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Hydrogen Alliance

How Poland and the Netherlands can strengthen cooperation in green hydrogen development

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Content

Executive summary

The Netherlands and Poland are the second- and third-largest producers of hydrogen in the EU. In both countries, hydrogen is obtained by steam reforming of natural gas. For both of them, green hydrogen is a way to accelerate the energy transition and decarbonise sectors that cannot be easily electrified. Both countries also plan to use blue hydrogen, which would be sourced through the use of CCS/CCUS facilities.

The hydrogen economy in the Netherlands is mature and developed; the sector consists of hundreds of specialised companies with innovative know-how. In Poland, the hydrogen sector is only just emerging; for now, there are just a few dozen companies interested in its development, despite its considerable potential.

For the Netherlands, clean hydrogen is an effective tool for moving away from the Groningen legacy and natural gas, which was the foundation of the country's energy security, while maintaining its status as an energy hub. For Poland, hydrogen is still a future prospect and a shaky supplement to the energy transition, which may help decarbonise certain industries.

Despite the differences in their approach to the development of the hydrogen sector, the Netherlands and Poland share a number of similarities that could become the starting point for synergies. The two countries could build a hydrogen alliance to speed up their decarbonisation. Here are the key synergies:

» **H2 production.** The growth engine for the hydrogen sector in the Netherlands and Poland will be the same: offshore wind energy. Both countries have big ambitions for offshore projects. The Netherlands already has farms in the North Sea with a capacity of 2.5 GW; this is expected to grow to 21 GW by 2030. Poland does not have offshore farms yet, but it wants to have 5.9 GW by 2030. In the coming decades, both countries will focus on developing the maritime economy, with industry growing at the fastest pace by the sea. The turn to the sea will require investment in ports, building new infrastructure, educating personnel, and creating new development policies. Here, the Netherlands' know-how could help Poland.

» **H2 transport.** Hydrogen pipelines will be the foundation of the future hydrogen market. The Netherlands already has 1000 km. The country's natural gas grid, made up of 136,000 km of pipelines, is also being retrofitted to transport hydrogen for both industry and households. This is the basis of the National Hydrogen Network, which will be ready in stages through 2031. Poland does not yet have this kind of infrastructure and will need support building its own. In this context, cooperation between Gaz-System and Gasunie (the gas transmission operators) — exchanging experience, know-how and best practices in the development of hydrogen transmission infrastructure — will be crucial.

» **H2 storage.** Providing sufficient hydrogen storage will be one of the main bottlenecks in the development of the hydrogen economy. Poland and the Netherlands have some of the best conditions in Europe for developing hydrogen storage in salt caverns. By 2030, Dutch Gasunie plans to commission up to four caverns for large-scale hydrogen storage in Zuidwending, near Veendam, in the province of Groningen. Poland's Gaz-System is analysing the possibility of building a hydrogen storage facility in a salt cavern in Damasławek, in the Kujawsko-Pomorskie Voivodeship. Exchanging experience and know-how on the construction of this type of infrastructure could be one of the key synergies between Poland and the Netherlands.

» **H2 import infrastructure.** Demand for green and blue hydrogen in Poland could rise from zero now to 450,000-510,000 tonnes by 2030. Meanwhile, the Polish Hydrogen Strategy envisages that 2 GW of electrolysers will be operating in the country by then, enabling it to produce approximately 193,000 tonnes of green hydrogen. To cover the shortfall, it will be necessary to prepare the infrastructure for hydrogen imports via dedicated pipelines and seaports. From Poland's perspective, it will be crucial to adapt ports to receive hydrogen produced by offshore wind farms in the Baltic Sea and imported hydrogen. Poland will be able to follow the transition of the port of Rotterdam, which is set to become a key hydrogen hub for the Netherlands and Europe.

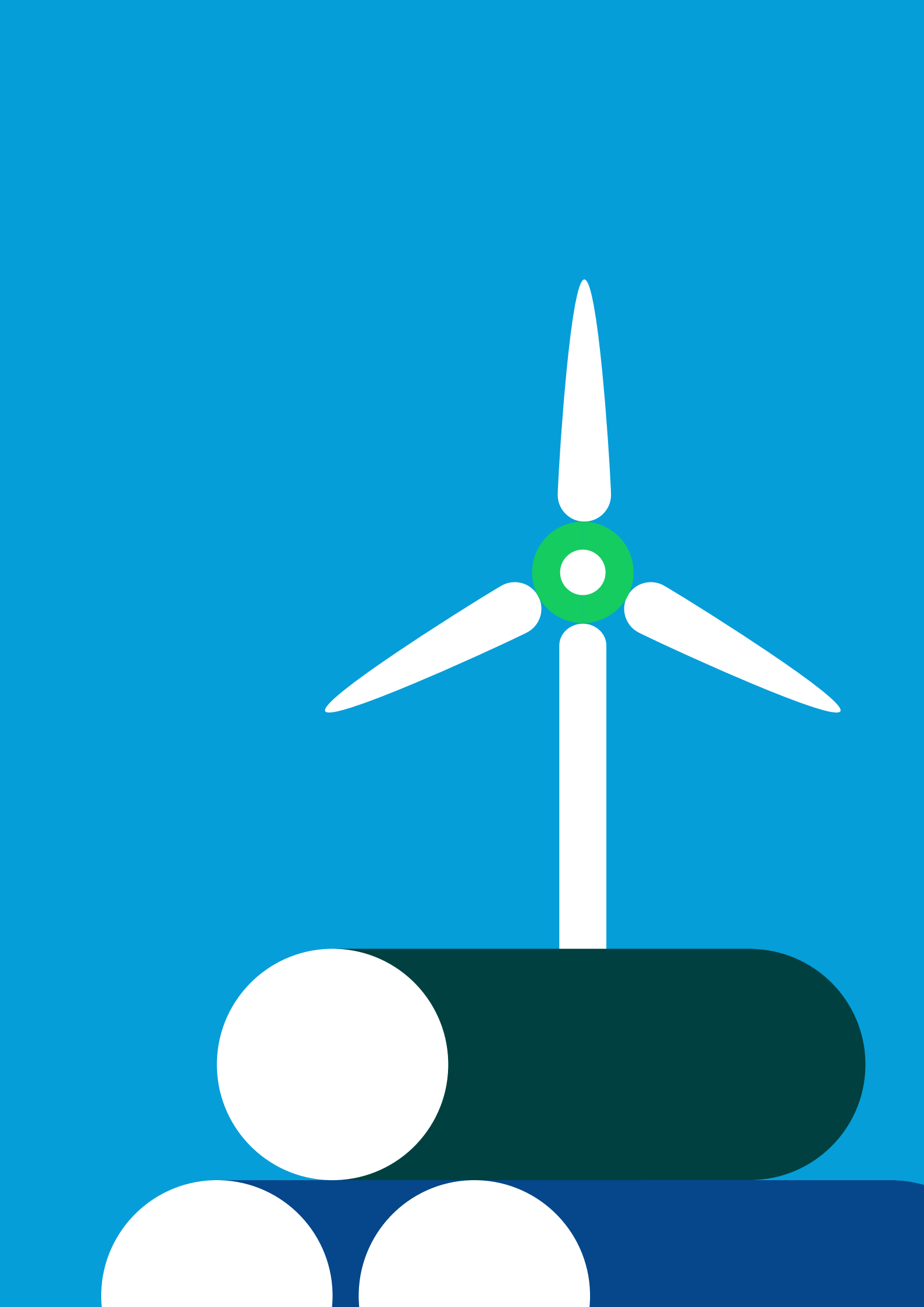
» **Blue H2.** CCS is a crucial part of the Dutch Hydrogen Strategy. The Hague's goal is to increase CO2 capture potential to 2-4 million tonnes per year in 2023-2025 and to 7 million tonnes per year after 2025. Poland will not be able to build the infrastructure needed to store large amounts of CO2 in geological formations rapidly, so it will need to export CO2 via seaports. Poland's first CO2 export port is set to be built in Gdańsk by French company Air Liquid. Between 2026 and 2030, this infrastructure's capacity is meant to amount to 2.7 million tonnes of CO2 per year. The need for Poland to start importing green hydrogen and exporting CO2 could become the flywheel of Polish-Dutch cooperation. In both cases, when it comes to planning Polish ports' development, Rotterdam's experience could be crucial.

» **Individual heating.** Polish-Dutch hydrogen cooperation could also develop in individual heating, particularly the prosumer market. Households producing their own energy from PV are a unique part of Poland's energy transition and one of its driving forces. The number of Polish prosumers has increased by as much as 41 per cent over the past year, to 1.2 million. In 2015, there were just 85,000. Poland's developed prosumer market makes it a good place to develop small electrolysers for the production of green hydrogen; for example, for heating. Polish companies (such as Sescom or ML System) are developing small electrolyser technology. The Netherlands has a strong ecosystem of condensing boiler manufacturers, who are investing heavily in the transition from natural gas to hydrogen. Polish and Dutch know-how could contribute to the use of hydrogen on a small scale, in households. However, to begin with, this solution could be of interest to businesses, including SMEs.

» **The H2 knowledge environment.** Compared to other EU countries, Poland has low technological potential when it comes to hydrogen. The choice of educational programmes in Poland for hydrogen industry specialists is still poor. Dutch companies and research institutes could leverage this by supporting Polish research and innovation through joint projects. Working with Polish universities, Dutch institutions such as TU Delft and the University of Groningen could explore the possibility of setting up a Centre of Excellence in Hydrogen Technology in Poland. It could focus on adopting technologies to convert them into marketable products, applying technology, setting up benchmarking, certification, testing facilities for hydrogen technologies, teaching technical professionals new skills, and so on.

01

The hydrogen market in Poland



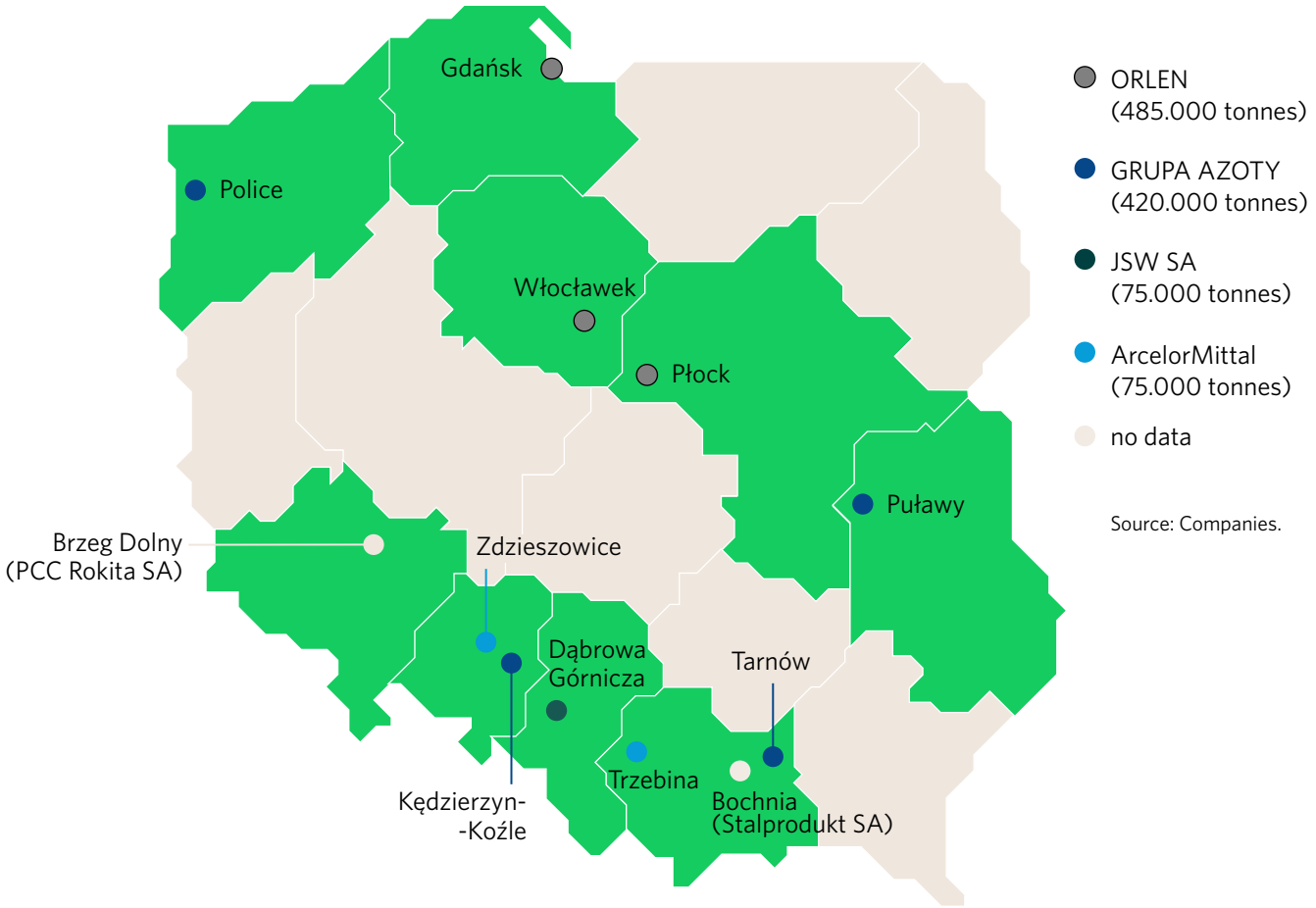
AN OVERVIEW OF THE POLISH HYDROGEN SECTOR

Poland is the third-largest producer of hydrogen in the EU and the fifth-largest globally. However, the share of green hydrogen in total hydrogen production is currently close to zero.

In Poland, the use of hydrogen originally resulted from the development of nitrogen plants and oil refineries in the 1960s. Demand for hydrogen increased with economic development, which generated greater demand for fuels and chemical products, including fertilisers.

Annual hydrogen production in Poland currently amounts to around 1 million tonnes. This is grey hydrogen produced at large industrial plants through the steam reforming of natural gas.

MAP 1. THE LARGEST PRODUCERS AND CONSUMERS OF HYDROGEN IN POLAND



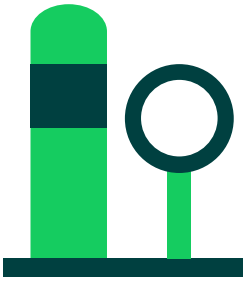
The largest producer and consumer of hydrogen in Poland is the chemical sector. The fuel is used to produce ammonia, an essential component of fertilisers, among other things. In 2022, the plants of Grupa Azoty, Anwil (Orlen), and private companies PCC Rokita and Synthos consumed around 545.000 tonnes of hydrogen in total. Major consumers of grey hydrogen include JSW's coking plants and ArcelorMittal's steel mills – approximately 160.000 tonnes (Esperis, 2022)[1].

Refineries and petrochemical companies are the second-largest producers of grey hydrogen in Poland; it is needed to process crude oil into fuels and petrochemicals by hydrocracking. In 2022, Orlen-controlled refineries in Płock, Gdańsk and Trzebinia produced around 322.000 tonnes of hydrogen in total. The largest producer of hydrogen is Orlen (485.000 tonnes), ahead of Grupa Azoty (420.000 tonnes). As a result, Poland's hydrogen market is 90 per cent dominated by two big, state-owned companies, which produce and consume almost all the hydrogen themselves. Like in most EU countries, there is no commercial market for hydrogen trading in Poland.

There are currently no electrolysers – the technology used to produce green hydrogen – in Poland, apart from demonstration or research installations. The most advanced commercial project is the electrolyser planned by private energy company ZE PAK[2]. The 5 MW installation at the Konin power plant is expected to be operational in 2023. The electrolyser will be powered by a biomass power unit. ZE PAK's green hydrogen is set to power a hydrogen bus fueling station in Konin[3].

Orlen has the most ambitious plan to develop green and zero-emission hydrogen production. In its hydrogen strategy, the company assumes that it will build electrolysers with a capacity of at least 1 GW by 2030. Combined with waste-to-hydrogen projects, this is expected to produce 130.000 tonnes of hydrogen[4]. The plants will produce both renewable and low-carbon hydrogen, which will require CCUS (Carbon capture, utilisation and storage) facilities. The company aims to achieve a CO2 absorption capacity of 3 million tonnes in 2030 (Orlen, 2023).

THE BOTTOM LINE



Green hydrogen is not a competitive alternative to grey hydrogen at the moment. However, Polish companies' investment plans point to considerable potential for the hydrogen market's development. The first stage will involve using blue hydrogen. Then, with the development of transmission and storage infrastructure and RES installations connected to electrolysers, the supply of green hydrogen will increase. The Polish Hydrogen Strategy assumes that the country will produce 193.000 tonnes of green hydrogen in 2030.

BARRIERS TO THE DEVELOPMENT OF THE HYDROGEN SECTOR

In Poland, the green hydrogen market is only just emerging and the barriers to its development are similar to those at the European and global level.

Key ones include:

- **Green hydrogen's lack of competitiveness** – producing it currently costs at least twice as much as a producing hydrogen, through the steam reforming of natural gas.
- **Lack of infrastructure** – the underdevelopment of facilities for producing green hydrogen, as well as hydrogen storage, transport and use in the economy,
- **Lack of regulations** — the lack of a support scheme for green hydrogen production and its certification; the lack of legal definitions of hydrogen.

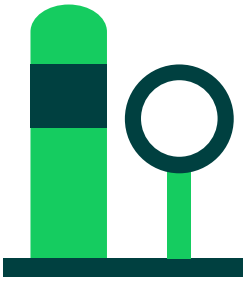
A Polish specificity that could slow down the green hydrogen market's development is the existence of regulations that hamper the development of RES (such as the 10H rule, which limited the possibility of building onshore wind farms in 2016-2023). In addition, the country lacks regulations that would enable faster decarbonisation in the energy sector. This includes allowing direct energy lines to be built, the development of a market for Power Purchase Agreements, and regulations concerning energy storage.

