MINISTRY OF ENERGY OF THE REPUBLIC OF AZERBAIJAN

Azerbaijan National Hydrogen Strategic Outlook

November 2024

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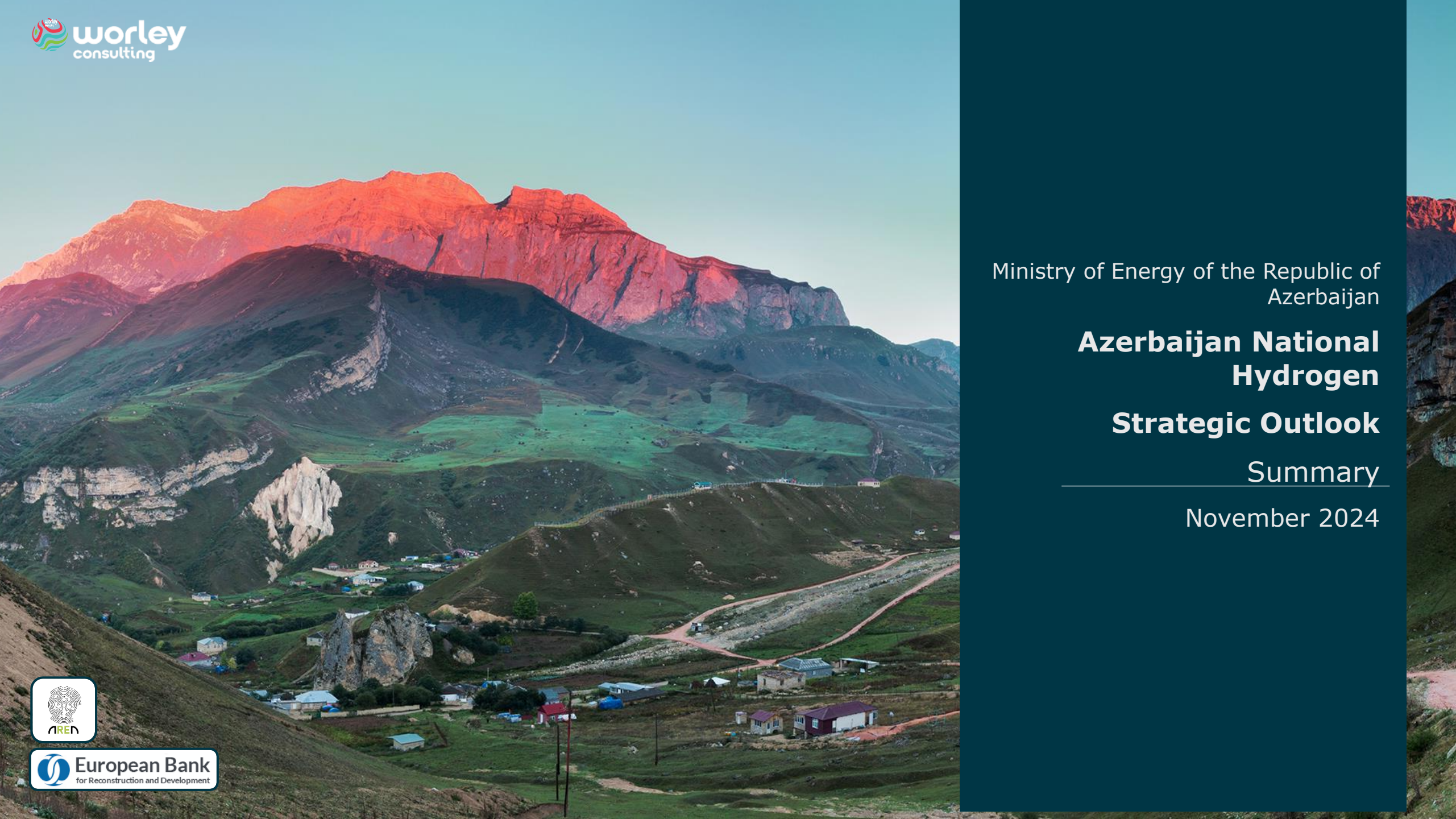
Acronyms

Acronym	Explanation
U.S.A.	United States of America
E.U.	European Union
H_2	Hydrogen references
CAES	Compressed Air Energy Storage
CBAM	(E.U.) Carbon Border Adjustment Mechanism
CECECO	Clean Energy Centre for the ECO region
CfD	Contract for Difference
CO_2	Carbon Dioxide References
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Utilization and Storage
CNG	Compressed Natural Gas
DRI	Direct Reduced Iron
EEF	Energy Efficiency Fund
EIA	Environmental Impact Assessment
ETS	Emissions Trading Scheme
FFI	Fortescue Future Industries
HFO	Heavy Fuel Oil
HHV	Higher Heating Value
IATA	International Air Transport Association
IMO	International Maritime Agency
LHV	Lower Heating Value
LOHC	Liquid Organic Hydrogen Carrier
MGO	Marine Gas Oil
NDC	Nationally Defined Contribution (at time of writing NDC 3.0 in progress)
PPA	Power Purchase Agreement
RES	Renewable Energy Sources
RED II	(E.U.) Renewable Energy Directive II
RFNBO	(E.U.) Renewable Fuel of Non Biological Origin
SAF	Sustainable Aviation Fuel
SGC	Southern Gas Corridor
TRL	Technology Readiness Level
UDB	(E.U.) Union Database

Units

Unit	Explanation
bcma	Billion cubic metres per annum
TPH	Tonnes per hour
TPD	Tonnes per day
TPA	Tonnes per annum
KTPA	**Kilo tonnes per annum (preferred H_2 unit)**
MTPA	Million tonnes per annum
Btu	British thermal units (natural gas)
m	Meter
m^2	Meters squared (area)
m^3	Meters cubed (volume)
Electrical Energy	
MW	Megawatts - Power capacity or demand
MWh/d	Megawatt hours per day - Power multiplied by 24 hours
Electrolyser Conversion	
0.43 TPD/MW	Average TPD of H_2 per MW of installed electrolyser capacity
Heating or Chemical Energy	
kJ/h	Kilo joules per hour for heat energy **(and state HHV or LHV)**
MJ/h	Mega joules per hour for heat energy **(and state HHV or LHV)**

Currency	
*All references in document will be in **Euros** and current year (unless otherwise stipulated)*	
€1,000 or - 2 significant figures €10,000 - 2 significant figures €100,000 or - 2 significant figures €1.1 million - 2 significant figures	In text use
(**Euros**) (Euros thousands) (Euros millions)	In tables and Graphs



Ministry of Energy of the Republic of Azerbaijan

Azerbaijan National Hydrogen Strategic Outlook

Summary

November 2024

Leveraging our abundant natural resources and strategic geographic position, Azerbaijan will become a leading exporter of low-carbon energy and improve regional energy security. Clean hydrogen will play a crucial role in establishing the Green Energy Corridor between East and West, supporting our decarbonisation efforts and helping to ensure a just transition, providing new economic opportunities and contributing to Global efforts in combating climate change.

Azerbaijan H_2 Strategic Outlook Working Group

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EBRD

European Bank of Reconstruction and Development

AREA

Azerbaijan Renewable Energy Agency

AZERBAIJAN H_2 STRATEGIC OUTLOOK WORKING GROUP

INSTITUTE OR ORGANIZATION
MINISTRY OF AGRICULTURE OF THE REPUBLIC OF AZERBAIJAN
MINISTRY OF DIGITAL DEVELOPMENT AND TRANSPORT
MINISTRY OF ECONOMY
MINISTRY OF ECOLOGY AND NATURAL RESOURCES
MINISTRY OF EMERGENCY SITUATIONS
MINISTRY OF SCIENCE AND EDUCATION
STATE OIL COMPANY OF THE REPUBLIC OF AZERBAIJAN (SOCAR)
STATE WATER RESOURCES AGENCY
AZERENERGY OJSC
BAKU INTERNATIONAL SEA TRADE PORT CLOSED JOINT STOCK COMPANY

INCLUDING ENGAGEMENT WITH:

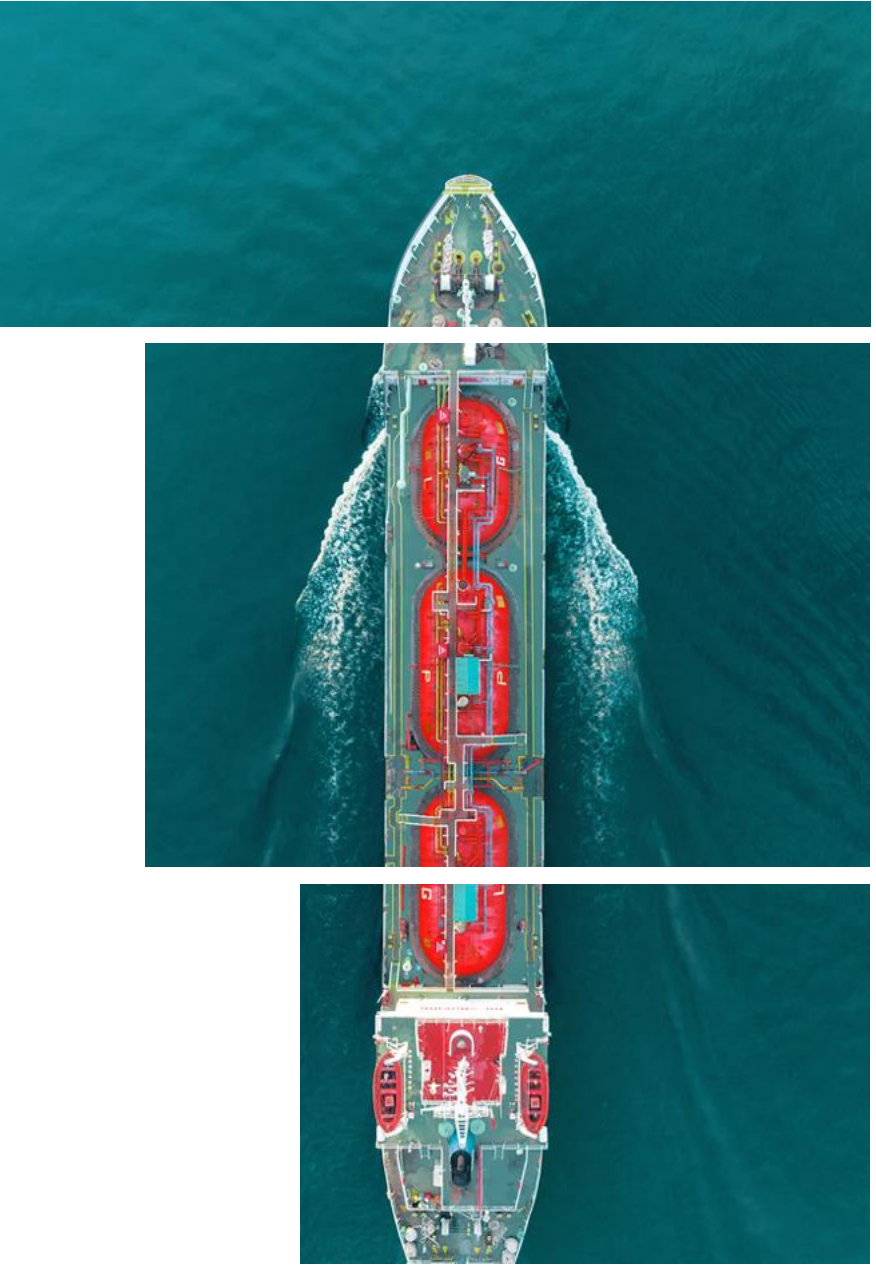
SOCAR — ACWA Power

ACWA Power

MASDAR

McKinsey & Company

CESI — CESI



Introduction

The Global Hydrogen Economy

Market Interest

Interest in hydrogen is still increasing as more countries push for net-zero emissions: hydrogen will increase energy security internationally, whilst enabling access to increasingly competitive low-carbon energy/products.

Creating Certainty

Giving certainty to the market at this time is essential. The MOUs signed, and the Hydrogen Strategy are the right first steps. Beyond this, Governmental support to the sector will maintain investor confidence and lower the cost of financing to develop projects, which is essential for the first projects.

Global Competition

There is great competition globally to establish a hydrogen economy, so moving early is likely necessary to establish a market position. At the same time, getting the growth rate is essential, as hydrogen production costs will continue to fall through the 2030s and 2040s.

Market Size

The size of the market is uncertain; however, an expanding hydrogen economy is expected. Estimations vary for the market from doubling from the 90Mt produced today to being five times larger by 2050. There are a number of reasons for that variation, including the ambition to decarbonise and other options to decarbonise, such as electrification.

