

Moreover, a significant component of the analysis was an assessment of the economic feasibility of green hydrogen production. In the proposed analytical model, CAPEX, OPEX and REPEX respectively denote the capital expenditures, operational and maintenance costs, and replacement expenditures associated with system components. The effective discount rate (r) is considered to be 5.0%.

The levelised cost of hydrogen (LCOH) is the most important indicator for evaluating the economic viability of green hydrogen facilities, and is defined as follows:

$$\mathrm{LCOH} = \frac{\mathrm{CAPEX} + \sum_{i=1}^{n}\left(\frac{\mathrm{OPEXi} + \mathrm{REPEXi}}{(1+r)^{i}}\right)}{\sum_{i=1}^{n}(M_{H2})}$$

In the above equation, MH2 is the quantity of hydrogen produced in year *i*, typically expressed in kilograms or tonnes. This parameter represents the annual hydrogen output of a facility and is needed for determining the LCOH because forms the denominator of the LCOH calculation, allowing the total discounted costs to be normalised per unit of hydrogen generated over a plant's operational lifetime.

b) Input-Output Model (I-O)

Using an input–output model, we assessed the potential impact on various sectors of the Azerbaijani economy of an additional USD 2 billion in revenues generated by hydrogen exports. The simulation was based on the Leontief input–output model constructed using 2021 inter-industry balance tables for products and services comprising the Azerbaijani economy.

The inter-industry balance tables for products and services are compiled and officially published by the SSC once every 5 years. The most recent edition (based on 2021 statistical data) covers 96 sectors of economic activity, which were aggregated into 19 categories of economic activity according to recommendations concerning the methodology.

RESULTS AND DISCUSSION

Hydrogen Production in Azerbaijan

Azerbaijan's domestic demand for hydrogen remains relatively limited, being largely confined to industrial applications, with no current need for imports. Notably, both the urea and methanol plants rely on reforming natural gas to generate synthesis gas (a mix of hydrogen and carbon monoxide) for their operations. The figure below illustrates the annual hydrogen production capacity of each facility.

Current grey H2 production capacity in Azerbaijan is estimated at around 240 KTPA, mainly from industry (ammonia, methanol and oil refineries). The expected trend is that industry will remain the primary user by 2030 (based on the average timeline requirement of low-carbon projects) (AHS 2024).

Table 1: ANNUAL HYDROGEN CAPACITY OF AZERBAIJAN IN 2024

Company	Hydrogen Capacity, kTPA
SOCAR Carbamide Plant (Urea)	78
SOCAR Methanol	120
SOCAR Heydar Aliyev Oil Refinery	36
SOCAR Azerkimya	17

Source: AHS 2024.

Global hydrogen demand is presently estimated at around 90,000 KTPA, with forecasts projecting a significant rise of nearly 60% by 2030 and as much as a fivefold rise by 2050. Around one-quarter of this supply is expected to be traded internationally, with the additional demand mostly met through clean hydrogen sources. In this context, Azerbaijan's current levels of hydrogen production and consumption remain modest, accounting for less than 0.5% of global demand. This underscores both the limited scale of the domestic hydrogen sector thus far and the substantial opportunities for future growth should the country successfully leverage its renewable potential and strategic geographic position (AHS 2024).

Azerbaijan has substantial potential for solar and wind energy, making the production of green hydrogen a promising endeavour. The increasing interest in this sector shown by the Azerbaijani government and international energy companies could help diversify the country's energy strategy. Among Azerbaijan's strategic energy objectives is ensuring future domestic demand via clean hydrogen and establishing a green energy corridor between Europe and Asia. The mentioned focus will likely prioritise the production of low-carbon fuels and expand market share in sectors like transportation fuel and the chemical industry. Further, Azerbaijan's geostrategic location and transport infrastructure, including the Baku–Tbilisi–Kars railway, create valuable opportunities for exporting green hydrogen.