Structural problems are also a challenge. They include:

- **A lengthy permitting process.** Obtaining the permits needed to implement hydrogen projects (such as building pilot networks) takes years. It takes 36 months to obtain certain permits in Poland, compared to up to 18 months in Germany.
- **Low spending on hydrogen innovation.** Poland spends around 40 times less on R&D in hydrogen and fuel cells than the leading EU countries in the field (Germany and France) and twelve times less than the Netherlands. These funds account for 2 per cent of all R&D spending in Poland (PIE, 2021).
- **Hydrogen know-how disconnected from business needs.** When it comes to the hydrogen economy, research and production of fuel cells, state research institutes have know-how, but it is often disconnected from business needs. Current projects are based on scientific knowledge and on integrating hydrogen infrastructure components using technologies developed abroad. Unlike in more developed countries, technological development in the Polish business sector often occurs independently of progress in the scientific world.
- **The lack of an adequate curriculum.** In Poland, the choice of educational programmes for specialists in the hydrogen industry is poor. Most faculties that cover energy, heating and RES do not provide students with adequate courses on hydrogen technology. Just four public universities currently offer postgraduate or master's degrees relating to hydrogen energy (three of them from the 2022/2023 academic year onwards)[5]. As a result, Poland will have a limited capacity to meet the demand for hydrogen specialists by 2030. Bringing in experienced staff from abroad may prove cost effective.
- **Limited knowledge about hydrogen.** Surveys show that just 16 per cent of Poles would agree to install backyard hydrogen energy storage, even if the installation costs were fully covered by subsidies[6]. The public's concerns are linked to the lack of knowledge about hydrogen technology – just 5 per cent of respondents said that they know how hydrogen cells work. Most people are also unaware of the potential uses of hydrogen.

THE BOTTOM LINE

Compared to other EU countries, Poland has relatively low technological potential when it comes to hydrogen. This is visible in the low number of private companies involved in developing hydrogen technologies and the low spending on R&D (PARP, 2020)[7]. The dominance of large state-owned fuel and energy companies means that Poland's hydrogen sector is being built in a top-down way. This leads to greater synergies, with hydrogen technology developing simultaneously in different segments (production, transmission, storage and consumption), in a way that is closely interlinked. Yet this top-down model limits the initiative of private entities, which often have a more innovative approach. Moreover, state-owned companies' greater ability to influence regulations and support instruments could distort market mechanisms, which may ultimately reduce Polish companies' competitiveness in international hydrogen economy supply chains.



PROSPECTS FOR HYDROGEN USE IN SECTORS OF THE POLISH ECONOMY

Industry

Polish industry generates 91 million tonnes of CO2 per year – 22 per cent of the country's emissions. The need for deep decarbonisation in a relatively short period of time means that it will be one of the first sectors to commercialise green hydrogen.

According to the agreed revision of the EU's RES Directive (RED III), by 2030, 42 per cent of hydrogen used in industry will come from non-biological renewable fuels. By 2035, this is supposed to rise to 60 per cent. This means that Polish industry alone will need to consume at least 420.000 tonnes of renewable or low-carbon hydrogen in 2030 and more than 600.000 tonnes in 2035.

Replacing even a small proportion of the grey hydrogen consumed by industry with its green equivalent will stimulate increased interest in hydrogen in other sectors. EY estimates that, for every 10 per cent of grey hydrogen consumption in the refining and chemical sectors that is replaced, demand for renewable hydrogen will grow by 96.000 tonnes (EY, 2023)[8].

The increase in industrial demand for green and low-carbon hydrogen will become a flywheel for the economy, stimulating the construction of transmission and storage infrastructure, generating investment in new RES capacity, and supporting the widespread use of hydrogen in other sectors.

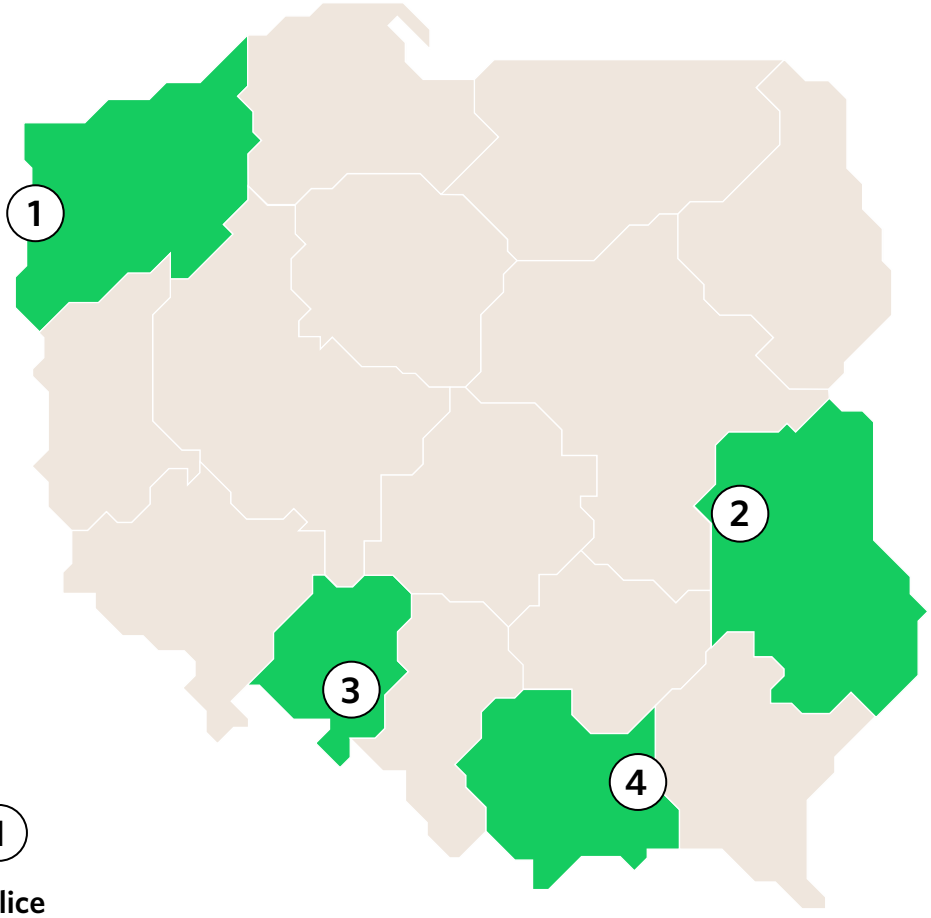
Spending linked to hydrogen technologies will directly generate between 1000-2400 jobs in 2020-2030 (in production, operation and maintenance) and another 2600-6200 indirectly[9]. Most of these jobs are expected to be created in the construction and operation of RES, electrolysers and hydrogen transport infrastructure[10].

THE CHEMICAL INDUSTRY

- **current consumption of grey H2:** 519.000 tonnes
- **likely time of commercialisation of green H2:** 2023-2025[11]
- **CO2 emissions:** 8.29 million tonnes of CO2 in 2022 (9.8 million tonnes in 2021)[12]

The Polish chemical industry is currently the largest consumer of grey hydrogen, which is essential for the production of fertilisers. To reduce CO2 emissions, including exposure to the EU ETS, the Polish chemical sector will need to switch to less emitting types of hydrogen in the ammonia production process.

MAP 2. LARGEST HYDROGEN PLANTS IN GRUPA AZOTY



1
Police
106.000 tonnes/year

Polyolefins
20.000 tonnes/year

2
Puławy
203.000 tonnes/year

3
Kędzierzyn Koźle
82.000 tonnes/year

4
Tarnów
40.000 tonnes/year

Source: Grupa Azoty.

The largest player in the chemical market is the state-owned Grupa Azoty, which assumes that green hydrogen will be used in the decarbonisation process, but also CCUS technology to produce blue hydrogen and, in the future, small modular reactors (SMRs)[13]. The company is currently experiencing financial difficulties. It may have to sell the Puławy plant to Orlen, further strengthening the latter's position on the hydrogen market[14].

REFINING INDUSTRY

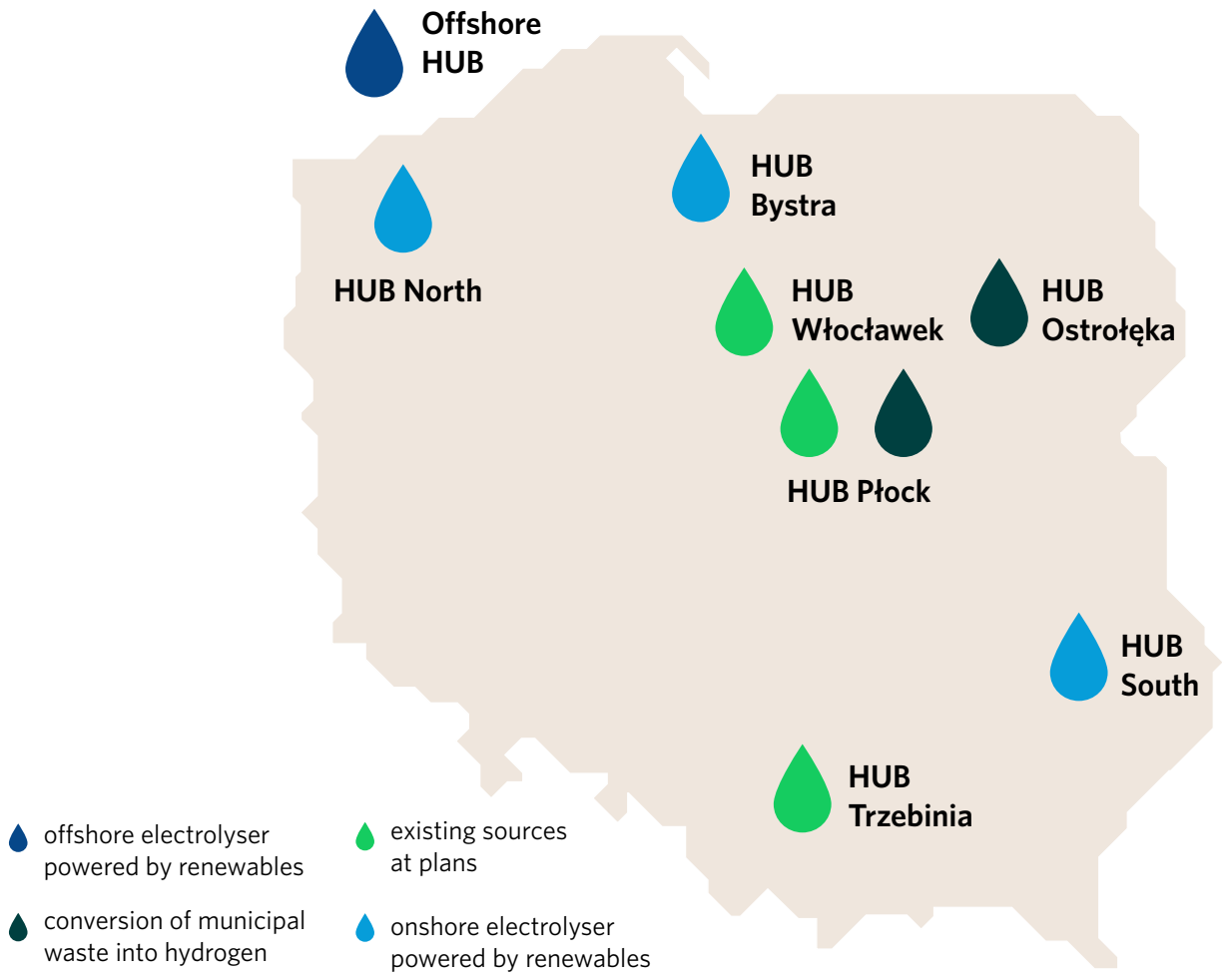
- **current consumption of grey H2:** 321.000 tonnes
- **likely time of commercialisation of green H2:** 2023-2025
- **CO2 emissions:** 10.38 million tonnes of CO2 in 2022 (9.96 million tonnes in 2021)

Hydrogen is a key feedstock in the refining industry, used in the processing of crude oil into fractions by hydrocracking. In addition to reducing refineries' exposure to CO2 prices, green and low-carbon hydrogen can also be used to produce synthetic fuels as new refinery products. The application of new

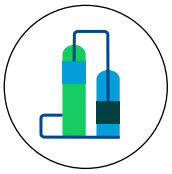
technologies in sectors known for hydrogen production, such as hydrotreated vegetable oil (HVO), will also be developed.

The biggest player in Poland's refinery market is Orlen. In its hydrogen strategy, the company assumes that it will build electrolysers with a capacity of at least 1 GW by 2030. The plants will produce both renewable and low-carbon hydrogen, which will require CCUS facilities[15]. Orlen plans to build eight hydrogen hubs in Poland by 2030. The first of these, with a capacity of around 50 kilogrammes of automotive-quality hydrogen per hour, started operating in Trzebinia in 2022.

MAP 3. ORLEN PLANS TO DEVELOP HYDROGEN INFRASTRUCTURE BY 2030.



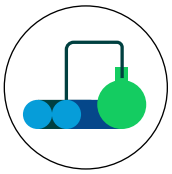
Source: Orlen



PETROCHEMICAL INDUSTRY

» **likely time of commercialisation of green H2:** 2030

The petrochemical industry uses hydrocarbons in the production of organic chemicals and polymers (such as paraffin, ethane, LPG and natural gas). Green and low-carbon hydrogen can be used in petrochemicals as feedstock for steam crackers or as an energy carrier in high-temperature processes, while reducing exposure to the EU ETS. One potential pathway for the production of organic chemicals is the use of renewable methanol as feedstock (methanol-to-olefins, MTO). Like in the refining sector, Orlen is the biggest player in the petrochemical market.



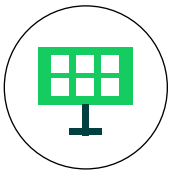
STEEL PRODUCTION

- **current consumption of grey H2:** 75.000 tonnes
- **likely time of commercialisation of green H2:** 2025-2030
- **CO2 emissions:** 4.8 million tonnes of CO2 in 2022 (5.8 million tonnes in 2021)[16]

Steel production in Poland is based on blast furnace technology (4.8 million tonnes) and electric furnaces (4.3 million tonnes). Between 2025 and 2035, "grey" steel will gradually be pushed out of the market due to rising CO2 emission costs.. It will be supplemented by low-carbon production processes, including those based on hydrogen. Poland will have to change the production process for the 4.8 million tonnes of steel produced by using hydrogen and/or biomethane. Blast furnace technology will be replaced by Electric Arc Furnace (EAF) steelmaking with Direct Reduced Iron (DRI) and Iron Bath Reactor Smelting Reduction (IBRSR) technology[17].

At the end of June 2023, ArcelorMittal announced that it will replace ammonia with hydrogen at its Kraków steelworks. This is expected to halve emissions and reduce them to zero in the future, once electrolysers are powered with energy from RES[18].

Energy sector



ELECTRICITY PRODUCTION

- **current consumption of grey H2:** 0
- **likely time of commercialisation of green H2:** 2030
- **CO2 emissions:** 104.9 million tonnes of CO2 in 2022 (104.9 million tonnes in 2021).

Poland's electricity sector is still 70 per cent based on coal-fired generation. It is mostly controlled by state-owned companies – PGE, Enea, Energa, Tauron – focused on decarbonisation and spinning off coal-fired power plants into a new state-owned company called National Energy Security Agency (NABE). This process is expected to be completed in 2023 and will enable RES investments to accelerate. For Poland's state-owned energy companies, investing in green hydrogen production is not a priority.
However, in the long term, hydrogen could act as large-scale energy storage, enabling the stabilisation of RES. Stored hydrogen in this way could be used later in gas-fired power plants adapted to burn it. However, frequent hydrogen state conversion generate large energy losses and creates new technical challenges. Hydrogen differs significantly from natural gas – its calorific value by volume is three times lower and its flame propagation rate is significantly higher. As a result, there is a risk of spontaneous combustion, especially at high temperatures, and flashback due to the significantly higher flame propagation speed.

HEAT PRODUCTION

- **current consumption of grey H2:** 0
- **likely time of commercialisation of green H2:** 2030
- **CO2 emissions:** 32 million tonnes of CO2 in 2022 (36 million tonnes in 2021).

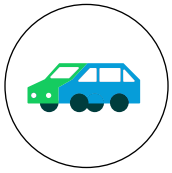
Poland has one of the largest district heating sectors in Europe. However, due high coal consumption (around 70 per cent), the sector is increasingly burdened by CO2 emission charges. Moreover, most small and medium-sized district heating plants are old and inefficient.

Looking ahead to 2040, the Polish district heating sector will mainly invest in gas-fired cogeneration, due to the lack of opportunities for the wider use of alternatives, such as RES. According to the EU Taxonomy's objectives, newly-built gas units for electricity and heat production should be adapted to burn 100 per cent low-carbon and renewable gases (including hydrogen) by 2035. This will open the way to the expansion of green hydrogen in district heating.

In the first phases of the modern heating sector's development, hydrogen may be in mixed with other gases (including natural gas) to completely replace fossil fuels in the long run (PTEZ, 2023)[19]. Hydrogen expansion will not only be possible in district heating, but also in individual heating. Hydrogen boilers or micro-CHP systems based on hydrogen could replace existing heating appliances that are not connected to the district heating network.

In the future, some gas cooling systems could also start using hydrogen. There are also plans to launch 1-10 kW micro-generation plants to produce hydrogen for heating or electricity, and for power applications in hard-to-reach areas.