180-500 Mt

Expected hydrogen market size by 2050 (range of estimates)

25%

Expected proportion of global hydrogen demand to be traded

Future Visions

Building Towards - 2030

Prioritise the expansion of renewable energy resources. Support smaller-scale hydrogen derivative projects with clear, established routes to market. Continue advancing plans for carbon storage in Azerbaijan and optimise the production of biogenic CO_2. Collaborate with international partners to further develop a green corridor through Azerbaijan, facilitating hydrogen exports. Establish a robust framework for targets and mandates to promote the adoption of clean hydrogen. Develop supportive policies and proactively improve legislation to support the economic viability and growth of the clean hydrogen economy. Engage with developers and international organisations to ensure best practices are implemented, making clean hydrogen a reality in Azerbaijan.

Delivering Towards - 2050

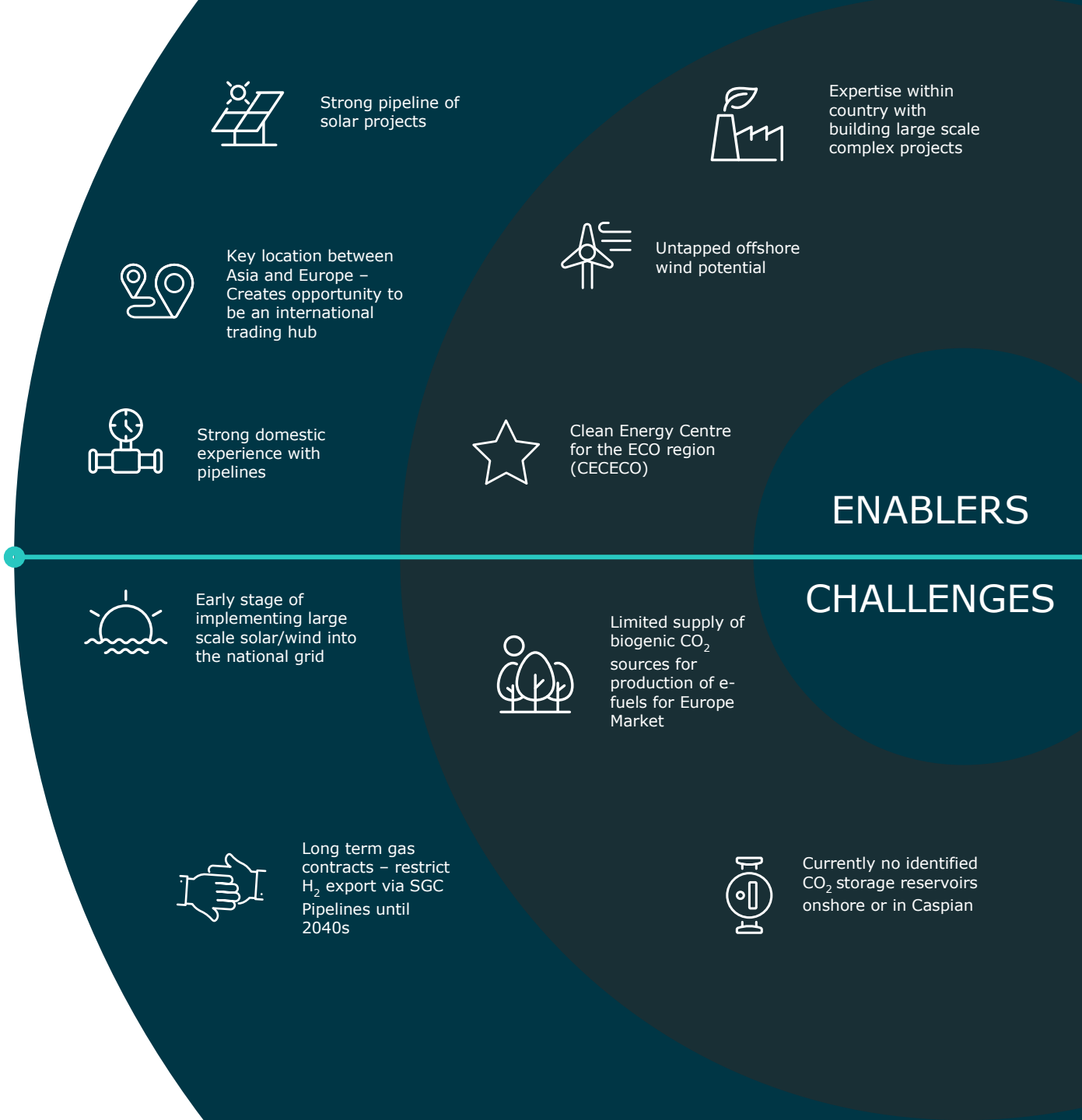
Position as a leader in the global hydrogen economy by leveraging our renewable resources and utilising CCUS technology. Azerbaijan aims to meet future domestic demand with clean hydrogen and establish a green energy corridor to enable international trade between Europe and Asia. Prioritise the production of low-carbon fuels and products, focusing on capturing market share in sectors such as transport fuels and chemicals. Support a just transition for our nation by providing the necessary training and resources to support workforce adaptation, while investing in R&D in the clean hydrogen industry to develop domestic parts of the supply chain.

Enablers and Challenges

For Azerbaijan to have a practical approach to establishing a clean hydrogen economy, we must be aware of our **enablers** and **challenges**.

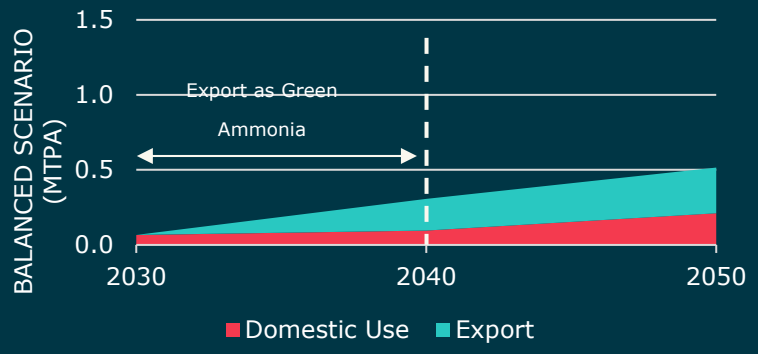
Key Enabling Actions:

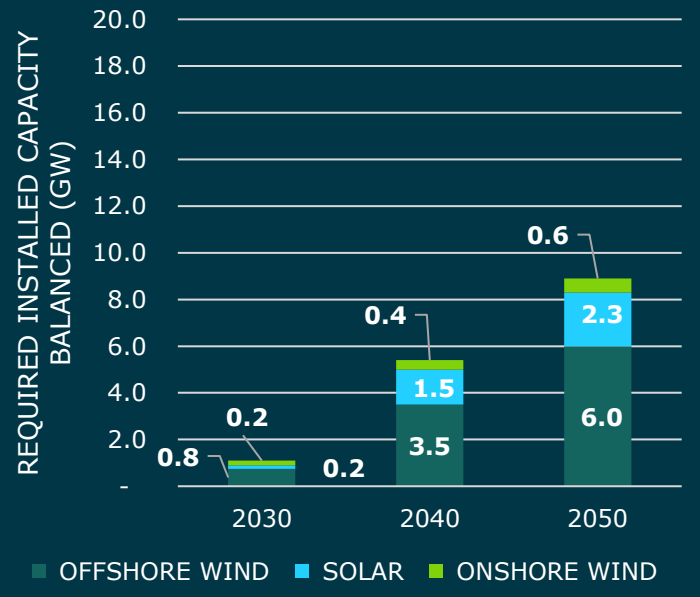
1. **Assess opportunities for the export of clean energy to establish a green corridor to enable direct access to the European market.**
2. **Collaborate with partner countries and international investors to build the clean hydrogen business case within Azerbaijan**
3. **Initiate and scale up the offshore wind industry and generation capacity.**
4. **Fund and explore CO_2 storage options either in Azerbaijan or in surrounding nations**



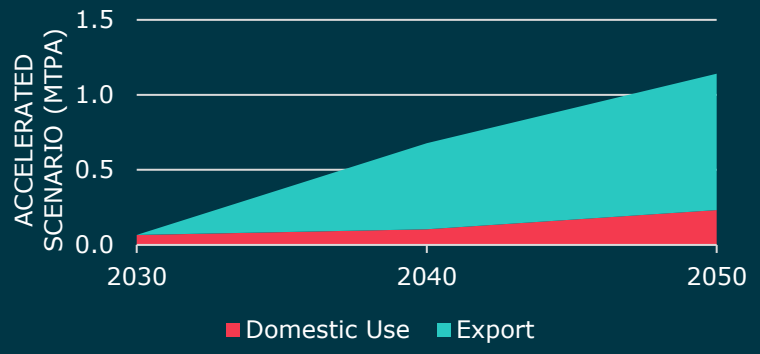
Green H_2 Production Ambition

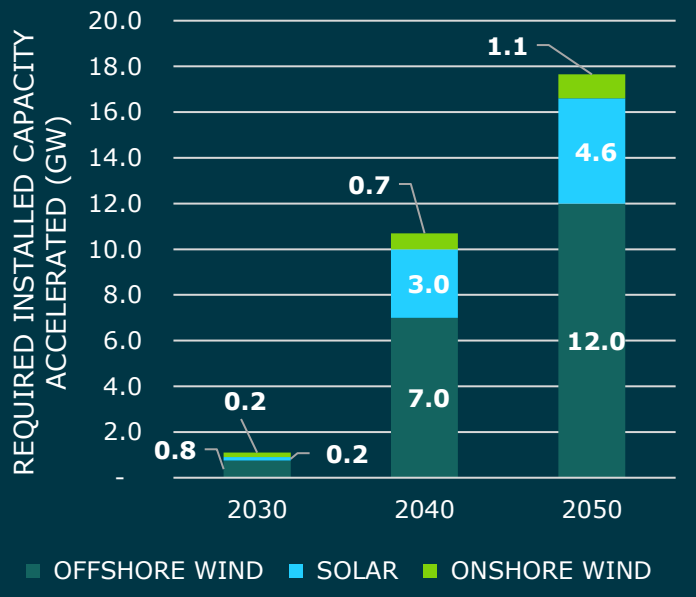
BALANCED SCENARIO





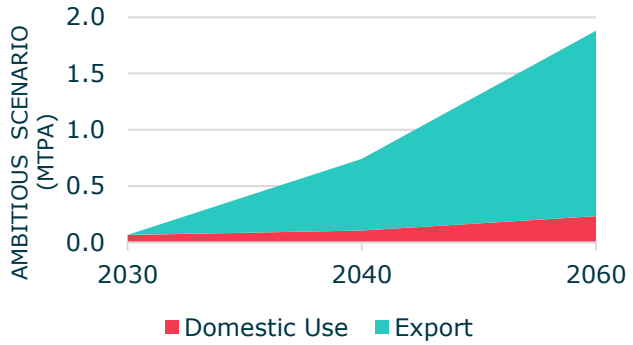
ACCELERATED SCENARIO

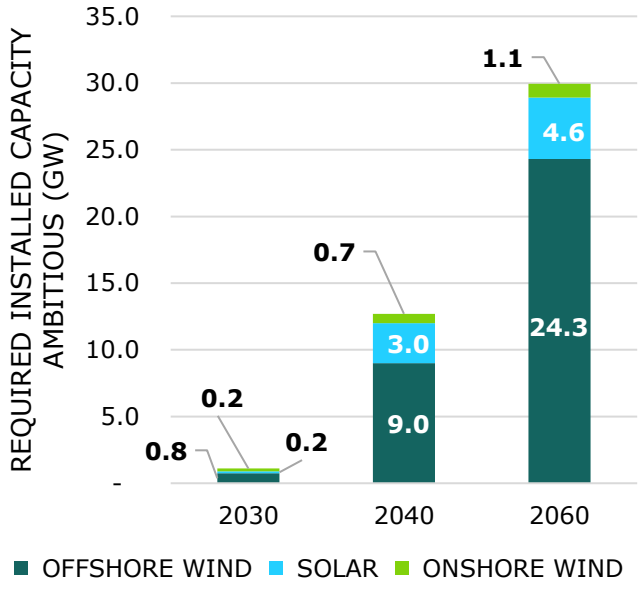




AMBITIOUS SCENARIO

2060 TARGET – High offshore wind





Green H_2 Production Ambition

Transport

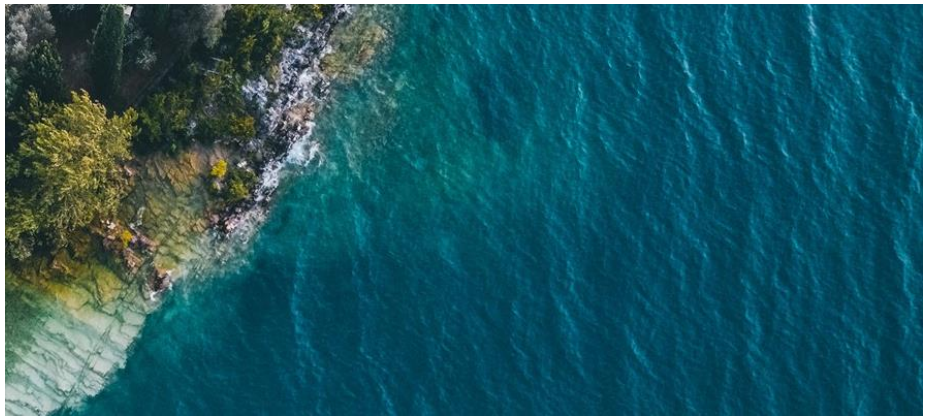
In the short-term transport demand can be grown to establish demand and confidence (predominantly aviation fuel). This will enable a longer-term confidence to switch to sustainable aviation and maritime fuel production, and consumption is critical with global pressure.