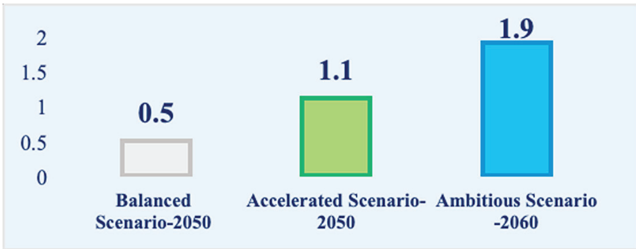
In the past 2 years, Azerbaijan has made significant progress in its renewable energy initiatives through international partnerships. Major developments include the commissioning of the 230 MW Garadagh Solar Plant by Masdar in 2023, as well as plans for an additional 1 GW from wind and solar projects. Future phases aim to expand this capacity to up to 4 GW, also encompassing offshore wind and green hydrogen projects. At the same time, ACWA Power completed the construction of the 240 MW Khizi-Absheron wind farm, which has been in operation since January 2026. In total, contracts and agreements for approximately 10 GW of clean energy capacity have been signed with companies from the UAE, Saudi Arabia, Europe, China, and others (Nuriyev and McFerren 2025).

Azerbaijan holds the potential to produce green hydrogen via electrolysis. Yet, Azerbaijan's substantial natural gas reserves also provide a foundation for the production of blue hydrogen by way of carbon capture and storage (CCS), capitalising on its existing energy infrastructure to meet growing international demand. Pursuing this dual approach would not only strengthen Azerbaijan's long-term decarbonisation efforts and contribute to it achieving its Nationally Determined Contribution (NDC) commitments, but also enable a sustainable export market to be established. In particular, Europe and Asia – regions where demand for clean energy is growing rapidly – offer useful opportunities for Azerbaijan to consolidate its role as a reliable and forward-looking energy partner (AHS 2024).

Azerbaijan 2030: National Priorities for Socio-Economic Development sets out a long-term vision for green growth, identifying clean hydrogen as a critical pillar of the country's green energy transition. Building on this framework, the *Socio-Economic Development Strategy for 2022–2026* further accentuates the role of hydrogen by supporting pilot projects and analysing their possible applications in energy storage and carbon capture. Together, these policy documents provide a coherent roadmap that positions hydrogen not simply as a tool for decarbonisation, but also as a driver of technological innovation and sustainable economic transformation.

In this scenario, annual green hydrogen production is expected to reach 0.5 MTPA per annum by 2050, with 0.39 MTPA being allocated to exports.

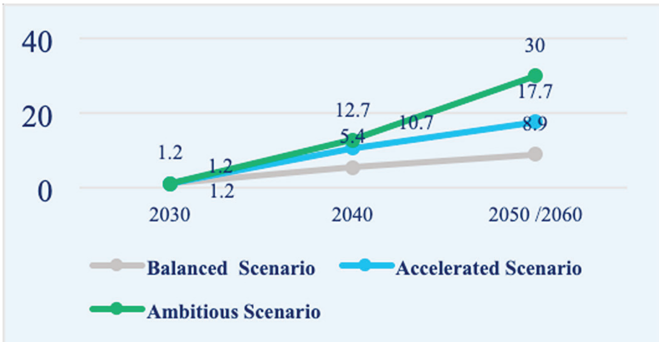
Figure 1: FORECAST FOR GREEN H2 PRODUCTION IN AZERBAIJAN, MTPA



Source: AHS 2024.

Figure 1 shows that in the Accelerated Scenario Azerbaijan's green hydrogen production is expected to rise to 1.1 MTPA by 2050. The Ambitious Scenario extends to 2060 and depends on utilising the country's potential of 30 gigawatts (GW) of offshore wind energy. The Accelerated Scenario also projects green hydrogen exports will reach 1.7 million tonnes per annum (MTPA) by 2060, effectively doubling the figure anticipated for 2050. For this development to occur, it is necessary to increase international demand and establish a favourable regulatory environment.

Figure 2: ELECTRICITY DEMAND FORECAST FOR GREEN H2 PRODUCTION IN AZERBAIJAN, GW



Source: AHS 2024.

Azerbaijan's hydrogen production and consumption currently represent less than 0.5% of global demand. We developed three scenarios for future green hydrogen and derivative demand to understand the domestic potential market for clean hydrogen based on the end users identified in section 4 and the potential for green hydrogen exports. These scenarios consider the country's need to balance hydrogen's internal benefits for decarbonisation against its export value. This challenge mirrors the country's approach to natural gas and the creation of green energy corridors, which at present are focussed on renewable electricity. The Accelerated Scenario relies on the accelerated rollout of renewables and substantial growth in international demand for clean hydrogen. The Ambitious Scenario carries projections through to 2060 and would utilise a bigger share of Azerbaijan's offshore technical capacity.