Transport



CARS AND BUSES

- **likely time of commercialisation of green H2:** 2025
- **TRL[20](Technology Readiness Level):** 8-9

Hydrogen-powered light vehicles (such as cars and small vans) have been mastered in technological terms and are gradually being commercialised, but refuelling infrastructure needs to be developed for them to become more widespread. This mode of transport will be in direct competition with battery drives (BEV vs FCEV). Only a few cities in Poland, including Warsaw, Gdańsk and Kraków, currently have hydrogen refuelling stations where people can refuel passenger cars. By 2030, Orlen plans to launch more than 57 publicly-accessible hydrogen stations in Poland.

The plans for the use of hydrogen in bus transport are more ambitious. The Polish Hydrogen Strategy envisages 100-250 hydrogen buses in Polish cities by 2025 and 800-1000 by 2030. It is assumed that these buses should be built by Polish entities , with local companies highly involved. In addition, it envisages at least 32 new hydrogen refuelling and bunkering stations by 2025, primarily for urban vehicles.

TRUCK AND RAIL TRANSPORT

- **likely time of commercialisation of green H2:** 2025-2030
- **TRL:** 7-8

Heavy vehicles (trucks, trains) can be directly electrified using battery drives, but using RFNBO fuels could make greater financial and logistical sense in selected cases. Drives based on hydrogen or derivatives may be better for long distances, continuous operation (short refuelling), and maximising the weight of goods transported. Access to refuelling infrastructure in the EU may be key when it comes to increasing the use of RFNBO fuels in this sector.

Conceptual projects for using hydrogen as a propulsion fuel are being carried out by the Polish company PESA (hydrogen fuel cell engine), as well as Orlen and Alstom (hydrogen fuel cell trains).

SEA AND AIR TRANSPORT

- **likely time of commercialisation of green H2:** 2030-2035
- **TRL:** 6-7

Maritime transport and aviation are difficult to electrify. To decarbonise these sectors, bio-based fuels (e.g. vegetable oils) will be used first (temporarily). In the medium to long run, these sectors can be fully decarbonised using hydrogen derivatives such as renewable ammonia, renewable methanol and synthetic fuels (e.g. e-kerosene).

Prospects for the development of hydrogen technology

Hydrogen production

In 2022, low-carbon (CCS) and zero-carbon (electrolysis) methods of hydrogen production accounted for about 1 per cent of total generation capacity in the EU. However, electrolysis capacity in Europe grew by over 30-50 per cent per year between 2018 and 2021.

Types of hydrogen:

Electrolysis powered by RES: green hydrogen

- Emissions (kg CO2/kg H2): 0-0.2
- Production cost (EUR/kg H2): 4-6 (wind) 5-7 (PV)
- TRL: 7-9

Producing "green hydrogen" involves the decomposition of water under the influence of electrical voltage from a wind or photovoltaic farm into hydrogen and oxygen. Water electrolysis can be carried out in various technical solutions using different electrolyte materials and process parameters. There are four basic technologies: alkaline electrolysers (ALK), two polymer electrolyser technologies (Proton Exchange Membrane (PEM), Anion Exchange Membrane (AEM), and solid oxide electrolyser (SOE). Of the electrolysers available, Solid Oxide Electrolysers (SOEs) have the highest efficiency (74-81 per cent), as well as huge potential for process and thermal integration with other technologies (due to their high operating temperature). However, on a large scale, this technology is in the early stages of deployment and is not yet commercially available. SOEs have been the subject of research and technological and patent development worldwide for several years.

"Green hydrogen" means hydrogen derived exclusively from RES other than biomass, meeting a lifecycle GHG reduction requirement of 73.4 per cent compared to fossil fuel. This results in lifecycle GHG emissions of less than 3 kg CO2/kg H2.

Electrolysis powered by nuclear: purple hydrogen

- Emissions (kg CO2/kg H2): 0-0.2
- Production cost (EUR/kg H2): 5-7
- TRL: 6-7

Producing "purple hydrogen" is based on the decomposition of water under the influence of an electrical voltage from a nuclear power plant into hydrogen and oxygen.

Steam Methane Reforming: grey hydrogen

- Emissions (kg CO2/kg H2): 8-12
- Production cost (EUR/kg H2): 2-4
- TRL: 9

Producing "grey hydrogen" involves processing natural gas in a reforming unit using process steam and a catalyst at a high temperature of 700-1100°C. This method has been mastered commercially, with medium emissivity.

Steam Methane Reforming + CCUS: blue hydrogen

- Emissions (kg CO2/kg H2): 2-3
- Production cost (EUR/kg H2): no data
- TRL: 7-8

Producing "blue hydrogen" involves fossil fuel processes, supplemented by carbon capture, usage or storage technologies (CCUS). According to Article 2 of the New Gas Directive (COM/2021/803/ final), low-carbon hydrogen must meet an emission reduction requirement of 73.4 per cent compared to fossil fuel, resulting in lifecycle GHG emissions of less than 3 kg CO2/kg H2.

Hydrogen produced from natural gas + CCUS will qualify as low-carbon hydrogen, as will hydrogen produced from nuclear energy (as long as they meet the 70 per cent CO2 reduction criterion). Biomass-produced hydrogen and derivatives do not currently qualify for any EU definition (RFNBO, low-carbon hydrogen or RCF), but they will count towards meeting RES targets in industry or transport under the RED.

Alternative methods

Waste treatment: grey hydrogen

- Emissions (kg CO2/kg H2): 7-9 kg
- Production cost (EUR/kg H2): 7-9
- TRL: 5-7

The reaction decomposing waste into synthetic gas takes place at a high temperature (700-800°C). The synthetic gas is then separated into hydrogen in a pressure swing adsorption (PSA) reaction. This method is at the preliminary stage of commercialisation with medium emissivity.

Coal gasification: black hydrogen

- Emissions (kg CO2/kg H2): 15-20
- Production cost (EUR/kg H2): 3-5
- TRL: 9

Producing "black hydrogen" involves processing lignite or hard coal under high pressure and temperatures of 800-1000°C, resulting in hydrogen and carbon monoxide. A commercially mastered method with high emissivity.

Biomass gasification – green hydrogen

- Emissions (kg CO2/kg H2): 2-3
- Production cost (EUR/kg H2): 4-6
- TRL: 6-8

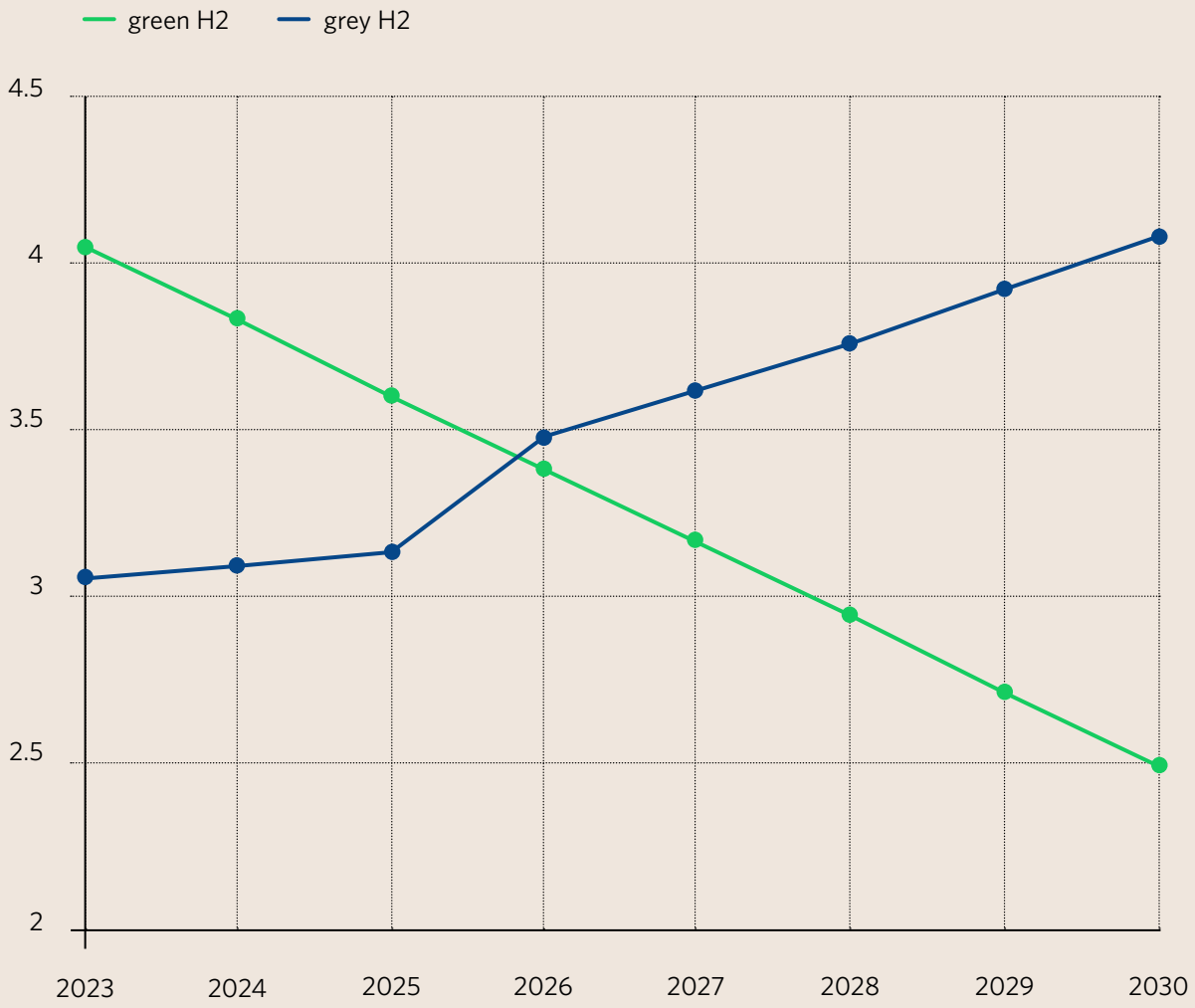
Biomass gasification is a mature technology pathway that uses a controlled process involving heat, steam and oxygen to convert biomass into hydrogen and other products, without combustion. The process has relatively emissivity; the first commercial projects are underway.

Steam reforming of biogas – green hydrogen

- Emissions (kg CO2/kg H2): 2-3
- Production cost (EUR/kg H2): 6-7
- TRL: 5-7

This hydrogen production method involves processing biogas in a reforming unit using process steam and a catalyst at a high temperature of approximately 700-1100°C (very similar to steam methane reforming). The method is in the preliminary stage of commercialisation, with low emissions.

CHART 1. COMPARISON OF PRODUCTION COSTS FOR 1KG OF HYDROGEN FOR SELECTED METHODS (1KGH2/EUR)



Source: Instytut Energetyki – Instytut Badawczy, Klub Energetyczny, Uniwersytet Warszawski.

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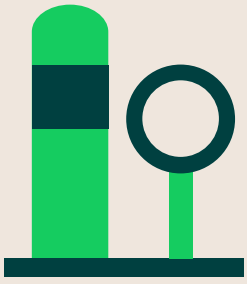


Grey hydrogen production costs have a high sensitivity to current natural gas and CO_2 prices[21]. With rising gas and CO_2 purchase costs, grey hydrogen will be rapidly pushed out of the market by green hydrogen. In the most optimistic scenario[22], the cost of producing green hydrogen at state-of-the-art facilities is expected to fall below the cost of producing grey hydrogen as early as 2026/2027. The increased attractiveness of green hydrogen will significantly reduce the demand for blue hydrogen in the future, but it is unlikely to affect the production of purple hydrogen from nuclear power.

Hydrogen storage

For the hydrogen market to function properly, storage in aboveground tanks and underground geological structures will be crucial. In Poland, salt caverns along the Baltic coast will lead the way.

Hydrogen storage methods

Pressure tanks

» TRL: 9

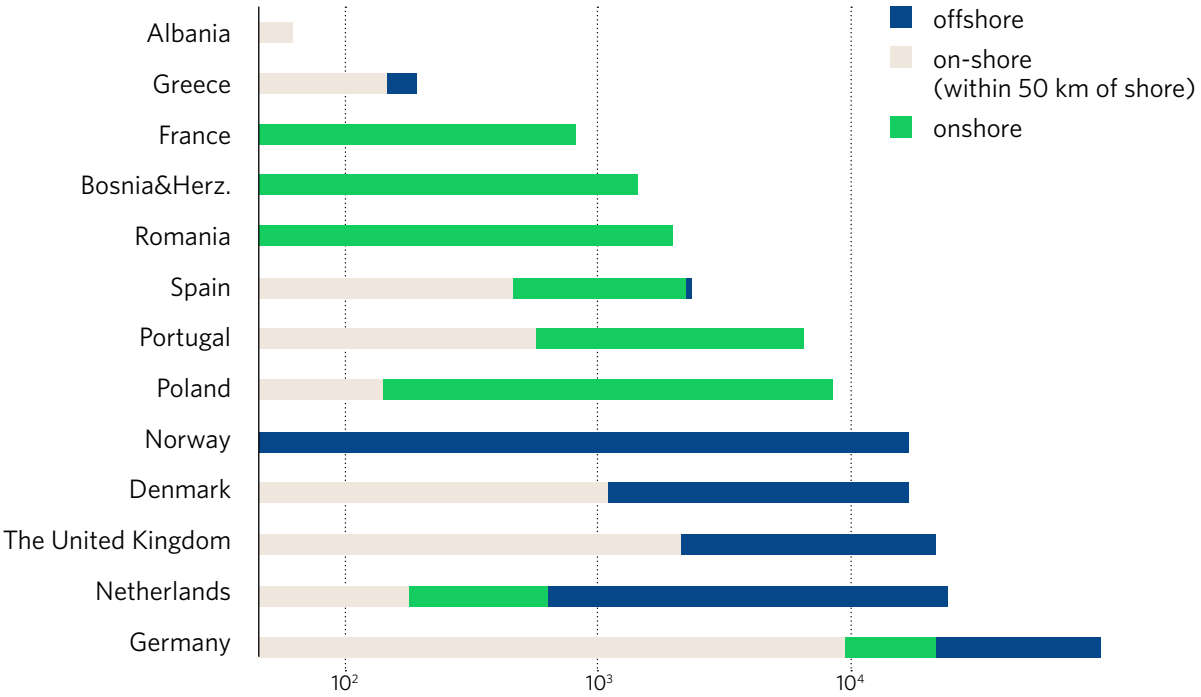
This is currently the most popular hydrogen storage method. There are both stationary (e.g. at industrial facilities) and mobile versions (e.g. in transport). The main disadvantage of pressurised tanks is their small capacity: up to 1.1 tonnes of H2. The world's largest tank, a liquid hydrogen tank at the Space Flight Centre in Florida, contains 3.200 tonnes of fuel. This would power a 430 MW gas turbine for just eight hours[23].

Salt caverns

» TRL: 8-9

Salt caverns have been used for hydrogen storage since the 1970s. They have several advantages. Pumping hydrogen into the caverns involves low losses (98 per cent efficiency) and a low risk of gas contamination. They have a relatively large storage area – 0.3-120.000 tonnes of hydrogen — and high pressure, which enables hydrogen to be pumped out quickly in response to the market situation[24].

CHART 2. TOTAL CAVERN STORAGE POTENTIAL IN EUROPEAN COUNTRIES (TWh)



Source: Technical Potential of Salt Caverns for Hydrogen Storage in Europe, 2019.

Several pilot projects in Europe are testing the adaptation of salt caverns for hydrogen storage, including in Germany, France and the Netherlands. In Poland, the use of salt caverns was tested as part of the HESTOR project carried out by Lotos (now Orlen) between 2015 and 2017. It sought to develop a method for storing hydrogen, which would later be used to power gas turbines, in salt caverns[25].

PGNiG (Orlen) also launched a hydrogen programme in 2020, with plans to build an exploratory salt cavern for storing hydrogen. If the research project is successful and receives support from the Important Project of Common European Interest (IPCEI) mechanism, the company intends to start building large-scale energy storage facilities in Kosakowo and Mogilno[26].

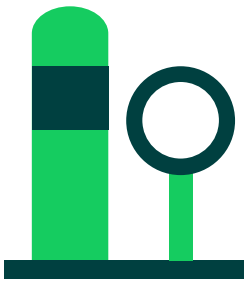
Moreover, Gaz-System is analysing the possibility of building a hydrogen storage facility in a salt cavern in Damasławek (Kujawsko-Pomorskie Voivodeship). In the first stage of the investment, the planned storage capacity could be approximately 1.44 billion m^3 of natural gas and 40 million m^3 of hydrogen. This location has also been reported as a potential hydrogen storage site in the European Hydrogen Backbone project.

Gaz-System has submitted the Damasławek project to the Projects of Common Interest (PCI) list for infrastructure enabling hydrogen transmission, storage, offtake and regasification. The draft PCI list for hydrogen will be published by the European Commission in autumn 2023. Gaz-System will be able to apply for hydrogen project subsidies from the Connecting Europe Facility.

Depleted gas fields

» TRL: 3

The gas fields' limited flexibility makes this form of hydrogen storage seasonal. It cannot be used during peaks in demand. Moreover, residual gas and oil can lead to chemical reactions with hydrogen and the formation of methane. In contrast, depleted reservoirs offer much greater potential in terms of hydrogen storage volume; up to 400.000 tonnes. There are two pilot plants worldwide, in Argentina and Austria, combining gas and hydrogen storage.



THE BOTTOM LINE

Poland has the second-largest potential in Europe when it comes to onshore salt caverns, after Germany. Caverns close to the Baltic coast could be used to store imported hydrogen and receive hydrogen produced by offshore wind farms in the Baltic Sea. Their development is likely to be handled by a state-owned hydrogen storage operator — potentially Gaz-System.