Industry

Current grey H_2 production capacity within Azerbaijan is estimated to be 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).

Export

Expected to become more feasible when clean hydrogen pipeline/ corridor infrastructure is constructed. Broadening export options away from using only shipping / rail via the Black Sea.



Water Demand

Depending on which scenario eventuates, there will be varying demand for water. Below peak demand numbers are shown based on a ratio of 11 kg H_2O / kg H_2 ratio.

BALANCED SCENARIO

Water Demand 2050

~17,000 m^3/day

ACCELERATED SCENARIO

Water Demand 2050

~40,000 m^3/day

AMBITIOUS SCENARIO

Water Demand 2060

~80,000 m^3/day

Azerbaijan - Levelised Cost of H_2 Production

The levelized cost of Azerbaijan's green and blue hydrogen production could be competitive with the average cost of European produced green hydrogen.

With an increase in scale of green hydrogen plants the LCOH is reduced – this will vary by plant, project and application.

LCOH values do not include transportation costs – this is also applicable for the average EU values (which will require some form of internal transport). Transportation options are currently being assessed by CESI and the results of which will indicate the most economic green corridor route.

Benefits of H_2 Economy

Azerbaijan has a lot to gain from growing H_2 economy. By focusing on low-carbon fuels and gaining social acceptance the hydrogen economy in Azerbaijan can grow.

Economic Benefit

The clean hydrogen economy is expected to at least double, with some experts predicting it will increase almost 500%. Much of the hydrogen is expected to be traded internationally, with the EU being a major importer. Azerbaijan will need to ensure that we are attractive to investors in developing hydrogen and that a more significant share of the value chain is captured to maximise the benefits of this opportunity.

Decarbonisation

Clean hydrogen will play a vital role in helping Azerbaijan hit our net-zero commitments. In particular, hydrogen will play a role in hard-to-abate sectors like industry and transport (aviation/marine).

Energy Security

Clean hydrogen will facilitate greater demand for renewable energy reducing reliance on oil and gas.

Near Term Actions

Green Corridor Creation and Partnerships

Existing SGC natural gas pipelines not available for high volumes of blended H_2 in the short to medium term. We will grow collaboration with neighbouring countries to improve understanding of the transport options of clean energy and fund joint pipeline projects.

Use similar approaches to the planned **Caspian Black Sea Energy Corridor** and **Azerbaijan-Türkiye-Europe–Corridor.**

Reduce Grid Emissions in line with NDC

We will grow the share of installed renewable energy capacity from 20% (2023) at a rapid pace to achieve decarbonisation targets in parallel with developing a hydrogen economy.

Explore CO_2 Storage and Utilization Feasibility

Azerbaijan has the advantage of having large natural gas reserves. We will conduct comprehensive studies on CO_2 storage to enable blue hydrogen production feasibility.

Additionally, there is a growing market for CO_2 utilization technologies in fuel and chemical production. We will explore pathways and feasibility within Azerbaijan.

Develop Required Infrastructure and Policy

We will ensure techno-economic studies are executed into the future infrastructure requirements specifically:

- Rail
- Ports
- Water Desalination and Brine Management

E-fuels for transport use we will ensure sectors are planned for in a way that is compatible with both the domestic needs and the future potential of clean hydrogen

Research and Development

We will support Clean Energy Centre for the ECO region (CECECO) and fund R&D in the hydrogen and CCUS Industries.

2. Future Visions - 2030 and 2050

Leveraging its abundant natural resources and strategic geographic position, Azerbaijan will become a leading exporter of low-carbon energy and improve regional energy security. Clean hydrogen will play a crucial role in establishing the Green Energy Corridor between East and West, supporting our decarbonisation efforts and helping to ensure a just transition, providing new economic opportunities and contributing to global efforts in combating climate change.

Building - Towards 2030

Prioritise the expansion of renewable energy resources. Support smaller-scale hydrogen derivative projects with clear, established routes to market. Continue advancing plans for carbon storage in Azerbaijan and optimise the production of biogenic CO_2. Collaborate with international partners to further develop a green corridor through Azerbaijan, facilitating hydrogen exports. Establish a robust framework for targets and mandates to promote the adoption of clean hydrogen. Develop supportive policies and proactively improve legislation to support the economic viability and growth of the clean hydrogen economy. Engage with developers and international organisations to ensure best practices are implemented, making clean hydrogen a reality in Azerbaijan.

Delivering - Towards 2050

Position as a leader in the global hydrogen economy by leveraging our renewable resources and utilising CCUS technology. Azerbaijan aims to meet future domestic demand with clean hydrogen and establish a green energy corridor to enable international trade between Europe and Asia. Prioritise the production of low-carbon fuels and products, focusing on capturing market share in sectors such as transport fuels and chemicals. Support a just transition for our nation by providing the necessary training and resources to support workforce adaptation, while investing in R&D in the clean hydrogen industry to develop domestic parts of the supply chain.

Azerbaijan is currently at the beginning of its clean hydrogen journey. To establish a new industry and become a key exporter, we will need to build on our strengths and develop new supportive legislation:

- Azerbaijan's strategic location as a gateway from East to West is a significant advantage, enhancing the feasibility of green exports. The Green Energy Corridor framework, signed by Azerbaijan, Georgia, Romania, and Hungary, is the first step in unlocking this potential (as well as the Azerbaijan-Central Asia-EU and Azerbaijan-Turkiye-EU corridors).
- A significant quantity of untapped renewable capability and capacity, combined with our experience with large-scale hydropower generation, will enable consistent renewable power generation, enhancing the competitiveness of green hydrogen.

- Azerbaijan's large underground resource network provides a low-cost source of natural gas for blue hydrogen, while depleted gas fields can facilitate the CO_2 storage required.
- An established work force which is highly experienced in the natural gas industry, and which will be essential in developing the hydrogen sector. Azerbaijan is also highly experienced in supporting the infrastructure required for hydrogen, such as pipelines, ports, and export facilities (including aviation and marine bunker fuel supply).
- Azerbaijan will develop supportive policies and proactively improve legislation to support the economic viability and growth of the clean hydrogen and derivatives economy, including:
    - Enabling access to the necessary land infrastructure and utilities
    - Protecting our water resources and ensuring the clean hydrogen industry has minimal impact on freshwater supply
    - Setting up a clear governance structure that simplifies decision-making for hydrogen projects, encourages investments, and includes regular strategy monitoring
    - Prioritising legislative and regulatory framework reviews that focus on reducing potential barriers and administrative burdens, providing both sufficient certainty and flexibility to investors and project developers
    - Enabling meeting NDC, ensuring that the developing hydrogen economy does not hinder the ability to meet targets
- Azerbaijan will assess a mix of financing mechanisms to de-risk and improve the profitability of clean hydrogen and stimulate its market uptake in the country.
- Build on an existing track record of attracting overseas investment in renewables and use hydrogen diplomacy to secure international assistance for launching clean hydrogen projects and accelerating hydrogen technology deployment.
- Work with future markets/purchases to ensure that the hydrogen produced complies with their low-carbon standards.
- Continue to promote R&D in the clean hydrogen industry in country. As a ECO region Member State and host country for Clean Energy Center, we will continue to promote clean energy initiatives, enhance regional cooperation, and support sustainable energy projects among ECO member countries. CECECO serves as a hub for knowledge-sharing, capacity-building, and fostering investments in renewable energy and clean technologies across the ECO region, and we are committed to advancing these goals.

3. Clean Hydrogen

3.1 Strategic Role of Hydrogen

Azerbaijan is committed to reducing its greenhouse gas emissions. The country intends to increase the percentage of installed renewable power generation capacity to 30% (of total installed capacity) by 2030 and diversify the existing energy system to become a leader in green energy. The production of low-carbon hydrogen and completion of ongoing solar and wind projects will play a vital role in achieving these aims.

Clean hydrogen will play a complementary and enabling role in the global energy transition. Future production is expected to substantially increase as the world looks to decarbonise and improve energy security. Serving as a versatile energy carrier, clean hydrogen not only helps to lower greenhouse gas emissions but also supports the transition to a sustainable energy future.

The expansion rate of the industry is uncertain. In some sectors, hydrogen or a derivative is essential to enable decarbonisation, while in others there are alternative, more cost-effective solutions, such as electrification. There is a large range of estimates for future hydrogen demand. However, while the estimates may vary, the use of clean hydrogen as a means to achieve the 1.5ºC Paris Agreement climate goal is undisputed. The initial demand for clean hydrogen is expected to be located in the USA, Europe, South Korea and Japan, with the most significant import market being Europe.

Global Hydrogen demand is shown in the below figure.

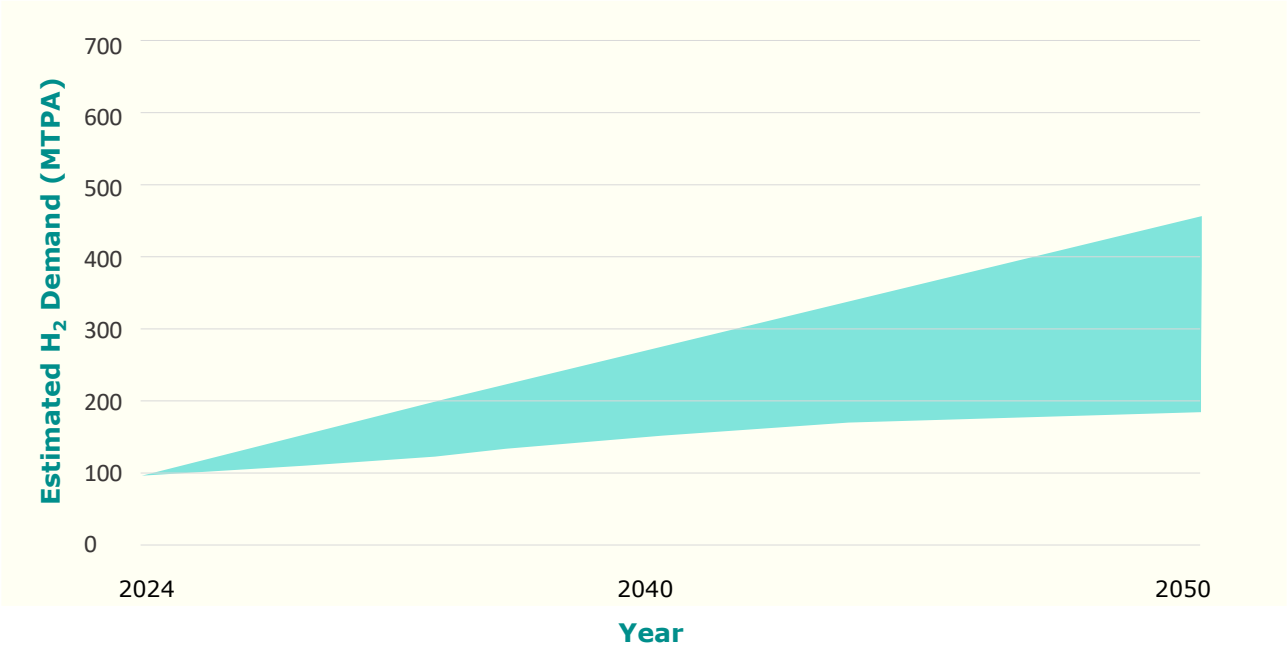
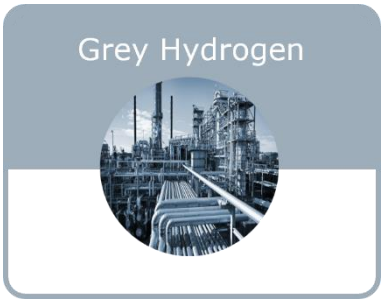


Figure 3-1: Global range of estimates for future H_2 demand

(Source – McKinsey& Company)

Hydrogen can be produced using a range of different feedstocks and is referred to as different colours. For the context of this strategy, the following hydrogen colours will be referenced:

Grey Hydrogen



Traditional method of producing hydrogen. Inclusion of upstream fugitive emissions could substantially increase the carbon intensity. Grey hydrogen is considered to be high carbon and therefore is only considered in the Hydrogen Strategy to be able to compare costs.

