ANALYSIS

KAZAKHSTAN

Sector Analysis Kazakhstan

Green Hydrogen for the C&I Sector

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

This publication was commissioned by the German
Energy Solutions Initiative of the German Federal
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TABLE OF CONTENTS

TABLE OF CONTENTS

List of figures

List of tables

Currency units

KZT	Kazakhstan Tenge
USD	United States dollar

Currency units and conversion rate as of 05.09.2024

EUR 1 = KZT 0.001870
KZT 1 = EUR 534.63

EUR 1 = USD 0.92275
USD 1 = EUR 1.0838

Source: Exchange-Rates.org, 2024

Technical units

bbl	Barrels (plural)
EJ	Exajoule (10^6 TJ)
GW	Gigawatt
GWh	Gigawatt hour
kN	Kilonewton
ktpa	Thousand tonnes per annum
Mt	Million tonnes
Mtpa	Million tonnes per annum
MW	Megawatt
MWh	Megawatt-hour
TJ	Terajoule (10^12 joules)

Abbreviations/acronyms

AEC	Alkaline Electrolysis Cell
AEMEC	Anion Exchange Membrane Electrolysis Cell
AN	Ammonium Nitrate
AS	Ammonium Sulphate
ASU	Air Separation Unit
ATR	Autothermal Reforming
BAU	Business as Usual
BMWE	Bundesministerium für Wirtschaft und Energie (German Federal Ministry for Economic Affairs and Energy (BMWE))
BT	Benzyltoluene
CAN	Calcium Ammonium Nitrate
CCUS	Carbon Capture, Utilisation, and Storage
CH_2	Compressed Hydrogen
CIS	Commonwealth of Independent States
CN	Carbon Neutrality
CO_2	Carbon Dioxide
DAC	Direct Air Capture
DAP	Diammonium Phosphate
DME	Dimethyl Ether
DRI	Direct Reduced Iron
EIA	Environmental Impact Assessment
ERG	Eurasian Resources Group
ETS	Emissions Trading Scheme
EU	European Union
FiT	Feed-in Tariff
GH_2	Green Hydrogen
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (Germany's main development agency)
HB	Haber-Bosch
IEA	International Energy Agency
KMG	KazMunayGas
LH_2	Liquid Hydrogen
LOHC	Liquid Organic Hydrogen Carriers
MAP	Monoammonium Phosphate
MCH	Methylcyclohexane
MeOH	Methanol
MTBE	Methyl Tertiary Butyl Ether
MTG	Methanol to Gasoline
MTO	Methanol to Olefins
NDC	Nationally Determined Contribution
NH_3	Ammonia
NPV	Net Present Value
OEM	Original Equipment Manufacturer
PDP	Project Development Programme
PEMEC	Proton Exchange Membrane Electrolysis Cell
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PSA	Pressure Swing Adsorption
PtX	Power-to-X (anything)
PV	Photovoltaic
R&D	Research and Development
RES	Renewable Energy Sources
SCO	Shanghai Cooperation Organisation
SME	Small and Medium-Sized Enterprises
SMR	Steam Methane Reforming
SOEC	Solid Oxide Electrolysis Cell
UAN	Urea Ammonium Nitrate
UCC	United Chemical Company
VAT	Value Added Tax
WACC	Weighted Average Cost of Capital

ENERGY SOLUTIONS – MADE IN GERMANY

The German Energy Solutions Initiative

The German Energy Solutions Initiative of the German Federal Ministry for Economic Affairs and Energy (BMWE) aims to globalise German technologies and expertise in climate-friendly energy solutions.

Years of promoting smart and sustainable energy solutions in Germany have led to a thriving industry known for world-class technologies. Thousands of specialised small and medium-sized enterprises (SMEs) focus on developing renewable energy systems, energy efficiency solutions, smart grids, and storage technologies. Cutting-edge energy solutions are also built on emerging technologies such as power-to-gas, fuel cells, and green hydrogen. The initiative's strategy is shaped around ongoing collaboration with the German business community.

The initiative creates benefits for Germany and the partner countries by:

- boosting global interest in sustainable energy solutions
- encouraging the use of renewables, energy efficiency technologies, smart grids, and storage technologies, while facilitating knowledge exchange and capacity building
- enhancing economic, technical and business cooperation between Germany and partner countries

THE PROJECT DEVELOPMENT PROGRAMME (PDP)

PDP is a key pillar of the German Energy Solutions Initiative and is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. It connects development cooperation with private-sector engagement and supports climate-friendly energy solutions in selected developing and emerging countries, enabling local businesses to adopt solutions in energy efficiency, electricity and heat supply, and hydrogen, while facilitating market access for German solution providers.

Developing and emerging economies offer promising business potential for climate-friendly energy solutions but also pose challenges for international business partners. The PDP team works closely with local industries to develop financially viable projects by providing technical expertise, financial guidance, and networking opportunities.

It identifies project leads, collects and analyses energy consumption data, and assesses projects from both a technical and economic perspective. This includes outlining the business case, calculating payback periods, and evaluating profitability. Companies can then choose to finance projects using their own funds or explore leasing and other financing options. PDP provides cost-free advice to local companies and connects them with German solution providers for project implementation.

Additionally, by offering training, organising reference project visits, and publishing studies on the potential of climate-friendly solutions and on navigating regulatory frameworks, the programme supports market development and fosters private-sector cooperation.

Executive summary

GREEN HYDROGEN FOR KAZAKHSTAN'S C&I SECTOR

The H_2 Sector Analysis for Kazakhstan provides an overview of the country's hydrogen landscape, assessing current industrial demand, potential for hydrogen production and future growth prospects. This study is part of a series, providing market insights and supporting pre-development efforts to stimulate interest in the green hydrogen economy across multiple countries.

The analysis explores Kazakhstan's potential to transition from grey to green hydrogen, with a focus on commercial and industrial sectors. It evaluates specific use cases and provides techno-economic estimates to inform local companies and companies based in Germany, identifying opportunities, challenges and pathways for green hydrogen integration.

Kazakhstan, the largest economy in Central Asia, is strategically located between Europe and Asia. The country possesses vast energy resources, including developed fossil fuel industries, and offers significant renewable energy potential. These resources could provide a strong foundation for electrolysis-based hydrogen production.

Zusammenfassung

GRÜNER WASSERSTOFF FÜR DEN C&I-SEKTOR KASACHSTANS

Die vorliegende H_2-Sektoranalyse für Kasachstan bietet einen Überblick über die Wasserstofflandschaft des Landes. Analysiert werden die aktuelle Nachfrage seitens der Industrie, das Potenzial für die Wasserstoffproduktion sowie Wachstumsperspektiven. Die Analyse ist Teil einer Serie, die Marktinformationen bereitstellt und Maßnahmen der Vorentwicklung unterstützt, um damit das Interesse an der Grüner-Wasserstoff-Wirtschaft in mehreren Ländern zu fördern.

Im Zentrum der vorliegenden Analyse steht Kasachstans Potenzial für den Umstieg von grauem auf grünen Wasserstoff, insbesondere in den Sektoren Gewerbe und Industrie. Untersucht werden konkrete Anwendungsfälle; zudem werden technoökonomische Einschätzungen abgegeben, um lokale Unternehmen und Unternehmen mit Sitz in Deutschland bei der Identifikation von Chancen, Herausforderungen und Einstiegswegen in den Markt für grünen Wasserstoff zu unterstützen.

Kasachstan, die größte Volkswirtschaft Zentralasiens, liegt strategisch günstig zwischen Europa und Asien. Das Land verfügt über umfangreiche Energieressourcen, darunter eine gut ausgebaute fossile Industrie, sowie über ein erhebliches Potenzial im Bereich der erneuerbaren Energien. Diese Voraussetzungen sind eine solide Grundlage für die Wasserstoffproduktion mittels Elektrolyse.

Kazakhstan's hydrogen demand is driven by the oil refining, fertiliser and petrochemical industries, and, to a smaller extent, the food processing sector. Additionally, the country's role in regional trade, most notably its integration into the Trans-Caspian International Transport Route, enhances its potential as a future hydrogen export hub for European and Asian markets.

BUSINESS OPPORTUNITIES FOR GERMAN SOLUTION PROVIDERS

Several factors make Kazakhstan an attractive location for green hydrogen development, with opportunities for German companies, particularly SMEs, in renewable energy, electrolysis technology, industrial applications and sustainable infrastructure development. Key advantages include:

- **Abundant renewable energy potential:** Kazakhstan's vast wind and solar resources, combined with its available land, create favourable conditions for large-scale green hydrogen production. Companies specialising in electrolysers, hydrogen storage and energy integration can play a role in scaling up these technologies.
- **Strategic trading position:** Kazakhstan's location along trade corridors linking Europe and Asia offers advantages for hydrogen export. German businesses involved in logistics, infrastructure and hydrogen transportation can benefit from early engagement.

Der Wasserstoffbedarf Kasachstans wird vor allem von der Ölraffination sowie der Düngemittel- und der petrochemischen Industrie bestimmt, in geringerem Maße auch von der Lebensmittelverarbeitung. Darüber hinaus stärkt Kasachstans Rolle bei dem regionalen Handel – vor allem durch seine Integration in die Transkaspische Internationale Transportroute – das Potenzial des Landes, sich zu einem Drehkreuz für den Export von Wasserstoff in europäische und asiatische Märkte zu entwickeln.

GESCHÄFTSMÖGLICHKEITEN FÜR DEUTSCHE LÖSUNGSANBIETER

Mehrere Faktoren machen Kasachstan zu einem attraktiven Standort für die Entwicklung grünen Wasserstoff – mit vielfältigen Chancen für deutsche Unternehmen, insbesondere für KMU aus den Bereichen erneuerbare Energien, Elektrolysetechnologie, industrielle Anwendungen und nachhaltige Infrastrukturentwicklung. Zu den wichtigsten Vorteilen des Standortes Kasachstan zählen:

- **Hohes Potenzial für erneuerbare Energien:** Kasachstan verfügt über große Wind- und Solarressourcen sowie über sehr große verfügbare Flächen – ideale Voraussetzungen für die großskalige Produktion grünen Wasserstoffs. Unternehmen, die sich auf Elektrolyseure, Wasserstoffspeicherung und Systemintegration spezialisiert haben, können maßgeblich zur Skalierung entsprechender Technologien beitragen.
- **Strategisch günstige Handelslage:** Die Lage an wichtigen Handelsrouten zwischen Europa und Asien prädestiniert Kasachstan für die Rolle als künftiger Exportstandort für Wasserstoff. Deutsche Unternehmen in den Sektoren Logistik, Infrastruktur und Wasserstofftransport können von einem frühen Markteintritt profitieren.

- **Industrial integration potential:** Kazakhstan has a strong industrial base, including the oil refining, petrochemical and fertiliser sectors, which could integrate green hydrogen into their processes. Companies with expertise in these industries could contribute to pilot projects and long-term developments.

CHALLENGES ON THE PATH TO A HYDROGEN ECONOMY

There are a number of key challenges at present that must be overcome if this potential is to be unlocked. These include:

- **High production costs and ageing infrastructure:** while Kazakhstan has strong industrial potential, much of its infrastructure is ageing. The cost of green hydrogen remains high. German companies could play a role in supporting cost reduction through innovation, investment partnerships and engagement in policy discussions.
- **Technology development and knowledge transfer:** adapting green hydrogen technologies to Kazakhstan's industrial and energy sectors requires further expertise. German companies with experience in these fields could provide valuable support.

- **Potenzial für die industrielle Integration:** Kasachstan verfügt über eine ausgeprägte industrielle Basis – insbesondere in der Ölraffination, Petrochemie und Produktion von Düngemitteln. Diese Branchen bieten Anknüpfungspunkte für die Integration grünen Wasserstoffs. Unternehmen mit Branchenkenntnissen können sich an Pilotprojekten beteiligen und langfristige Entwicklungen mitgestalten.

HERAUSFORDERUNGEN AUF DEM WEG ZUR WASSERSTOFFWIRTSCHAFT

Derzeit bestehen mehrere zentrale Herausforderungen, die überwunden werden müssen, um das Potenzial von grünem Wasserstoff in Kasachstan zu erschließen:

- **Hohe Produktionskosten und veraltete Infrastruktur:** Trotz des industriellen Potenzials ist ein großer Teil der kasachischen Infrastruktur überaltert. Zudem sind die Produktionskosten für grünen Wasserstoff weiterhin hoch. Hier nun können deutsche Unternehmen eine wichtige Rolle spielen – etwa durch technologische Innovationen, Investitionspartnerschaften und die aktive Mitgestaltung politischer Rahmenbedingungen für die Kostensenkung.
- **Technologieentwicklung und Wissenstransfer:** Die Anpassung von Technologien für grünen Wasserstoff an die kasachische Industrie und Energiewirtschaft erfordert weiteres Know-how. Deutsche Unternehmen mit entsprechender Erfahrung können hierzu einen wertvollen Beitrag leisten.

OPPORTUNITIES FOR GREEN HYDROGEN PROJECTS

Kazakhstan's renewable energy potential, strategic location and industrial base create a promising landscape for German SMEs to engage in pilot projects, infrastructure development and policy discussions. While challenges remain, targeted investment and collaboration could help to position Kazakhstan as a future player in the green hydrogen economy. German companies that establish a presence early on can shape this market while also benefiting from its long-term growth potential.

POTENZIALE FÜR GRÜNE WASSERSTOFFPROJEKTE

Kasachstans Potenzial im Bereich der erneuerbaren Energien, seine strategische Lage sowie die industrielle Basis bieten ein vielversprechendes Umfeld für deutsche KMU, sich an Pilotprojekten, Infrastrukturentwicklung und politischen Dialogen zu beteiligen. Trotz der Herausforderungen können gezielte Investitionen und eine partnerschaftliche Zusammenarbeit dazu beitragen, Kasachstan als zukünftigen Akteur in der Wirtschaft für grünen Wasserstoff zu positionieren. Deutsche Unternehmen, die frühzeitig vor Ort aktiv werden, haben die Chance, den Markt mitzugestalten und zugleich vom langfristigen Wachstumspotenzial zu profitieren.