Hydrogen transport

In the first phases of the Polish hydrogen market's development, the main method for transporting hydrogen will be by road. Road tankers and compressed hydrogen tankers, which will cover relatively short distances, may be used. Transporting liquid hydrogen by sea tankers involves significant economic, technological and environmental constraints and will therefore be a marginal mode of hydrogen transport in the run-up to 2030. In the next phases of the market's development, as hydrogen producers and consumers disperse, the need for pipeline infrastructure will increase.

The development of hydrogen transmission and distribution networks will require adapting existing natural gas pipelines to transport this fuel. According to various studies, blending hydrogen into transmitted natural gas could allow for a 10-20 per cent share of hydrogen in Europe's gas transmission and

distribution infrastructure. Poland's current energy policy assumes that by 2030 the country will be able to use a blend of natural gas with 10 per cent hydrogen and biomethane in pipelines.

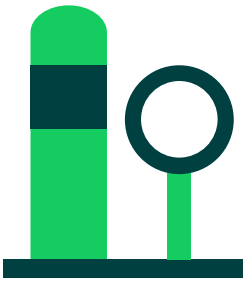
However, due to hydrogen's specific properties, including its high permeation coefficient, brittleness phenomenon and explosiveness, it will be difficult to transport using transmission infrastructure. Polish gas pipelines' technical condition prevents them from being profitably adapted for hydrogen transmission in the long run, so dedicated pipelines will be needed.

As the demand for hydrogen in heating and transport grows, the need for hydrogen pipelines — that is, pipelines dedicated to hydrogen – will increase. Their construction will become viable in the early 2030s, but as the commercialisation of green hydrogen accelerates, decisions on building hydrogen pipelines will be made more rapidly. Decisive factors will include the pace at which hydrogen technologies develop, competition from other low-carbon technologies, and the further development of hydrogen valleys. Ultimately, in an international market with a large number of trade links, access to maritime transport of hydrogen via terminals will be necessary.

Poland is lagging behind in the development of hydrogen pipeline projects compared to western EU. In the first versions of the European Hydrogen Backbone report, the Polish transmission network was, in practice, excluded from hydrogen planning. Poland was included for the first time in 2022, with national operator Gaz-System providing input to the document.

The European Hydrogen Backbone will include the construction of the Nordic-Baltic Hydrogen Corridor. An agreement was signed in December 2022 by six gas system operators from Finland, Estonia, Latvia, Lithuania, Germany and Poland. The corridor will enable green hydrogen produced in the Baltic Sea area to be transported to off-take points and industrial clusters along the entire corridor, as well as in Central Europe. A feasibility study will be carried out in 2023, followed by a final decision on the investment.

THE BOTTOM LINE



In the 2020s, the Polish hydrogen market will be decentralised. Demand for green hydrogen in hydrogen valleys will grow and industry will be the centre of its distribution. The main method of transporting hydrogen will be by road for short distances. Later, dedicated hydrogen pipelines are likely to be developed. The first projects of this kind will be built in the West Pomeranian Voivodeship. This will be followed by the construction of large national hydrogen pipelines connecting the north of the country with the south; a decision on this will be made in 2025. Due to technical difficulties in blending hydrogen in gas networks, it should be assumed that this type of hydrogen transport will not play a significant role in the future.

The most promising technological H2 projects in Poland

Manufacturers of electrolysers

Sescom: small hydrogen boiler

Polish company Sescom is working on its own boiler, which would burn a mixture of oxygen and hydrogen derived from RES[27]. The process of combustion and heat generation will take place in an airtight system with no emissions into the atmosphere. The company assumes that the hydrogen boiler will be supplied with fuel (hydrogen) and oxidant (oxygen) directly from an electrolyser powered by green energy, for instance. If the project is successful, the Polish company will be one of the first in the world to master this technology. Sescom wants the current version of its electrolyser to reach a stage that allows commercialisation within a year.

ML System: a high-pressure electrolyser

Polish technology company ML System, which is listed on the Warsaw Stock Exchange, has developed a prototype of a high-pressure electrolyser that would mainly be used by small and medium-sized companies and individual consumers, especially prosumers. It will be modular and designed for low-voltage operation, enabling it to be powered using solar panels[28]. The hydrogen produced is expected to be 99 per cent pure. ML Systems is a member and co-founder of the Subcarpathian Hydrogen Valley. For now, it is unclear when its electrolyser will be commercially available.

The potential for the development of small-scale hydrogen installations in Poland is high due to the rapidly growing prosumer market; there are already over 1.2 million prosumers.

H2 producers

Faraday Research and Development Centre (Orlen), Institute of Fluid Power Machinery, Institute of Energy: SOEC electrolyser

In 2023, a bi-directional solid oxide cell (SOEC) electrolyser was commissioned in Elbląg, working with the biomass unit of a nearby combined heat and power plant[29]. The installation is a prototype with a capacity of 10 kW. The project, called rSOC, is co-financed by the EU from the European Regional Development Fund, via Poland's National Centre for Research and Development. The installation can also function as a fuel cell that converts hydrogen into electricity. This solution can be used to produce hydrogen and to store energy.

H2 storeges manufacturers

STAKO (Worthington Industries): hydrogen tanks

The Słupsk-based company started producing boilers, tanks and vessels in the 1960s. Over the decades, it has developed, evolved and established cooperation with German IFA and Polish Fiat, among others. Since 2011, Stako has been part of the Worthington Cylinders group, the largest US manufacturer of pressure vessels. The company manufactures composite hydrogen storage tanks, which are used in hydrogen vehicles.

Railway manufacturers

PESA: Hydrogen engine

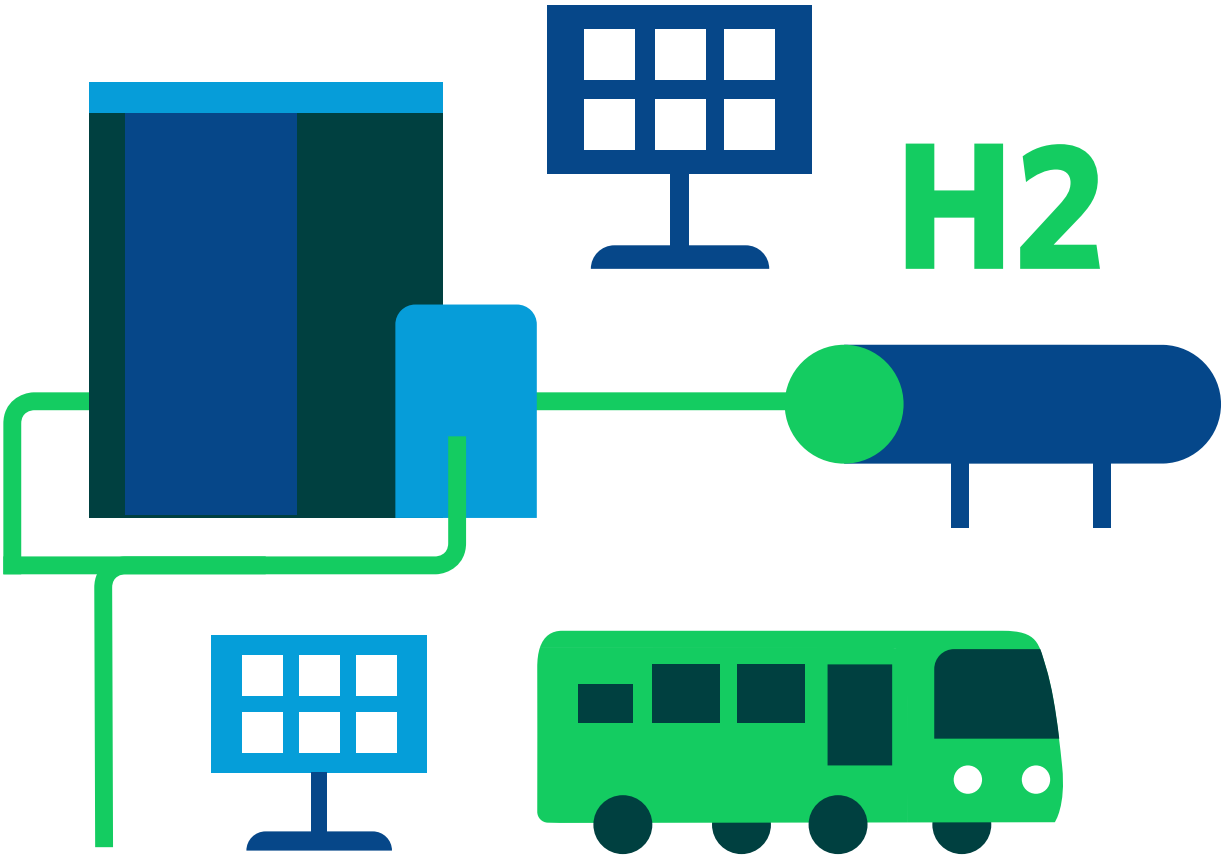
The Bydgoszcz-based company manufactures and repairs rolling stock: engines, multiple units, carriages and trams. PESA started working on the 6Dn hydrogen engine in 2019[30]. The concept and design is the

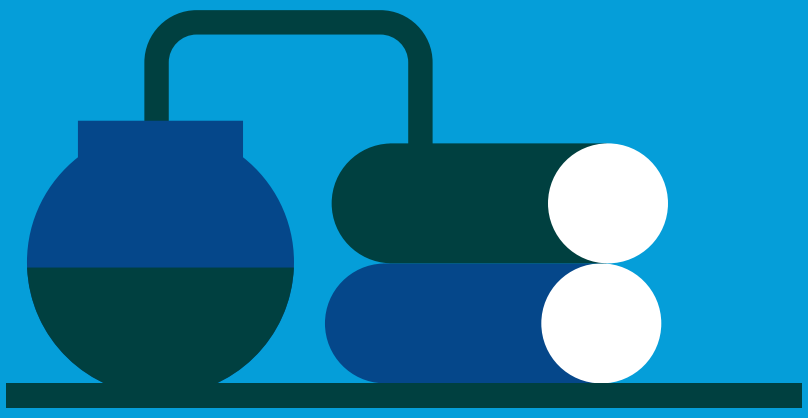
work of PESA's constructors. Companies such as ABB, Ballard, Worthington, Luccini, Rawag, TSA and CADD participated in the project. Modernised and equipped with hydrogen propulsion, the engine is completely emission-free, while retaining the same traction parameters as a diesel engine. Two hydrogen cells with a total output of 170 kW are responsible for power generation, allowing speeds of up to 90 km/h. Hydrogen is drawn from tanks with a total capacity of 175 kg. Under standard conditions, one fill-up is enough to run the engine around the clock. The 6Dn has also been equipped with an autonomous driving system and an anti-collision obstacle recognition system. PESA stresses that its product has been approved for sale as the first vehicle of its kind in the world.

Bus manufacturers

Solaris: hydrogen bus

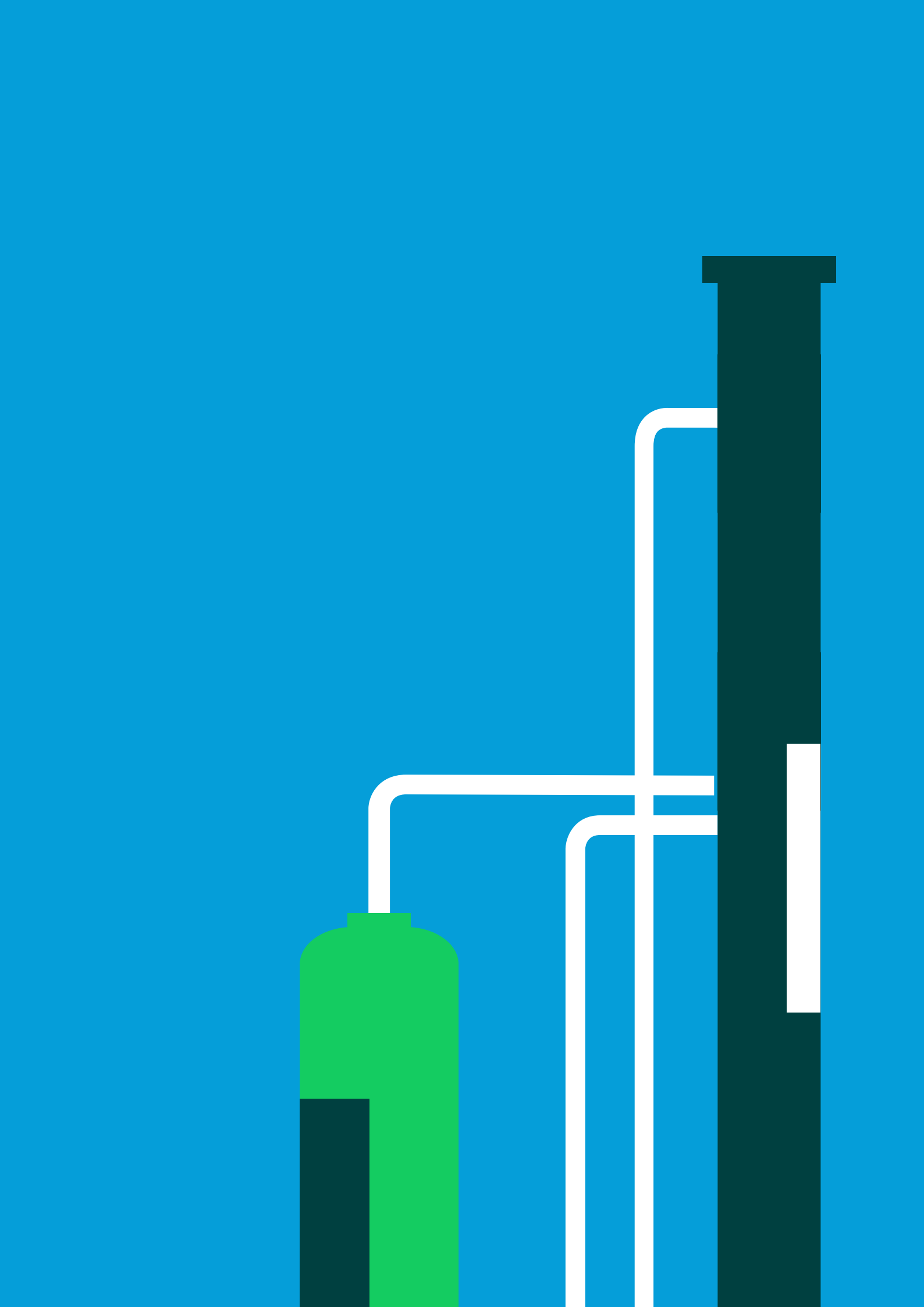
The Polish bus and trolleybus manufacturer is based in Bolechowo-Osiedle, near Poznań. Solaris has already delivered more than 100 hydrogen Urbino buses to transport operators in Italy, Germany, the Netherlands, Sweden and Poland. A further 100 hydrogen units are being produced. In April 2023, Solaris Bus & Coach received a record order for Solaris Urbino hydrogen buses from German operator Rebus Regionalbus, which is based in Güstrow and responsible for public transport in the Rostock region. Solaris will deliver a total of 52 hydrogen buses. The contract is expected to be completed by the end of 2024[31].





02

The role of hydrogen in Poland's energy transition



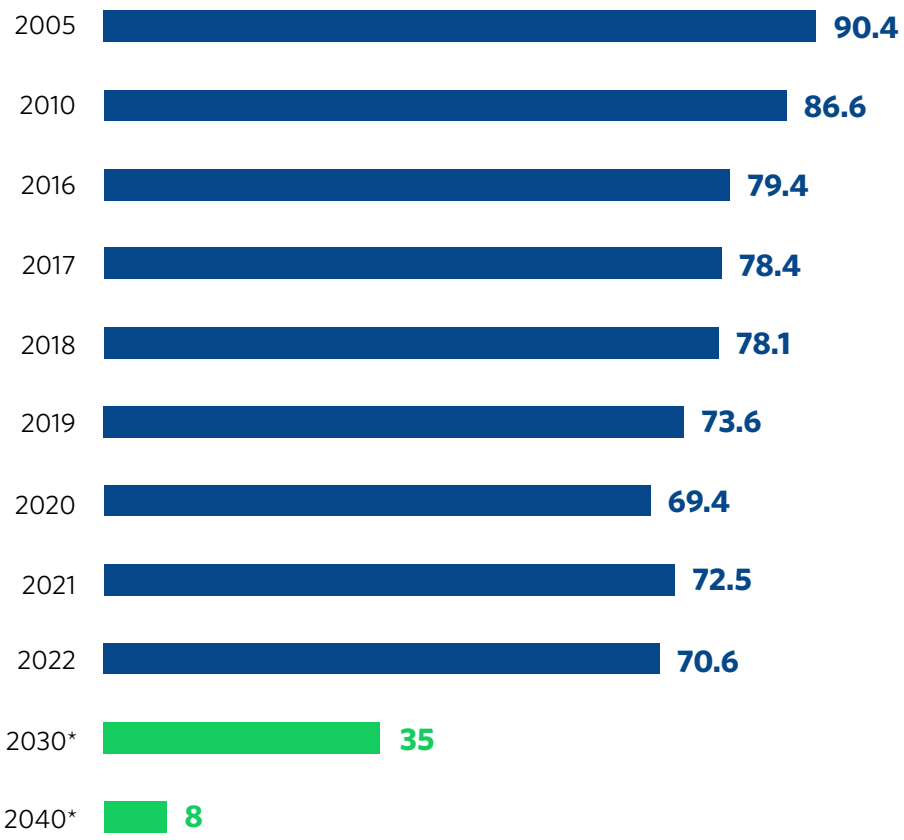
Hydrogen in Poland's energy policy

The Polish energy sector's transition

Poland's energy transition will accelerate rapidly over the next ten years. Coal, which currently provides over 70 per cent of the country's energy, will rapidly lose ground to RES and gas, influenced by the stabilisation of natural gas prices and the increase in the cost of purchasing CO2 emission allowances.