Blue Hydrogen

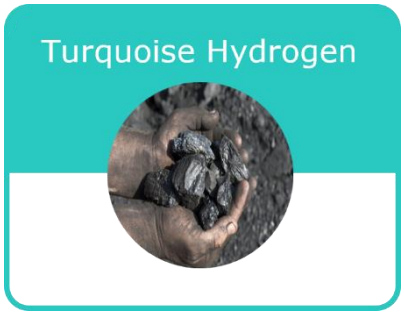
Based on the same processes as grey hydrogen, however, with the addition of CCS. Carbon capture could be retrofitted to an existing hydrogen production asset or incorporated into a new build. Reliant on CO_2 storage. Depending on the selected process, the carbon intensity is 0.8–4.4 kg CO_2/kg H_2; however, international standards increasingly include upstream emissions. Any focus on producing blue hydrogen in Azerbaijan will need to ensure that future clean hydrogen standards are met. The EU is still developing standards for blue hydrogen; the UK standard is for a carbon intensity of 2.4 kg CO_2/kg H_2.

Electrolytic (Green) Hydrogen

Using electrolysers for water splitting uses renewable power to split water into its constituents, hydrogen and oxygen. It requires substantial volumes of water. Produced via several technological pathways. R&D is progressing around all technologies, which will lower the costs whilst increasing performance.

Many regions are introducing constraints to the renewable power which can be used, in particular principle of additionality and temporal correlation. Azerbaijan will need to assess the requirements of potential export markets.

Turquoise Hydrogen



Turquoise hydrogen production requires electricity (a lower amount than green H2) and natural gas. It uses pyrolysis to convert natural gas into hydrogen and solid carbon. The carbon produced can have a market value and be sold; therefore, no permanent storage of CO2 is required. However, the technology is at an earlier stage of development, and the market for carbon black is uncertain. The potential of turquoise hydrogen needs to be ascertained. However, if CO2 stores are not accessible and renewable electricity and water supply are limited, it has merit in Azerbaijan.

Other forms of Hydrogen

White, Gold or Natural hydrogen - Relatively new commercial discovery. Refers to naturally occurring hydrogen found in underground reservoirs.

Pink hydrogen - Generated from nuclear power; in its simplest form, it uses the electricity from the nuclear power station to produce hydrogen via electrolysis using electricity. In the absence of nuclear power in Azerbaijan, this is not discussed further in the strategy.

3.2 Clean Hydrogen in Azerbaijan

Azerbaijan has an excellent opportunity to continue being a leader in the global energy market and transition to clean energy by adopting clean hydrogen. With abundant wind and solar resources, Azerbaijan can generate green hydrogen through electrolysis. Additionally, Azerbaijan could use its natural gas reserves to produce blue hydrogen with carbon capture and storage (CCS), building on its established energy infrastructure to meet market demands. This move would support long-term efforts to reduce carbon emissions to meet NDC goals and create a sustainable export market in Europe and Asia, where the demand for clean energy is growing.

Developing clean hydrogen and its derivatives would not only diversify Azerbaijan's economy but also attract significant foreign investment in clean energy technologies, driving innovation and economic growth. The clean hydrogen economy would also help protect and grow the highly skilled jobs developed in the oil and gas sector. Furthermore, Azerbaijan's strategic location proves vital in creating a green energy corridor between East and West, facilitating energy flows between Europe and Asia and enhancing regional energy security.

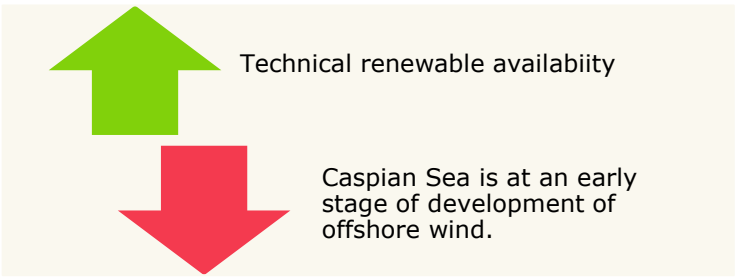
As the market for clean hydrogen and its derivatives expands, new global trade routes will be created, with shipping and pipeline distribution set to dominate.

3.3 Local Context

Azerbaijan has a number of key advantages when it comes to developing a hydrogen sector, both for local use and export. This is not without its challenges but as part of this strategy, these are being addressed.

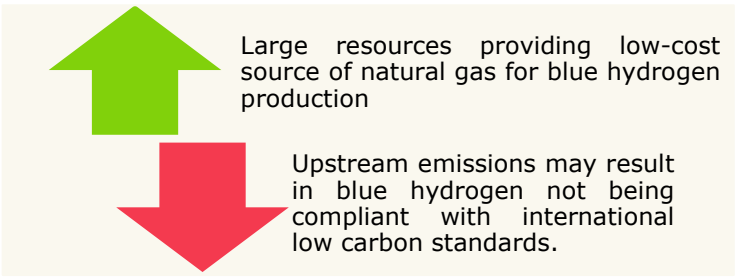
Natural Resources

Renewables



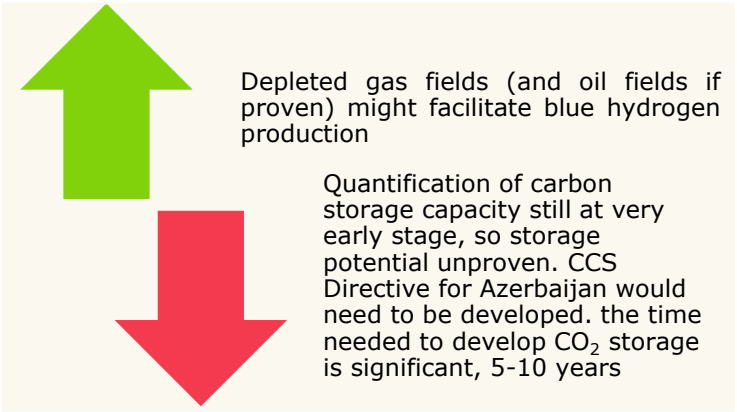
Next Steps: We have committed to raise the share of renewable energy in total generating capacity to 30% in 2030. Actualisation of these targets is critical; hydrogen could support wider rollout.

Gas Reserves



Next Steps: In line with our Global Methane Pledge we are committed to reduce methane emissions. Will develop and implement required emission monitoring.

CO2 Storage



Developments: Continue to support SOCAR in the rapid research into carbon storage for future blue production pathways, and wider emission reduction pathways.

Strategic Location

Stratgic location accessible to both European and Asian markets

Pipeline fees need to be understood with relevance to overall project profitability.

Next Steps: Collaboration with neighbouring countries for transportation of low-carbon energy. Green Energy Corridor framework signed by Azerbaijan, Georgia, Romania, and Hungary (as well as the Azerbaijan-Central Asia-EU and Azerbaijan-Turkiye-EU corridors).

Water

Fresh water source under active management

With water levels dropping in the Caspian, additonal desalination for hydrogen might be not viable.

Next Steps: Research into water options, including the potential use of Turquoise Hydrogen, which requires less water use and could still allow us to utilise natural gas resources.

Assets and Infrastructure

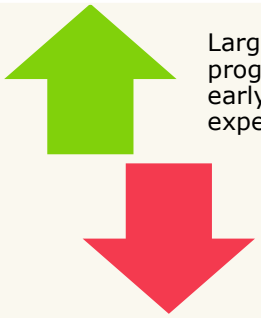
International Pipelines Experience

Azerbaijan has knowledge and experience of building and running a multinational **natural gas export pipeline**.

A new dedicated **hydrogen pipeline** would take substantial uplift.

Next Steps: Develop further collaboration with neighbouring countries that are also looking to export hydrogen and its derivatives to Europe. Collaboration required in order to make a future new hydrogen pipeline cost-effective.

Desalination

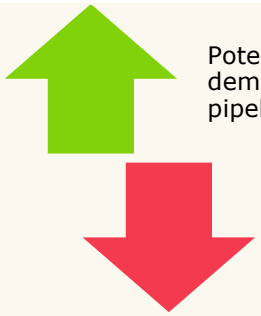


Large scale desalination project in progress with completion targeted for early in the next decade. Increase in experience and knowldege.

Current plans for project is domestic use and agriculture.

Next Steps: Water availability should be considered when developing hydrogen projects, and an environmental impact assessment carried out.

Existing domestic hydrogen demand

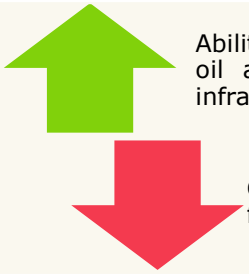


Potential to replace grey hydrogen demand in advance of new export pipeline.

Cost competiveness with grey hydrogen will be challenging.

Next Steps: Opportunities for demand in emerging growth sectors, predominantly domestic shipping and aviation. Develop suitable subsidies to promote uptake.

Experience and Knowledge



Ability to leverage current expertise in oil and gas sectors and large scale infrastructure.

Competition for skilled work force.

Next Steps: Prioritise creation of a skilled domestic workforce. Progress multiple educational programmes and complete a skills gap analysis to identify required profiles of workers and their subsequent education and training.

Financial - Overseas Investment

Proven track record in attracting investment in renewables and hydrogen. CBAM will enable a market for low carbon products to develop. Concessional fianace availabe

Investment has so far not shown a return.

Next Steps: Ensure clear communications between the government and the private sector. Develop a clean hydrogen focal point /department within the government to manage all items related to private investment and project finance. Continue to work with development banks such as EBRD to enable access to concessional finance

3.3.1 National Policy Context

Azerbaijan's energy sector is currently heavily reliant on fossil fuels, particularly natural gas, which dominates its domestic energy supply and export economy. The nation's energy infrastructure has been predominantly focused on oil and gas production, with limited diversification into other energy sources, apart from a small contribution from run-of-river hydro.

Azerbaijan's NDC sets out ambitious targets for emissions reduction, demonstrating the country's strong commitment to sustainability and environmental protection.

The transition to low-carbon is supported by several critical laws, strategies, and financial mechanisms that also support Azerbaijan's clean hydrogen development.

The **Law on Use of Renewable Energy Sources in the Generation of Electricity** encourages investment in low-carbon technologies, including hydrogen, through auctions and direct negotiations, offering guaranteed tariffs and grid priority incentives. This law supports hydrogen and integrates it as a crucial part of the broader renewable energy landscape.

The law on the **Rational Use of Energy Resources and Energy Efficiency** promotes energy efficiency across all sectors and supports the use of innovative, low-carbon technologies like hydrogen. This legislation provides financial incentives such as grants and subsidies, making hydrogen development feasible within the country's energy transition.

Strategically, the **Azerbaijan 2030: National Priorities for Socio-Economic Development** sets the vision for green growth, with clean hydrogen identified as a critical green energy technology. The **Socio-Economic Development Strategy for 2022-2026** expands on this by supporting hydrogen pilot projects and exploring its potential in energy storage and carbon capture.

Creating a **Green Energy Zone in the Liberated Territories** under the 2022-2026 Action Plan prioritises these regions' hydrogen and other low-carbon technologies.

In accordance with the **Tax Code of the Republic of Azerbaijan** and the **Law on Customs Tariffs**, tax breaks are available for the promotion of green technologies, including property tax, land tax, income or profit tax, VAT and custom duties.

3.4 International Context

3.4.1 Looking West

Through the REPowerEU Plan, the EU has set ambitious targets for renewable hydrogen, aiming to produce 10,000 KTPA within the EU by 2030 and import an additional 10,000 KTPA by the same year.