In all scenarios, the main assumption is that Azerbaijan's hydrogen and electricity markets will evolve like natural gas has, with long-term offtake contracts. During this critical period of evolution, there is a noticeable absence of strategic reserves of hydrogen. This means the market is likely to remain balanced, with supply and demand closely aligned.

The scenarios focus on green hydrogen production and, while blue and potentially turquoise could significantly raise production, there are too many uncertainties to include them in the scenarios. If blue is possible, it is expected that it would meet most of the country's domestic demand. Moreover, discovering and exploiting natural hydrogen would lead to a higher volume of exports. Still, it is not included in these scenarios since this is still at a very early stage.

The scenarios are expected to become more feasible once a clean hydrogen pipeline/corridor infrastructure is constructed, broadening export options away from just using shipping/rail via the Black Sea (AHS 2024).

Investment in H2 Production and the Cost

Several international energy companies, including Masdar, ACWA Power, China Energy and BP have actively invested in Azerbaijan's green energy sector. At present, these companies are participating in the construction of large-scale wind and solar power plants.

In 2024, Masmar initiated investment projects with a total value of some USD 1 billion, including the development of two solar power plants and one wind power facility with a combined planned capacity of 100,000 MW. The strategic roadmap envisages the construction of eight integrated solar–wind power plants with a total capacity of around 2 GWh. Supported by both foreign and domestic investors, these projects are scheduled to be implemented in Azerbaijan by 2027, reflecting the country's commitment to advancing large-scale industrial renewable energy infrastructure.

Simultaneously, the State Oil Company of Azerbaijan (SOCAR) has further committed to RES by establishing SOCAR Green LLC.

SOCAR Green is implementing a 240-megawatt solar power project, with Masdar as a partner in the initial stage. In addition, cooperation with ACWA Power, Masdar, and China Energy is envisaged for renewable energy projects in the Nakhchivan Autonomous Republic. SOCAR Green has also started to research the potential held by green hydrogen production in Azerbaijan.

Masdar is actively engaged in hydrogen-related projects, while the Chinese company Gezhouba Group Overseas Investment has also expressed interest in exploring the potential of investing in green hydrogen production projects in the country.

The LCOH for Azerbaijan's green and blue hydrogen production is anticipated to be competitive with the average cost of green hydrogen produced in Europe. The LCOH is expected to decline as the hydrogen plants are scaled up, yet the degree of reduction will vary depending on the plant, project and application involved. Importantly, current LCOH estimates exclude transportation costs, a consideration equally applicable to the average European figures, which will require some form of internal transport costs. CESL is currently evaluating the transport options the outcomes of which are expected to determine the most economically viable route for the placement of green energy corridors (AHS 2024).

The cost of green hydrogen production continues to be a major challenge. According to an IRENA (2024) report, the production cost of green hydrogen today ranges from USD 5 to USD 6 per kilogram, which is significantly higher than that for grey hydrogen, priced at approximately USD 1.5 per kilogram. In any case, numerous reports predict the cost of green hydrogen will fall in the near future, which in turn is expected to drive an increase in demand (Hydrogen Council 2023; IRENA 2024; IEA 2024b).

Table 2: PROJECTED GREEN HYDROGEN COST REDUCTIONS (2024–2030)

Year	IEA projection (USD/kg)	IRENA projection (USD/kg)	Hydrogen Council projection (USD/kg)	Global hydrogen production (million tonnes)	Global hydrogen demand (million tonnes)
2024	5.00	5.50	4.50	90	120
2025	4.80	5.30	4.30	95	125
2026	4.60	5.00	4.10	100	130
2027	4.40	4.80	3.90	105	135
2028	4.20	4.60	3.70	110	140
2029	4.00	4.40	3.50	115	145
2030	3.00	3.00	3.00	120	150

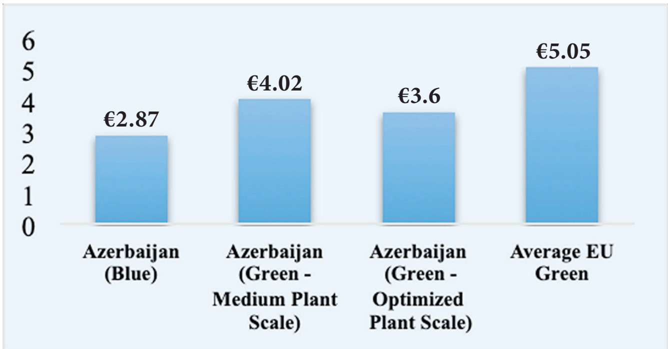
Sources: Hydrogen Council, 2023; IRENA, 2024; IEA, 2024b; Yin, 2025.