Coal power plants still constitute the bulk of the Polish power system, with an installed capacity of approximately 27 GW — 68 per cent of total installed capacity and around 71 per cent of power generation in 2022. According to the Polish government's latest forecasts[32], coal power plants' capacity will fall to 19.5 GW in 2030 and 10 GW in 2040. As a result, coal's share in electricity generation is expected to fall to 35 per cent in 2030, and 8 per cent in 2040.

CHART 3. THE SHARE OF COAL IN ELECTRICITY PRODUCTION IN POLAND (PER CENT)



Source: ARE, Polish Ministry of Climate.
*PEP2040 forecast

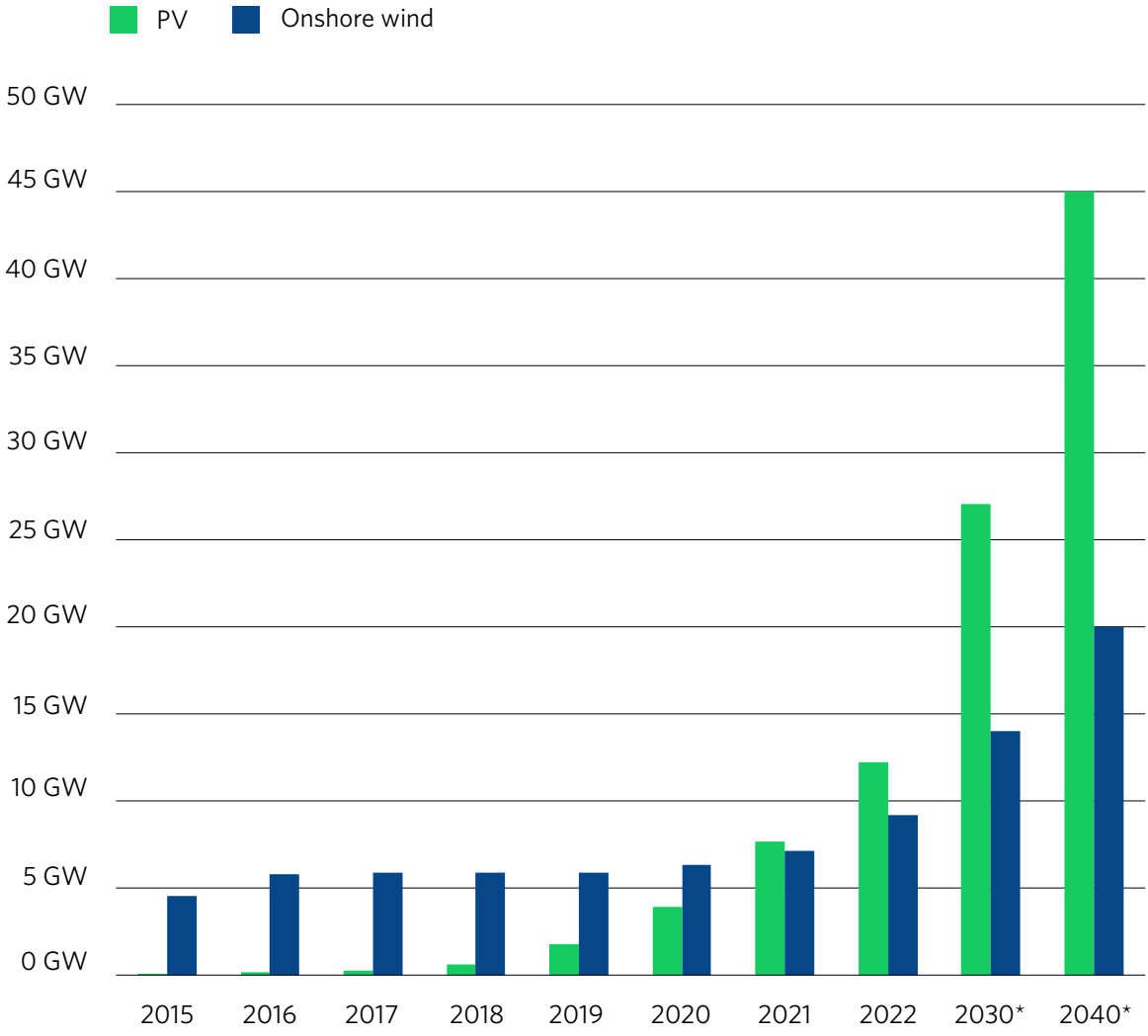
However, the decarbonisation process is likely to be even faster, due to the rising price of CO2 allowances and the rapid growth of RES. According to estimates by Aurora Energy Research, coal's operating capacity may drop to slightly over 5 GW by 2030, with only the newest coal plants (built in the past few years) and a few CHP plants remaining in the power system, creating a substantial capacity gap (Dentons, Aurora, 2023). This means that by the end of the decade, Poland may struggle to maintain an adequate level of available capacity in its power system.

RES

Rapid decarbonisation will force Poland to build an almost completely new electricity system mainly based on RES in a relatively short period of time. In 2022, production of energy from RES surged by nearly 21 per cent, to 36.8 TWh (ARE, 2022). This was the biggest ever increase in the share of RES in electricity production: 20.6 per cent, compared to 16.9 per cent the previous year.

Poland's transition is being driven by prosumers; that is, households that produce their own electricity. They are responsible for more than two-thirds of solar energy production. Their number has increased by 41 per cent over the past year, to 1.19 million – up from just 85.000 in 2019.

CHART 4. INCREASE IN PV AND ONSHORE WIND FARM CAPACITY BY 2040 IN POLAND BY 2040



Source: updated PEP2040, Polish Ministry of Climate.
*PEP2040 forecast

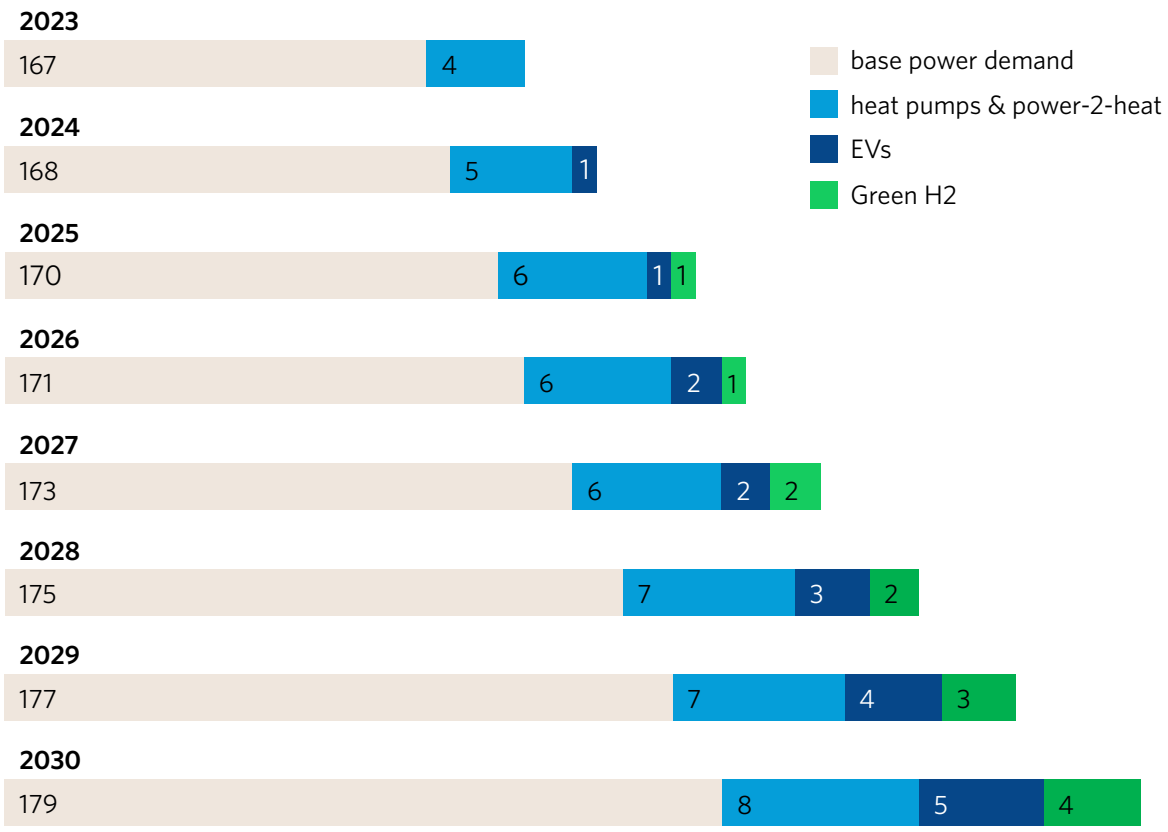
Poland's Ministry of Climate assumes that RES capacity, which is currently 24 GW, will double to 50 GW by 2030, and then reach 88 GW in 2040. At the same time, the share of green installations in electricity production is expected to increase from 20 per cent in 2022 to 46.6 per cent in 2030 and 50.8 per cent in 2040.

RES is likely to develop more rapidly than the government's estimates suggest. As early as 2030, green installations in Poland could reach 62 GW, of which 33 GW will be photovoltaics, 21 GW onshore wind farms and 8 GW offshore wind farms. As a result, as early as 2030, nearly 62 per cent of Poland's electricity production could come from RES. This is 15 pp higher than the government's new estimates (Dentons, Aurora, 2023).

The rapid growth in RES capacity will make investing in green hydrogen production more attractive. The use of electrolysers in times of electricity oversupply on the market will be an important way to avoid the costs associated with negative electricity prices and improve RES installations' profitability by 2040 (Instrat, 2021)[33].

The Polish Hydrogen Strategy (Ministry of Climate, 2021) assumes the construction of 2 GW of electrolysers by 2030, which is expected to enable the country to produce approximately 193.000 tonnes of green hydrogen. Achieving this goal will require concrete policy mechanisms and long-term planning; it is important to remove barriers that are currently slowing down the development of RES. Approximately 12 TWh of electricity will be needed to produce this amount of hydrogen; it will mainly be generated by on-site installations fully dedicated to powering electrolysers. Grid-connected RES installations will be used to produce green hydrogen to a lesser extent. According to Aurora Energy Research, the demand for energy to power electrolysers will amount to around 4 TWh in 2030 (Dentons, Aurora, 2023).

CHART 5. FORECAST OF ELECTRICITY DEMAND GROWTH IN POLAND TO 2030 (TWh)



Source: Aurora Energy Research.

In the 2030s, the power of electrolysers will increase rapidly. According to the draft new version of Poland's energy policy (PEP2040), the electrolysers' capacity could increase to 10-12 GW in 2040, which would allow 1.3 million tonnes of green hydrogen to be produced. Around 70 TWh of renewable energy will be needed to produce this amount of green hydrogen (Ministry of Climate, 2023).

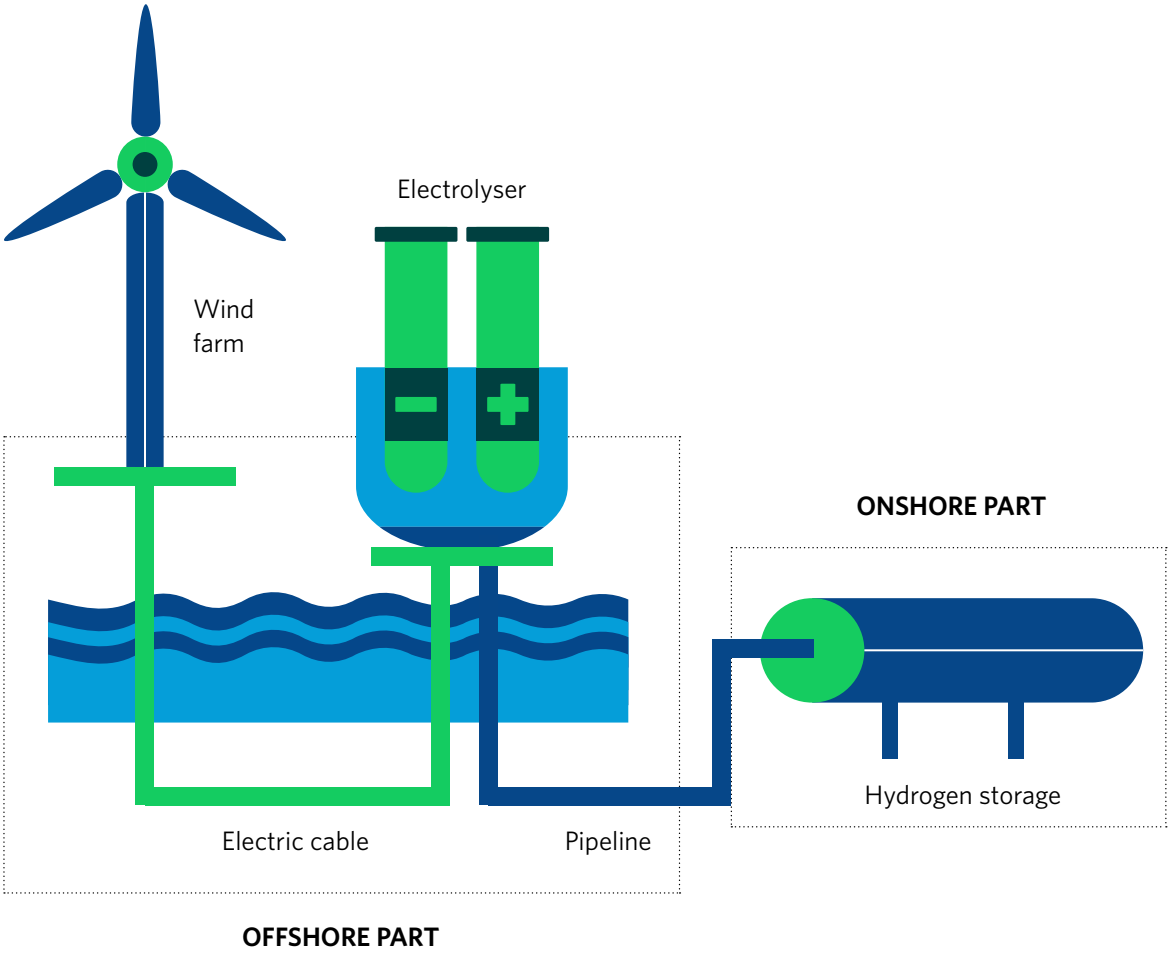
Moreover, the potential for electrolysers' development is much greater; the government's estimates appear to be underestimated. According to the EU Hydrogen Strategy (European Commission, 2020), 40 GW of electrolysers are expected to be built by 2030, with as many as 500 GW by 2050. Poland could ultimately have an electrolysis capacity of more than 20 GW (Instrat, 2021).

The need to enhance green hydrogen production will increase pressure on the Polish government to liberalise regulations for the development of onshore wind farms and solar power plants.

Offshore – the main driver of H2

Under Polish weather and geographic conditions, green hydrogen production will achieve profitability in the shortest period of time using energy from offshore wind farms. These kinds of projects have a relatively high annual efficiency factor; in the Polish Baltic Sea zone, it oscillates between 45 and 50 per cent (Ministry of Climate, 2021).

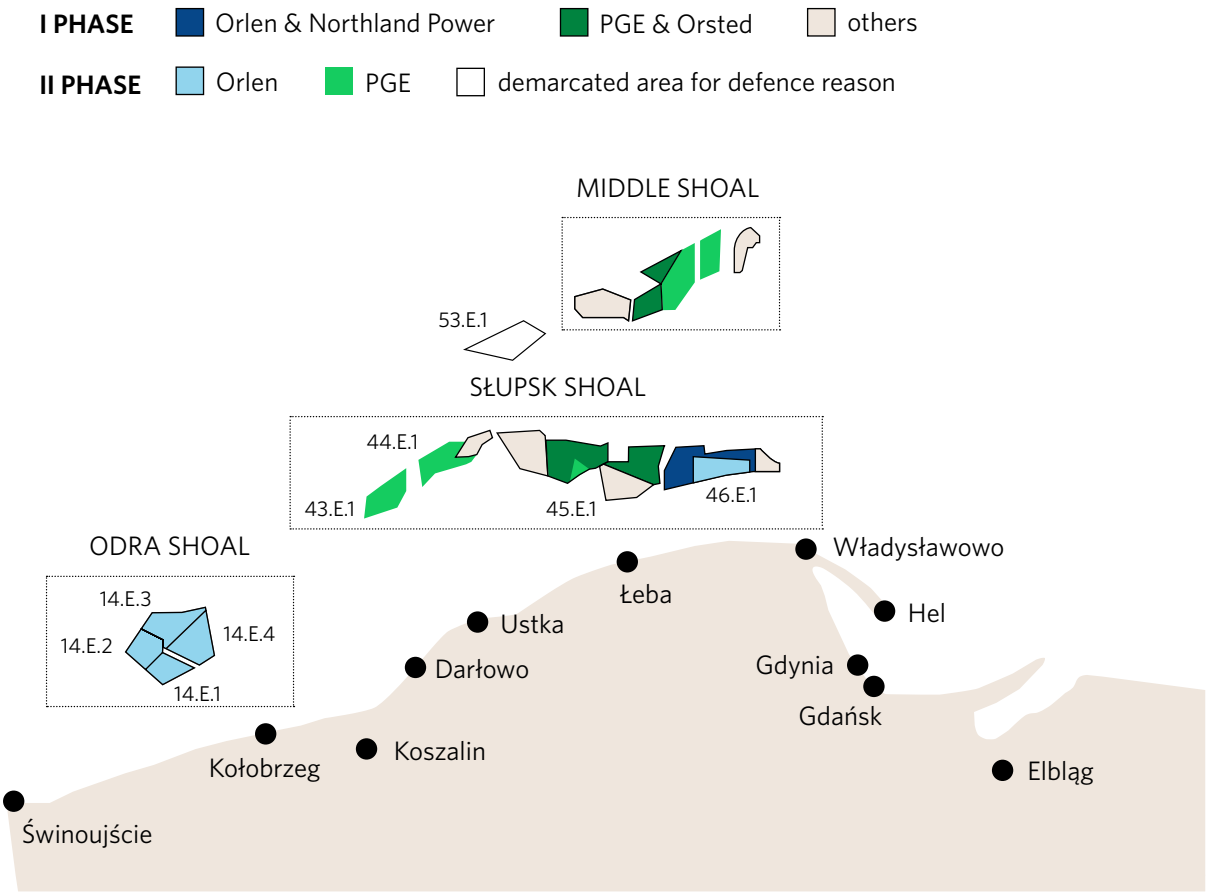
CHART 6. DIAGRAM OF AN OFFSHORE WIND TURBINE INTEGRATED WITH AN ELECTROLYSER CENTRALIZED SYSTEM.