The definition of "renewable energy" is set under the First Delegated Act under the Renewable Energy Directive II (RED II), and any export to the EU will need to be "Renewable Fuels of Non-Biological Origin" (RFNBO) compliant and comply with the data requirements of the Carbon Border Adjustment Mechanism (CBAM) and Union Database (UDB). Renewable hydrogen is more strictly defined than green hydrogen and requires the hydrogen to be produced to be temporally correlated (matching production) to an additional (one that is less than three years old) renewable source.

Current Announced Export to the EU Nations

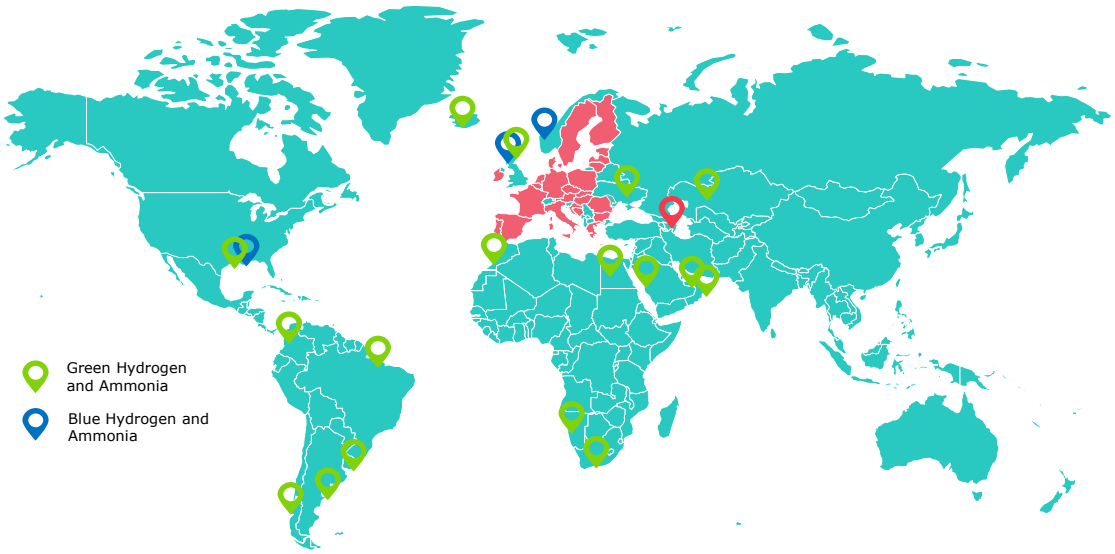


Figure 3-2: Regions Currently Targeting the EU for Export of Green and Blue Hydrogen and Ammonia

Source: Worley Consulting, 2024

3.4.2 Turning East

Europe is not alone in promoting the import of clean hydrogen. South Korea and Japan are openly courting the import of hydrogen through subsidy mechanisms. Closer to home, an increasing number of analysts are expecting China to be a significant importer of clean hydrogen in the short term, with Deloitte forecasting that China will be the world's largest hydrogen importer with 13,000 KTPA by 2030, dropping off to 10,500 KTPA by 2050. This is expected to be in the form of ammonia and, latterly, sustainable aviation fuel (SAF).

Currently, import regulations into these three countries, China, Japan and South Korea, are based on carbon content and therefore are not focussing on renewable hydrogen but are more willing to accept a broader range of clean hydrogen, which offers an opportunity to Azerbaijan. We will assess the requirement to develop a standard on Sustainable Clean Hydrogen, aligned with domestic needs while ensuring compliance with international standards.

4. Hydrogen Exploitation

4.1 End Users

Azerbaijan has a relatively small domestic hydrogen demand for industrial use, with no requirement for import. Note, both the urea and methanol plants utilise natural gas reforming to produce a syngas (hydrogen and carbon monoxide mixture). The figure below presents the annual hydrogen capacity for each facility:

Figure 4-1: Annual Hydrogen Capacity

Looking ahead, clean hydrogen has the potential to drive decarbonisation across many sectors of the economy, both by displacing existing demand and by enabling new applications.

4.1.1 Expected Use

While hydrogen has numerous potential applications, many still require thorough testing. In some cases, alternative decarbonisation solutions may be more cost-effective or socially or politically appealing.

For Azerbaijan, the applications most likely to adopt clean hydrogen in the short to medium term are listed at the top. In contrast, those requiring further technology development, subsidies, or significant market intervention are towards the bottom; with some of these applications expected to materialise after 2040.

Table 4-1: Azerbaijan Strategic Hydrogen Sectors

Sector Viability	High	Medium	Low

Application	#	Incumbent in Azerbaijan	Dependence on Hydrogen for decarbonisation	Economic Gap	Ready by 2030 / Remark
Ammonia/Urea	1	Grey ammonia produced from natural gas	High, alternative methods of production at low levels of maturity	Medium, O&G market dependant	
Methanol	2	Grey methanol produced from natural gas	High, although limited by the availability of biogenic CO_2	Medium, biogenic CO_2 would have to be acquired	
Oil refining	3	Grey Hydrogen	Medium, reliant on CCS for the majority of emissions savings	Medium, Oil & Gas market dependant	
Transport – Maritime	4	Fossil based transport fuels	High, although electrification may be possible on some routes	Medium, double the price of incumbent fuel	
Transport – Aviation	5	Jet Fuel	High, although electrification may be possible on some routes	Medium, 2 to 3 times the price of incumbent fuel	SAF will be available by 2030
Iron and Steel	6	n/a	Medium, CCS is an option and full electrification (although low TRL)	Medium, new major plant items required	Expected to be available around 2030
Heat – High Temp	7	Natural gas	Medium, technologies are more developed than electrification. CCS potential alternative	Higher cost than natural gas and electrification	Some applications will be available
Transport - HGV	8	Diesel	Medium, competitive with electrification at longer distances	Expected to be higher than diesel	
Mining Industry - Trucks	9	Diesel	Medium, competitive with electrification	Expected to be higher than diesel	

Application	#	Incumbent in Azerbaijan	Dependence on Hydrogen for decarbonisation	Economic Gap	Ready by 2030 / Remark
Power – Longer duration storage/ peaking	10	n/a	Alternatives such as compressed air energy storage and pumped storage	Uncertainty surrounding the cost of utilising geological storage	Beyond salt caverns, geological storage is still to be tested
Transport - Buses	11	Diesel	Low, likely higher costs compared to electrification	Expected to be higher than diesel/electrification	Busses are being electrified
Transport - Rail	12	Electricity	Medium, competitive with electrification at longer distances	Expected to be higher than diesel and potentially electrification	75% of rail is electrified or being converted in Azerbaijan so low opportunity for H2 application
Heat – Low Temp	13	Natural gas	Low, likely higher costs compared to electrification	Higher cost than natural gas and electrification	Safety trials currently postponed
Transport - Cars	14	Petrol/Diesel	Low, likely higher costs compared to electrification	Expected to be higher than diesel/electrification	

4.1.2 Short to Medium Term – 2024 - 2040

During this period, the focus on replacing current grey hydrogen but developing greenfield opportunities will dominate.

4.1.2.1 Replacement for Grey Hydrogen

Typically, replacing the existing hydrogen demand in Azerbaijan with clean hydrogen is the easiest route to market for clean hydrogen projects.

Ammonia/Urea Production

Urea, also known as carbamide, is produced by reacting ammonia (produced from breaking down natural gas to release hydrogen and then reacting nitrogen in the Haber-Bosch process) with carbon dioxide under high pressure and temperature. While it is possible to replace some or all of the hydrogen used with low-carbon hydrogen, an alternative source of CO_2 will need to be found. The type of CO_2 used will either limit the volume or the carbon intensity of the resulting urea, thereby limiting the market size for the urea. The impact of different sources of CO_2 is discussed in Section 4.2.4.1.

Another option would be to develop a new clean ammonia plant for local markets, such as shipping or export.

Conventional Methanol and e-Methanol

As with urea production, methanol requires a source of CO_2; therefore, there is limited potential for replacing the existing methanol plant with a clean hydrogen supply. Alternatively, Azerbaijan should look to produce e-methanol, which is produced via reacting CO_2 with hydrogen.

Demand for e-methanol is expected to grow, particularly from new sectors like shipping. However, the source of CO_2 may limit the export market, with the EU requiring biogenic CO_2 by 2040; where biogenic CO_2 is not a requirement, other sources of CO_2 can be used, such as from industry or natural gas processing.

Oil Refineries

Replacing grey hydrogen with a low-carbon alternative supports SOCAR's net zero (Scope 1 and 2) ambition. Green hydrogen is increasingly important for reducing emissions and meeting future fuel standards, as demonstrated by projects like REFHYNE in Germany. A challenge would be to find a market for this fuel, which will have a higher production cost.

4.1.2.2 New Hydrogen Demand

As the energy transition accelerates, new markets for clean hydrogen will develop where there are no decarbonization alternatives. This will present new opportunities for Azerbaijan such as:

Marine Shipping

In 2023, 70-80 KT of bunker fuel was used in Azerbaijan Ports. As a member state of the International Maritime Organisation (IMO), Azerbaijan contributes to global efforts in reducing greenhouse gas emissions from ships. The 2023 IMO Strategy on Reduction of GHG Emissions from Ships, the IMO revised strategy included:

- An ambition to reach net-zero GHG emissions from international shipping by or around 2050.
- An uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources to increase 2030 targeting by at least 5%, striving for 10% by 2030.

The ambition set out by the IMO allows Azerbaijan to target this market, initially replacing 5% of the bunker fuel with low-carbon alternatives such as methanol or ammonia.

Aviation

In 2023, 147 kilotons of aviation fuel were used in international flights in Azerbaijan. Azerbaijan, as a member of the International Civil Aviation Organization (ICAO), aims to achieve a 5% reduction in CO_2 emissions by 2030 compared to the use of zero cleaner energy. The use of Sustainable Aviation Fuel (SAF) will play a significant role in reaching this goal. Additionally, Azerbaijan is a member of the International Air Transport Association (IATA), and its national airline, AZAL, is an active member. IATA has committed to a net-zero emissions target for the aviation industry by 2050.

SAF can be produced through various methods, including biomass conversion, waste-to-fuel processes, power-to-liquid technologies (e-SAF), and advanced biofuel refining techniques. e-SAF is produced using clean hydrogen and CO_2. Similar arguments for e-methanol and urea can also be applied to biogenic and non-biogenic CO_2 as feedstock.

While e-SAF is currently one of the more expensive ways to produce SAF, forecasts indicate that global demand for SAF will be high enough to require all forms of SAF production. Therefore,

Azerbaijan could establish SAF mandates to promote investment in e-SAF production, particularly by encouraging e-SAF as a pathway to develop the industry.

Iron and Steel

In Azerbaijan, steel production currently relies on scrap metal and electric arc furnaces, with no primary steelmaking. However, there is potential for the country to develop primary steel production using a low-carbon method called the direct-reduced iron (DRI) process, which uses hydrogen as the reductant. The commercialisation of green steel production processes is expected to occur by 2030, with some pilot demonstrations already in operation. Additionally, there is ongoing exploration of using ammonia instead of hydrogen.

Transitioning to decarbonised primary steel production methods will offer significant competitive advantages as the global demand for low-carbon steel grows. The European Union's proposed Carbon Border Adjustment Mechanism (CBAM) will favour low-carbon steel imports into the EU.

Surface transport

Whilst most surface transport is electrifying, hydrogen combined with a fuel cell could support further decarbonisation of heavy-duty vehicles, specific bus routes and mine vehicles.

4.1.3 Longer Term – Post 2040

High-Temperature Heat

Natural gas is the primary source of heat used in Azerbaijan's industry. Hydrogen is a crucial technology in decarbonizing high-temperature processes used by industry as it can directly replace natural gas with minimal changes to the burners. The challenge is transporting the hydrogen to the site. At the volumes required by industry, there are four main options: via the electricity grid, blended into the gas network and deblended at industrial sites, fully repurposing the gas grid, or building a dedicated hydrogen network. Each option presents different significant challenges.

Whilst switching industry to hydrogen is expected to occur later post-2040; when planning where to build the hydrogen plants in Azerbaijan, the distance from industry should be considered to minimize any future transport challenges.

Power

Hydrogen is increasingly being considered for power generation, particularly in peaking plants that operate during periods of high electricity demand, which are crucial in energy systems with significant renewable energy use. As renewables like wind and solar are variable, hydrogen can be used to generate electricity when these sources are insufficient.