As shown in Table 2, a reduction of USD 3 a kilogram in the cost of green hydrogen would substantially add to the country's competitiveness, thereby stimulating greater demand.

Green hydrogen produced in Azerbaijan is anticipated to be more cost-competitive than that generated in many European countries, particularly if cost-efficient transportation options such as the repurposing of existing natural gas pipelines are implemented. Given the challenges of intermittency with renewable energy, an optimised mix of wind and solar resources that maximises the load factor could yield a LCOH of approximately 2.92 €/kg. The mentioned cost is projected to decline further over time as technological efficiencies improve and economies of scale are realised (Advisian 2023).

By assessing Azerbaijan's renewable resource potential and incorporating international gas price forecasts, we estimated the projected cost of hydrogen production for projects expected to commence in the early 2030s. If carbon capture and storage (CCS) technologies prove technically and economically viable, blue hydrogen is likely to be the lowest-cost production pathway. At the same time, Azerbaijan has the capacity to generate green hydrogen at a cost competitive with European benchmarks, establishing favourable conditions for export. Further, the deployment of Chinese-manufactured electrolysers could significantly lower the cost of producing green hydrogen, in turn enhancing the country's export competitiveness (AHS 2024).

Figure 3: ESTIMATED LCOH OF BLUE AND GREEN HYDROGEN IN AZERBAIJAN AND THE EU IN 2024, EUR/KG



Source: AHS, 2024.

Transporting hydrogen from Azerbaijan to the EU would add to the cost of the hydrogen and probably require a new pipeline, increasing costs by €0.8/kg.

Our estimates indicate that if green hydrogen production is launched in Azerbaijan in 2026 the projected cost per kilogram in USD would be as follows:

$$\mathrm{LCOH} = \frac{\$1400000 + \dfrac{\$350000 + \$140000}{(1+0.05)^{20}}}{\$500000} = \frac{\$1400000 + \dfrac{\$490000}{2.653297705}}{\$500000}$$

$$= \frac{\$1400000 + \$184675.8466}{\$500000} = \frac{\$1584675.847}{\$500000} = \$3.17$$

The result indicates that the average cost of hydrogen production will be around USD 3.17 per kilogram over a 20-year project horizon.

Undoubtedly, this calculation reflects the initial baseline, and one may anticipate the cost of green hydrogen production will fall in the coming years as technological advances take hold.

The European Union places considerable emphasis on the green transition (Banjac 2025; Tomazın 2025) and so its demand for green hydrogen is expected to be pivotal in shaping the development of hydrogen production in Azerbaijan given that Europe is likely to become the primary export market. Current studies indicate the green hydrogen market in Europe is still in an early stage of development. Nevertheless, establishing a hydrogen economy is seen as essential for meeting the EU's 2050 Net Zero objective, as well as the interim 2040 target (Lambert et al. 2024). In this context, the EU has set ambitious goals for 2030, including 10 million tonnes (Mt) of domestic production and an additional 10 Mt of imports from international partners (Hydrogen Europe 2024; EY and Hyvolution 2025).

Global demand for hydrogen is forecast to rise steadily over the coming decades, and to accelerate after 2030, notably from 2035 onwards. Estimates suggest that by 2050 hydrogen demand could range between 150 and 500 million metric tonnes annually, subject to the stringency of climate targets and the extent of sector-specific activities, energy-efficiency measures, direct electrification, and deployment of carbon-capture technologies (PwC 2025). Importantly, several industrial sectors – in particular those currently dependent on grey hydrogen – may be prepared to pay around or above €6/kg for green hydrogen by the end of the decade (Burchardt et al. 2023). Such price levels could make green hydrogen exports from Azerbaijan economically attractive.

Green hydrogen in Europe presently remains considerable more expensive than grey hydrogen. While its cost varies between €3 and €8/kg across regions (PwC 2025), estimates for 2025 suggest average costs in the range of USD 8–USD 10/kg. However, technological advances and market scaling are expected to drive substantial cost reductions. Some projections indicate that by 2027 companies may be able to supply green hydrogen at approximately \$3–\$3.5/kg, partly linked to pricing dynamics in the ammonia market (Eckert 2025). A critical question is therefore the extent to which Europe will be able to meet its green hydrogen demand domestically by 2050.