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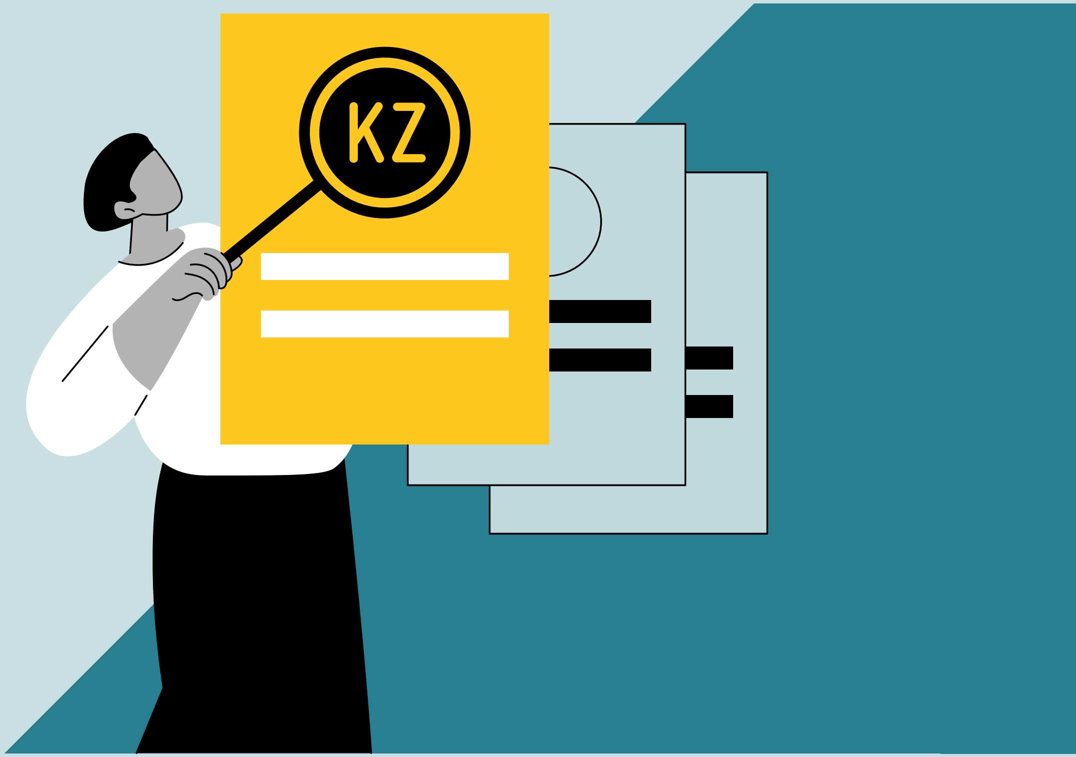
Outline of the current context

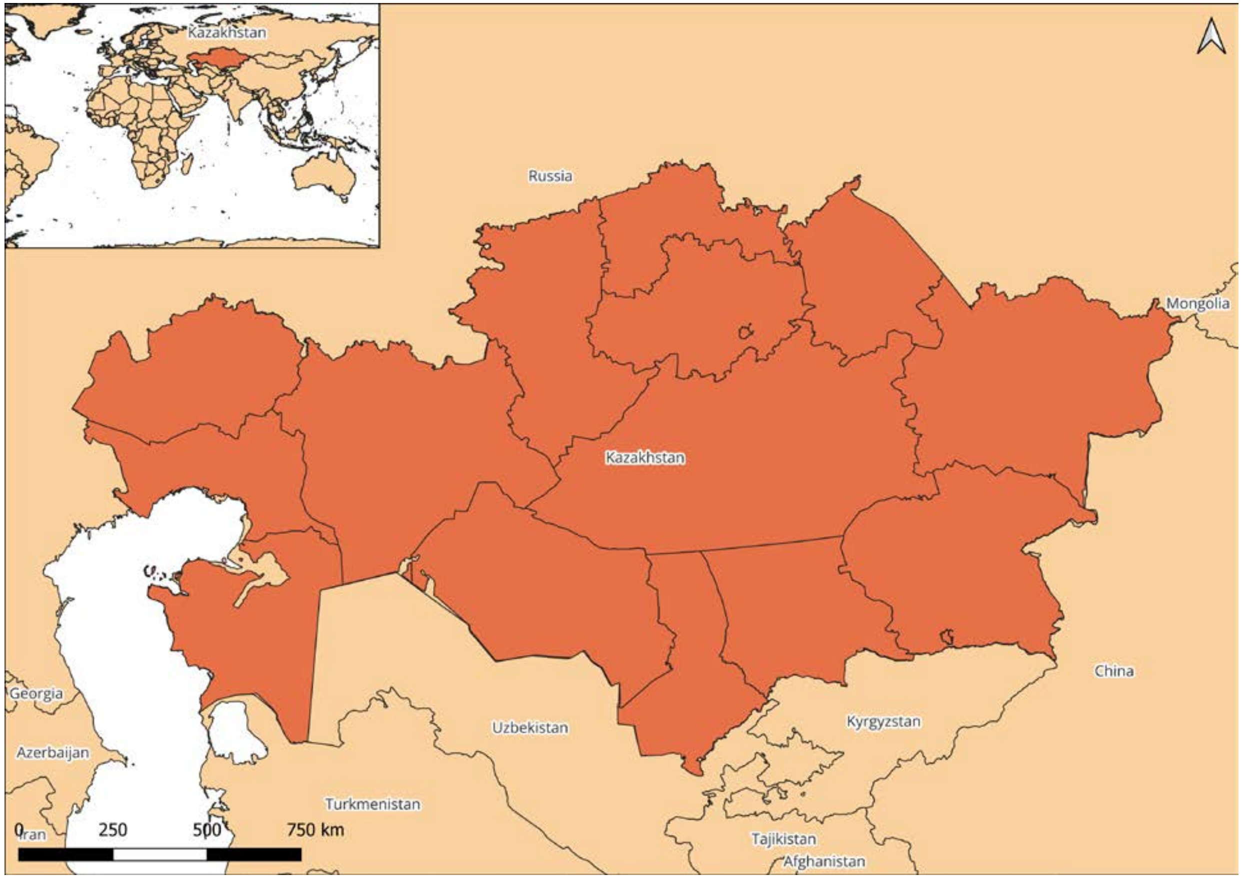


2.1 General country information

Kazakhstan is a landlocked country located in Central Asia (see Figure 1). Covering an area of approximately 2.7 million km^2, it has a population of about 20 million as of 2023 (World Bank, 2024a). The Kazakh economy is heavily reliant on natural resources, particularly oil, gas and minerals. The country is the world's largest producer of uranium (World Nuclear Association, 2024b). Kazakhstan's GDP reached USD 261 billion in 2023, which equates to USD 13,137 per capita (World Bank, 2024a).

Kazakhstan's economy is heavily reliant on the export of mineral fuels, mineral oils and oil production (54.8%), along with precious stones and metals (11.7%). Iron, steel and copper articles account for around 10% of the exported volumes, while inorganic chemicals make up approximately 4%. At the same time, the categories 'machinery, mechanical appliances and parts', 'cars, tractors, trucks & parts thereof', and 'electrical machinery and electronics' represented the largest import volumes in 2022, at 14.5%, 11.6%, and 9.4% respectively. In total, export volumes reached USD 98.7 billion and import volumes USD 57.9 billion in 2022 (OEC, 2024).

FIGURE 1. Location of Kazakhstan



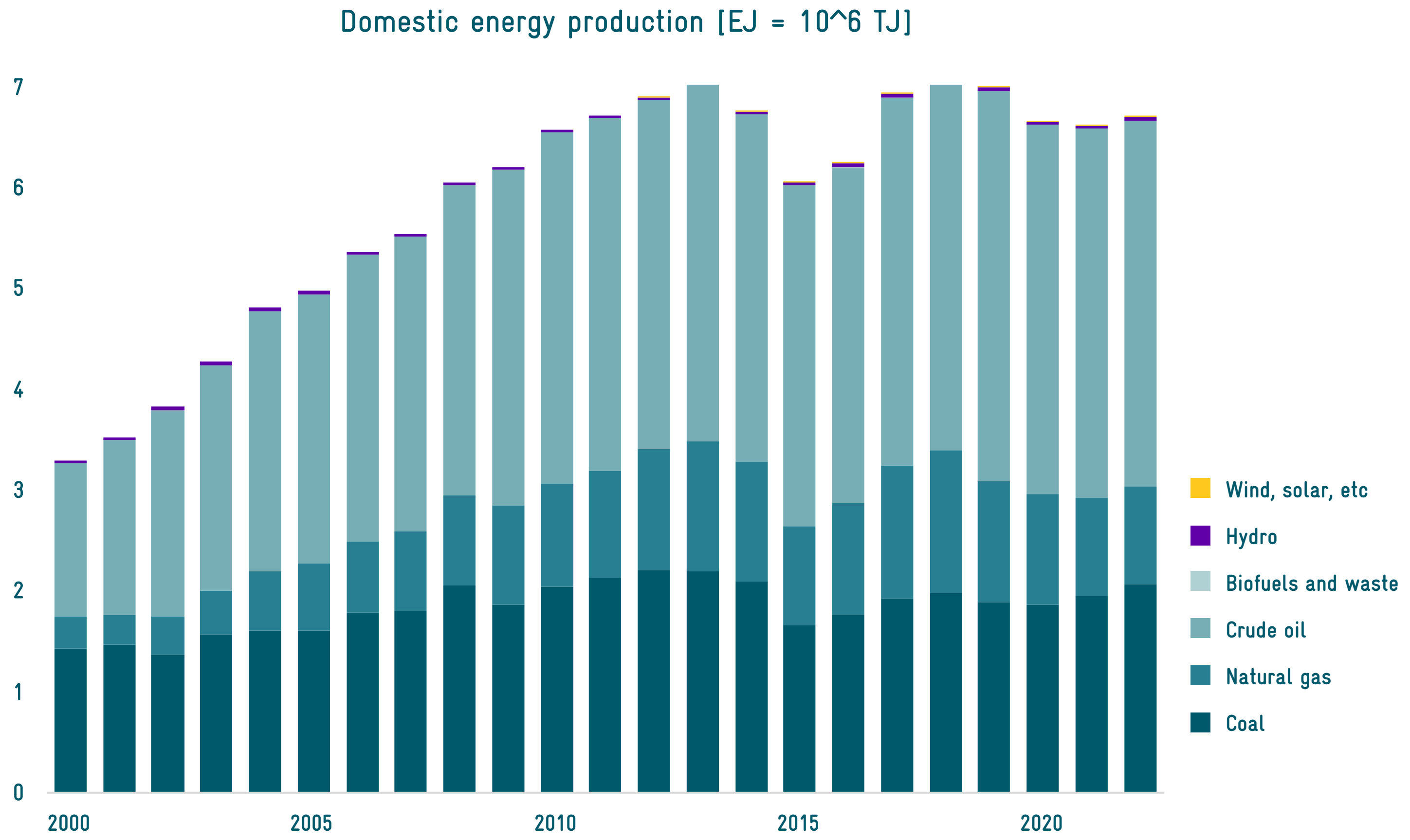
Source: Authors' own compilation, Fichtner (2025) based on (OpenStreetMap, 2024)

2.2 National energy sector analysis

2.2.1 Evolution of the energy sector to the present

Figure 2 shows the evolution of domestic energy production since 2000 (in exajoules, EJ = 10^6 terajoules, TJ), with fossil fuels being the major sources. Energy production includes any exploitation of fossil fuels, which can be burned to produce electricity and heat or used directly, as fuel for instance. It also covers energy produced from renewable sources, such as biomass, solar photovoltaic (PV), wind, geothermal and hydropower, if relevant. Energy production is largely dominated by crude oil, coal and natural gas. Kazakhstan is one of the largest oil producers in the world, with rich coal deposits and substantial natural gas reserves. Domestic crude oil production has more than doubled since 2000, while natural gas production has tripled over the same period. Domestic coal production has increased by almost 50%. As another primary energy source in Kazakhstan, hydro has seen a far more moderate increase of 20% since 2000, while energy production from biofuels and waste has decreased by around 40%. Renewable energy sources, such as solar PV and wind, have been in use since 2012, but their contribution to overall energy production remains minimal.

FIGURE 2. Evolution of domestic energy production in Kazakhstan since 2000 (in EJ)



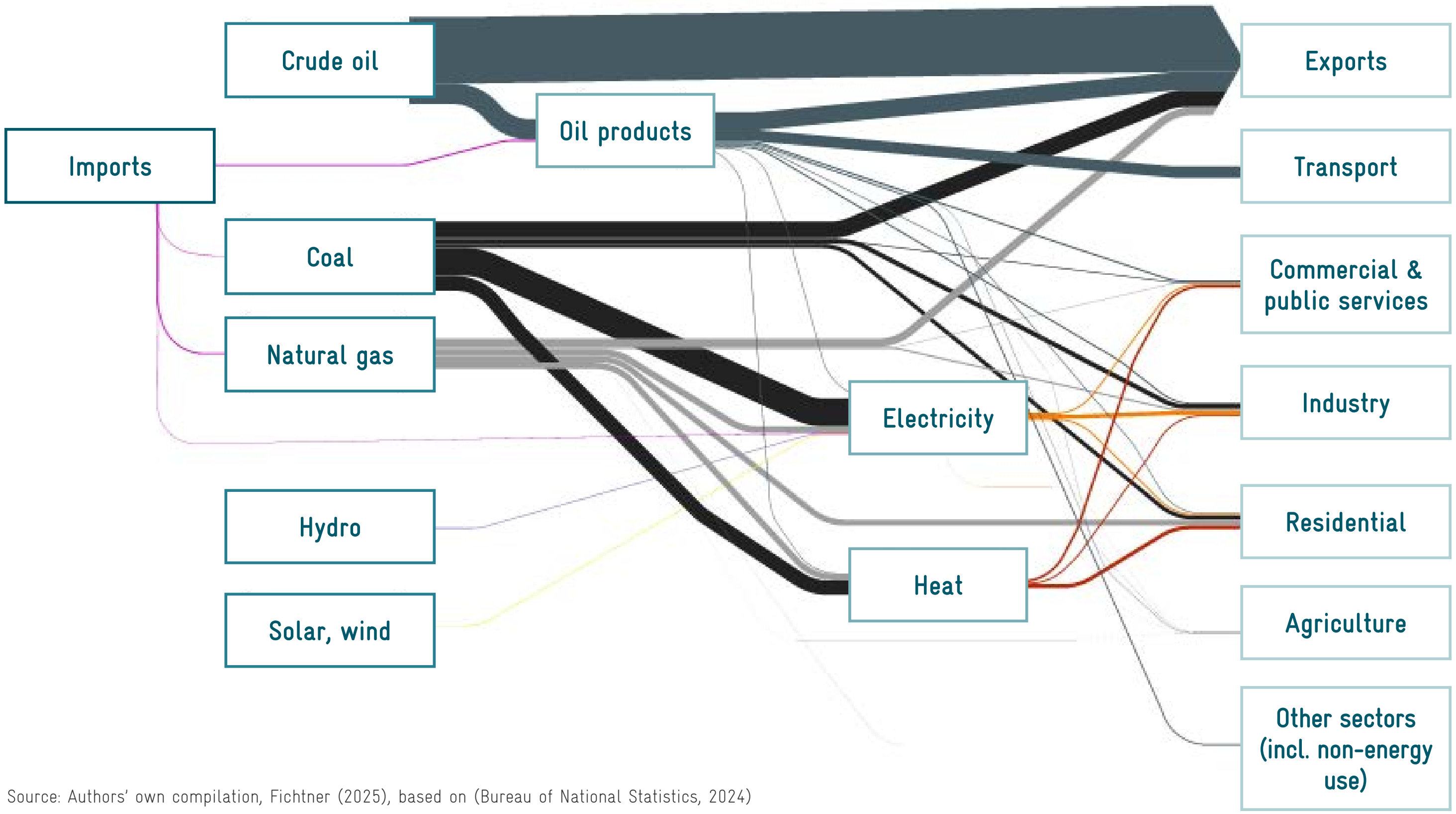
Source: Authors' own compilation, Fichtner (2025) based on (IEA, 2024a)

Electricity generation is based primarily on coal. Of the total 113,546 Gigawatt hours (GWh) of electricity generated in 2022, coal accounted for 62%, followed by natural gas at 25%. Renewable electricity is principally generated from hydropower (8%), wind (2%) and solar PV (almost 2%). While the share of hydropower remained rather constant between 2000 and 2022, wind and solar PV both saw a marked increase between 2012 and 2022 (IEA, 2024a).

Figure 3 presents Kazakhstan's energy balance for 2023 (Bureau of National Statistics, 2024) in the form of a Sankey diagram, illustrating energy flows from primary sources to secondary sources and end-use sectors. The total primary energy supply reached 6.5 EJ, sourced almost entirely domestically from crude oil (47%), coal (33%) and natural gas (19%). Imports contributed just 1% or so of the total primary energy. Secondary energy sources, such as oil products and electricity, were also produced predominantly domestically, with imports accounting for approximately 4%. Final energy consumption was highest in the residential sector (32%), which relied on a diverse energy mix, including coal. This was followed by industry (27%) and transport (23%), with transport primarily dependent on oil products, while industry and other sectors used a mix of energy sources similar to that used by the residential sector.

As shown in the Sankey diagram, Kazakhstan is a net energy exporter, with crude oil accounting for 62% of total energy exports, followed by coal (16%), oil products (14%) and natural gas (8%). In 2023, 75% of the country's total crude oil production (3.1 EJ) was exported. Although not included in the national energy balance, Kazakhstan is also the world's largest uranium producer. With no nuclear power plants, its entire uranium output is destined for export (World Nuclear Association, 2024a). However, the country is currently developing a project on nuclear energy production (Ministry of Energy of the Republic of Kazakhstan, 2025).

FIGURE 3. Energy flow in Kazakhstan in 2023



Source: Authors' own compilation, Fichtner (2025), based on (Bureau of National Statistics, 2024)

Energy prices

Table 1 provides indicative energy prices for key energy sources, along with prices under Kazakhstan's Emissions Trading Scheme (ETS). These prices serve as a reference only, as they vary by region, quality and time period. Electricity and natural gas prices are government-regulated. The Ministry of Energy sets wholesale natural gas prices annually (1 July – 30 June) for 17 regions. The table shows the minimum and maximum wholesale prices for the period from 1 July 2024 to 30 June 2025. Retail gas prices also vary by region, with the table displaying the minimum and maximum consumer prices of KazTransGaz as of 1 May 2024. For electricity, the Ministry of Energy determines marginal tariffs for producers based on costs and investment needs (Kazakhstan, 2022) and sets regulated tariffs for end users, which vary by region and consumer type. The table provides the minimum and maximum prices set by energy supplier Astana Energo for illustrative purposes. Electricity prices for major consumers are determined through bilateral agreements and are not publicly available.