In particular, green hydrogen use in the power sector will be limited when combined with long-duration storage to balance seasonal fluctuations in renewable energy supply.

As the demand for power increases due to the proliferation of datacentres, maintaining power in these facilities is essential. Hydrogen is regarded as a clean alternative to diesel for power maintenance.

4.2 Key Considerations for Developing a Hydrogen Economy

4.2.1 Renewable Energy Availability

Azerbaijan has significant renewable resources: 23 GW of economic potential of Solar, 3 GW of economic potential of onshore wind, 157 GW of technical capacity of offshore wind and is only just starting to exploit the resource. The country also boasts 1.2 GW of installed, mostly 'run of river', hydro.

The scenarios for green hydrogen in this strategy depend on a significant amount of renewable energy dedicated to hydrogen production. However, the targets set by the NDC also rely heavily on renewable power, as do plans for the new green corridor. It is, therefore, necessary to ensure it has enough renewable energy to meet its own goals but also ensure that the most economically advantageous option is chosen for the export of the energy as electricity or hydrogen.

4.2.2 Committed to Protecting Our Water Resources

When discussing a hydrogen strategy in Azerbaijan, it is crucial to consider the country's water resources.

Around 75% of Azerbaijan's water resources come from outside of its territory, making it highly dependent on its upstream neighbours within the Kura-Araks basin. The shortage of drinking water resources in Azerbaijan is a crucial resource consideration when developing a national strategy for large-scale hydrogen production. Green hydrogen requires significant quantities of high-purity water, over 9 kg water/kg hydrogen (excluding cooling demand). Blue hydrogen will require comparatively smaller volumes of water (25% reduction depending on cooling methods). However, water is still expected to be a constraint and requires consideration in developing blue hydrogen projects.

As the clean hydrogen market expands in Azerbaijan, it is crucial that this growth occurs with minimal impact on the freshwater supply. Therefore, projects must carefully consider water supply when selecting the location for the hydrogen plant. This includes conducting a comprehensive environmental impact assessment (EIA) and exploring alternative water sources. It is imperative that the potential impacts of these processes, such as brine disposal and water reuse from desalination, are thoroughly addressed.

Given the multiple stakeholders involved in the Caspian Sea, any large-scale use of water resources and waste and brine disposal must take into account the Tehran Convention. It is essential that all parties reach a consensus on the approach to water use for the development of clean hydrogen. With strong regional cooperation, we are confident that we can achieve these aims.

We will ensure that clean hydrogen is developed sustainably to protect our water resources and take environmental findings from the Sumgayit Industrial Area desalination project. We will assess the requirement to establish a sustainable clean hydrogen standard aligned with domestic needs while ensuring compliance with international standards.

4.2.3 Natural Gas Market

Azerbaijan possesses substantial natural gas reserves and serves as a major natural gas exporter, primarily to the European market through the Southern Gas Corridor. In 2022, Azerbaijan entered into a Memorandum of Understanding with the EU to double the volume of natural gas exports by 2027. The gas contracts are valid until mid-2040's.

Both blue and turquoise hydrogen rely on natural gas. However, they are unable to fully convert all the energy stored in the gas to hydrogen, resulting in an increase in natural gas demand to provide the same energy flows. Therefore, a strategic evaluation of the energy security and economic impact of developing blue or turquoise hydrogen in Azerbaijan is necessary.

4.2.4 Support the CCS Industry

The main challenge for developing blue hydrogen production is finding a suitable store for CO_2. While there may be some scope for using CO_2 to produce urea, methanol, and e-SAF, the market is likely limited.

CCS, alongside clean hydrogen, will also play a vital role in NDC in Azerbaijan's achievement of its ambitions for decarbonisation.

Azerbaijan's most credible CO_2 store would be the reuse of depleted gas reservoirs (and potentially oil reservoirs) under the Caspian Sea. However, any transportation or storage of CO_2 on or underneath the Caspian Sea will require legal support, highlighting the complexity of the development of blue hydrogen in the region.

CCS in the Caspian Sea is not without its challenges:

- There are significant legal issues internationally around the subsea storage of CO_2 and the transboundary shipping of CO_2 for storage. Within the EU, the storage issues are primarily addressed through the CCS Directive and the transboundary aspects through the 2009 amendment to the London Protocol (still to be ratified). The CCS Directive establishes the overall legal framework for the environmentally safe geological storage of CO_2. The European Union CCS Directive can be considered an example of "best practice" when developing CCS legislation for Azerbaijan.
- The applicability of the London Protocol, an international agreement that regulates the dumping of wastes at sea, including the storage of CO_2 beneath the seabed, to the Caspian Sea, is uncertain.
- Shipping CO_2 across the Caspian Sea (say, between Kazakhstan and Azerbaijan) is unlikely. Still, it is assumed it would require negotiations between contracting parties under principles established under the Convention on the Legal Status of the Caspian Sea.
- Subsea storage under the Caspian Sea may well also require negotiations between contracting parties under principles established under the Convention on the Legal Status of the Caspian Sea.
- Both CO_2 shipping and subsea storage are likely to fall under at least one protocol of the Tehran Framework Convention, particularly in terms of environmental impact assessment.
- Some form of CCS Directive for Azerbaijan would need to be developed, including procedures for monitoring, reporting and verification (MRV) of CO_2 storage.

At this point, the availability of CO_2 storage needs to be clarified; therefore, blue hydrogen has not been included in the production forecast scenarios. Given the time required to establish a suitable storage site, any potential storage is unlikely to be available until post-2030.

Any potential blue hydrogen development will be aligned with the country's broader CCS strategy. We will work to stimulate rapid research into carbon storage in the Caspian (and in onshore sites), aiming to unlock blue hydrogen development in Azerbaijan.

If CO_2 storage is unavailable, further exploration of Turquoise hydrogen may allow Azerbaijan to utilise its vast natural gas reserves while supporting decarbonisation efforts.

4.2.4.1 CO_2 Availability

Many hydrogen derivatives, such as methanol, urea, and e-fuels (such as e-SAF), rely on CO_2 as feedstock. There are three potential sources of CO_2 in Azerbaijan: CO_2 produced from burning fossil fuels, industrial processes, and biogenic produced from using bioenergy. The EU will not count e-fuels produced from non-biogenic sources as renewable after 2040, whereas other markets currently do not differentiate.

There is currently a limited supply of biogenic CO_2 in Azerbaijan, which is primarily produced from Azerbaijan's biomass power stations; production from the biomass power stations could increase by ten times by fully utilising this resource, generating 6 Mtpa of biogenic CO_2, which in turn could produce approximately 3.5 Mtpa of e-methanol.

An alternative source of biogenic CO_2 would be via the anaerobic digestion of organic matter. Anaerobic digestion produces biogas, primarily composed of methane and biogenic CO_2. Captured CO_2 would provide a source of biogenic CO_2, while the methane could be used as biomethane or further upgraded to produce hydrogen. Further synergies with green hydrogen production onsite could improve the overall energy efficiency of the process.

There is a plentiful supply of non-biogenic CO_2 in Azerbaijan, for example, from the cement works or gas treatment; this could provide an early route to market for Azerbaijan in developing a hydrogen economy.

We will investigate the potential to maximise biogenic CO_2 production alongside the use of non-biogenic CO_2 and the impact of using non-biogenic sources of CO_2 on Azerbaijan's ability to meet targets set in the NDC.

4.2.5 Hydrogen Storage

As the production of hydrogen increases in Azerbaijan, there will be a greater need for storage. This is especially the case with increasing production of green hydrogen which relies on variable renewable energy, meaning that to ensure the security of supply, a large amount of storage will be required. How much storage is required will depend upon the demand profile.

Hydrogen is relatively expensive to store; as a gas, it has comparatively low energy density (a third of natural gas). Depending on the scale of storage required, there are a number of options for compressed hydrogen storage, such as high-pressure storage tanks, a buried pipeline or geological storage. To date, geological hydrogen storage has been limited to salt caverns and is a proven technology that has been deployed in countries such as the UK and USA. Hydrogen storage in depleted gas fields is being considered, although there are concerns regarding the contamination of nearly pure hydrogen with hydrocarbons.

It is understood there is not currently any viable, large-scale salt caverns in Azerbaijan, so large-scale hydrogen storage may prove challenging unless storage in depleted gas fields is proven feasible.

Alternatively, hydrogen can also be stored as a liquid, as ammonia, or integrated with a carrier (Liquid Organic Hydrogen Carriers); however, these options have significant roundtrip energy penalties The advantage of these liquid alternatives is they are more readily transportable and can be potentially moved to more isolated pockets of hydrogen demand.

The increasing use of renewables will require increasing amounts of energy storage in order to balance the electricity grid. Hydrogen offers the potential to balance the electricity grid by converting the electricity to hydrogen at the point where the grid is congested.

4.2.6 Strategically Located to Support Export Markets

Azerbaijan's strategic location enables it to connect and cater to Eastern and Western markets. By leveraging and expanding the existing export infrastructure, this allows Azerbaijan to develop a green energy corridor to export clean hydrogen.

4.2.6.1 Rail and Shipping

Azerbaijan has an extensive rail network, which plays an essential role in transportation and trade, especially as part of the East-West transport corridor. While the scale is relatively small, the rail network will provide an opportunity to transport, both in export and transit regime, hydrogen and its derivatives in the short to medium term, enabling the hydrogen economy to develop while other export routes are assessed. It is recognised that to unlock the potential of hydrogen and hydrogen derivatives transport by rail; we will have to address several challenges, including safety concerns with the movement of these products through populated areas. These concerns will be addressed in a broader Rail and Shipping Transport and Infrastructure Study, assessing potential pathways for clean hydrogen derivatives exports.

4.2.6.2 Pipeline Infrastructure

The Southern Gas Corridor (SGC) enables Azerbaijan to export natural gas to Europe. It comprises three major pipelines allowing gas from the Shah Deniz field to be transported to Georgia, Türkiye, Greece, Italy, and further destinations within Europe.

Theoretically, the SGC could allow Azerbaijan to export clean hydrogen by either blending with natural gas (however, recent analysis from SOCAR suggests that the technical limits for blending is from 2-6% hydrogen without significant infrastructure upgrades) or fully repurposing the pipes, although this will also take considerable investment.

Whilst technically feasible when considering the long-term gas contracts with committed volumes and the commercial challenges associated with ensuring Georgia, Türkiye, Italy and other downstream users are willing to accept the hydrogen, the use of the current SGC for exporting hydrogen is not considered feasible in the short to medium term, until the demand for natural gas declines significantly.

Developing a new export pipeline offers the potential for Azerbaijan to export clean hydrogen at scale. As a strategic gateway between East and West, Azerbaijan is uniquely positioned to collaborate with neighbouring countries seeking to export clean hydrogen to European markets. Leveraging our expertise from developing the Southern Gas Corridor and the possibility of utilizing existing pipeline routes provides a strong foundation for advancing this initiative. As part of our national hydrogen strategy, we will continue to work with our partners to advance studies on Green Energy Corridors and engage in active dialogue with neighbouring countries to align and synergize our hydrogen export strategies.

5. Azerbaijan’s Hydrogen Production

Global hydrogen demand is currently around 90,000 KTPA, with projections indicating a substantial increase—up 60% by 2030 and up to five times by 2050. 25% of this supply is expected to be traded internationally, with the rise in demand met with clean hydrogen.

Azerbaijan's hydrogen production and consumption currently represent less than 0.5% of global demand. We've 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 Azerbaijan's need to balance hydrogen's internal benefits for decarbonization against its export value. This challenge mirrors the country's approach to natural gas and the creation of green energy corridors, which currently focus on renewable electricity. An Accelerated scenario has been developed, relying upon an accelerated rollout of renewables and international demand for clean hydrogen to increase substantially. An Ambitious Scenario has also been developed, which pushes through to 2060 and utilizes a higher percentage of our offshore technical capacity.

Balanced Scenario	0.5 MTPA - 2050
Accelerated Scenario	1.1 MTPA - 2050
Ambitious Scenario	1.9 MTPA - 2060*

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

The scenarios focus on green hydrogen production; whilst blue and potentially turquoise could significantly increase production, there are too many uncertainties to include in the scenarios. If blue is possible, it is expected that most of our domestic demand will be fulfilled by it. Furthermore, discovering and exploiting natural hydrogen would change our ability to export hydrogen at a higher volume. However, as this is still at a very early stage, it is not included in these scenarios.

Common Points in Scenarios

In all scenarios, the short-term period out to 2030 sees the same trajectory with the development of common areas.