Source: Green hydrogen from RES in Poland, DISE 2021.

According to the updated version of the PEP2040, offshore wind capacity is expected to reach 5.9 GW in 2030 and 17.9 GW ten years later, compared to the 9.6 GW projected in the earlier version of the PEP2040. In addition, the government is set to revise offshore development plans, which will allow offshore capacity to further increase in future. The Polish Baltic Sea's potential is 33 GW of offshore wind energy, which would translate into 130 TWh of electricity per year (PSEW, 2022).

MAP 4. AREAS OF THE CONSTRUCTION OF OFFSHORE WIND FARMS



Source: Companies.

Unfortunately, despite ambitious plans, the first round of projects, with a capacity of 5.9 GW, faces serious delays. Therefore, a larger fleet of offshore wind farms is unlikely to be commissioned before 2030. It may take another few years to complete and commission the entire 5.9 GW capacity with the technical grid connection conditions obtained (Aurora, Dentons, 2023).

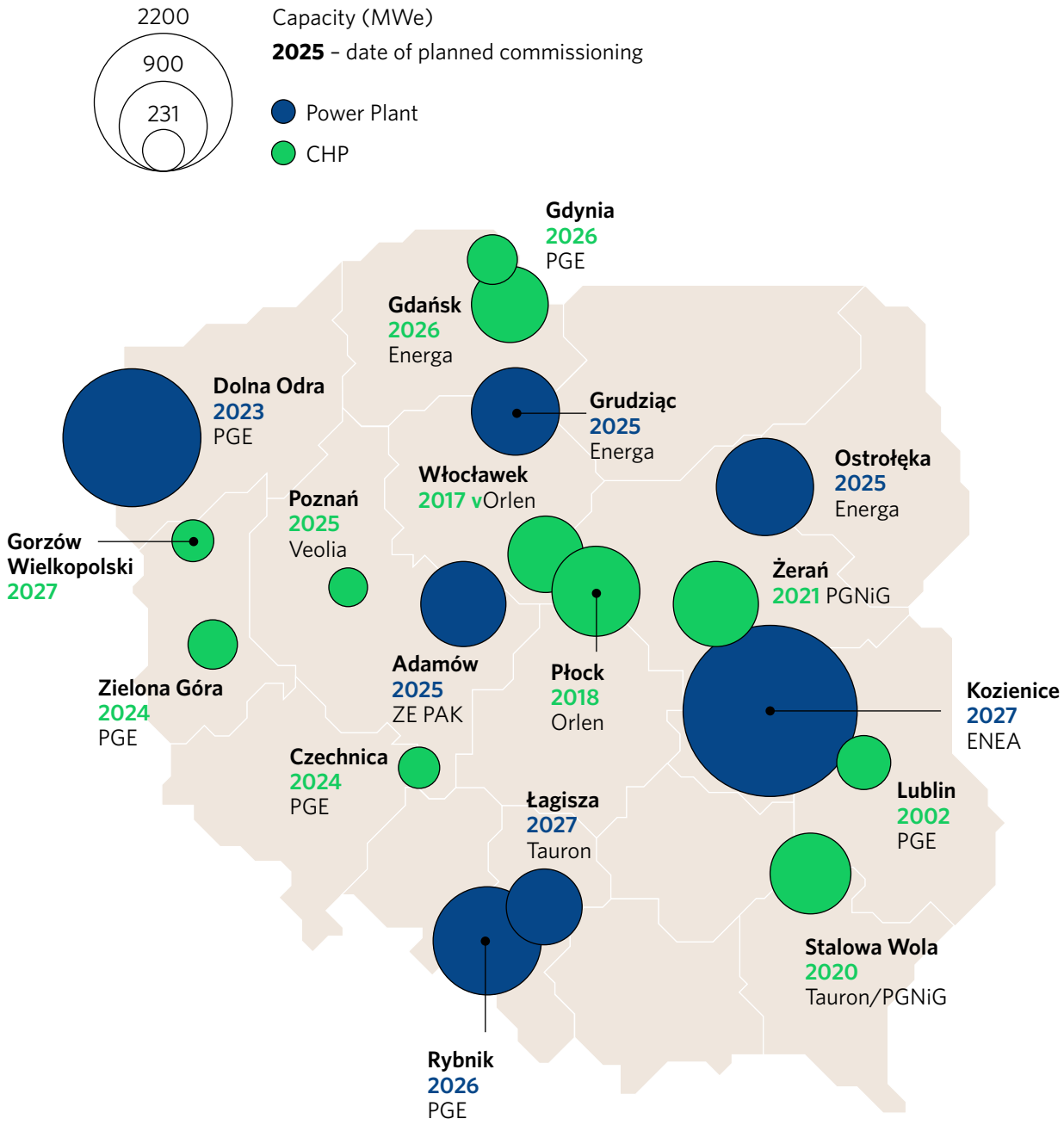
Gas — the bridge to green hydrogen in the energy sector

Hydrogen could be burned at gas-fired power plants in the future, increasing the chances of using existing gas infrastructure. Poland is preparing major gas investments, which will create the conditions for the expansion of green hydrogen in the power sector after 2040. Before that, hydrogen will mainly be needed in industry.

According to the new draft of the PEP40, the share of gas is expected to rise from the current 6 per cent to 15 per cent in 2030 and remain at this level in 2040. However, the share of gas is likely to be higher due to the faster closure of coal-fired power plants. Gas may account for nearly 27 per cent of Poland's electricity production in 2030 (Aurora, Dentons, 2023). This will result in the rapid expansion of gas capacity.

Poland's gas plants currently have an installed capacity of 4 GW (ARE, 2022). These are mostly CHPs providing heat for district systems and industrial use, such as the Płock and Włocławek CCGTs owned by Orlen. It is expected that gas plants' capacity will need to quadruple by 2030 to over 17 GW, predominantly at CCGTs and smaller flexible units, to keep up with coal-fired power plant closures and the system's rising security requirements.

MAP 5. POLAND'S LARGEST GAS-FIRED POWER PLANTS AND CHPs



Source: PGE, Orlen, Enea, ZE PAK, Tauron, Veolia.

This sharp increase of gas plant capacity in the Polish power system would obviously have a major impact on the actual consumption of natural gas in Poland. The total gas consumption for power needs would have to increase from around 20 bcm in 2022 to over 30 bcm in 2030, increasing the need for gas imports significantly and largely depending on the ability to put supporting infrastructure in place.

Poland currently plans to install two FSRU units in the Gdańsk Bay to increase LNG import capacity by 10 bcm. This increase could trap Poland with gas assets for years to come. To mitigate this risk, it will be necessary to increase the use of hydrogen in the electricity and heating sectors significantly.

The combustion of green hydrogen at CCGT units will enable Poland to reduce natural gas imports, CO2 emissions and, ultimately, maintain CCGT units amid rising CO2 prices and competition from RES and energy storage. Green hydrogen can also be used to produce energy in fuel cells, which could prove their worth as a peak power source providing surplus power. The first large-scale projects of this type, which would provide green energy continuously, are set to be completed before 2030 (RechargeNews.com, 2021).

Nuclear — an uncertain source of purple hydrogen

Poland wants to use nuclear power plants to produce so-called purple hydrogen. However, these plans could face significant delays, so this type of fuel[34] should not be seen as competition for green hydrogen. In the new draft of the PEP2040, government maintains the assumption that the first large-scale nuclear reactor will start operating in 2033. However, these assumptions are overly optimistic due to the lack of an investment financing scheme, regulatory uncertainty at the EU level, competition from RES and energy storage sources, and Poland's lack of experience in building and operating nuclear power plants.

Nevertheless, Poland cannot currently achieve climate neutrality in 2050 without nuclear power, so the government intends to develop this technology. Nuclear-generated hydrogen's competitive advantage is based on the potential large production scale. Nuclear hydrogen production is particularly justified during "night valleys", when nuclear units can use surplus electricity to power the electrolysers (Polish Hydrogen Strategy, 2021).

In 2040, Poland's nuclear power plants' capacity is expected to amount to 7.8 GW and account for 22.6 per cent of electricity production (the new draft of the PEP2040). Of these, Small Modular Reactors (SMRs) will account for 2.1 GW. The first SMR (an Orlen and Synthos unit) is expected to start operating by the end of the decade and deliver 1 TWh of electricity to the grid in 2030. The primary purpose of using SMRs is to provide clean and cheap electricity, with the possibility of powering electrolysers that produce hydrogen. Again, this assumption is overly optimistic due to the lack of commercially operational SMRs. It is estimated that the first SMRs could be operational around 2035 (Polityka Insight, 2022). It therefore seems that purple hydrogen should be seen as an supplemental option for the development of the hydrogen market in Poland.

The Polish Hydrogen Strategy

In December 2021, the Ministry of Climate and Environment published the final version of the Polish Hydrogen Strategy until 2030 with an outlook until 2040. The strategy sets out a framework for development of the hydrogen economy in Poland, with a focus on the use of hydrogen in energy, heating, transport and industry.

The Strategy's main objective is to increase the number of new hydrogen production facilities in Poland to lead the transition from grey hydrogen to low-emission and green hydrogen. It prioritises installations that produce green hydrogen; low-emission hydrogen produced from natural gas with CCS would be an interim option, generating economies of scale in the first phase of market development (until about 2030).

The Strategy identifies six objectives:

- the deployment of hydrogen technologies in the power and heating sectors;
- the use of hydrogen as an alternative fuel in transport;
- the use of hydrogen to support the decarbonisation of industry;
- the production of hydrogen at new installations;
- the efficient and safe transmission, distribution and storage of hydrogen;
- the creation of a stable regulatory environment.

INDICATORS FOR THE DEVELOPMENT OF THE HYDROGEN ECONOMY IN POLAND:

INDICATOR	2025	2030
Installed capacity of electrolysers	50 MW	2000 MW
Number of hydrogen buses	100 - 250	800 - 1000
Number of hydrogen valleys	<5	5
Number of hydrogen refuelling stations	32	>32

The Strategy assumes that the key objective in the short to medium term is to create supply and demand for hydrogen; the development of hydrogen supply infrastructure must take place in parallel with the creation of market demand. To achieve this, the construction of electrolysers is set to be concentrated in hydrogen valleys. This will result in production facilities located close to demand centres, which can meet the local demand for hydrogen in industry and transport.

The document also assumes that Poland's first hydrogen-fuelled combined CHP, with a capacity of up to 50 MWt, will be built by 2030.

The Polish government plans to spend around PLN 11 billion (EUR 2.5 billion) by 2030 on achieving the goals outlined in the Strategy. This will mainly be used to finance investments in electrolysers and purchase hydrogen buses. One of the key sources of funding in Poland's hydrogen transition could be the National Fund for Environmental Protection and Water Management (NFOŚiGW), which already offers preferential refundable financing or grants for the development of hydrogen technologies.

It should be expected that the funding options for developing hydrogen in Poland will be supplemented by a regulated support system in the future; for example, hydrogen auctions or Contract for Differences (CfD), which are already emerging in other EU member states, such as Germany and Romania.

The Sectoral Agreement for the Development of the Hydrogen Economy in Poland

In October 2021, representatives of the government administration, the business community, science and business environment units signed a "Sectoral Agreement for the Development of the Hydrogen Economy in Poland". Its main objective is to maximise the Polish contribution ("local content") in the procurement chain for the construction of the hydrogen economy.

According to the document, the "local content" indicator should reach no less than 50 per cent of the total value of the national hydrogen economy. The government estimates that the added value for the Polish economy from achieving this indicator will be EUR 343-870 million.

The Sectoral Agreement was signed by 138 entities representing various sectors in which the production, transmission, storage and use of hydrogen is expected to play an important role in the future, including transport, energy, heating and industry.

It seeks to bring together the economic, research and development potential for the development of the hydrogen market in Poland, also in terms of developing human resources, increasing international competitiveness and obtaining financing.

On the basis of the objectives set out in the Sectoral Agreement, a Coordinating Council for the Hydrogen Economy was established at the Ministry of Climate in March 2022 to coordinate actions linked to the construction of the hydrogen economy in Poland.

The regulatory environment for hydrogen

EU law

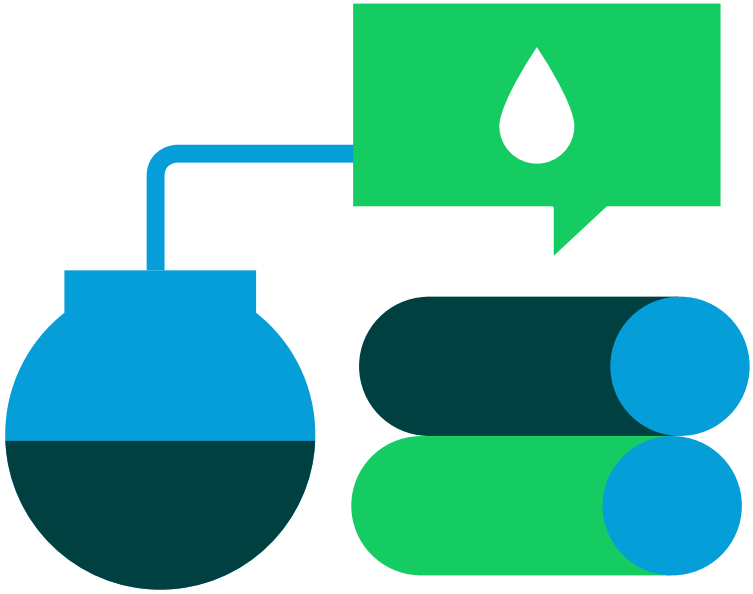
In 2020, the European Commission (EC) adopted a hydrogen strategy setting out a vision for the creation of a European hydrogen ecosystem, from research and innovation to production and infrastructure, as well as the development of international standards and markets. Hydrogen is expected to play an important role in the decarbonisation of industry and heavy transport in Europe and globally. As part of the Fit for 55 package, the Commission introduced a number of incentives for its use, including mandatory targets for industry and transport.

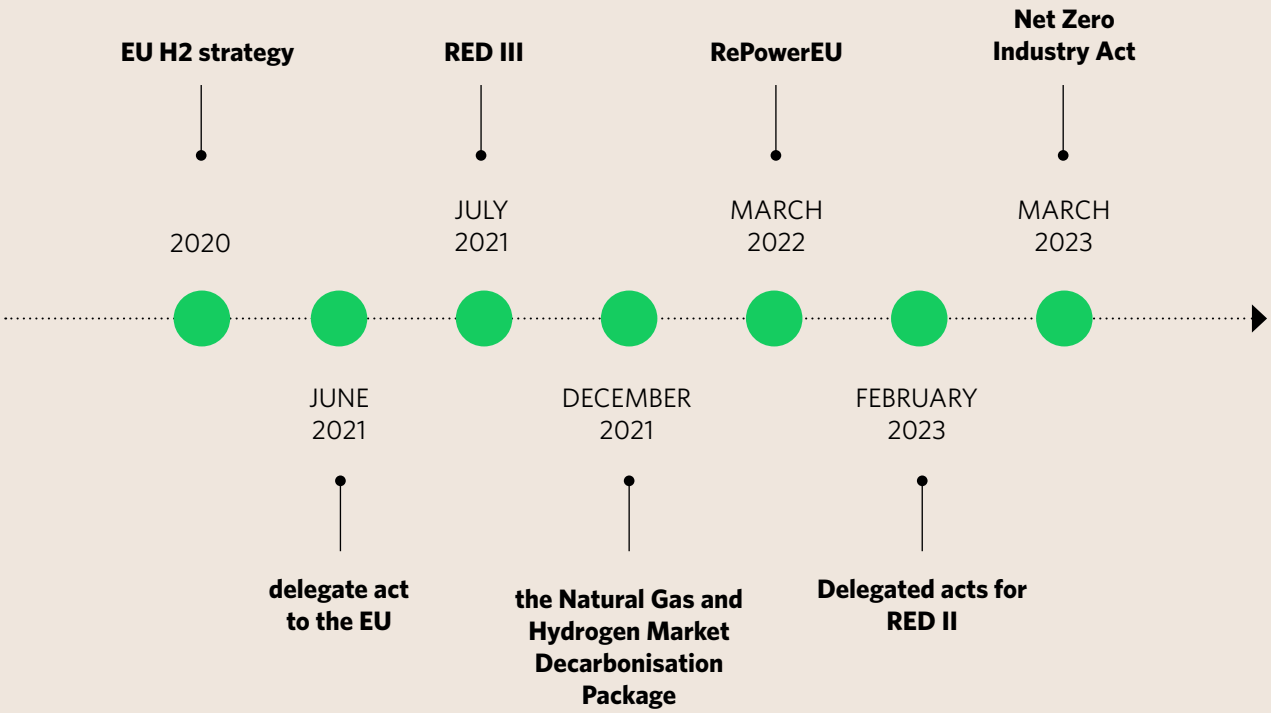
Hydrogen is also a key pillar of the REPowerEU plan, which aims to end imports of Russian fossil fuels. To increase the use of renewable hydrogen, the EC put forward the concept of "accelerating the use of hydrogen". By 2030, hydrogen production within the EU is expected to reach 20 million tonnes, with the other half imported. This is set to be achieved through investment in hydrogen infrastructure; the EC proposes to allocate EUR 28-38 billion for transmission infrastructure and EUR 6-11 billion for storage facilities.