TABLE 1. Indicative energy prices for Kazakhstan

Energy source		Price [KZT]	Price [USD]	Unit	Date
Coal	Steam coal (export)	52,589	106.6	/ t	26.10.2024
	Domestic use	~10,000	19.4	/ t	2023
Crude oil	Brent	27,133	55.0	/ bbl	2023
Natural gas	Retail sale	min. 428 max. 5,591	min. 0.9 max. 11.3	/ MWh / MWh	01.05.2024
	Wholesale	min. 717 max. 2,781 max. 4,206*	min. 1.4 max. 5.6 max. 8.5*	/ MWh / MWh / MWh	01.07.2024
Electricity	Individuals	23,130	46.9	/ MWh	01.04.2024
	Differentiated tariff	min. 18,660 max. 34,700	min. 37.8 max. 70.3	/ MWh / MWh	01.04.2024
	Business	Not available	–	–	–
ETS/CO_2	ETS	473	1.06	/ t_{CO2}	2024

bbl barrels

* max. marginal wholesale price for industrial customers purchasing gas for production of compressed or liquified natural gas

Source: Authors' own compilation, Fichtner (2025), based on: coal (Coal Price, 2024), (CCX, 2024), crude oil (CEIC, 2024), natural gas (KazTransGaz, 2024), (Kazakhstan, 2023), electricity (Astanaenergosbyt, 2024), ETS (World Bank, 2024b)

Forecast evolution of the energy sector

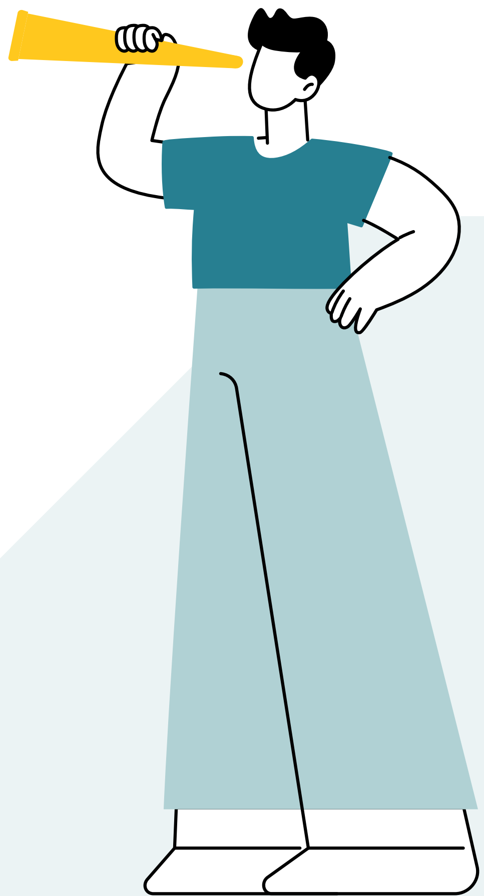
In 2021, the Kazakh Government approved the 'Doctrine (strategy) for achieving carbon neutrality of the Republic of Kazakhstan until 2060' (Ministry of Ecology and Natural Resources, 2021), which sets specific goals and objectives for transitioning to climate neutrality by 2060. Two scenarios are set out for future developments up until 2060: the business as usual (BAU) scenario assumes that there will be no significant technological changes or policy measures aimed at achieving carbon neutrality in Kazakhstan, while the carbon neutrality (CN) scenario reflects the efforts for reaching the goals set out in the Paris Agreement and Kazakhstan's commitment to achieving carbon neutrality by 2060.

In the BAU scenario, there is a 34% decline in coal supplies by 2050, relative to 2017 levels (1.6 EJ), while oil, oil products and natural gas supplies increase by 57%, relative to 2017 levels (1.5 EJ combined). Renewable energy supplies, primarily from solar PV and wind energy, increase by 283%, relative to 2017 levels (0.04 EJ).

In the CN scenario, coal, natural gas, and oil supplies decline by 2050, relative to 2017 levels: Coal decreases by 99.98%, natural gas by 5.9% and oil and oil products by 34.65%. Renewable energy supplies, primarily from solar PV and wind energy, increase to 1.6 EJ by 2050, a 3,538% gain relative to 2017 levels.

Regarding electricity generation, solar PV and wind are expected to cover 46% and 33% of total production respectively by 2050, while biomass and hydro will have a share of <1% and 6% respectively. At least 30% of generated electricity should come from renewable energies by 2030 and this share should increase to 50% by 2060. Specific targets include 10 GW of solar PV, 6 GW of wind and 3 GW of hydropower by 2030.

The targets set for 2030 are ambitious and will require an acceleration in project implementation and the development of relevant infrastructure. Attracting corresponding investment will require suitable and stable policies.



2.3 Legislative and regulatory framework

Kazakhstan is expanding its legislative and regulatory framework for renewable energy, climate change issues and emerging sectors such as green hydrogen (GH_2) in response to both domestic energy needs and international climate commitments. Key national laws and regulations guiding Kazakhstan's energy transition are outlined below.

Environmental Code (Kazakhstan, 2007)

OVERVIEW:

This code is a comprehensive legal framework governing environmental protection and the management and sustainable use of natural resources. The code was revised in 2021 to enhance environmental protection measures and bring it into line with international standards.

KEY PROVISIONS:

- **Environmental impact assessments (EIAs):** mandated for projects with potential environmental impacts to ensure sustainable development.
- **Climate change mitigation:** requires the development of policies and strategies for reducing greenhouse gas (GHG) emissions and adapting to climate change effects.
- **Public participation:** encourages stakeholder engagement in environmental decision-making processes.
- **Penalties and compliance:** established for environmental violations and include mechanisms for enforcement and compliance monitoring.

Law on the Use of Renewable Energy Sources (Kazakhstan, 2009)

OVERVIEW:

This law establishes the legal basis for developing and promoting renewable energy sources in Kazakhstan, aiming to diversify the energy mix and enhance energy security. It was amended in 2014.

KEY PROVISIONS:

- **Renewable energy targets:** Kazakhstan aims to generate 30% of its electricity from renewable sources by 2030 and 50% by 2050.
- **Incentives for investment:** fiscal incentives such as tax exemptions and grants for renewable energy projects.
- **Feed-in tariffs (FiTs):** guaranteed tariffs for electricity generated from renewable sources to attract investment. Renewable energy power plants are eligible for guaranteed power prices for a 15-year period.
- **Mandatory purchase:** energy suppliers are required to purchase renewable electricity, ensuring market access for renewable energy producers.
- **Promotion of local production:** encourages the use of locally manufactured equipment for renewable energy projects to stimulate domestic industries.

Concept for Transition of the Republic of Kazakhstan to Green Economy (Kazakhstan, 2013)

Overview:

The concept outlines a strategic framework geared to sustainable development, environmental protection and economic diversification.

Key provisions:

- **Policy integration:** the concept calls for green economy principles to be integrated into national and regional development policies and strategies.
- **Carbon neutrality by 2060:** 15% reduction in GHG emissions by 2030, relative to 1990 levels.
- **Renewable energies:** share of renewables in the national electricity mix to be increased to 30% by 2030.

- **Energy efficiency:** 25% reduction in energy consumption per unit of GDP by 2025, relative to 2015 levels.
- **Promotion of sustainable practices:** initiatives aimed at reducing emissions from agricultural practices and improving land use to enhance carbon sequestration.

Nationally Determined Contribution (NDC) (Ministry of Ecology and Natural Resources, 2023)

OVERVIEW:

Kazakhstan's updated NDC outlines the country's commitments to addressing climate change and reducing greenhouse gas emissions in alignment with the Paris Agreement. The NDC adopts the targets presented in the concept for transition.

KEY PROVISIONS:

- **GHG emissions target:** commitment to achieve a 15% reduction in greenhouse gas emissions by 2030, relative to 1990 levels, with further reductions anticipated through international cooperation. Kazakhstan aims to become carbon neutral by 2060.
- **Sectoral focus:** prioritises emissions reduction initiatives in the energy, transport, agricultural and industrial sectors.
- **Afforestation:** plans for increasing forest cover.
- **Transition to cleaner technologies:** encourages the adoption of low-emission technologies in various sectors, particularly in energy production and industrial processes.

Kazakhstan's Concept for the Development of Hydrogen Energy until 2030 (Kazakhstan, 2024)

OVERVIEW:

This strategy outlines a strategic framework for establishing a hydrogen economy, leveraging the country's rich natural resources and exploiting its potential for renewable energy. The concept aims to position Kazakhstan as a key player in the hydrogen economy at international level, focusing on blue and green hydrogen.

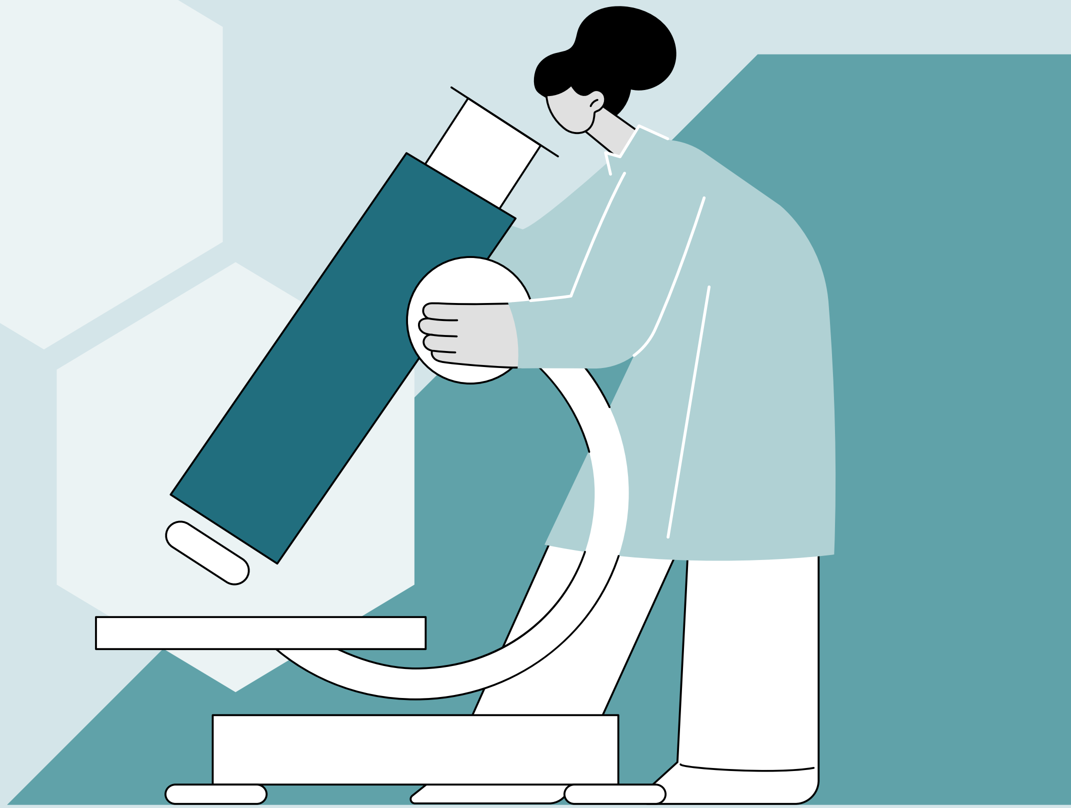
KEY PROVISIONS:

- **Hydrogen production goals:** the concept aims to produce 10 ktpa of hydrogen by 2027, 18 ktpa by 2029 and 25 ktpa by 2030 (and at least 50% green hydrogen). Export volumes should start at 36% and reach 60% by 2030.
- **Infrastructure development:** the goal is to establish 100,000 m^3 of hydrogen storage capacity, create a network of hydrogen refuelling stations and install 100 km of hydrogen pipelines, all by 2030.
- **Local use:** in the transport sector, the aim is to introduce hydrogen buses in at least three cities by 2030 and to develop a network of hydrogen refuelling stations in these cities to provide uninterrupted transportation services.
- **International cooperation:** attracting about KZT 1 billion in investments by 2030, concluding five international agreements for joint hydrogen projects by 2030 and implementing at least one international hydrogen project by 2030.

Kazakhstan's legislative and regulatory framework supports the development of renewable energy sources and other efforts to mitigate climate change. The government has established ambitious targets and implemented policies to attract investment, promote clean energy deployment and enhance energy security. Moreover, Kazakhstan offers political stability and has a strategic position as a link between Central Asia and Europe. As the country continues its energy transition, there are a variety of opportunities for domestic and international companies to engage in the renewable energy sector and contribute to Kazakhstan's sustainable development goals.

2

Industrial applications of hydrogen



Global hydrogen demand reached 97 million tonnes per annum (Mtpa) in 2023 and remains concentrated in traditional uses such as refining and industry applications, principally ammonia and methanol production and steel manufacturing (IEA, 2024b). Considering the potential of current (or traditional) and potential new uses of hydrogen as a decarbonisation solution, this demand is expected to increase significantly to 200-600 Mtpa by 2050, depending on the analysis and scenario in question. It should be covered primarily by clean hydrogen (produced either by electrolysis powered by renewable energies (green hydrogen) or by fossil fuel reforming combined with CCS (blue hydrogen)).

3.1 Hydrogen production methods

Hydrogen production processes vary, depending on the energy source and technology used, as summarised in the following table. The hydrogen used to meet current demand comes almost exclusively from the processing of fossil fuels (natural gas and coal) within methane reforming and coal gasification.

TABLE 2. Hydrogen production methods

Production process	Energy source	Technology options	Products	CO_2 emissions
Methane reforming	Natural gas	• Steam methane reforming (SMR) • Autothermal reforming (ATR)	H_2, CO, CO_2, N_2	• High CO_2 emissions • Potential combination with CCS to reduce CO_2 emissions
Coal gasification	Coal	• Gasification/reaction with O_2 and steam at high pressure and temperatures	H_2, CO, CO_2, N_2	
Methane pyrolysis	Natural gas	• Thermal decomposition at high temperatures without O_2	H_2, CO, CO_2	
Biomass gasification	Biomass	• Heating with limited oxygen	H_2, CO, CO_2	• Low to zero CO_2 emissions
Electrolysis	Electricity	• Electrolysis (AEC, PEMEC, SOEC, AEMEC)	H_2, O_2	• CO_2 emissions depend on electricity source • Low to zero for renewable energy sources

CCS	carbon capture and storage
AEC	alkaline electrolysis cell
PEMEC	proton exchange membrane electrolysis cell
SOEC	solid oxide electrolysis cell
AEMEC	anion exchange membrane electrolysis cell

Source: Authors' own compilation, Fichtner (2025)

3.2 Hydrogen uses

Hydrogen is a key component of the global energy and industrial landscape, with similar applications worldwide. The data presented in this section reflects the global context of hydrogen and is location-independent.

With a hydrogen demand of 97 Mtpa in 2023, the largest consumers of hydrogen are refining (44%), ammonia production (33%) and methanol production (17%). Around 5% of hydrogen is used for direct reduced iron (DRI) in the iron and steel sector and small amounts are used in other segments such as glassmaking, electronics and metal processing, accounting for 1 Mtpa or 1% of current global hydrogen demand (IEA, 2024b).

Additionally, hydrogen is produced as a by-product in different production processes.

In 2023, approximately 25% of hydrogen was produced as a by-product in refineries and petrochemical production (IEA, 2024b).