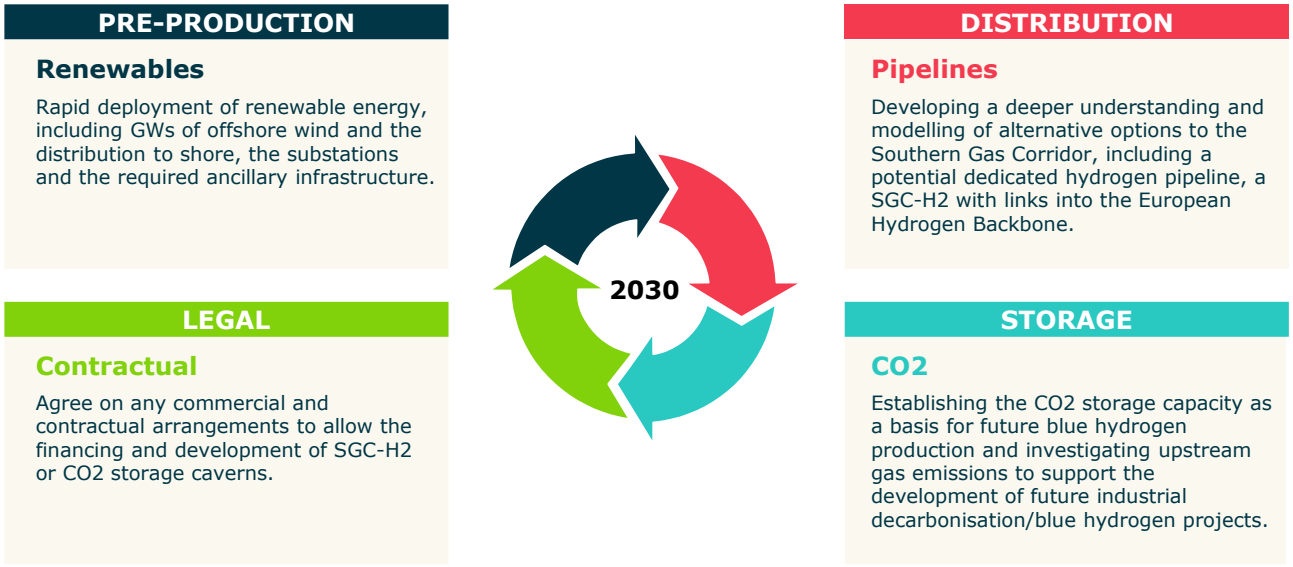


Figure 5-1: Common Points in Both Scenarios

Balanced Scenario

In the Balanced Scenario, the production of green hydrogen will reach 500 KTPA of green hydrogen per annum by 2050, with 390 KTPA exported either as hydrogen or a range of hydrogen derivatives. Overall, though, this scenario is balanced in terms of deployment of additional renewables being ambitious but not overly so and demand internally being balanced with export.

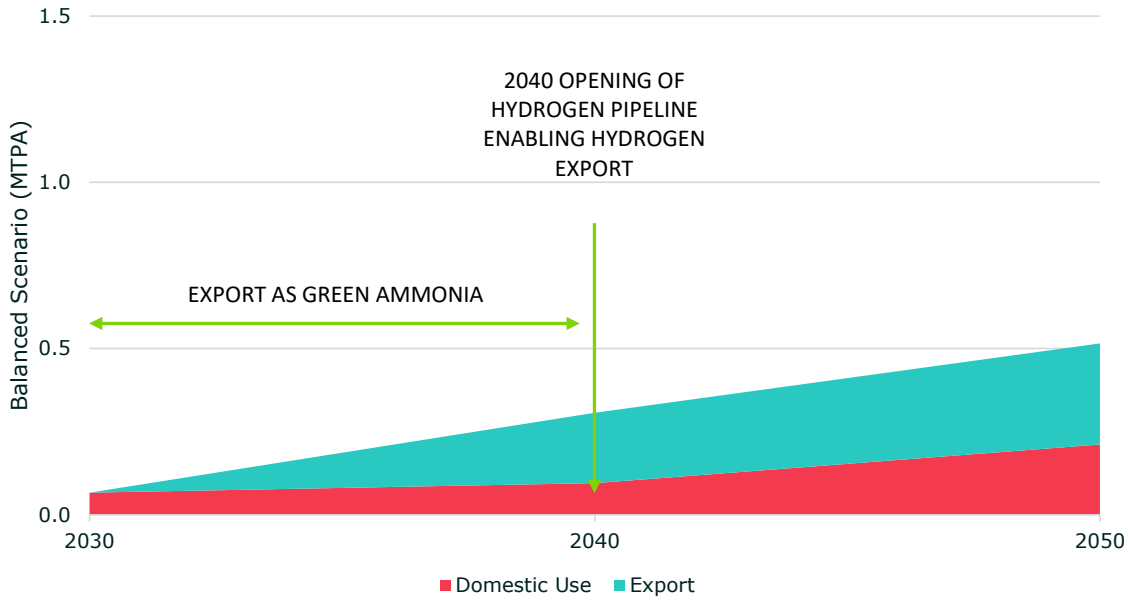


Figure 5-2: Azerbaijan Green Hydrogen Production Potential under a Balanced Scenario

(Source – Worley Consulting)

Accelerated Scenario

Through innovation in offshore wind development and learning from developed offshore wind markets, it is credible to increase the rollout of offshore wind predominantly for green hydrogen production. This scenario also requires a favourable regulatory and economic environment for green hydrogen production and use/export, with international demand increasing significantly.

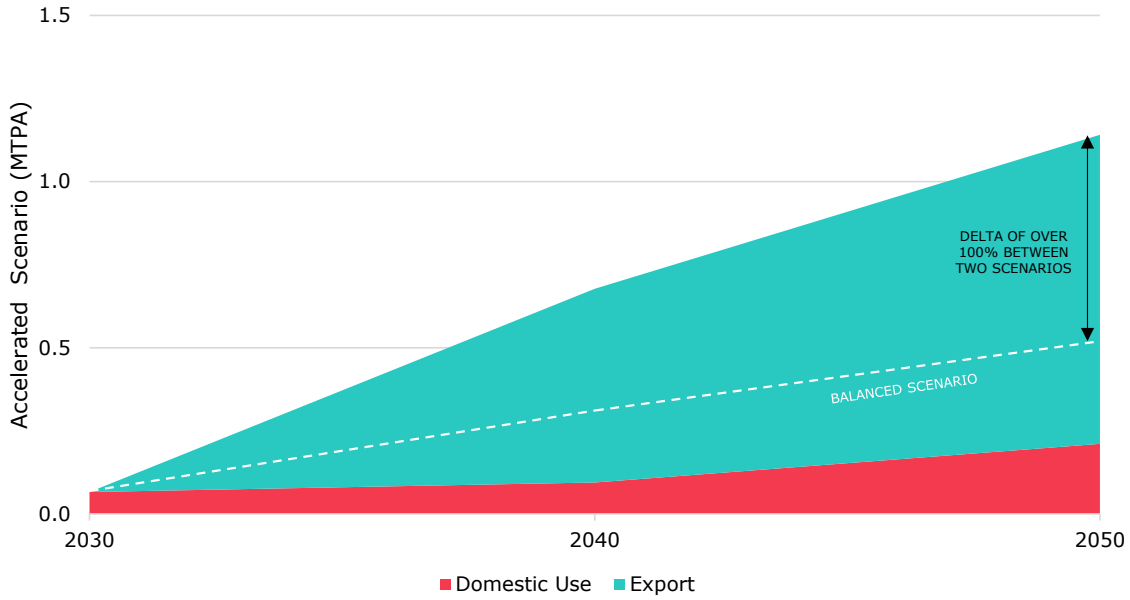
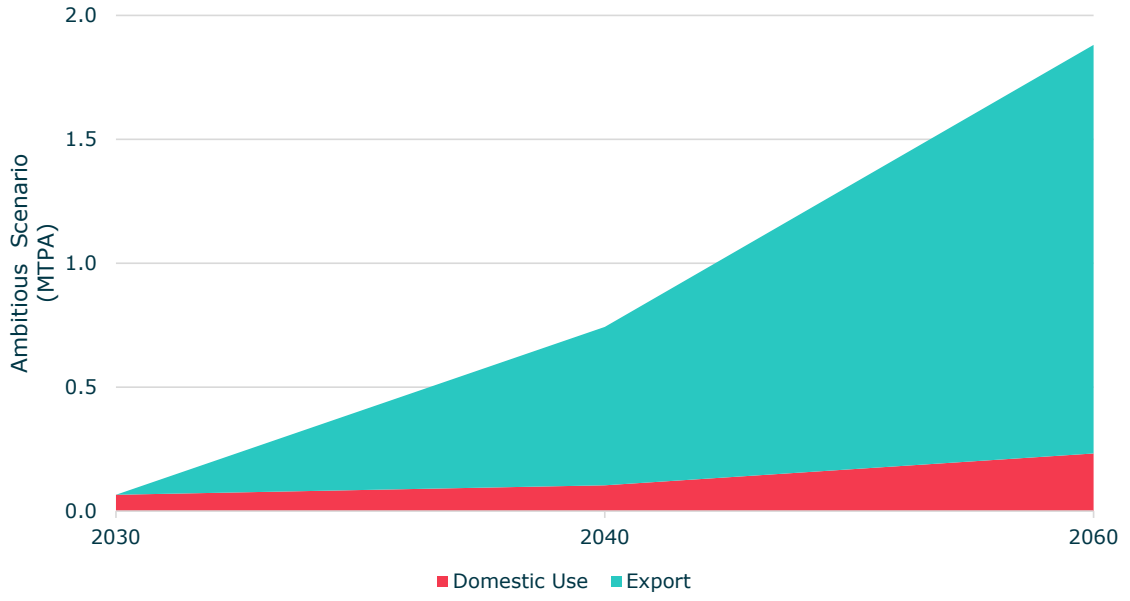


Figure 5-3: Azerbaijan Green Hydrogen Production Potential under the Accelerated Scenario

Ambitious Scenario

The case below is the Ambitious Scenario tracking further into 2060, as opposed to the above scenarios, which only extend to 2050. For this scenario to become a reality, there is a significant increase in investment in offshore wind (around 30 GW by 2060), utilizing a higher percentage



of the technical generation capacity. Compared to the Accelerated Scenario, the green hydrogen export volume in 2060 (1.7 MTPA) is almost double the 2050 amount of 0.9 MTPA.

Figure 5-4: Azerbaijan Green Hydrogen Production Potential under the Ambitious Scenario

5.1 Maximise use of Renewable Resources

We have already committed to raising the share of renewable energy in total generating capacity from 16% in 2018 to 30% in 2030, representing 1.7 GWs of renewable capacity. There are plans to bring approximately 2000 MW of solar and wind power plants for the internal grid online by 2027.

In addition to the planned expansion of renewables for grid decarbonization and electrification, the production of hydrogen will require a further 17.7 GWs by 2050 of installed capacity to meet the Accelerated Scenario. The Ambitious Scenario would require offshore wind rollout to increase above previous estimates, with almost 12.7 GW by 2040 and 30 GW by 2060.