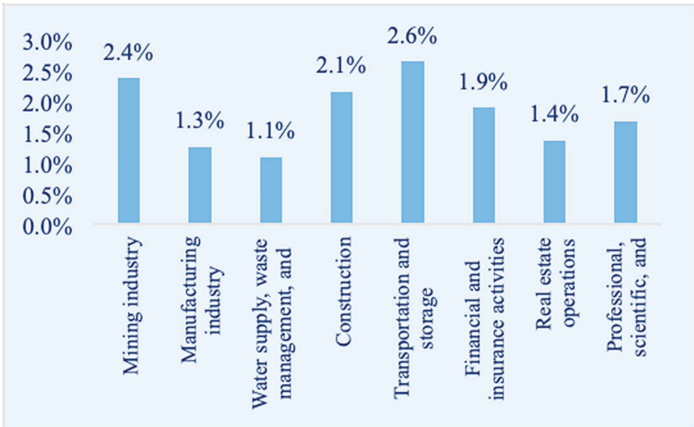
As an established energy exporter to Europe with oil and gas, and with emerging plans to export renewable electricity, Azerbaijan holds a strategic position allowing it to diversify into green hydrogen.

Result of the Input-Output Model

The applied shock pertains to the economic activity category encompassing the production, supply and distribution of electricity, gas and steam. The increase in exports in this sector assumes that export levels in other subsectors remain constant, with the observed growth attributed exclusively to hydrogen energy exports. This expansion in exports is modelled as a USD 2 billion rise in the final output of the respective economic activity under the assumption of *ceteris paribus* (other conditions remaining unchanged).

Thus, a USD 2 billion increase in hydrogen energy exports leads to 3.52% growth in GDP. At the same time, this expansion will generate significant growth in other sectors of the economy. Figure 4 displays the main increases by sectors of economic activity.

Figure 4: GDP GROWTH BY ECONOMIC ACTIVITY



Source: Authors' calculation.

PESTEL Analysis

Analysis of the scientific literature and reports by influential organisations indicates that green hydrogen is a transformative opportunity for decarbonising a wide range of sectors. Yet, major challenges such as the high production costs, limited infrastructure and insufficient market differentiation must be overcome to unlock its full potential. Against this backdrop, we conducted a PESTEL analysis of green hydrogen production in Azerbaijan (see the appendix).

The mentioned analysis reveals the importance of a comprehensive and integrated approach for Azerbaijan to be able to fully utilise its green hydrogen potential. Key factors for success include improving education and increasing public awareness, promoting technology transfer, and enhancing the legal and institutional framework. Considering these factors, a phased and systematic strategy for developing green hydrogen could contribute substantially to the country's sustainable development goals.

Discussion

While green hydrogen production and exports hold considerable potential, a range of technical, economic and social challenges must be addressed. In particular, the high production costs and deficiencies with the infrastructure require targeted interventions to fully release the potential of green hydrogen. Hydrogen production is becoming a promising focus of Azerbaijan's green energy policy. As part of its low-carbon development strategy up to 2050, the promotion of hydrogen production and the exploration of potential export opportunities are a priority. Here, the policy and technological trends of major global players, specifically the United States, the European Union (EU) and China, have a strong influence on Azerbaijan's hydrogen strategy.

Since Azerbaijan seeks to export green hydrogen primarily to European markets, the stance of Europe on green hydrogen has a decisive role in shaping Azerbaijan's export strategy. This situation could raise the initial investment and operational costs of green hydrogen projects in emerging markets like Azerbaijan, which may lower their economic appeal. The fact the United States is a global leader in hydrogen technologies, notably in the areas of electrolyser equipment, hydrogen transportation and storage systems, means Azerbaijan could encounter major technological and financial challenges in this sector.

The current situation plainly shows the relative passivity of the United States in green hydrogen policy, coupled with the European Union's rise to become the principal driving force in this market, which significantly influences the sector's development trajectory. The described situation could encourage Azerbaijan to adjust its hydrogen export strategy to focus more on the European market. Energy corridors connecting the Caspian region with Europe could create new opportunities for Azerbaijan's energy cooperation with European countries. This makes harmonising standards with Europe and accelerating logistics and infrastructure projects for hydrogen export critically important.

The ongoing changes in global energy policy, as well as the shifting positions of the main players, provide both challenges and fresh opportunities for Azerbaijan. The country's ability to craft a nimble, diversified and strategic approach, along with developing secure models for technological and financial cooperation, will be crucial for the sustainable development of its green hydrogen sector.