TABLE 3. Current uses of hydrogen

Current uses	Main processes/products	Specific requirements
Refining[1]	• Hydrocracking, hydrotreating and desulphurisation	• Depends on refinery complexity and oil quality: 8–14 kg H_2/tonne refined product
Ammonia	• Fertiliser production • Chemical production: e.g. nitric acid, amines, explosives • Refrigeration	• Stochiometric: 178 kg H_2/tonne ammonia
Methanol	• Fuel: methyl tertiary butyl ether (MTBE) • Solvent • Antifreeze • Chemical feedstock: e.g. formaldehyde, acetic acid	• Stochiometric: CO_2 hydrogenation: 189 kg H_2/tonne methanol CO hydrogenation: 126 kg H_2/tonne methanol
Chemical industry	• Oxo alcohols	• Depends on olefin, process and product, stoichiometrically between 10–30 kg H_2/tonne oxo alcohol
	• Fatty alcohols	• Depends on production process and product, stoichiometrically between 10–20 kg H_2/tonne fatty alcohol
	• Hydrogen peroxide (H_2O_2)	• Stochiometric: 59 kg H_2/tonne H_2O_2
	• Cyclohexane (C_6H_{12})	• Stochiometric: 71 kg H_2/tonne cyclohexane
	• Hydrochloric acid (HCl)	• Stochiometric: 55 kg H_2/tonne HCl
	• Caprolactam	• Depends on the production process, between 30–50 kg H_2/tonne caprolactam

1 In refineries, hydrogen is required for hydrocracking and hydrotreating, but it is also generated, mainly during catalytic reformulation: 18 kg of hydrogen/tonne of crude oil (Fuel Cells and Hydrogen Observatory, 2021).

Current uses	Main processes/products	Specific requirements
Chemical industry	• Phenol production* • Acetone production* via hydrogenation of isopropyl alcohol • 1,4-Butanediol (BDO) • Fine chemicals and pharmaceuticals as reducing agent	• Depends on the production process, between 10–30 kg H_2/tonne phenol • Stochiometric: 34 kg H_2/tonne acetone • Stochiometric: 23 kg H_2/tonne BDO • Depends on processes and products
Iron and steel	• As reducing agent in direct reduced iron (DRI) • As reducing atmosphere in annealing process in steel roll mills	• Depends on iron ore quality: ~60 kg H_2/tonne steel
Glass	• Glass melting as reducing agent to improve quality • Specialty glasses to control optical properties • Alternative fuel or furnaces to replace e.g. natural gas	• As reducing agent: 0.4 kg H_2/tonne float glass
Electronics	• Chemical vapour deposition, mainly e.g. for semiconductor manufacturing and LED production • Reduction agent	• 45–90 kg H_2/tonne semiconductor
Food industry	• Hydrogenation of oils (fats) and fatty acids	• Depends on oil/fat, required product and process: 5–100 kg H_2/tonne unsaturated fat processed
Metal processing	• Pure or in a mixture as shielding gas for welding processes	• Depends on process

Source: Authors' own compilation, Fichtner (2025) based on (Bressan, L. et all, 2009), (Fuel Cells and Hydrogen Observatory, 2021), (Wasserstoff Kompass, 2022), (Semiconductor Digest, 2018)

* The most common production process for phenol and acetone is the cumene process. This process does not require hydrogen directly, but it can be required for refining acetone (removal of impurities).

3.3 The hydrogen industry in Kazakhstan

3.3.1 Overview of the national industry

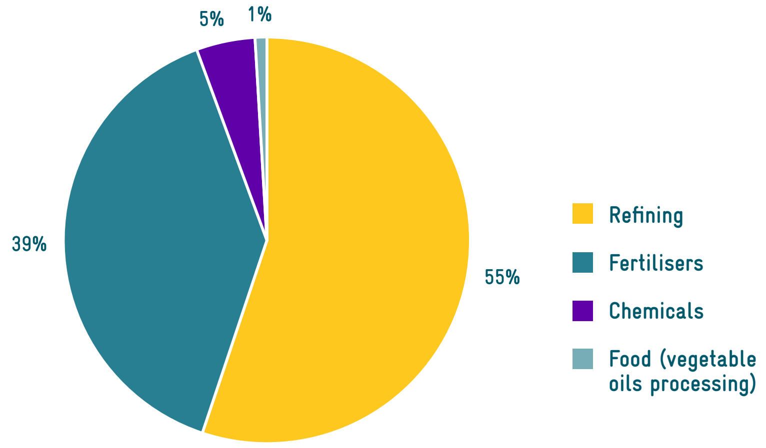
Hydrogen demand in Kazakhstan is primarily driven by oil refining and fertiliser production, with smaller-scale consumers including the petrochemical sector, glass manufacturing and vegetable oil processing. The mining industry also relies on ammonia-based explosives, making it another key sector that indirectly consumes hydrogen.

Since hydrogen is typically produced on-site, there is no large-scale hydrogen trading. In terms of main derivatives, Kazakhstan imports key hydrogen derivatives, including nitrogen-based fertilisers with net imports of 11 ktpa, urea with net imports of 22 ktpa and methanol with imports of 33 ktpa to meet domestic demand, as the country lacks operational methanol production facilities.

There are no official hydrogen statistics currently available for Kazakhstan. To provide an overview of the country's hydrogen industry, existing hydrogen demand has been estimated for key industrial sectors. This estimation is based on known production capacities of main industries, typical hydrogen consumption ratios per unit of final product and the assumption of continuous full-load operation of the plants. Consequently, the estimates represent the maximum theoretical hydrogen demand in Kazakhstan, though actual annual demand is likely to be lower. The results of this assessment are presented in Figure 4 and Table 4, with further details provided in the following sections.

The current estimated hydrogen demand for major industrial applications in Kazakhstan is about 110 ktpa. This demand is expected to grow significantly in future, driven by the development of new production facilities for fertiliser (ammonia and urea), methanol and planned expansions in oil refining capacity. If all proposed projects are successfully implemented, Kazakhstan's hydrogen demand is projected to triple, reaching an estimated 359 ktpa by around 2030.

FIGURE 4. Estimated local hydrogen demand in Kazakhstan



Source: Authors' own compilation, Fichtner (2025)

TABLE 4. Estimated local hydrogen demand in Kazakhstan

Product	Specific H_2 demand [t_{H2}/t product]	Local capacity [Mtpa]	Potential H_2 demand [Mtpa]
Petroleum refining	0.003	18	0.059
Fertilisers (various)	various	1.4	0.042
Chemical MTBE	0.069	0.08	0.005
Food (vegetable oils)	Various	0.3	0.001
Total	-	-	0.11

Source: Authors' own compilation, Fichtner (2025)

The fertiliser industry

Kazakhstan's fertiliser industry is expanding, driven by its abundant reserves of raw materials such as phosphates, potash and natural gas. Nitrogen fertilisers are primarily produced using natural gas as a feedstock. The country is prioritising increased production to support domestic agriculture and boost exports, particularly to neighbouring countries, as fertiliser demand grows across Central Asia and beyond.

In 2023, Kazakhstan imported 25 ktpa of nitrogen-based chemical fertilisers, with 95% sourced from Russia, and exported 14 ktpa, 96% of which went to Poland (WITS, 2025b). Furthermore, the country imported 61 ktpa of urea (69% from Russia) and exported 39 ktpa (97% to Poland) (WITS, 2025e).

Production is highly concentrated, with 96% covered by two companies: Kazphosphate (in Zhambyl region) and KazAzot (in Mangystau region) (AIFC, 2024). Table 5 shows the location, production capacities and estimates for hydrogen demand for key players in the fertiliser industry.

The current installed capacity of Kazakhstan's two main fertiliser producers totals 1,400 ktpa, with 400 ktpa dedicated to ammonium nitrate and 1,000 to monoammonium phosphate. The hydrogen demand for this capacity is estimated at 42 ktpa[4] . Both companies currently use natural gas as feedstock for their processes.

Several expansion projects are underway, including those by KazAzot and Zhaik Petroleum, which will significantly boost production capacity in the short-term. The urea production plant announced by KMG and China's CNPC will be located at the Zhanazhol gas processing plant and is planned to be commissioned by 2029. Hydrogen demand, estimated for a total production capacity of 700 ktpa ammonia (KazAzot and Zhaik) and 1,200 ktpa urea (KMG + CNPC), comes to 244 ktpa.

TABLE 5. Main fertiliser plants in Kazakhstan

Company	Location	Status	Capacity [ktpa]	Estimated hydrogen demand [ktpa][2]
KazAzot	Aktau	Current	AN: ~400	16
		Planned	NH_3: 660 Urea: 577.5 AN: 500 HNO_3: 395	For NH_3: 117
Kazphosphate (Mineral Fertilisers Plant)	Taraz	Current	Ammophos[3] MAP: ~1000	26
Zhaik Petroleum	West Kazakhstan Oblast	Planned	NH_3: 40 Urea: 100	For NH_3: 7
KMG + CNPC Zhanazhol	Aktobe	Planned	Urea: 1,200	120

2 The estimations are indicative, as they take no account of processes' efficiencies or part load operation. Specific requirements of 0.177 t_{H2}/t_{NH3} have been taken into account.
3 Ammophos is a type of phosphatic fertiliser that contains ammonium and phosphate, typically in the form of monoammonium phosphate (MAP) or diammonium phosphate (DAP).
4 Indicative, as neither processes' efficiencies nor part load operation are taken into account.

Source: Authors' own compilation, Fichtner (2025), based on (Kazenergy, 2023), (World Fertilizer, 2023), (Kazphosphate, 2024), (kz.media, 2024)

The chemical industry

Kazakhstan's chemical industry is diverse, but has a strong focus on petrochemicals, given the country's vast hydrocarbon reserves. However, the sector also produces basic chemicals, sulphuric acid and other industrial chemicals, often linked to the mining and metallurgy sectors.

State-owned companies such as KMG and United Chemical Company (UCC) play a significant role in Kazakhstan's chemical industry. Table 6 provides an overview of key players, with details of location, products, status of the plants and capacities.

Production of MTBE using methanol requires the indirect use of hydrogen. Of the companies listed, this applies to Neftekhim and Shymkent Chemical Company. Most of the hydrogen requirements in Kazakhstan's chemical sector are tied to processes integrated with oil refining, such as oil refining itself and methanol production for MTBE production.

At present, Kazakhstan has no domestic methanol production facilities and so relies on imports to meet its methanol requirements. In 2023, the country imported 33 ktpa of methanol (WITS, 2025a).

Given the current MTBE production capacity of 77 ktpa, an estimated 5 ktpa of hydrogen would be required if green methanol were used as precursor.

Furthermore, with the planned construction of a 130 ktpa-capacity methanol plant, expected to be operational in 2029, an estimated 25 ktpa of additional hydrogen will be required for the production process.

For other chemicals, Kazakhstan meets its demand primarily through imports, though consumption levels remain relatively low. In 2023, for instance, the country imported just 142 tonnes of hydrogen peroxide and 1,000 tonnes of phenol (WITS, 2025c).

TABLE 6. Main chemical plants in Kazakhstan

Company	Location	Product	Status	Capacity [ktpa]
KPI Inc.	Atyrau Oblast	Polypropylene	Operational	500
Neftekhim Ltd	Pavlodar Oblast	MTBE, polypropylene	Operational	20 70
SAT Operating Aktau	Aktau city	Polystyrene	Operational	200
Shymkent Chemical Company	Shymkent city	MTBE	Operational	57
JSC Caustic	Pavlodar city	Caustic soda, chlorine, hydrochloric acid	Operational	30 26 45
KMG PetroChem	Atyrau Oblast	Ethylene, polyethylene	Planned	1,250
Zhaik Petroleum	West Kazakhstan Oblast	Methanol	Planned	130
Westgasoil Pte	Atyrau Oblast	Olefins	Planned	800
Almex Polymer	Shymkent city	Polypropylene	Planned	80
Almex Petrochemical	Atyrau Oblast	Terephthalic acid, polyethylene terephthalate	Planned	600 430
Butadien	Atyrau Oblast	Butadiene rubber	Planned	187
Topan Chemical Industries LLP	Aktau city	Caustic soda	Planned	54

Source: Authors' own compilation, Fichtner (2025), based on (Kazenergy, 2023), (Neftekhim, 2025), (Caustic, 2025), (Kazakh Invest, 2025b)

The steel and metallurgy industry

Driven by its abundant natural resources, particularly iron ore and coal, Kazakhstan's steel industry is a significant sector within the country's industrial economy. Regions such as Kostanay, Karaganda, and Aktobe are home to major iron ore deposits. In 2023, crude steel production in Kazakhstan was about 4.2 Mtpa (WorldSteel Association, 2025). Table 7 provides an overview of the main steel and metallurgy plants in Kazakhstan, specifying their location, products and installed capacities.

Based on GIZ research, Qarmet has rolling mill production and a daily hydrogen production volume of 350 m^3, which roughly corresponds to 0.28 ktpa.

Based on the information currently available, Kazakhstan has no operational DRI furnaces. However, as the industry considers expansion and modernisation, H_2-DRI remains a viable future technology. To illustrate potential hydrogen demand in the sector, if Kazakhstan's 4.2 Mtpa crude steel production in 2023 were entirely based on H_2-DRI, it would require approximately 252 ktpa of hydrogen.

Additionally, in the longer term, hydrogen could serve as a substitute for coal or natural gas in providing high-temperature heat for steelmaking and aluminium processes.

TABLE 7. Main steel and metallurgy plants in Kazakhstan

Company	Location	Product	Capacity [ktpa]
KSP Steel	Pavlodar	Steel	Pipes: 350
Qarmet	Temirtau	Steel	5,200
Kazchrome – Aksu Ferroalloys Plant	Pavlodar	Ferroalloys	1,000
Kazchrome – Aktobe Ferroalloys Plant	Aktobe	Ferroalloys	700
Aluminium of Kazakhstan JSC	Pavlodar	Alumina	1,400
Kazakhstan Aluminium Smelter JSC	Pavlodar	Aluminium	250
Ekibastuz FerroAlloys*	Ekibastuz	Ferrosilicon	80
TB Alloys Kazakh*	Taraz	Ferroalloys	100

* Planned

Source: Authors' own compilation, Fichtner (2025), based on (KSP Steel, 2024), (Qarmet, 2025), (Kazchrome, 2024), (GMK Center, 2024), (GTAI, 2024), (ERG, 2025)

Oil refineries

According to KazEnergy's national report, Kazakhstan's three main refineries – Atyrau, Pavlodar, and Shymkent – process approx. 17.5 million tonnes of oil annually, accounting for over 90% of the country's total refining throughput. The remaining output is processed by 34 smaller refineries, which, despite their limited individual capacity, play a crucial role in supplying fuel, primarily for agriculture (dena, 2023). One notable example is the Caspi Bitum Refinery in Aktau, with a capacity of 500 ktpa (Kazenergy, 2023).

Kazakhstan's Ministry of Energy has announced plans to expand the country's oil refining capacity by early 2030, focusing on upgrading the three major refineries. These expansions, outlined in Kazakhstan's Oil Refining Industry Development Concept for 2024-2040, aim to increase capacity by some 10 Mtpa (AstanaTimes, 2025): Atyrau Refinery - expansion to 6.7 Mtpa, Pavlodar Refinery - expansion to 8 Mtpa, Shymkent Refinery - expansion to 12 Mtpa.

Table 8 shows the main oil refineries in Kazakhstan, specifying their location, capacity and estimated hydrogen demand. The hydrogen demand for oil refining is highly dependent on the complexity of the refineries and the quality of the crude oil.

Estimates were calculated using a reference hydrogen requirement of 18,000 tonnes for the Atyrau Refinery (AirLiquide, 2021), which results in a specific requirement of 3.3 kg of hydrogen per tonne of oil. The estimates take no account of variations among the refineries.

A total hydrogen demand of 59.6 ktpa is estimated for the listed refineries. Modernisation work and expansion plans mean demand might rise due to increased processing capacity and more hydrogen-intensive pro cesses such as hydrocracking. The foreseen expansion of the three main refineries as mentioned above will result in a total hydrogen demand of 89.8 ktpa.

Several of these key mining resources require explosives for extraction. In recent years, the country has imported large volumes of explosives, amounting to some 5 ktpa (WITS, 2025d). Since explosives are essential to the mining processes, those based on ammonia could present a potential avenue for hydrogen consumption in the future.