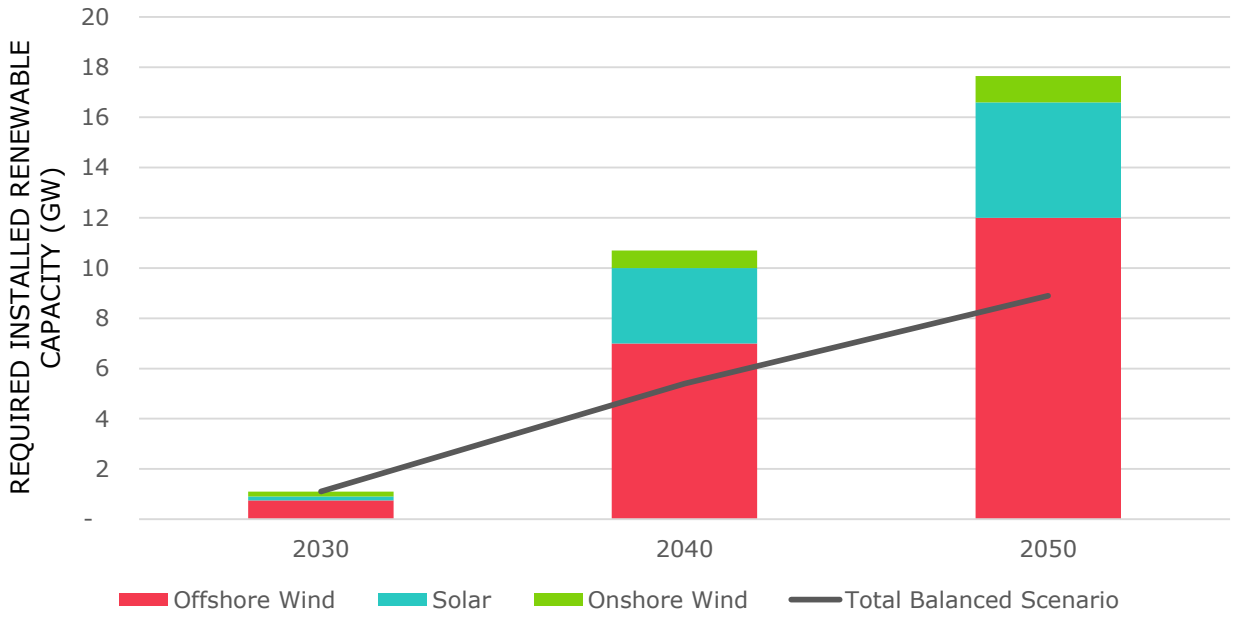


Figure 5-5: Additional Renewable Deployment Dedicated to Hydrogen Production in the Accelerated Scenario (Balanced Scenario shown for comparison)

5.2 Hydrogen Production Cost Analysis

Assessing the renewable resources available in Azerbaijan and using international gas price forecasts, we have estimated the cost of hydrogen production for projects commencing in the early 2030s. If CCS proves viable, blue hydrogen will offer the lowest cost of hydrogen production. Azerbaijan can produce green hydrogen at a competitive rate to Europe, presenting an opportunity for export. The green hydrogen costs would come down further if Chinese-developed electrolysers were to be deployed.

Figure 5-6: Estimated LCOH of Blue and Green Hydrogen in Azerbaijan and EU

(Source: Worley Consulting)

Transportation of hydrogen from Azerbaijan to the EU will increase the cost of the hydrogen; this will likely require a new pipeline, increasing costs by 0.8 EUR/kg.

6. Financing Mechanisms

As Azerbaijan has an abundant supply of oil and gas, the energy transition will initially add significant costs; therefore, accelerating the rollout of low-carbon technologies, including hydrogen, will require financial mechanisms to support the market development. There are different approaches to the type of financial support; the US prefers to use tax credits, whereas the EU uses carbon taxation combined with grants.

6.1 Carbon Pricing

Our updated climate goals (in NDC) will require incentives for clean hydrogen, including introducing a carbon price. A carbon price would make clean hydrogen more competitive against grey hydrogen and support its use in replacing natural gas in other sectors, such as industrial heat. Carbon pricing is crucial to scaling up clean hydrogen technologies and creating a market for cleaner energy by signalling that the cost of inaction for industry will continue to rise. With an increasing number of countries, including Kazakhstan, adopting carbon markets, Azerbaijan could benefit domestically and in exports. The EU's CBAM may raise export costs. However, CBAM also creates opportunities for Azerbaijan to export low-carbon products like green ammonia.

6.2 Concessional Finance

Today, most clean hydrogen projects rely on public funding to enhance technology competitiveness and viability. There is a range of concessional finance instruments that offer more favourable terms than market rates. These include below-market-rate loans with extended repayment periods, grants which provide direct funding without repayment, loan guarantees, and, to a lesser extent, equity investments with lower share value requirements that support targeted projects. A further alternative is tax credits, which reduce tax liability based on investment in qualifying projects.

Development banks and multilateral funds, like the Climate Investment Funds' Clean Technology Fund, provide concessional finance. This type of funding can play a crucial role in accelerating the deployment and expansion of hydrogen technologies, particularly in countries like Azerbaijan.

6.3 Foreign Investment Possibilities

We are increasingly attracting foreign investment to support the energy transition and the development of green hydrogen. Notable examples of such foreign investment include Masdar, one of the world's leading clean energy companies, with a 10 GW renewables agreement, with integrated offshore wind and green hydrogen projects accounting for a combined capacity of 6 GW. Additionally, in December 2022 a Framework Agreement was signed between the Ministry of Energy and Australia's Fortescue Future Industries (FFI) for cooperation on studying and developing renewable energy projects and the potential of "green hydrogen" in Azerbaijan. The agreement anticipates investigating and implementing projects with a total capacity of up to 12 GW for producing renewable energy and "green hydrogen" in Azerbaijan.

These initiatives are crucial for launching the development of the country's hydrogen sector and sending a clear signal to the market and investors. It is essential that they incorporate a gradually phased commitment to local content requirements, where not in conflict with any

subsidy requirements, which will add value to Azerbaijan's economy in terms of technology transfer, creating new local jobs, and supporting decarbonization efforts.

International subsidy, such as that provided by the H2Global mechanism, is an increasingly powerful opportunity to help the development of an export-based industry. Application by developers for such subsidy will be supported as and when is appropriate for a project, but also aligns with country ambitions.

6.4 Country Level Financial Support Mechanisms

Azerbaijan can consider implementing a range of financial incentives to attract and support the development of pilot projects, especially for clean hydrogen. The establishment of the Energy Efficiency Fund (EEF) marks a crucial step in this direction. The EEF will provide financial backing for energy transition projects, including clean hydrogen, with funding sourced from energy tariffs, loans, grants, voluntary donations, and contributions from international organizations.

Although the specific forms of support are yet to be finalized, the EEF could offer incentives such as local content requirements, reduced customs rates on machinery, and exemptions from electricity levies, stamp duties, and notary fees. Additionally, other countries leading in hydrogen development use tools such as tax reductions for clean hydrogen fuels, lower road tolls and parking fees for hydrogen vehicles, relaxation of land taxes for project developers, preferential energy tariffs, and Contracts for Difference (CfD) to support low-carbon steel and chemicals production by covering the cost gap between conventional and clean hydrogen production.

7. Opportunities for Azerbaijan

Azerbaijan is in a strong position to play an important role in any future clean hydrogen industry, employing its experience in developing a strong gas export sector, renewable energy potential and strategic location between East and West.

Implementation of the hydrogen vision will bring many economic benefits to the country, allowing economic growth to be decoupled from decarbonization.

These benefits will include:

Economic Growth: The development of an international trading market for hydrogen from Azerbaijan will create economic growth in the form of foreign investment, transport tariffs and new export markets.

New Economies and Clean Exports: Clean hydrogen opens the door to exports of local value-added commodities and goods. Beneficiation includes the potential to export SAF, e-methanol, and green steel; all potentially produced in-country from clean hydrogen. The longevity of such clean exports supports long-term economic stability as the demand for traditional oil and gas and fossil-based derivatives declines.

Increased Energy Security and Resilience: By enabling increased use of renewable energy, green hydrogen will enable greater diversification in our energy sources, reducing reliance on oil and gas and preparing for any future transition away from oil and gas.

Promotion of Regional Development: Implementing this strategy enables a balanced use of resources and land, boosting regional economies, particularly in areas rich in renewable energy resources where hydrogen production can be centred. Realizing hydrogen export opportunities may improve transport infrastructure such as rail, road, and ports.

Development of Energy Hubs or Industrial Clusters: Developing clean hydrogen further opens up the opportunity to develop integrated hubs or clusters, areas of heavy industry focused on decarbonization where shared infrastructure can help minimize cost and maximize synergies. In particular, the opportunity to integrate blue hydrogen production with neighbouring carbon capture plants can develop a CCS cluster.

Opportunities to Diversify the Supply Chain: Oil and gas supply chains that currently support high-carbon industries could be diversified to utilize their base capabilities and expertise to meet the needs of the Azerbaijan hydrogen sector. Increased R&D in the clean hydrogen industry will enable Azerbaijan to retain larger portions of the supply chain in-country, either directly or through higher-value products, as outlined in New Economies and Clean Export.

Local Growth, Jobs and Skills Development: It is recognized that a large portion of the country's workforce currently operates in the oil and gas industry. To ensure a just transition, it is imperative to ensure that any growth in renewables and shift to a clean economy is fair and inclusive through a directed programme of reskilling alongside new training. Establishing a hydrogen economy will create jobs, a high proportion of which will be highly skilled. It is estimated that each 1000 MW facility would require around 750 personnel.

Attracting Investment: The development of a clean hydrogen industry presents unique opportunities for investment in local projects, associated infrastructure, supply chain companies, technologies and innovation.

Support Decarbonisation Pathways: Adoption of hydrogen into Azerbaijan's hard-to-abate sectors would support the country's NDC targets.

7.1 Action Plan

To ensure this vision becomes a reality, swift and decisive actions are required to launch the industry and identify potential barriers to accelerated development.

To unlock the industry, we will execute the following:

- We will maintain active and comprehensive engagement with developers, the private sector, and international partners to shape and implement our hydrogen vision. This will be through our Hydrogen Working Group, which centralises all relevant government departments under one umbrella.
- A review of existing State Regulations and Legislation to identify and provide recommendations for the removal of any unintended barriers to the development of the clean hydrogen economy.
- To ensure a just transition and capitalise on the potential for jobs creation, we will undertake a skills and knowledge gap assessment, identifying the required skills and definition of required profiles of workers, their subsequent education and training. Further to this, we will maximise work-based learning and apprenticeships while developing first-time hydrogen projects.
- We will work with universities and innovators to assess the potential to increase R&D in the clean hydrogen industry, enabling Azerbaijan to retain larger portions of the supply chain in the country. We will continue establishing the Clean Energy Centre for the ECO region (CECECO) and fund R&D in the hydrogen and CCUS Industries.
- There is a clear need to stimulate rapid research into carbon storage in the Caspian, which will be undertaken.
- We will expand and deepen collaboration with neighbouring countries also looking to export renewable power, hydrogen and hydrogen derivatives, including on the low hanging fruit of identifying opportunities for shared infrastructure.
- We continue to progress studies on Green Energy Corridors to better understand the best export pathway for renewable energy and clean hydrogen. In addition, we will explore the various pathways for low-carbon fuels considering which pathway makes most economic sense for Azerbaijan.
- Azerbaijan will comprehensively assess all relevant production pathways to identify the most economically viable options, balancing domestic needs with export opportunities and supporting national energy security and economic growth. We will identify and complete relevant studies and develop plans to enable the development of the hydrogen sector. We anticipate the following studies will be required:
    - Renewable energy resource availability aligned with NDC requirements.
    - Biogas management from organic material.
    - Land and water resource availability including the impact of brine.
    - Rail and shipping transport and infrastructure study, assessing potential pathways for clean hydrogen derivatives exports.
    - Optimum route for e-fuels production.
    - Electrical grid study identifying any potential grid constraints.

- Economic assessment on best use of natural gas resource for blue and turquoise hydrogen.

- We will assess the requirement to develop a standard on Sustainable Clean Hydrogen, aligned with domestic needs while ensuring compliance with international standards.

Appendix A. Strategy Stakeholders

Sector	Key Players	Responsibilities
Government	Ministry of Energy, Ministry of Economy, Azerbaijan Energy Regulatory Agency, Azerbaijan Renewable Energy Agency, Ministry of Ecology and Natural Resources, Ministry of Digital Development and Transport, State Maritime Agency, State Civil Aviation Authority	Developing and implementing hydrogen policies and regulations, overseeing hydrogen energy production and distribution, environmental regulations, and promoting hydrogen adoption in the national energy mix.
Project Developers	SOCAR, BP, ACWA Power, Masdar, FFI, ENI	Developing hydrogen production projects (e.g., green hydrogen using renewable energy), and the potential of CCS, exploring hydrogen applications in transport and industrial sectors.
Supply Chain	ADO-G, Azfen, SOCAR's, Sumqayit Technology Park, Baku Shipyard Azerenerji Nobel Energy, Baltech and Total Energies	Supporting hydrogen and renewables production.
Non-Governmental Organizations	European Bank for Reconstruction and Development, UNDP Azerbaijan, UNIDO, World Bank Group, WWF-Caucasus, International Finance Corporation, International Renewable Energy Agency (IRENA), ASCO, AZAL, and Port of Baku	Providing financial assistance, research, and global standards for hydrogen project development, while promoting sustainability and climate goals through hydrogen solutions.
Academic Institutions	Azerbaijan National Academy of Sciences (Institute of Chemistry of Additives, Institute of Chemical Processes), Baku State University, Azerbaijan Technical University	Conducting research on hydrogen technologies, such as electrolysis, fuel cells, hydrogen storage, and providing technical education and skilled workforce development for the hydrogen sector.