The scarcity of potable water resources in Azerbaijan is a major consideration while formulating a national strategy for large-scale hydrogen production. Green hydrogen generation needs substantial volumes of high-purity water; namely, approximately 9 kilograms of water per kilogram of hydrogen (excluding additional cooling requirements). While blue hydrogen production typically consumes comparatively less water, with an estimated 25% reduction depending on the cooling methods employed, water demand continues to be a considerable constraint and must be factored into project development.

As Azerbaijan expands its clean hydrogen market, it is essential that this expansion occur with a minimal impact on freshwater supplies. The siting of hydrogen production facilities should accordingly be guided by comprehensive environmental impact assessments (EIAs) and a rigorous evaluation of alternative water sources. Close attention must be paid to managing the by-products of these processes, including brine disposal and opportunities for water reuse through desalination technologies.

One should also consider the fact that Azerbaijan plans to produce green hydrogen exclusively from fully renewable sources. Thus, if the balanced scenario (0.5 MTPA) is implemented, Azerbaijan's contribution to the lowering of annual carbon emissions will amount to an additional 3.37 million tonnes of CO_2 provided that green hydrogen is substituted for natural gas.

As hydrogen production grows in Azerbaijan, the requirement for adequate storage infrastructure will become ever more critical. Despite persistent global challenges associated with its production, green hydrogen holds significant potential to assist with meeting global decarbonisation targets and fostering a sustainable energy future.

In conclusion, Azerbaijan is expected to develop green hydrogen production in the upcoming years, initially oriented to satisfying domestic energy needs. The scale of future production will largely be determined by global demand trends, particularly in the European market. Should European demand continue to rise, Azerbaijan could emerge as a green hydrogen exporter so long as the biggest infrastructure challenges are effectively addressed.

CONCLUSIONS

It is a positive development that Azerbaijan, irrespective of its abundant oil and gas resources, is directing attention to green hydrogen production and even exploring the prospect of becoming an exporter in the near future. By advancing green hydrogen production, the country can preserve its role as a major energy exporter even amidst a gradual decline in oil production.

The presented research shows that Azerbaijan possesses substantial potential for green hydrogen production and that in recent years various initiatives have explored the possibilities for harnessing this opportunity. Still, uncertainties surrounding the export routes for green hydrogen are at the moment hindering the timely implementation of certain projects in this sector.

The implementation of Azerbaijan's green hydrogen strategy is expected to bring the setting up of a hydrogen export corridor to the forefront of policy discussions in the coming years. In this context, together with the Caspian–Black Sea–Europe and Azerbaijan–Türkiye-Europe corridors which are currently envisaged for electricity exports, the creation of a dedicated corridor for green hydrogen exports will become ever more relevant. Moreover, the substantial progress made in opening the Zangezur corridor, referred to as the Trump Route for International Peace and Prosperity (TRIPP), makes it reasonable to suggest that the prospect of developing a green hydrogen corridor along this strategic route might be considered in upcoming discussions.

In addition, Azerbaijan is still in the early stages of its green hydrogen development journey. In order to establish this emerging industry and position it as a key exporter, the country must build on its existing strengths while simultaneously formulating and enacting supportive legislative and regulatory frameworks.

The development of green hydrogen and related derivatives may be seen as a strategic opportunity for Azerbaijan to diversify its economy and attract substantial foreign investment in clean energy technologies, thereby fostering innovation and long-term economic growth. A transition to a hydrogen-based energy system would also safeguard and further expand the highly skilled workforce cultivated within the oil and gas sector, assuring the continued utilisation of national expertise. Azerbaijan's geostrategic location also positions it as a pivotal hub for establishing a green energy corridor between East and West, facilitating energy flows across Europe and Asia while bolstering regional energy security. As the global market for clean hydrogen and associated derivatives expands, new trade routes will inevitably emerge, with shipping and pipeline networks anticipated to become the dominant modes of distribution.

Azerbaijan's green hydrogen policy is well grounded in detailed assessments, and includes strategic preparations prior to investment in this field. This level of readiness will enable the country to enter the green hydrogen market at a time that is both advantageous and in harmony with its long-term interests.