TABLE 8. Main oil refineries in Kazakhstan

Refinery, company	Location	Capacity [ktpa]	Estimated hydrogen demand [ktpa]
Atyrau Refinery, KazMunayGas	Atyrau region	5,500	18
Pavlodar Refinery, KazMunayGas	Pavlodar region	6,000	20
Shymkent Refinery, KazMunayGas and China National Petroleum Corporation	Shymkent, Turkistan region	6,000	20
Caspi Bitum	Aktau, Mangistau	500	1.6

Source: Authors' own compilation, Fichtner (2025), based on (AMOZ, 2025), (KazMunayGas, 2024), (PetroKazakhstan, 2024), (Caspi Bitum, 2025), (Kazenergy, 2023)

The food industry

Kazakhstan's food industry is a significant part of the country's economy, contributing to both domestic consumption and export markets. With its vast agricultural resources, the sector is diverse, ranging from raw agricultural product processing to the production of more value-added food items. One major sector includes the vegetable oils of crops such as sunflowers, soybeans and canola. The process of refining these vegetable oils often involves hydrogen in the hydrogenation process.

Table 9 below provides an overview of key players in the vegetable oils sector in Kazakhstan, specifying their location, products and capacity.

While the production of raw vegetable oils does not directly require hydrogen, further refining and processing – such as hydrogenation for the production of margarine and other fats – does. Based on a total installed capacity of 259 ktpa, estimated hydrogen demand would range from 1 to 26 ktpa, depending on the specific final products.

TABLE 9. Main vegetable oil companies in Kazakhstan

Company	Location	Product	Capacity [ktpa]
Eurasian Foods Corporation	Almaty	Vegetable oils	25
Eurasian Foods Corporation	Karaganda	Margarine, fats, butter	110
Maslo-Del Company	Almaty	Vegetable oils	Refining: 73 Hydrogenation: 36.5

Source: Authors' own compilation, Fichtner (2025), based on (Eurasian Foods, 2023a), (Eurasian Foods, 2023b), (MASLODEL, 2024), (Made in Russia, 2016), (World of Nan, 2023)

The glass industry

Kazakhstan has abundant raw materials for glass production, such as silica sand, soda ash and limestone, which provide a strong foundation for domestic manufacturing. Despite these resources, Kazakhstan has historically relied on imports to meet its glass demand, most notably from Russia. However, efforts have been made in recent years to develop domestic production capacity. Table 10 provides an overview of the main companies in the sector, specifying their location, products and capacities.

Assuming a total production of 197 ktpa of float glass, the hydrogen demand for the process is estimated at 0.08 ktpa. There is potential demand for green hydrogen in this sector, albeit very low compared with sectors such as oil refining and ammonia production. And hydrogen could also be used in future as a fuel to provide high-temperature heat for manufacturing processes.

TABLE 10. Main companies in the glass industry in Kazakhstan

Company	Location	Product	Capacity
Orda Glass	Kyzylorda	Float glass, coated glass	197 ktpa
StekloMir	Pavlodar	Flat glass, mirrors	unknown
SAF Glass Company	Almaty	Glass bottles/containers	220 million units

Source: Authors' own compilation, Fichtner (2025), based on (Orda Glass, 2025), (StekloMir, 2025), (SAF Quazag Glass, 2024)

3.4 Industrial clusters and enabling infrastructure

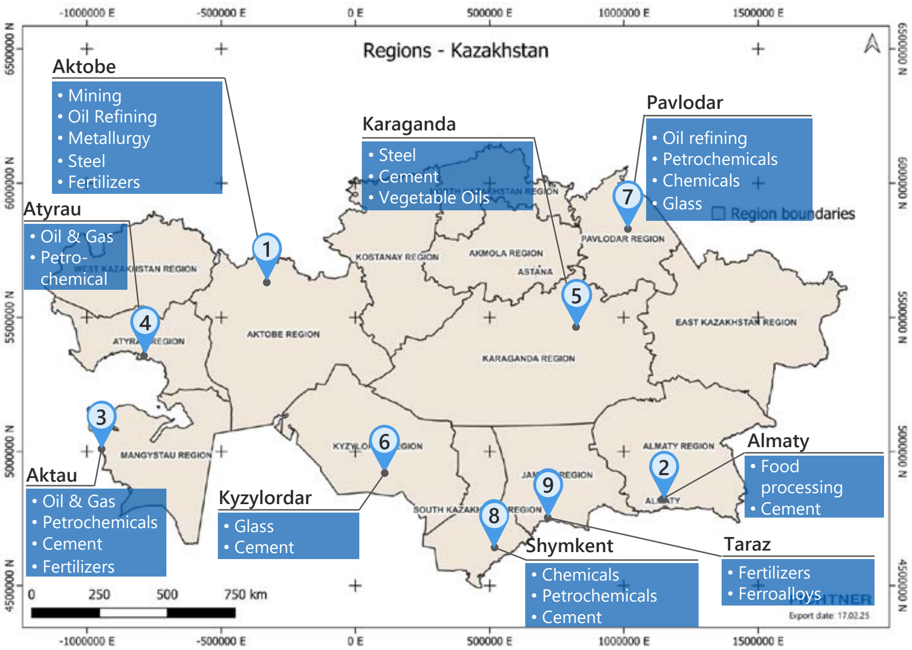
The main existing industrial clusters in Kazakhstan are depicted in Figure 5. It identifies nine clusters that are likely to use hydrogen and that offer potential for transitioning from grey to green hydrogen. Further details on the industrial clusters are provided in Annex 1 Details on industrial clusters.

Kazakhstan's industrial landscape is shaped by a network of key clusters that play a crucial role in the country's economic development. Identifying clusters with a higher likelihood of hydrogen use is the first step in assessing the short-term feasibility of transitioning from grey to green hydrogen.

It should also be noted that local availability of coal and natural gas may present economic challenges to the immediate adoption of green hydrogen. However, as decarbonisation efforts advance and global markets increasingly favour sustainable products, the viability of green hydrogen is expected to improve. A phased approach may be effective, starting with partial substitution in industries such as oil refining and fertiliser production, followed by gradual expansion as demand for sustainable solutions grows.

FIGURE 5. Main industrial clusters in Kazakhstan

Industrial Clusters



Key Companies

	Company	[kTPA]
1	**KMG + CNPC Zhanazhol** (Urea) **KazChrome** (Ferroalloys) **ERG** (Mining)	1,200 700 -
2	**Maslo del Company** (Vegetable Oils) **EFCO Almaty** (Vegetable Oils)	73 51
3	**KazAzot** (Fertilizer (AN)) **SAT Operating** (Polystyrene)	400 200
4	**KPI** (Polypropylene) **Atyrau Refinery** (Refinery) **Atyrau Refinery** (Aromatics)	500 5,500 630
5	**Central Asia Cement** (Cement) **Eurasian Foods** (Vegetable Oils)	2,000 110
6	**Orda Glass** (Glass) **Gezhuba Shieli** (Cement)	197 1,000
7	**Pavlodar Refinery** (Refinery)	6,000
8	**Shymkent Refinery** (Refinery) **Shymkent Cement** (Cement)	6,000 1,200
9	**KazPhosphate** (Fertilizer (MAP)) **TB Alloys Kazakh** (Ferroalloys)	1,000 100

Source: Authors' own compilation, Fichtner (2025)

The industrial clusters represented in Figure 12 above represent some of Kazakhstan's key industrial hubs. While other zones are emerging, these clusters are among the most significant due to their strategic location, industrial base and infrastructure connectivity. The following overview of key enabling infrastructure offers an initial assessment of the feasibility of industrial expansion and the integration of new technologies, such as green hydrogen.

- **Grid connection:** all clusters are connected to Kazakhstan's power grid, ensuring a stable power supply. However, the country's ageing energy infrastructure has led to shortages in the recent past. In response, Kazakhstan has outlined plans for new power generation capacity and modernisation of existing power plants, taking into account the expansion of renewable energy in selected regions.
- **Water supply:** while all clusters have access to regional water sources, growing industrial demand is raising concerns over long-term water availability. Seasonal fluctuations further impact supply. Regions such as Aktau have limited freshwater sources and rely on water desalination. For those clusters located near the Caspian Sea, installation of new desalination plants and extension of water distribution networks could provide a sustainable solution.
- **Transport infrastructure:** each cluster benefits from well established road networks, some of which form part of international transit corridors (e.g. Almaty and Aktau). Moreover, Kazakhstan's rail network ensures connectivity between major cities and international markets, with some clusters positioned along the Trans-Caspian International Transport Route (also known as the Middle Corridor), which links Central Asia to Europe. There are plans to expand railway capacity in future to enhance the corridor's efficiency and competitiveness, promoting the connectivity of the clusters.
- **Gas and oil infrastructure:** Kazakhstan's existing oil and gas pipeline network offers a potential strategic advantage for the future hydrogen economy. As green hydrogen and synthetic fuels develop, pipeline repurposing could become a viable solution for transport and distribution.
- **Ports:** clusters near the Caspian Sea benefit from port access, creating opportunities for trade and export. As the Middle Corridor expands, additional port capacity upgrades may be required. The Port of Kuryk is expected to play a key role in supporting storage, transport and export of clean hydrogen and ammonia. A partnership is already underway between Hyrasia One and Semurg Invest, operator of the Sarzha Marine Terminal at Kuryk, to facilitate future hydrogen exports (Kazinform, 2023).

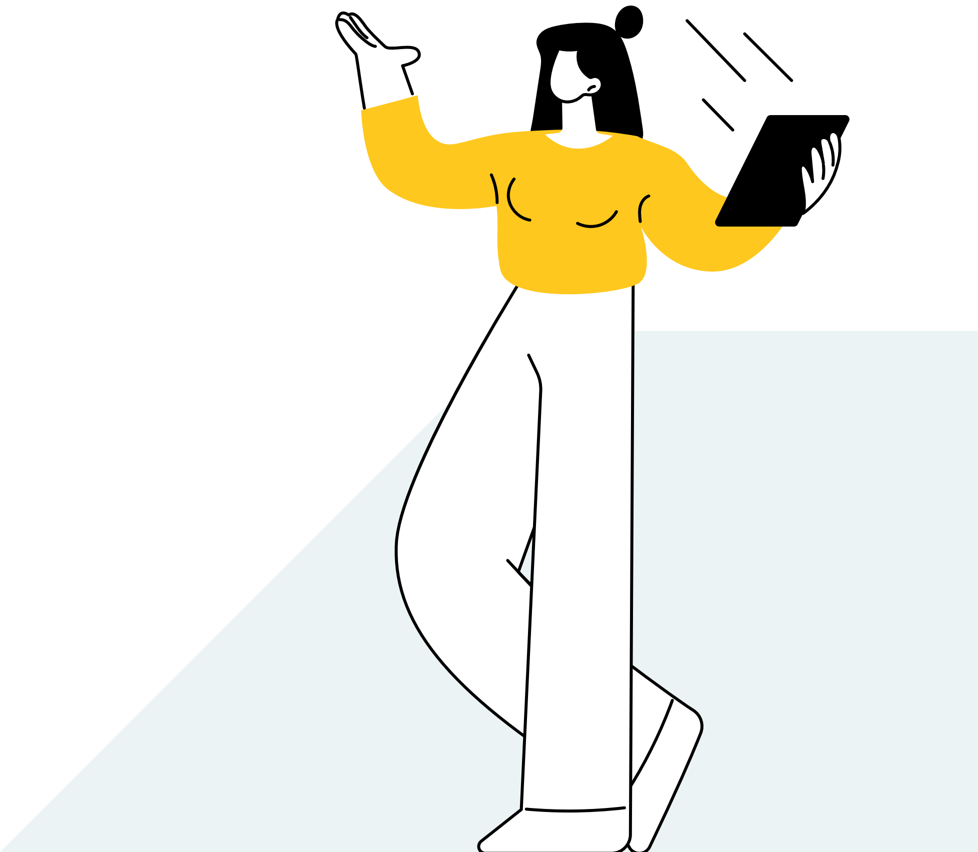
3.5 Pilot projects

Kazakhstan is making significant strides in developing its green hydrogen sector, with multinational companies like Svevind already exploring major investments in large-scale projects. Several key infrastructure developments are currently underway, underscoring the country's commitment to this emerging industry (Carnegie Politika, 2024). The country could use these kinds of projects to position itself as a green hydrogen hub in Eurasia.

The following are some pilot projects under evaluation or in progress:

- **Aksai Pilot Project:** a collaboration arrangement between KMG Engineering and Green Spark, featuring a 25 kW electrolyser, powered by solar PV for electricity supply (KMG, 2022).
- **Memorandum of Understanding:** signed between Green Spark, Kazakhstan's Green Hydrogen Alliance, and L.N. Gumilyov Eurasian National University to advance hydrogen project development (Green Spark, 2024).
- **KMG initiatives:** KMG plans to implement pilot projects at its refineries and in chemical production. The company has also established a department focused on alternative energy (including blue and green hydrogen) and launched the Hydrogen Technologies Research Laboratory (RIFS, 2024).

In addition to these pilot projects and early hydrogen supply chain activities, consideration is also being given to large-scale projects, such as the Hyrasia One project in Mangystau Region. Developed by German company Svevind, this initiative combines 40 GW of wind and solar power with a view to producing up to 2 Mtpa of green hydrogen by 2030. The project is currently in the conceptual engineering stage and the final investment decision is expected in 2026 (dena / AHK Central Asia, 2022).



3

Green hydrogen potential in Kazakhstan and use cases

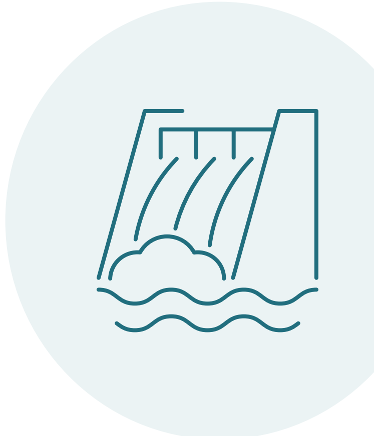
Kazakhstan has the potential to become a major producer of green hydrogen by leveraging its renewable energy resources, strong industrial base and strategic geographical location. With significant hydrogen demand in oil refining and ammonia, as well as proximity to major international markets in Europe and Asia, Kazakhstan is well positioned to develop a competitive hydrogen industry.

4.1 Renewable resource potential within Kazakhstan

Kazakhstan offers exceptional renewable energy potential that could be harnessed for green hydrogen production. The country's vast land area, high solar radiation, strong wind corridors and access to hydropower create a strong foundation for developing a large-scale hydrogen economy.

- **Solar resources:** Kazakhstan receives high levels of solar irradiation, particularly in the southern and central regions, with global horizontal irradiance (GHI) exceeding 5 kWh/m^2/day. These conditions make PV power a viable and scalable energy source for hydrogen production through electrolysis.
- **Wind resources:** the country has some of the greatest wind potential in Central Asia, particularly in regions such as Zhambyl, Akmola, and Mangystau, where wind speeds often exceed 7 m/s. Kazakhstan's large open steppe landscapes provide ideal conditions for utility-scale wind farms, which could provide a stable supply of electricity for green hydrogen production.
- **Hydropower:** while hydropower plays a smaller role in Kazakhstan's electricity mix than fossil fuels, existing hydropower plants along the Irtysh and Ili rivers could provide supplementary power for green hydrogen production, particularly in regions where solar and wind energy may fluctuate seasonally.

Water availability is another key factor in hydrogen production. While Kazakhstan has several major rivers and lakes, such as the Irtysh, Syr Darya and Balkhash, water scarcity is a growing concern, particularly in southern and western regions. Since electrolysis requires significant water input, localised water shortages and competing demands from agriculture and industry may necessitate desalination or wastewater recycling solutions to ensure a sustainable water supply for green hydrogen production. However, desalination costs are expected to represent only a small fraction of the total levelised cost of hydrogen and should not pose a major barrier to large-scale project implementation.