The main hydrogen corridors will run through the Mediterranean, the North Sea and Ukrainian territory, if possible. Ultimately, hydrogen technology is supposed to replace natural gas, coal and oil in industry and transport. In the REPowerEU plan, the EC also announced the possibility of submitting new proposals for projects of common interest in hydrogen with the possibility of receiving funding from the Connecting Europe Facility, with an estimated budget of EUR 800 million.

In addition to the regulatory framework, the EC is also supporting the emergence of the hydrogen sector in the EU through Important Projects of Common European Interest (IPCEIs). The first IPCEI (IPCEI Hy2Tech)[35], comprising 41 projects, was approved in July 2022. It aims to develop innovative technologies for the hydrogen value chain to decarbonise industrial processes and the transport sector. In September 2022, the EC approved IPCEI Hy2Use[36], a second project that complements IPCEI Hy2Tech and that will support the construction of hydrogen-related infrastructure and the development of innovative and more sustainable technologies for integrating hydrogen into the industrial sector.

	EU HYDROGEN STRATEGY	REPOWEREU	POLISH HYDROGEN STRATEGY
Year	2020	2022	2021
Hydrogen producation level (target)	1 Mt by 2024 10 Mt by 2030	20 Mt by 2030 (10 Mt production in EU + 10 Mt import)	-
Capacity of electrolysers (target)	6 GW by 2024 40 GW by 2030	2 x 40 GW by 2030 (EU + non-EU)	50 MW by 2025 2 GW by 2030
Type of hydrogen	Green	Green	Green and low-carbon
Hydrogen imports	No	Yes	No
Other targets	» 80-120 GW of additio-nal RES capacity to power electrolysers » Development of a European electrolyser industry with a capacity of +100 MW » Hydrogen alliance with North African countries and Ukraine	» Establishment of EU Energy Platform for importing LNG and hydrogen from third countries » Approximately 30 per cent reduction in CO2 emissions in the steel sector through the use of green hydrogen » 8 million tonnes of renewable hydrogen to replace imports of around 27 bcm of gas	» At least 5 hydrogen valleys by 2030 » 100-250 hydrogen buses by 2025 » 800-1000 hydrogen buses by 2030 » 32 hydrogen stations by 2025





REDIII Directive

Act number: COM/2021/557/final

» **Date of publication: July 14, 2021**

» **Status: Awaiting Parliament's position in 1st reading (end of August 2023)**

The draft's provisions stipulate that, by 2030, 42 per cent of hydrogen used in industry will be renewable fuels of non-biological origin (RFNBO); that is, ones that derive energy from renewable sources other than biomass. By 2035, this ratio will have to increase to 60 per cent. At the same time, the share of RFNBO in transport will have to increase to 1 per cent in 2030 and 5.5 per cent for advanced biofuels and RFNBO.

The RFNBO target in industry will require new legislative solutions, as well as identifying selected technological processes so that RFNBO targets can be calculated. Achieving the RED III targets for RFNBO development will require a dedicated support system; for example, contracts for difference for hydrogen producers and consumers in Poland. It will also be necessary to develop dedicated RES installations for the production of green hydrogen from electrolysers and infrastructure for hydrogen imports.

Delegated Regulation supplementing the REDII directive

» **Act number: 2023/1184 and 2023/1185**

» **Date of publication: February 10, 2023**

» **Status: in force from July 10, 2023.**

Delegated Regulation 2023/1184 establishes a methodology setting out detailed rules for the production of RFNBO in transport. The regulations distinguish between two situations: 1) when the electrolyser — that is, the equipment for the production of RFNBO — is directly connected to the RES installation (for example, by a direct line, onsite) and 2) when it is connected to the grid.

In the first case (onsite), the RES installation must have been commissioned no more than 36 months before the electrolyser was commissioned. At the same time, if the installation is connected to the grid, it must have a smart metering system to ensure that grid energy does not supply the electrolyser. In the second case (grid-connected), the electrolyser must be located in an energy balancing zone where the average amount of connected RES sources is over 90 per cent or its average emissivity is at most 18 grams of CO2 per megajoule of energy. In practice, these criteria can only be met in France and Sweden, due to

the high share of nuclear power.

Delegated Regulation 2023/1185 establishes the minimum emission reduction thresholds for hydrogen to be considered green. The fuel's entire life cycle will be calculated, from production to transport and consumption. The regulation indicates that hydrogen will achieve green status its emissions are 70 per cent lower than those of fossil fuel. In practice, this means that the hydrogen's emissivity cannot exceed 3 kg CO2/kg H2.

Delegated Regulation relating to the EU Taxonomy

- **Regulation number: 2021/2139**
- **Date of publication: June 4, 2021**
- **Status: in force from January 1, 2023.**

Delegated Regulation 2021/2139 sets EU-wide standards for the production of low-emission and renewable hydrogen (including synthetic fuels), in line with the requirements in the EU Taxonomy. The emission limit for low-carbon hydrogen is set at 3 kg CO2/kg H2. In addition, renewable and low-carbon hydrogen will have to reduce emissions by at least 73.4 per cent, compared to fossil fuels.

Hydrogen produced from zero-carbon energy technologies (wind turbines, solar and nuclear power) should easily meet the 73.4 per cent lifecycle C02 reduction target and be below the emission limit of 3 kg CO2/kg H2. The definition of low-carbon hydrogen will be met by hydrogen produced from natural gas + CCUS, as well as hydrogen produced from nuclear power (as long as they meet the 73.4 per cent CO2 reduction effect). Biomass-produced hydrogen does not currently qualify for any EU definition (it is neither RFNBO, low-carbon hydrogen nor RCF), but can count towards meeting RES targets in industry or transport under the RED.

Directive on common rules for the internal markets in renewable and natural gases and in hydrogen (The "new gas package")

- **Act number: COM/2021/803/final; COM/2021/804**
- **Date of publication: December 15, 2021**
- **Status: Awaiting Parliament's position in 1st reading (end of August 2023)**

According to the regulation, hydrogen storage will be operated by separate operators, who will be obliged to ensure the infrastructure's safety and development. Operators will have to provide third parties with non-discriminatory conditions of access to the storage service (the so-called TPA principle), as well as the provision of hydrogen injection and extrusion services. Tariff rebates on storage for the injection of renewable and low-emission hydrogen will be mandatory.

The package also provides for the establishment of a European Network of Network Operators for Hydrogen (EENOH), which will coordinate the construction of hydrogen networks across borders and develop detailed technical rules for the networks' operation, the implementation of mandatory ten-year network development plans, and the inclusion of hydrogen networks in national energy and climate plans.

FuelEU Maritime Regulation

- **Act number: COM/2021/562**
- **Date of publication: July 14, 2021**
- **Status: Act adopted by Council after Parliament's 1st reading; awaiting signature of act**

The regulation seeks to reduce CO2 in maritime transport using LNG, bio-based fuels and RFNBO (including renewable methanol and renewable ammonia). The draft implements the target of obtaining 2 per cent of energy from RFNBO from 2034.

Regulation for the deployment of alternative fuels infrastructure (AFIR)

» **Act number: COM/2021/559 final**

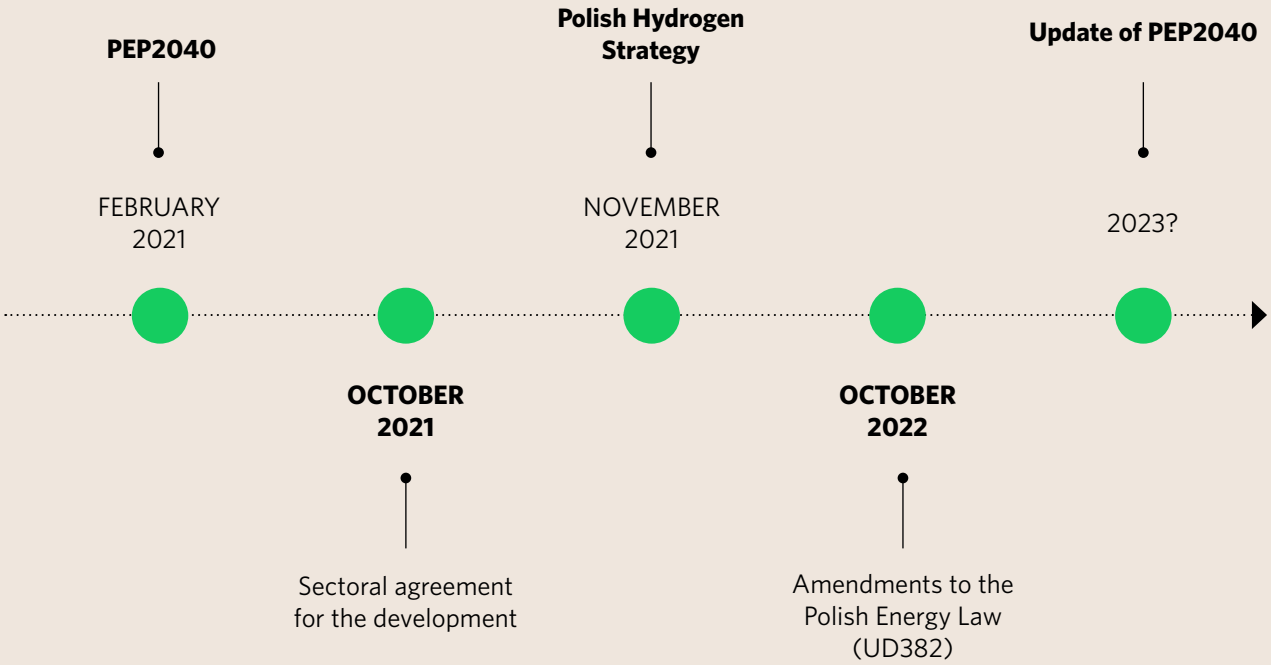
» **Date of publication: July 14, 2021**

» **Status: Act adopted by Council after Parliament's 1st reading, Awaiting signature of act (end of August 2023)**

The AFIR sets out milestones for the creation of alternative vehicle charging infrastructure, including the hydrogen refuelling of fuel cell electric vehicles (FCEVs) on the road. According to the draft, by 2030, there will have to be at least one hydrogen refuelling point every 200 km on main roads (the TEN-T network) and one refuelling point at each urban node.

Assuming that the stations will operate 365 days a year, with a capacity of 1 tonne of hydrogen per day, the annual demand for hydrogen in the EU road transport sector on the TEN-T network will be at least 239,800 tonnes in 2030. In the case of Poland, this would mean that 49 hydrogen refuelling points would have to be in operation by 2030, consuming 17.800 tonnes of hydrogen per year.

Polish law



The Constitution for Hydrogen

» **Title: draft act of October 21, 2022 amending the Energy Law and certain other acts**

» **Act number: UD382**

» **Status: awaiting adoption by the government**

At the beginning of 2022, the Polish Climate Ministry announced the preparation of the so-called "Constitution for Hydrogen", a legislative package to regulate and support the construction of this industry in Poland. A key element of the package is an amendment to the Energy Law.

The bill introduces a general definition of hydrogen with a distinction between types: low-emission hydro-

gen, electrolytic hydrogen and renewable (green) hydrogen. It extends the definition of "fuel" to include hydrogen and introduces a definition of electrolytic conversion and electrolysers.

In addition, it provides for the creation of a hydrogen system operator. This will be an energy company appointed by the president of the Energy Regulary Office to manage hydrogen systems, including the hydrogen storage system; like in the energy system as a whole, it will have to meet independence criteria. The legislation will allow the gas system operator to fulfil this role.

The hydrogen system operator will be responsible for the security of supply, maintaining infrastructure and operating the network. The detailed conditions for the hydrogen system's operation and the use of interconnectors in the long run will be defined by the Ministry of Climate in a separate regulation.

Hydrogen activities will be licensed. Any entity involved in hydrogen storage, transmission or trading will have to obtain a licence. The exceptions will be hydrogen storage in stationary installations with a capacity of up to 5000 Nm3 and hydrogen trading with an annual value of up to EUR 100.000.

The draft lists the environmental requirements for hydrogen investments and the construction requirements for hydrogen stations and purification facilities.

To support hydrogen-related R&D, the new law will establish a Hydrogen Research and Development Committee, a new body of the National Centre for Research and Development. It will include representatives of the Ministries of Climate, Development, Finance, and Education, as well as the business community. Their main task will be to develop strategic research programmes in this area, which will be funded from the education budget.

The Geological and Mining Law

- **Title: Draft act amending the Geological and Mining Law and certain other acts**
- **Act number: UD280**
- **Status: approved by the Sejm, work in the Senat**

The amendment to the Geological and Mining Law provides for the extension of permitted CO2 injection and storage activities, among other things. The government wants to abolish concessions for the exploration or prospecting of underground complexes capable of storing CO2 and make it easier to adapt extinguished hydrocarbon deposits, including ones gradually reducing production, for this purpose.

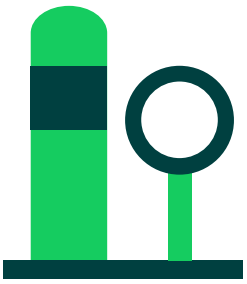
The amendment also seeks to speed up the construction of hydrogen storage facilities in salt caverns, depleted hydrocarbon deposits and saline water-bearing formations. Underground tankless hydrogen storage will be given the status of a public purpose investment and become a licensed activity. Companies exploiting the deposits will be given priority when it comes to obtaining a licence for storing hydrogen in the deposit.

Act on monitoring and control system fuel quality

- **Title: act of August 25, 2006 on the system for monitoring and controlling fuel quality**
- **Act number: Dz. U. z 2021 r. poz. 133**
- **Status: In force**

The act establishes the basic principles of hydrogen certification. It defines the scope of hydrogen certification testing through an accredited laboratory, the deadlines for hydrogen quality testing and certification, and the content and details presented in the hydrogen quality certificate. The Ministry of Climate's implementing decree on the methods of testing hydrogen quality by an accredited laboratory was published in December 2022.

THE BOTTOM LINE



EU and Polish regulations will increase certainty in the development of the hydrogen market. The acts will cover European producers, but also foreign producers who plan to export hydrogen to the EU. The regulations will favour the construction of hydrogen energy islands — that is, electrolysers powered by RES installations connected by a direct line, without connection to the grid. The high carbon intensity of Poland's energy mix means that supplying hydrogen production facilities with energy from the grid will be unprofitable.

Hydrogen in local governments' strategies and policies

Hydrogen valleys in Poland

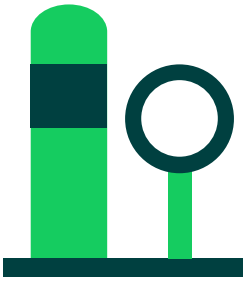
Hydrogen valleys are political, social and economic undertakings aimed at building regional hydrogen markets in the full value chain of hydrogen technologies: production, transmission and storage, and use of hydrogen. For now their main objective is to create a platform for cooperation between business, local administrations and universities for hydrogen projects.

Hydrogen valleys offer: advisory support for hydrogen-related products or services, business promotion, networking support, participation in business events. Ultimately, hydrogen valleys are intended to facilitate the business application of solutions and technologies developed at universities.

Hydrogen valleys will differ from one another because of differences in geographic location, the region's industrial and natural resources, and its needs. Clusters in the south of Poland will produce hydrogen for the needs of industrial plants, and the clusters in central and northern parts of the country – for refineries and transport. The legal form of the hydrogen valleys will not be predetermined, and the entities involved will be free to choose; for example, the Podkarpacka, Subcarpathian, Lower Silesian and Silesian valleys are associations. The rest valleys are commercial chambers, clusters or advisory boards to the Voivodeship administration.