LIMITATIONS AND FUTURE RESEARCH

Since green hydrogen production is an emerging field, there is currently limited information and research available. This makes the presented study one of the pioneering efforts to investigate green hydrogen production specifically in Azerbaijan. It is thus essential to continue and expand upon the initial work presented here to deepen understanding and support the development of this promising sector.

In particular, the challenges related to storing green hydrogen and being able to export it to the European market require in-depth research. It is anticipated that scholars and practitioners will increasingly focus on this subject and in that way contribute to the effective implementation of Azerbaijan's green hydrogen strategy.

Ultimately, this study provides a foundation for future research aimed at advancing the utilisation of RES in Azerbaijan, while aligning with global efforts regarding the energy transition, decarbonisation and sustainability. By addressing current limitations and identifying untapped opportunities, the study helps to open up fresh pathways for the effective deployment and expansion of green energy in Azerbaijan.

DATA AVAILABILITY

Gasimli Vusal, Ramil Huseyn, Latif Zeynalli, Arzu Suleymanov. 2026. "Strategic transition from hydrocarbons to green hydrogen: long-term pathways for Azerbaijan's export diversification". *Social Science Data Archives*.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY

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APPENDIX

PESTEL Analysis of Azerbaijan's green hydrogen

Political	Economic	Social	Technological	Environmental	Legal
Robust governmental backing for the gas sector's expansion	Azerbaijan's hydrocarbon reliance makes green hydrogen diversification both necessary and strategically important	Public awareness of green hydrogen is limited, but investments in education can address this	Azerbaijan is beginning to develop green hydrogen infrastructure, requiring major investment in electrolysers, storage, and transport	Green hydrogen advances Azerbaijan's climate goals and emissions-reduction strategies	Specific legal frameworks and incentives for green hydrogen are lacking, although renewable energy laws are under revision
Strong ties with the UAE, Saudi Arabia, and the EU have boosted foreign investment in renewables, vital for green hydrogen	Major investments by Masdar and ACWA Power are laying the groundwork for green hydrogen infrastructure	Transitioning to green hydrogen can create jobs and support regional development	Collaboration with European institutions is key to adopting the best hydrogen technology practices	Azerbaijan has strong solar and wind resources, particularly in Garadagh and Absheron, ideal for green hydrogen production via electrolysis	Azerbaijan should align its green hydrogen production with global standards to be able to access international markets
Energy reforms are opening up the electricity market, which will boost private investment and support green hydrogen development	Azerbaijan's proximity to the EU gives it the economic potential to become a green hydrogen supplier to support Europe's decarbonisation efforts		Smart grids and energy management systems are vital for integrating green hydrogen efficiently	Electrolysis requires large quantities of water, which demands careful management to avoid environmental stress, especially in arid areas	As local expertise grows, providing legal safeguards for innovation in hydrogen technologies will grow in importance

Source: The authors.

STRATEŠKI PREHOD OD OGLJIKOVODIKOV K ZELENEMU VODIKU: DOLGOROČNE POTI ZA DIVERZIFIKACIJO IZVOZA AZERBAJDŽANA

Povzetek. *Zaradi naraščajočega svetovnega povpraševanja po čisti energiji postaja zeleni vodik ključni dejavnik razogljičenja in trajnostne gospodarske rasti. Študija obravnava proizvodni potencial in možnosti izvoza zelenega vodika v Azerbajdžanu. Analiza se osredotoča na oceno tehničnih zmogljivosti Azerbajdžana, stanja infrastrukture, institucionalnega in regulativnega okvira ter investicijskega okolja za razvoj proizvodnje zelenega vodika. Ugotovitve kažejo, da lahko Azerbajdžan z učinkovitim izkoriščanjem svojih obsežnih vetrnih in sončnih virov razvije pomembne zmogljivosti za proizvodnjo zelenega vodika z elektrolizo. Razvoj čistega vodika in s tem povezanih derivatov pomeni strateško pot za diverzifikacijo nacionalnega gospodarstva, privabljanje tujih naložb v čiste energetske tehnologije ter spodbujanje dolgoročne rasti, ki temelji na inovacijah. Geostrateški položaj države lahko dodatno krepi možnost, da postane pomembno vozlišče v zelenem energetskem koridorju med Vzhodom in Zahodom, ki vzpostavlja energetske tokove med Evropo in Azijo ter prispeva h krepitvi regionalne energetske varnosti.*

Ključni pojmi: *vodikova energija, izvoznik zelene energije, energetska varnost, podnebno nevtralni energetski sistemi, vetrna energija.*