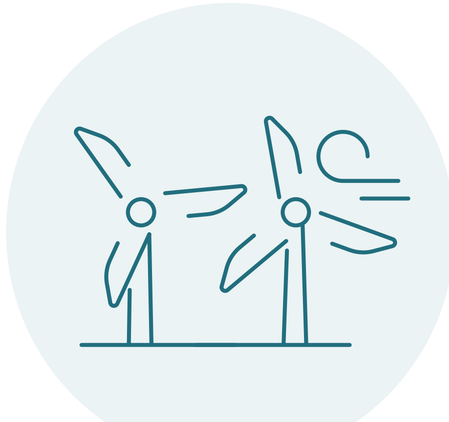
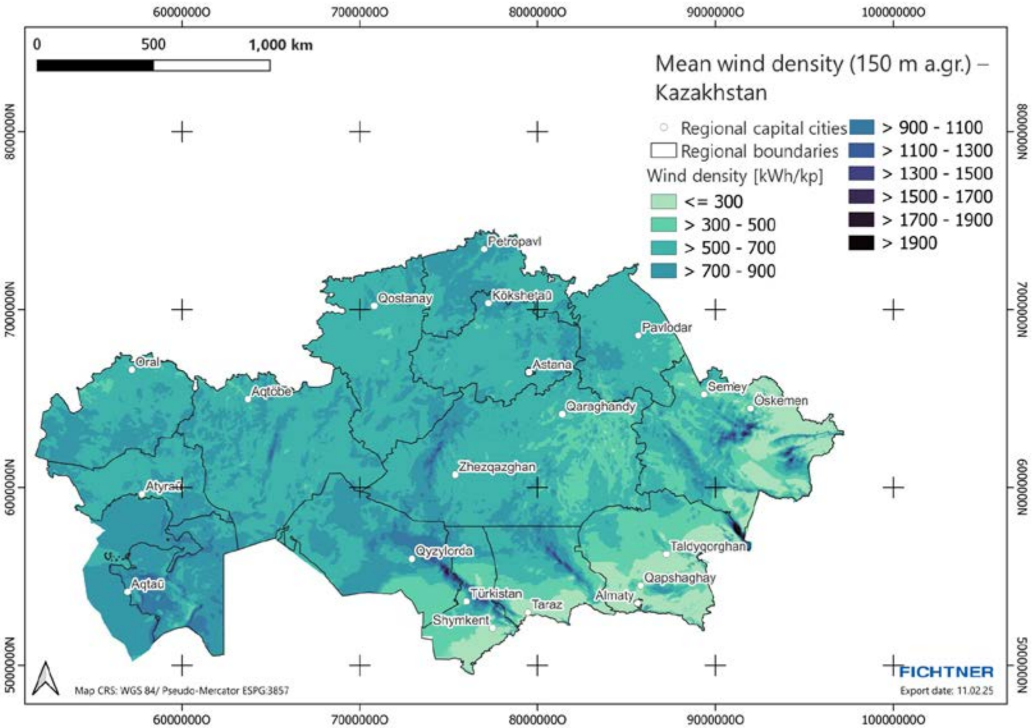
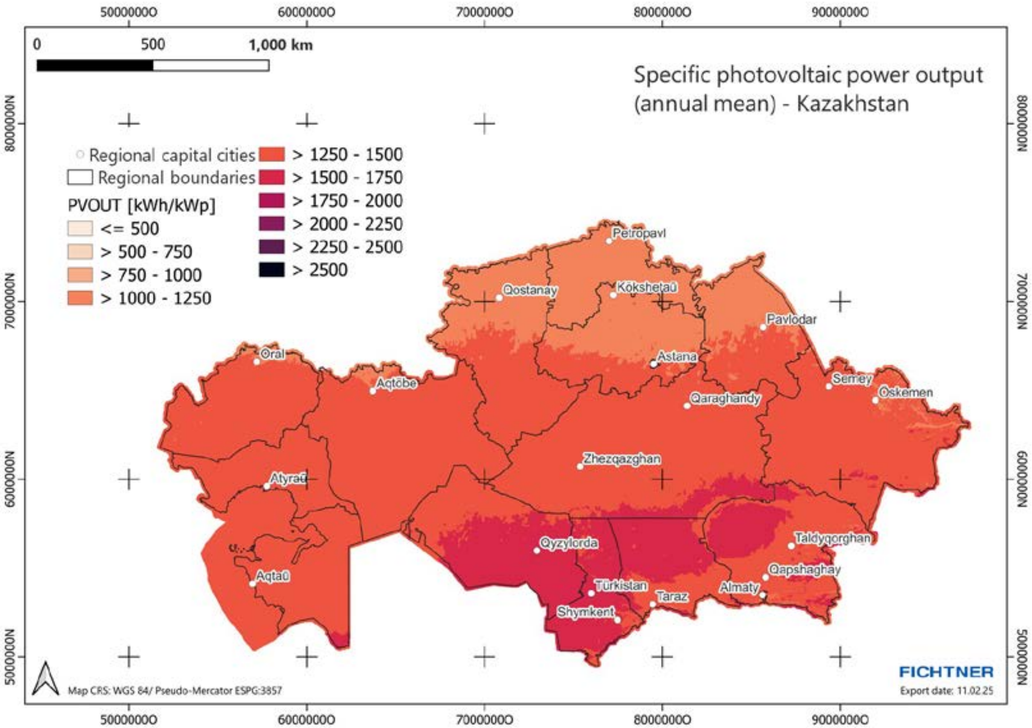


FIGURE 6. Mean wind power density and specific photovoltaic power output



Source: Authors' own compilation, Fichtner (2025) based on (Neil N. Davis, 2024)[5]



Source: Authors' own compilation, Fichtner (2025) based on (Global Solar Atlas, 2024)[6]

5 Data obtained from the Global Wind Atlas version 3.3, a free, web-based application developed, owned, and operated by the Technical University of Denmark (DTU). The Global Wind Atlas version 3.3 is released in partnership with the World Bank Group, utilising data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalwindatlas.info

6 Data obtained from the Global Solar Atlas 2.0, a free, web-based application developed and operated by Solargis s.r.o. on behalf of the World Bank Group, utilising Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalsolaratlas.info

4.2 Potential use cases

Kazakhstan's industrial landscape presents several opportunities for green hydrogen integration, although its current hydrogen demand remains relatively modest compared with major global markets. The country's primary hydrogen consumption is concentrated in oil refining, fertiliser production and petrochemicals, with smaller applications in glass manufacturing, vegetable oil processing and explosives for the mining sector. As the hydrogen economy develops, additional use cases may emerge, particularly in steel, cement and chemical production. These potential applications can be categorised into **small-scale** and **large-scale projects**, aligning with global trends in hydrogen market development.

Small-scale use cases (electrolyser capacity: 1+ MW)

Small-scale green hydrogen projects serve industries with moderate hydrogen demand or decentralised production needs. These set-ups prioritise on-site or near-site generation to minimise logistics costs and seamlessly integrate with existing processes.

Electrolysers will then typically be powered by local wind or solar PV plants, supported by battery energy storage or hydrogen storage to manage fluctuations in electricity supply and hydrogen demand. In most cases, hydrogen is consumed directly on-site, ensuring efficiency and reliability.

Typical small-scale applications include electronics, speciality glass production, welding processes and the food industry, either for hydrogenation or as protective gas in food packaging. Potentially promising applications in Kazakhstan include:

1. **Food industry – hydrogenation of vegetable oils**

   Kazakhstan has a large vegetable oil industry, producing sunflower, soybean and canola oils. Hydrogen is commonly used in the hydrogenation process, which modifies fats to improve stability and shelf life for margarine, processed foods and other edible products. Major vegetable oil processors in Kazakhstan, such as Eurasian Foods Corporation (Almaty and Karaganda), Maslo-Del Company (Almaty), and EFCO Almaty LLP, could integrate on-site hydrogen production to decarbonise hydrogenation processes. While the industry's overall hydrogen demand is relatively small compared with other sectors, switching from fossil-based hydrogen to green hydrogen would align it with global sustainability trends and future regulatory requirements.

2. **Glass manufacturing**

   Kazakhstan's glass manufacturing sector is small, but expected to grow. Key players such as Orda Glass (Kyzylorda), StekloMir (Pavlodar) and SAF Glass Company (Almaty) produce float glass, coated glass and container glass. Hydrogen is used in glass furnaces as a reducing agent and to achieve high-temperature processing.

   While total hydrogen demand for glassmaking is currently low, the industry could benefit from on-site green hydrogen production, particularly as new environmental regulations encourage low-emission industrial processes.

3. **Speciality chemicals and petrochemicals**

   Kazakhstan's chemical industry primarily focuses on petrochemicals and industrial chemicals, with companies such as KazMunayGas (KMG), United Chemical Company (UCC) and Neftekhim Ltd. producing polypropylene and MTBE. Hydrogen is an essential feedstock in these industries, especially for refining processes. Currently, Kazakhstan has no domestic methanol production and so has to meet demand through imports. The planned Zhaik Petroleum methanol plant will require on-site hydrogen production, providing an opportunity for integrating green hydrogen into chemical manufacturing.

Large-scale use cases (electrolyser capacity: 10 MW and above)

Large-scale green hydrogen projects serve industries with high and ongoing hydrogen demand, maximising economies of scale through larger electrolyser installations and optimal utilisation of wind and solar resources.

These projects typically pair large renewable energy facilities with nearby large-scale electrolysers, supported by infrastructure for electricity transmission, water supply, wastewater management and hydrogen storage and transport to off-takers or ports. Extensive hydrogen storage is essential either to offset production fluctuations without disrupting downstream processes or to accommodate the periodic nature of maritime transport for export-oriented projects.

Unlike smaller-scale projects, large electrolysers are housed in dedicated buildings, as containerised solutions are more common for smaller installations. In some cases, desalination units may be required to ensure a sustainable water supply, depending on local availability.

Typical large-scale applications include ammonia and fertiliser production, chemicals (incl. methanol) and crude oil refining. In future, iron and steel and cement may also emerge as major hydrogen consumers.

The primary opportunities in Kazakhstan include:

1. Ammonia and fertiliser production

- Kazakhstan has a growing fertiliser industry, with production primarily carried out by KazAzot (Mangystau region) and Kazphosphate (Zhambyl region).
- Current fertiliser production relies on natural gas-based hydrogen; transitioning to green hydrogen could significantly reduce emissions and align the industry with sustainability trends in global agriculture.
- The country is increasing its fertiliser production capacity to support domestic agriculture and exports to neighbouring countries. By integrating green hydrogen into ammonia synthesis, Kazakhstan could enhance its competitiveness on the global fertiliser market.

2. Refining and petrochemicals

- Kazakhstan's oil refining sector is a major hydrogen consumer, with its three largest refineries – Atyrau, Pavlodar and Shymkent – processing approximately 17.5 Mtpa of crude oil.
- Hydrogen is essential for hydrotreating and hydrocracking processes, which remove sulphur and improve fuel quality. Current hydrogen supply is primarily derived from natural gas, but the transition to green hydrogen could help refineries meet stricter international environmental standards.
- Planned expansion in the refining sector will increase hydrogen demand, making it a strategic sector for green hydrogen integration.
- Additionally, Kazakhstan's chemical industry, including planned methanol and olefins production facilities, could benefit from green hydrogen as a feedstock, reducing reliance on imported methanol and petrochemicals.

Techno-economic calculations of the use cases

To provide a preliminary indication regarding the techno-economic feasibility of projects of varying scales, three different scenarios have been assessed for direct hydrogen use in Mangystau Region, which contains the Aktau industrial cluster, where fertilisers are currently produced. Here, a transition to green hydrogen could be considered in the short term. For these selected cases, the analysis examined the levelised cost of hydrogen and ammonia based on different renewable energy mixes of PV and wind to fulfil a particular annual hydrogen demand. Different electrolyser sizes were used. The main results from these three cases are summarised in the following table. These results are based on exemplary renewable profiles at the location (43.7284° N, 51.2872° E). It should be noted that the results may vary significantly if industries in other parts of the country (with different nearby wind resources, for instance) are chosen or if utility scale projects with significantly larger component sizing are planned.

TABLE 11. Techno-economic calculations for direct hydrogen use cases

Case	Small-scale H_2 (wind & PV)	Small-scale H_2 (PV only)	Large-scale H_2 (wind & PV)
Demand (H_2) in tonnes/a	45	45	450
Installed RE (capacity) in MW	PV: 0.4 Wind: 1	PV: 4.2	PV: 5.3 Wind: 6.0
Electrolyser size in MW	0.5	1.2	4.9
Weighted average cost of capital (WACC) (%)	7.1	7.1	7.1
Total investment in million USD	3.6	7.5	27.1
Oxygen sales in million kg	0.35	0.35	3.5
Excess RE sales/ consumed in GWh[7]	1.3	2.6	6.9
LCOH grey (USD/kg)	2.0	2.0	2.0
LCOH proposed case/ green (USD/kg)	6.6	16.2	4.4
Project IRR in %	2.6	–2.1	4.6
Net present value (NPV) in million USD	–1.0	–3.7	–4.2

Source: Analyses performed by GIZ (2025)

7 Excess RE is calculated for the value chain including ammonia. If only H_2 is to be produced, the amount of excess renewables can be increased by ~5%.

The complete assumptions, sizing, cost breakdown, financial parameters and results are detailed in Annex 3 Techno-economic calculations. Based on the results presented in the table above, the following conclusions can be drawn:

- **Resource utilisation and cost analysis:** the 'Small-scale H_2 (PV only)' case requires a significantly larger electrolyser than the 'Small-scale H_2 (wind & PV)' case and so has the highest levelised cost. The green LCOH for the 'Small-scale H_2 (wind & PV)' and 'Large-scale H_2 (wind & PV)' cases are approximately 220% and 150% higher respectively than the current grey hydrogen costs.
- **Financial viability:** with a very low LCOH for grey hydrogen (2.0 USD/kg), which takes into account external supply from a third party (no own production), the 'Large-scale H_2 (wind & PV)' case shows the lowest finance gap[8] of the analysed scenarios at USD 2.4 per kg of hydrogen and the highest IRR (4.6%). This makes it the most financially feasible option for implementation based on these estimates. Lower LCOHs for grey hydrogen will increase the finance gap accordingly. By leveraging a single funding source or a mix of sources described in more detail in section 4.3, the finance gap could be closed, rendering the project economically feasible.

8 Defining finance gap as the difference between LCOH for green hydrogen and LCOH for grey hydrogen.

Given that Kazakhstan's current hydrogen use is directly linked to oil refining and ammonia-based fertiliser production, a complementary techno-economic analysis has been conducted for three ammonia use cases that align with the hydrogen use cases presented above. The results are summarised in the following table.

TABLE 12. Techno-economic calculations for ammonia use cases

Case	Small-scale NH_3 (wind & PV)	Small-scale NH_3 (PV only)	Large-scale NH_3 (wind & PV)
Demand (NH_3) in tonnes	270	270	2,700
Installed RE (capacity) in MW	PV: 0.4 Wind: 1	PV: 4.2	PV: 5.3 Wind: 6.0
Electrolyser size in MW	0.5	1.2	4.9
WACC (%)	7.1	7.1	7.1
Total investment in million USD	4.3	8.2	31.4
LCOA grey (USD/kg)	0.7	0.7	0.7
LCOA proposed case (USD/kg)	1.7	3.4	1.1
Oxygen sales in million kg	0.35	0.35	3.5
Excess RE sales/ consumed in GWh	1.3	2.6	6.9
Project IRR (%)	2.8%	-4.2%	5.2%
NPV in million USD	-1.2	-3.9	-3.8
Finance gap (USD/kg)	1.0	2.7	0.5

Source: Analyses performed by GIZ (2025)

- **Cost competitiveness:** the 'Large-scale NH_3 (wind & PV)' case presents the lowest green LCOA of all at USD 1.1 per kg, making it more competitive than the alternatives.
- **Financial feasibility:** despite having financial gaps and negative net present values in all scenarios, the 'Large-scale NH_3 (wind & PV)' case has the smallest finance gap at USD 0.5 per kg of ammonia, highlighting its potential for large-scale implementation. As with hydrogen, the remaining gap could be closed by leveraging funding mechanisms.
- **Investment returns:** although the project IRR is modest across all cases, the 'Large-scale NH_3 (wind & PV)' case offers the highest return at 5.2%.

Overall, and based on current assumptions, the results provide a general rationale of larger projects being more cost efficient than small-scale ones. Nevertheless, they also require higher initial investment, while the lower LCOH is still not enough to offset it and reach a positive NPV. It is thus clear that these projects are not economically feasible in the short term without intensive funding. From a funding perspective, it may be more feasible to opt for small-scale projects, as the funding required to set up these projects is lower in absolute value terms, though this is highly dependent on the funding scheme that is to be used.

It is important to note that the aforementioned options provide an estimate of potential green hydrogen and ammonia costs. However, cost evaluations should be conducted on a project-by-project basis, as factors such as the local renewable profile and the required industry's offtake profile (the analysis above is based on a constant profile) can significantly influence the levelised cost, particularly due to their impact on the sizing of the electrolyser and storage system required. This effect is smaller for ammonia than for hydrogen, as the former has significantly smaller storage costs. Additionally, securing an off-taker for the produced oxygen can be challenging, as revenue from the sale of this byproduct does not generally justify investment in extensive transport infrastructure. The calculation also takes account of the fact that the full amount of renewable electricity generated could be sold to the associated industry for an average price of USD 60 MWh, depending on the technology feeding into the grid. The industries will most likely be interested in purchasing the otherwise curtailed renewable electricity. However, this might not always be the case, and without the sales of excess renewables, the implementation of battery storage might become an option. In certain scenarios, it may also be feasible to derive additional benefits from using the electrolyser's waste heat for applications such as district heating or industrial pre-heating processes and to conclude a PPA with other renewables, for instance to make use of the constant renewable profile of existing hydropower assets.

4.3 Analysis of hydrogen production potential

For large-scale hydrogen production, it is essential to align renewable energy resources, water availability, export infrastructure and regulatory frameworks. Combined with its extensive land area, Kazakhstan's vast wind and solar potential provides a solid foundation for green hydrogen production. Given the good wind resources in central and western regions, high solar irradiation in the south and existing industrial hydrogen demand, Kazakhstan has the potential to develop a large-scale hydrogen economy. Additionally, the low population density of many of its regions reduces land-use conflicts, potentially lowering project development costs and making large-scale renewable energy installations more feasible.

Conversely, small-scale hydrogen projects require proximity to industrial end-users to minimise transportation costs and ensure economic viability. Industrial centres such as Aktau, Atyrau, Pavlodar, and Shymkent offer strategic locations for hydrogen pilot projects. These areas have existing energy and water infrastructure, as well as a concentration of industries (including oil refining and fertiliser production) that could integrate green hydrogen into their processes. Leveraging these established industrial clusters could help reduce investment costs and accelerate project implementation, enabling the progressive adoption of green hydrogen.

Kazakhstan's access to key trade routes, its extensive natural gas pipelines and its existing rail and port infrastructure leave the country well positioned to export green hydrogen and its derivatives, such as ammonia or methanol, to European and Asian markets. In the long term, Kazakhstan's extensive pipeline network, which currently supports its natural gas exports to China, Russia, and Europe, could be retrofitted or expanded to facilitate hydrogen transport, reducing the need for brand new infrastructure investments.

Nonetheless, challenges remain. Kazakhstan's cold winters and extreme seasonal temperature variations could impact renewable energy performance, requiring energy storage solutions to ensure year-round green hydrogen production. Water availability, particularly in the drier western and southern regions, could also pose challenges for scaling up electrolysis-based hydrogen production, necessitating investments in desalination or water recycling infrastructure.

4.4 Multi-criteria assessment for small-scale hydrogen projects

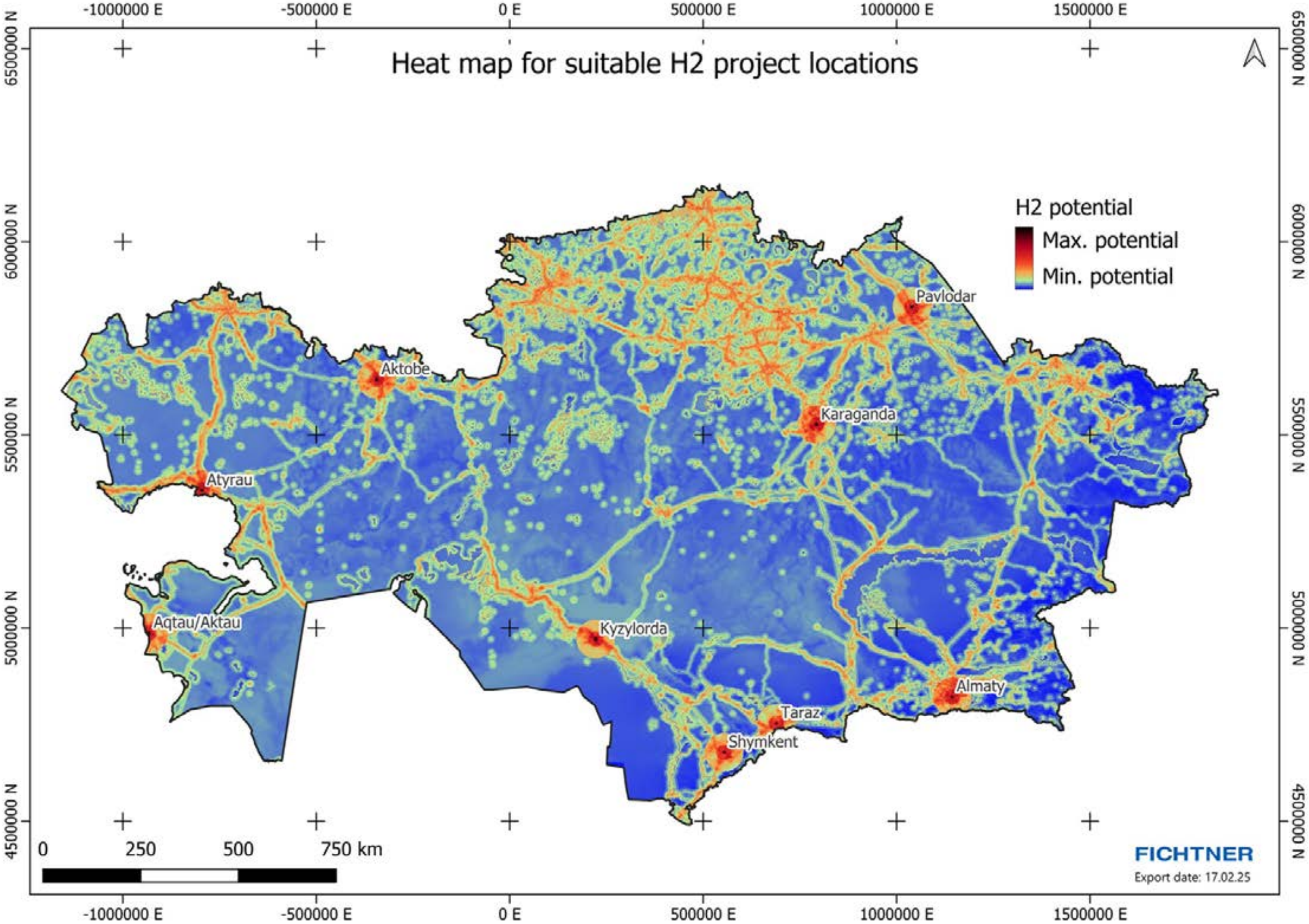
A multi-criteria assessment (MCA) was applied to identify optimal locations for small-scale hydrogen projects. The evaluation took account of the following:

- Renewable energy availability (wind and solar potential)
- Proximity to industrial clusters (potential off-takers)
- Access to water resources (for electrolysis)
- Connection to existing energy and transport infrastructure

Each criterion was assigned specific scoring thresholds based on factors such as distance from off-takers, high-voltage grid connections, water sources, roads and port facilities. Industrial proximity received the highest weighting, followed by grid access, renewable resource quality and water availability. Transportation infrastructure (roads and ports) was also factored in to assess export feasibility.

The results of the MCA are visually illustrated in Figure 7, highlighting high-potential areas in red as prime locations for engaging industrial off-takers and initiating project development. Areas with less favourable conditions are marked in blue, indicating greater development challenges.

FIGURE 7. Country heat map indicating potential locations for green hydrogen pilot projects



Source: Authors' own compilation, Fichtner (2025)

4

The way forward

The analysis of Kazakhstan's energy sector and its green hydrogen prospects reveals both opportunities and key challenges. While the country benefits from abundant coal, natural gas and oil reserves, its renewable energy potential for wind and solar PV remains underdeveloped, despite some progress over the past decade. A robust industrial base, with hydrogen requirements for oil refining, petrochemicals and fertilisers, creates a promising environment for green hydrogen development. Nonetheless, the current dominance of fossil fuels could undermine the competitiveness and adoption of green hydrogen without a dedicated legislative framework to promote decarbonisation.

5.1 Opportunities and supporting frameworks

Although Kazakhstan's energy mix is still heavily reliant on fossil fuels, integrating green hydrogen could drive industrial decarbonisation, enhance energy security and position the country as a key player in the emerging green hydrogen market, especially in light of global decarbonisation goals.

- **Renewable energy potential for green hydrogen production:** with significant solar PV and wind resources, Kazakhstan can generate the renewable electricity needed for large-scale green hydrogen production. Targeted investments in solar PV, wind and hybrid systems could ensure a stable power supply for electrolysis.
- **Strategic position for hydrogen exports:** Kazakhstan's strategic location between Asian and European markets, combined with its role in the Trans-Caspian International Transport Route, affords it an advantageous position for exporting green hydrogen to European markets.
- **Industrial applications for green hydrogen:** existing industrial sectors (such as oil refining, petrochemicals, ammonia and ammonia-based fertilisers) present immediate opportunities for adopting green hydrogen. These sectors, which already rely on hydrogen as a feedstock, are well positioned to transition to greener alternatives. Hydrogen could also support industries like steel and cement in future.
- **International partnerships and investment:** Kazakhstan's biggest trading partner is the EU. Multinational companies have already expressed interest in investing in Kazakhstan's green hydrogen projects, with Hyrasia One being a prime example. Such partnerships can accelerate technology transfer, infrastructure development and market expansion.
- **Job creation and social infrastructure development:** the transition to green hydrogen can drive local economic growth by diversifying the energy mix. Investments in renewable energy, water supply and transportation infrastructure will benefit both industry and local communities. Moreover, Kazakhstan's existing expertise in areas such as oil refining and petrochemicals could help to upskill the workforce, facilitating a smoother transition to clean energy technologies while generating new employment opportunities.

To fully unlock its green hydrogen potential, Kazakhstan needs a well-defined supporting framework that integrates policy, regulatory and technological measures. This framework will provide clarity for both local and international investors, ensuring that green hydrogen is effectively incorporated into national energy strategies.

- **Policy framework:** clear government policies must outline the role of green hydrogen in the national energy mix and set measurable targets for production and consumption. Kazakhstan already has a strong foundation with its 2013 green economy transition concept, the 2023 NDC and the development of a hydrogen concept in 2024 for the period up to 2030. These initiatives promote renewable energy projects and the industrial adoption of hydrogen technologies, including specific targets for production (e.g. 25 ktpa of hydrogen by 2030, at least 50% of which must be green), infrastructure and local use. These policies will need to be updated regularly to keep pace with market developments.
- **Regulatory framework:** Kazakhstan's current renewable energy and climate regulations provide a solid basis for integrating green hydrogen. To support this, recognised as an energy source and as an energy carrier in legislation, for instance in the Law on the Use of Renewable Energy Sources. Specific regulations governing hydrogen production, storage, transportation and quality need to be developed in line with international standards to facilitate cross-border trade and comply, for example, with the EU's Carbon Border Adjustment Mechanism as a key target market. Additionally, introducing financial support mechanisms such as tax breaks, subsidies or a carbon pricing mechanism would help to attract both local and foreign investment. State-owned enterprises like KMG are expected to play a key role in scaling up hydrogen projects, further supported by customised regulations.
- **Technology framework:** green hydrogen production offers a valuable opportunity to enhance Kazakhstan's large-scale renewable energy capabilities. The country's diverse industrial landscape offers a good technological foundation for further development along with numerous potential applications for green hydrogen, supporting economies of scale. Initiating pilot projects in specific industrial clusters would be beneficial for testing the integration of green hydrogen into existing processes and evaluating its scalability for broader deployment.

By establishing a comprehensive supporting framework, Kazakhstan could position itself as a competitive player in the green hydrogen economy, driving industrial growth and diversification and supporting both domestic industrial needs and export opportunities to Asian and European markets.

5.2 Challenges and considerations

There are a number of economic, technical and regulatory challenges when it comes to implementing green hydrogen technologies in Kazakhstan. Despite the country's industrial base and strategic location, key barriers remain, including the current dominance of fossil fuels, high production costs and a regulatory framework for hydrogen that is still in its infancy. Even if some of the challenges are global in nature, addressing them locally will require robust policy support, targeted investment and effective public-private collaboration.

- **Economic challenges:** high production costs for green hydrogen and the local availability of low-cost coal, natural gas and oil pose substantial economic hurdles for green hydrogen. Although industrial demand could be strong, primarily from the oil refining, petrochemical and fertiliser production sectors, it is difficult to make green hydrogen cost-competitive compared with fossil fuels, a situation that is compounded further by failing to meet specific sectoral targets for the adoption of green hydrogen. The uncertainty around the willingness of industrial off-takers to pay a premium for green hydrogen further complicates the market. Without committed, large-scale consumers and financial incentives, achieving economies of scale will prove challenging.
- **Technological challenges:** Kazakhstan's significant renewable energy potential for wind and solar PV remains underutilised, making it hard to secure a consistent, sustainable power supply for large-scale green hydrogen production. Moreover, the spatial separation between renewable generation sites and industrial hubs adds another layer of technical complexity to the development and operation of hydrogen projects. This will require major upgrades to the electricity transmission and distribution infrastructure and the integration of large-scale storage systems for both electricity and hydrogen.
- **Regulatory challenges:** while Kazakhstan has initiated strategic plans, including the green economy transition concept and the hydrogen development concept, the regulatory framework specifically tailored to green hydrogen is still taking shape. Clear, comprehensive regulations that address hydrogen production, storage, transportation and quality standards are essential to provide the certainty needed for investment. The current lack of dedicated legislative support and financial incentives may hinder the competitiveness and broader adoption of green hydrogen, especially when compared with established fossil fuel infrastructure. Although there is a national emissions trading system in place, CO_2 prices are too low (around USD 1/tCO_2) to offer any incentive for green products at present.

Despite these challenges, Kazakhstan possesses significant potential to lead on the regional green hydrogen market. By addressing economic, technical and regulatory barriers through targeted policy reforms, strategic investment and enhanced public-private partnerships, Kazakhstan could leverage its industrial strengths and untapped renewable energy resources to build a competitive, sustainable hydrogen economy.

5.3 Green hydrogen financing opportunities for German companies

The green hydrogen sector requires substantial financial investment to overcome high initial costs and infrastructure challenges. Several funding mechanisms exist to address this, as described below with selected examples:

German instruments for investment in the international market

- **International Hydrogen Ramp-up Programme** (H2UPPP) (BMWK, 2025): supports early-stage public-private partnerships for pilot projects, with a minimum public contribution of EUR 100,000 and total project costs of at least EUR 200,000. Companies must contribute at least 50%. Runtime of the program is 2024-2026 (BMWK, 2024).

- **UFK – Untied Loan Guarantees** (UFK-Garantien.de, 2025): provides loan guarantees to reduce political and economic risks in target countries. Green hydrogen projects may be eligible if they align with Germany's energy strategy.

European instruments for investment in the international market

- **Green Hydrogen Fund (GHF)** (European Investment Bank, 2025): the European Investment Bank (EIB) established this trust fund to support large-scale green hydrogen infrastructure projects through substantial investments. It requires a 30-40% contribution from applicants. Countries outside the EU, such as Kazakhstan, may be eligible, provided they meet the specific requirements of the fund at the time of application.

- **Kazakhstan Green Economy Financing Facility II** (GEFF, 2023): launched in 2023 with a budget of USD 150 million, it provides green financing to businesses and households. The facility also offers financing to vendors and producers of high-performing green goods and equipment. As of now, green hydrogen technologies do not seem to be eligible, but this could still be integrated into the programme as the market evolves and interest grows.

Multilateral instruments

- **MIGA (Multilateral Investment Guarantee Agency)** (MIGA, 2025): offers political risk insurance and credit guarantees for hydrogen investments in developing countries, focusing on projects with significant developmental impact. There is no strict minimum investment amount, but larger projects, especially those aligned with national development priorities, are likely to be prioritised.

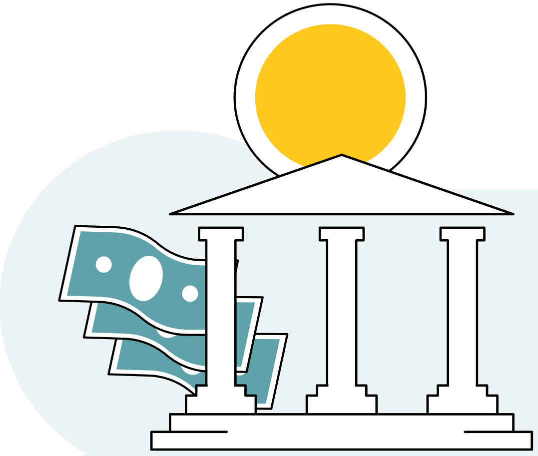
- **Global Environment Facility (GEF)** (Green Climate Fund, 2025): provides grants and concessional loans to help renewable energy projects, including green hydrogen, to achieve decarbonisation and environmental goals.

- **World Bank loans:** the World Bank runs a number of programmes and initiatives to promote implementation of renewable energies, including hydrogen. In 2023, for example, the bank reported that it had approved USD 1.6 billion in funding for renewable hydrogen loans in that year (World Bank Group, 2023).

- **International Finance Corporation:** is a member of the World Bank Group and the largest global development institution focused on the private sector in emerging markets. In 2024, IFC committed over USD 1 billion in the Central Asia region, including Kazakhstan, aiming to increase private sector participation, create jobs and support the green transition (IFC, 2024).

Private finance

- **HydrogenOne Capital Growth** (HydrogenOne, 2025): a private venture fund specialising in direct or indirect investments in hydrogen infrastructure and technology.
- **Breakthrough Energy Ventures** (Breakthrough Energy, 2022): Breakthrough Energy runs a number of programmes to support cutting-edge research and development by investing in companies with clean products to accelerate the clear energy transition.
- **Green bonds:** these bonds are fixed-income financial instruments designed to fund sustainable projects in areas such as renewable energies and clean transportation. There are different standards that can be applied, two of the most common being the Green Bond Principles issued by the International Capital Market Association (ICMA, 2025) and the Climate Bond Standard (Climate Bonds, 2025). In Kazakhstan, the issuance volume of green financial instruments amounted to KZT 150.2 billion by October 2023, with green bonds accounting for 75% and green loans for 25% (AIFC, 2023). The Astana International Financial Centre (AIFC) can facilitate the issuance of green bonds specifically targeted at hydrogen projects in Kazakhstan.



5.4 Next steps for German companies

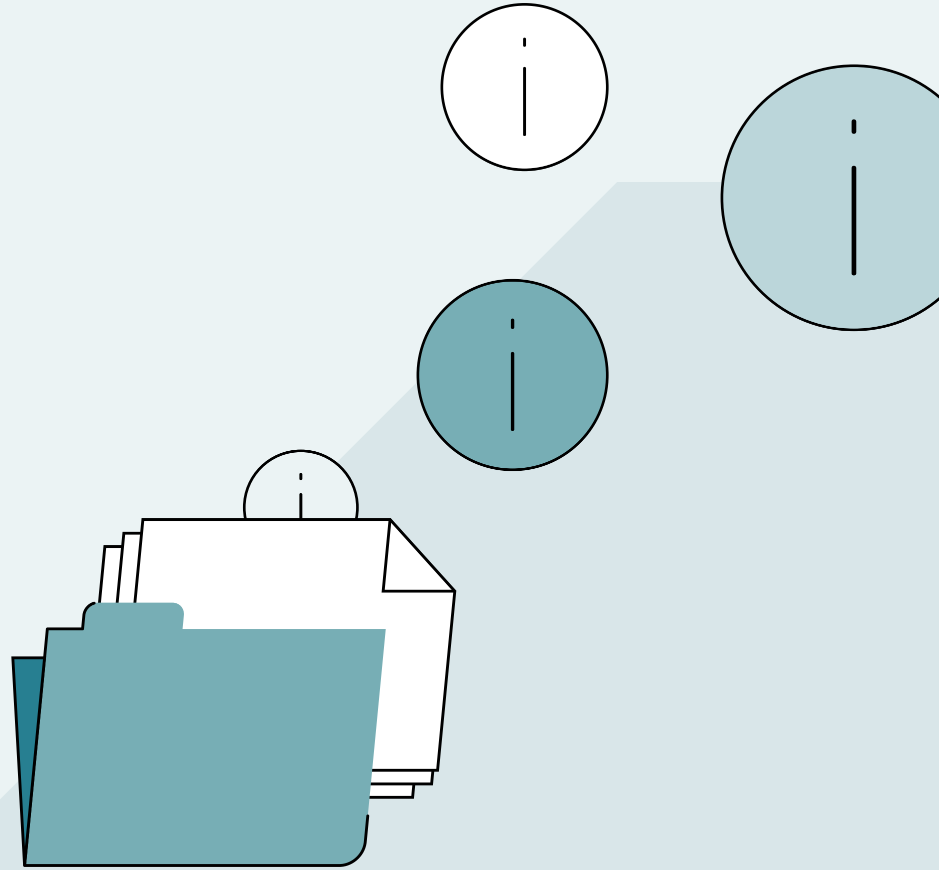
Kazakhstan is a promising location for green hydrogen development due to its vast potential for renewable energy generation from wind and solar resources, its substantial expertise in energy production and infrastructure, and its strategic geographic position linking Eastern and Western markets. While challenges such as high production costs, regulatory gaps and infrastructure limitations remain, a coordinated approach involving public and private investment, policy alignment and technological advancements could enable the country to emerge as a key player in the regional hydrogen market.

German companies interested in green hydrogen projects in Kazakhstan are recommended to take the following next steps:

1. **Engage with local stakeholders:** establish partnerships with key government bodies such as the Ministry of Energy, Ministry of Ecology, Geology and Natural Resources, and the Ministry of Industry and Infrastructural Development. Collaborate with organisations including JSC NC Kazakh Invest, JSC Samruk-Kazyna and relevant local authorities to stay informed about regulatory updates and investment opportunities.
2. **Leverage European and multilateral funding:** explore available financing mechanisms such as H2 Global, the Clean Hydrogen Partnership and the Green for Growth Fund (GGF) to secure funding and risk mitigation for green hydrogen projects. Additionally, consider engaging with the Astana International Financial Centre (AIFC) for structured finance solutions and green investment frameworks.
3. **Assess infrastructure and market viability:** conduct feasibility studies to evaluate electrolysis production potential, hydrogen blending with natural gas, and export logistics via pipelines and rail connections across Eurasia. Early-stage pilot projects in oil refining, ammonia and fertilisers could provide initial demand and scale-up opportunities.
4. **Monitor regulatory developments:** stay up to date with Kazakhstan's emerging hydrogen strategy, other energy plans and potential carbon pricing mechanisms to ensure compliance with evolving standards. Advocacy for hydrogen-specific legislation, tax incentives and streamlined permitting processes could further improve market conditions. Engage with the Committee on Regulation of Natural Monopolies and other regulatory bodies to understand policy development.
5. **Participate in pilot and R&D projects:** collaborate with leading Kazakh higher education institutions such as Nazarbayev University, as well as research institutions such as the Institute of Fuel, Catalysis, and Electrochemistry (IFCE). Develop and test hydrogen technologies, ensuring alignment with EU and international safety and efficiency standards.
6. **Collaborate with industry and NGOs:** network with industry associations such as the Renewable Energy Association of Kazakhstan (AREK) and relevant NGOs to foster a supportive environment for hydrogen initiatives. Engage with advocacy groups such as the Association of Environmental Organizations of Kazakhstan (AEOK) and the Green Hydrogen Alliance of Kazakhstan to promote hydrogen adoption and policy support.

Taking these steps will enable German companies to position themselves at the forefront of Kazakhstan's green hydrogen market, capitalising on early-mover advantages while supporting the country's transition to a sustainable energy economy.

Annexes



Details on industrial clusters

Table 13 shows the main existing industrial clusters across the country, selected based primarily on a higher likelihood of hydrogen use. In these clusters, one or more of the following sectors have been identified: petroleum refining, ammonia and ammonia-based fertilisers, methanol or derivatives production, vegetable oil and fats processing, and flat glass manufacturing. The table is ordered alphabetically and includes the location of the clusters, the main sectors, key products and main companies in each cluster.

TABLE 13. Main industrial clusters in Kazakhstan

Cluster	Location	Main sectors	Key products/main companies
1 Aktobe	Aktobe	Mining, oil refining, metallurgy, steel, fertilisers*	Compounds for metallurgy, phosphates, steel, urea* Aktobe Ferroalloys Plant (Kazchrome), Eurasian Resources Group (ERG), Kazchrome Ferroalloy plant, KMG+CNPC Zhanazhol*
2 Almaty	Almaty	Food processing, cement	Fat and oil products, glass (containers), cement Eurasian Foods Corporation, Maslo-Del Company, EFCO Almaty LLP, SAF Glass Company, Qazaq Glass Company, Alacem Cement Plant
3 Aktau	Aktau	Oil and gas, petrochemicals, cement, fertilisers	Petroleum products, cement, fertilisers (ammonia, urea) KMG, Caspian Cement, Caspi Bitum Refinery, KazAzot
4 Atyrau	Atyrau	Oil and gas, petrochemicals	Refined petroleum products, ethylene, polypropylene, polyethylene, rubber Atyrau Oil Refinery (KMG), KMG PetroChem, KPI Inc., Westgasoil Pte, Almex Petrochemical, Butadien
5 Karaganda	Karaganda	Steel, cement, vegetable oils	Steel, iron ore, cement, oils and fats Central Asia Cement, Eurasian Resources Group (ERG), Kazakhmys Corporation, Kaz Minerals, Eurasian Foods Corporation
6 Kyzylorda		Glass, cement	Float glass, coated glass, cement Orda Glass, Gezhouba Shieli Cement Company
7 Pavlodar		Oil refining, petrochemicals, chemicals, glass	Refined petroleum, ethylene, polypropylene, MTBE, flat glass Pavlodar Refinery (KMG), KSP Steel, Aksu Ferroalloys Plant (Kazchrome), Aluminium of Kazakhstan (ERG), Kazakhstan Aluminium Smelter (ERG), Neftekhim Ltd, StekloMir
8 Shymkent		Chemicals, petrochemicals, cement	Refined products, MTBE, sulphur, cement Shymkent Oil Refinery (KMG), Shymkent Cement, Shymkent Chemical Company, Almex Polymer, LLP Standard Cement

* Planned

Source: Authors' own compilation, Fichtner (2025)

Stakeholder mapping and institutional overview

Developing Kazakhstan's green hydrogen sector will require collaboration between various stakeholders, including government agencies, regulatory authorities, academic institutions, private-sector players, non-governmental organisations and international partners. Each of these groups will play a crucial role in shaping the policy landscape, advancing pilot projects and developing the necessary regulations to enable widespread adoption of hydrogen technologies. Some of the key stakeholders involved in this process are listed in Table 14.

TABLE 14. Key stakeholders for hydrogen development in Kazakhstan

Institution	Hydrogen-related role
Government ministries and committees	
Ministry of Energy	Responsible for national energy policy and its implementation, including the hydrogen strategy. Devises and implements policies for developing green and blue hydrogen and integrating them into the national energy mix.
Ministry of Ecology, Geology and Natural Resources	Manages and protects natural and ecological resources, regulates environmental standards. Ensures that projects in various sectors of economy meet environmental criteria and sustainability standards.
Ministry of Industry and Infrastructural Development	Develops industrial policy and infrastructure planning, which can be crucial for scaling hydrogen production. Facilitates industrial development projects and infrastructure upgrades needed for hydrogen.
Ministry of National Economy	Oversees national economic policy, which includes facilitating the economic environment for sustainable energy initiatives, such as for hydrogen. Prepares strategies and plans for economic transition towards green and blue hydrogen.
Committee on Regulation of Natural Monopolies	Regulates tariffs and competition within natural monopolies, which typically include energy and utility companies. Could expand responsibilities to ensure fair practices and pricing for hydrogen production and distribution.
Committee for Economic Reform and Regional Development	Implements economic reforms and regional development projects that could include hydrogen infrastructure. Supports regional development programmes focused on renewable energy projects.
Local executive authorities or akimats	Implement national policies at regional and local level. Assist with local project approvals, development permits and community engagement for project implementation.
State-owned enterprises and government-related entities	
JSC Kazakh Invest	Promotes foreign direct investment in Kazakhstan, which could include the hydrogen sector. Provides support and facilitation services for international investors looking into local projects.

Institution	Hydrogen-related role
JSC Samruk-Kazyna	State wealth fund that invests in and manages the largest state-owned enterprises, including those in the energy sector. Could spearhead investments in green and blue hydrogen projects as part of its energy portfolio.
JSC KazTransGas	National gas transportation company, vital for potential hydrogen transport infrastructure. Develops pipeline infrastructure which could be adapted for hydrogen transportation.
JSC KazMunayGas	National oil and gas company potentially transitioning to including hydrogen in their energy portfolio. Could play a major role in investing in and developing hydrogen production facilities and integrating them into existing operations.
Kazakhstan Electricity Grid Operating Company (KEGCOC)	Manages the national electricity grid and wholesale electricity market. Its work includes planning for the integration of renewable energy sources into the power grid.
International and intergovernmental entities	
Astana International Financial Centre (AIFC)	Facilitates financial services and investment and could assist with raising capital for large-scale hydrogen projects. Provides a legal and regulatory framework conducive to green finance initiatives.
NGOs	
Association of Environmental Organizations of Kazakhstan	Coordinates and supports environmental NGOs, promotes environmental protection and sustainable resource management. Facilitates a platform for various stakeholders to collaborate on environmental issues, including renewable energy. Engages in extensive advocacy work and policy dialogue which can influence the hydrogen agenda.
Renewable Energy Association of Kazakhstan	Promotes renewable energy sources and technologies, including solar, wind and potentially hydrogen. Facilitates the development, implementation and scaling of renewable energy projects and could be instrumental in promoting hydrogen as part of the renewable energy mix.
Industry associations and research institutes	

Institution	Hydrogen-related role
RES Association QAZAQ GREEN	Promotes renewable energy solutions, advocates for the development of green hydrogen. Conducts awareness and advocacy campaigns to integrate hydrogen into Kazakhstan's energy policy.
National Nuclear Centre of the Republic of Kazakhstan	Conducts research and development that could include advanced hydrogen technologies. Engages in high-tech research that overlaps with clean energy solutions.
Kazakh-German University	Academic institution promoting education and research collaboration, including in energy sectors. Facilitates academic research initiatives and educational programmes focused on hydrogen.
Nazarbayev University	Known for its School of Engineering and Digital Sciences and School of Science and Technology. Active in research related to renewable energy and sustainable technologies, including potential work on hydrogen.
Kazakh National Research Technical University	Specialises in engineering and technical sciences. Has departments and research centres focused on energy, chemical technology and materials science that could contribute to hydrogen research.
Institute of Fuel, Catalysis and Electrochemistry	Involved in research on fuel technologies, including hydrogen. Develops catalysts and electrochemical systems relevant to hydrogen production and storage.
Green and renewable energy organisations	
JSC Zhasyl Damu	Government agency dedicated to environmental protection and sustainable development. Implements green technology projects, including those related to green hydrogen.
Green Hydrogen Alliance of Kazakhstan	Industry group promoting the development and adoption of green hydrogen technologies. Advocates for policy changes and partnerships to accelerate hydrogen projects.
Economic development and trade promotion authorities	
Delegation of German Economy in Central Asia	Facilitates trade relations and business connections between Germany and Central Asian nations, including those focused on energy. Supports German businesses seeking to invest in Kazakhstan’s hydrogen sector.

Source: Authors’ own compilation, Fichtner (2025) based on, (GBR, 2023), (YPF Quimica, 2024a), (Unipar, 2023) (Petroken, 2024)

Techno-economic calculations

Parameter	Value
Equity cost (%)	10
Debt interest rate (%)	6
Debt tenor (years)	10
Debt-to-Equity ratio (%/%)	35/65
Project lifetime (years)	25
Electricity price (Feed in tariff) (€/kWh)	0.15
Water cost (€/kg)	2
Grey hydrogen benchmark price (€/kg)	2.8
Oxygen selling price (€/kg)	0.33
Ammonia price (€/kg)	0.23

Source: Authors' own compilation, Fichtner (2025) based on (YPF química, 2024b) and (ARAUCO química, 2024), (Bicego, F et all, 2018)

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