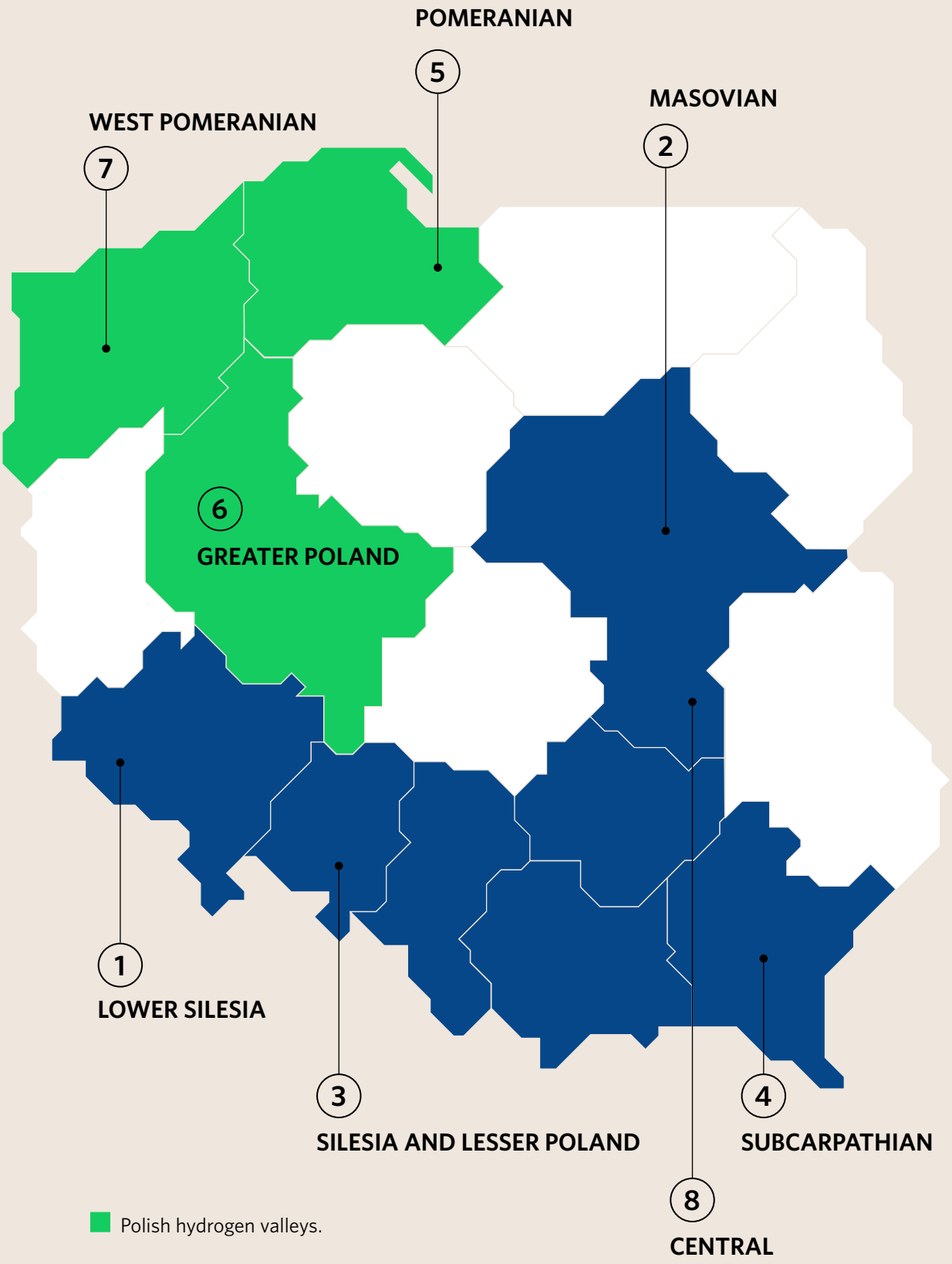
The state-owned Industrial Development Agency (ARP) is involved in work to create four hydrogen valleys: the Subcarpathian, Lower Silesian, Mazovian and Silesian and Lesser Poland valleys. Entry to the Hydrogen Valleys is open to companies registered in Poland. For example, entry into the Lower Silesian Hydrogen Valley costs a one-off fee of PLN 6.000 and an annual membership fee of PLN 12.000.

THE BOTTOM LINE



The creation of hydrogen clusters or valleys will facilitate the construction of a decentralised hydrogen market in Poland. Connecting producers and consumers of this fuel in one place will help to solve the problem of the lack of development of hydrogen infrastructure caused by low demand. The success of hydrogen clusters will, however, depend on accelerating the development of RES, especially unblocking the possibility of building land-based wind farms. Without them, the production of cheap and zero-emission hydrogen will not be possible.

MAP 6. POLISH HYDROGEN VALLEYS.



Source: ARP SA.[37]

① LOWER SILESIAN HYDROGEN VALLEY

Form of business activity: association
Registered seat: Wrocław
Website: www.dolinah2.pl
Concept: hub management – hydrogen hub management.

Main stakeholders: KGHM Polska Miedź S.A., ZAK Kędzierzyn-Koźle S.A., ARP S.A., Toyota Motor Manufacturing Poland Sp. z o.o., Z-Klaster, Wrocław University of Technology, Wrocław University, Office of the Marshal of the Lower Silesian Voivodeship, Linde Gas Polska Sp. z o.o.
Specialisations: green ammonia, green heat, green copper and metallurgy, green river transport, hydrogen storage, RES, biogas, hydrogen pipelines.
Achievements so far: two applications for the development of a regional hydrogen economy submitted to Horizon Europe submitted in 2022 as part of an international consortium, participation and promotion of the Hydrogen Valley during Hydrogen Week in Brussels, finalisation of the first green hydrogen production project, publication of the Lower Silesian Regional Energy Strategy to support the region's energy transition.

② MAZOVIAN HYDROGEN VALLEY

Form of business activity: association
Registered seat: Wrocław
Website: www.dolinah2.pl
Concept: hub management – hydrogen hub management .

Main stakeholders: KGHM Polska Miedź S.A., ZAK Kędzierzyn-Koźle S.A., ARP S.A., Toyota Motor Manufacturing Poland Sp. z o.o., Z-Klaster, Wrocław University of Technology, Wrocław University, Office of the Marshal of the Lower Silesian Voivodeship, Linde Gas Polska Sp. z o.o.
Specialisations: green ammonia, green heat, green copper and metallurgy, green river transport, hydrogen storage, RES, biogas, hydrogen pipelines
Achievements so far: two applications for the development of a regional hydrogen economy submitted to Horizon Europe submitted in 2022 as part of an international consortium, participa.

③ SILESIAN AND LESSER POLAND HYDROGEN VALLEY

Registered seat: Katowice
Website: www.h2dolina.eu/index.php/o-nas
Concept: Silesia and Lesser Poland's energy transition based on Just Transition Fund.

Main stakeholders: Orlen Południe S.A., Polenergia S.A., ARP S.A. Branch Katowice, JSW Nowe Projekty, Grupa Azoty Tarnów S.A., Silesian University of Technology, AGH University of Science and Technology, KOMAG, Institute for Fuels Technology and Energy (formerly IPCHW), Katowice SEZ, Upper Silesian Metropolis, Columbus S.A.
Specialisations: green glycol, Silesia's energy transition, hydrogen production, hydrogen storage, green steel, zero-emission public transport, CCUS.
Achievements so far: one of the main players in the Hydrogen Valley, Orlen Południe, has set up a green glycol production unit; development of the hydrogen website H2Poland.eu, which supports the development of the hydrogen economy in Poland and the Silesian and Lesser Poland Hydrogen Valley's activity.

④ SUBCARPATHIAN HYDROGEN VALLEY

Form of business activity: association
Registered seat: Rzeszów
Website: www.dolinawodorowa.org
Concept: Integration around the university and the aviation valley.

Main stakeholders: Rzeszów University of Technology, Subcarpathian Marshal's Office, Polenergia Elektrociepłownia Nowa Sarzyna Sp. z o.o., the town of Sanok, ARP S.A., aviation valley entities, Autosan S.A., ML System S.A.
Specialisations: hydrogen buses, hydrogen in aviation, hydrogen-generated power, green heat, hydrogen pipelines.
Achievements so far: application for Project Development Assistance — the development of a hydrogen valley based on the experience of experts from the Clean Hydrogen Partnership, qualification for stage I of the NCBiR competition by the Nowa Sarzyna CHP Plant, beginning a feasibility study for the modernisation of a heating plant in Sanok based on hydrogen technology.

⑤ POMERANIAN HYDROGEN VALLEY

Form of business activity: commercial chamber/cluster
Registered seat: Gdynia
Website: www.klasterwodorowy.pl/pomorska-dolina-wodorowa.53.pl
Concept: integration around local government initiatives, decarbonisation of the Port of Gdynia, "Shore H2 Valley".

Main stakeholders: Pomeranian Marshal's Office, Hydrogen Technology Cluster, city of Gdynia, PKP Energetyka S.A., Port of Gdynia, Sescom S.A., Gdańsk University of Technology.
Specialisations: zero-emission public transport, hydrogen production, offshore, port decarbonisation, hydrogen storage, electrolyser production, HRS.
Achievements so far: Development of the NeptHyne project, which aims to produce hydrogen at sea using wind farms and transfer electricity and hydrogen to land. The author of the concept is Tomasz Pelc, Nexus Consultants, a member of the Hydrogen Technology Cluster.

Gdynia, together with Gdańsk, Tczew and Wejherowo, will be one of 11 European regions to benefit from Project Development Assistance (PDA) support – advice on the implementation of hydrogen vehicles in public transport. The application for PDA support was prepared by a consortium of local authorities with the cooperation of representatives of Lotos Group (now Orlen), members of the Pomeranian Hydrogen Valley.

⑥ GREATER POLAND HYDROGEN VALLEY

Form of business activity: advisory board to the Marshal's Office of the Greater Poland Voivodeship
Registered seat: Poznań
Website: www.h2wielkopolska.pl
Concept: integration around local government initiatives and a major company's decarbonisation needs.

Main stakeholders: Greater Poland Marshal's Office, ZE PAK, Solaris, Adam Mickiewicz University, Poznań University of Technology, Regional Development Agency in Konin, city of Piła, Wielkopolska Council of Thirty.
Specialisations: hydrogen production, storage, refuelling stations, hydrogen buses, RES.
Achievements so far: Greater Poland is the only voivodeship to have prepared a regional strategy for the development of the hydrogen industry[38]. The document assumes an increase in the capacity of electrolysers to 400 MW in 2030. The estimated potential for green hydrogen production in Wielkopolska is 600.000 tonnes per year.

⑦ WEST POMERANIAN HYDROGEN VALLEY

Form of business activity: letter of intent
Registered seat: Szczecin
Website: –
Concept: integration around a major chemical company, "Shore H2 Valley".

Main stakeholders: West Pomeranian Voivodeship Office, Grupa Azoty Police S.A., ARP S.A., Enea S.A., Port Police S.A., Maritime University of Technology, National Fund for Environmental Protection and Water Management, West Pomeranian University of Technology, Koszalin University of Technology.
Specialisations: green ammonia, low carbon maritime transport, low carbon river transport, ammonia collection infrastructure, hydrogen production, offshore.

⑧ CENTRAL HYDROGEN VALLEY

Form of business activity: claster
Registered seat: Kozienice
Website: –

Main stakeholders: Enea, ARP SA, Grupa Przemysłowa Industria S.A., ARP S.A., the city of Kielce, the municipality of Chęciny, Kielce University of Technology, Columbus S.A., ML System S.A., AIUT S.A., SBB Energy S.A.
Specialisations: hydrogen production from RES, hydrogen haulers, hydrogen storage, RES, green public transport.

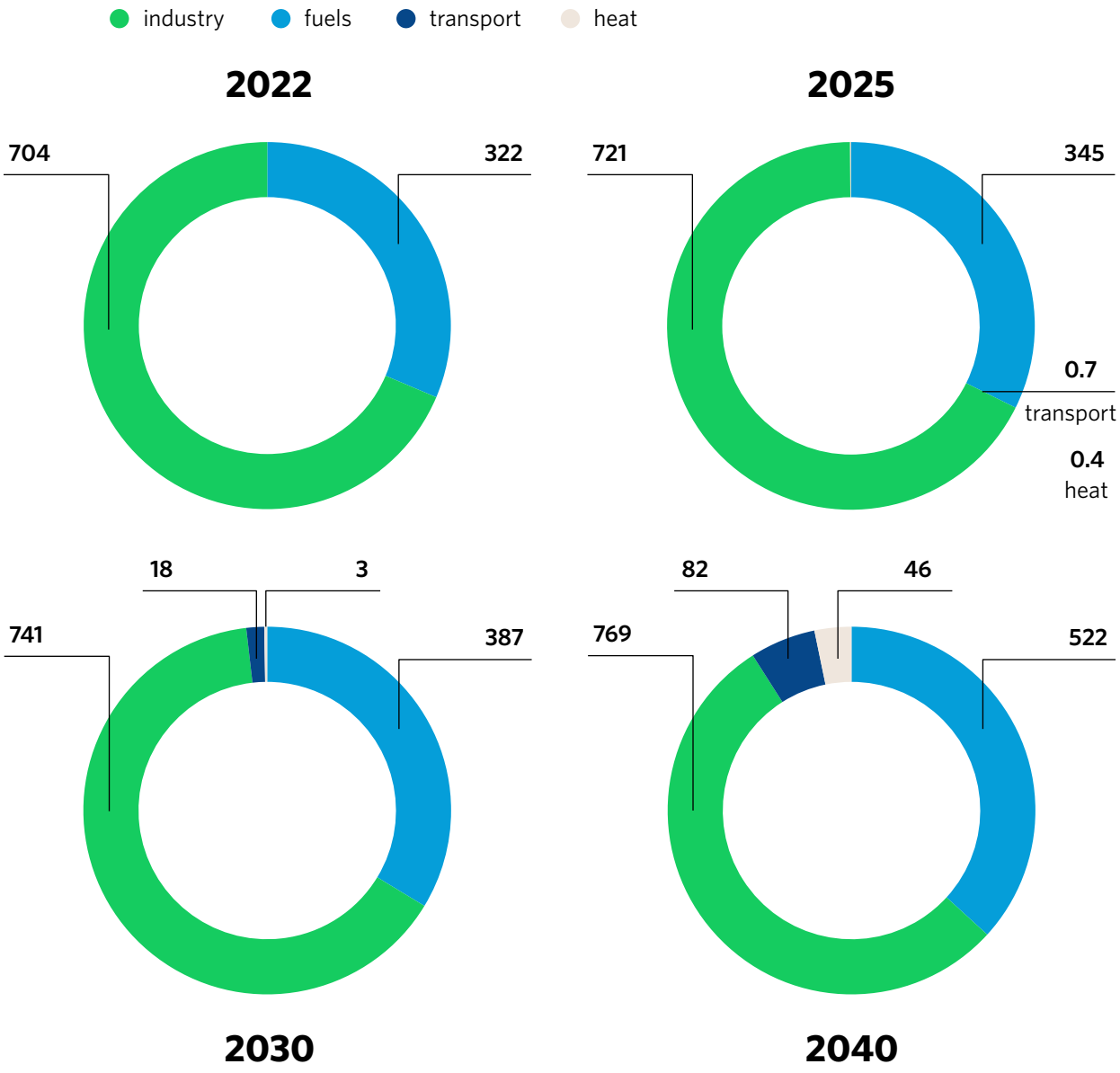
The aim of the initiative is to produce hydrogen for the gas units being built by Enea in Kozienice, which are to be adapted to burn hydrogen. The Central Hydrogen Valley is assumed to have 250 MW of electrolysers in operation. The first green hydrogen in the Świętokrzyskie Voivodeship could be obtained in 2024.

Estimated demand for hydrogen in Poland

The government's strategy assumes that Poland will produce around 193.000 tonnes of green hydrogen in 2030. Demand from industry and transport could be twice as high, reaching 450.000-510.000 tonnes by the end of the decade.

Poland is the third-largest producer of hydrogen in the EU (about 1 million tonnes a year), but it is grey hydrogen produced by reforming gas, which creates CO2. The Fit for 55 package will force EU countries to move away from this type of fuel and replace it with "green" hydrogen produced from RES-powered electrolysers.

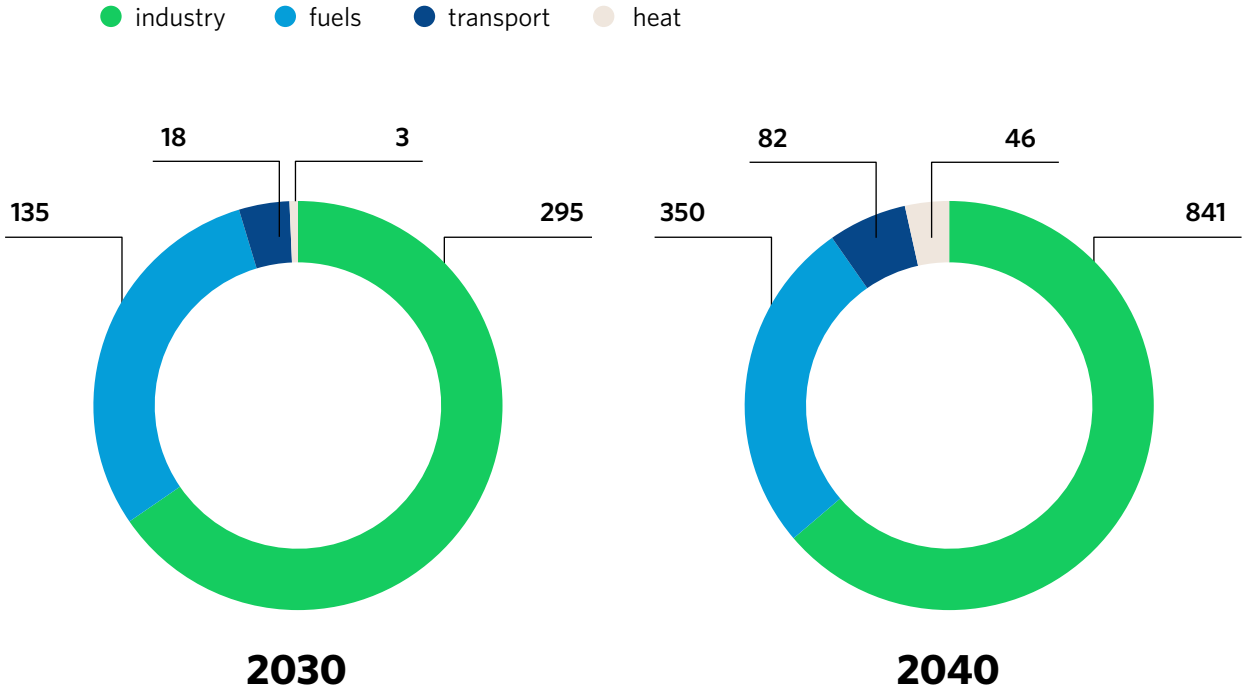
CHART 6. PROJECTED GROWTH IN DEMAND FOR HYDROGEN IN POLAND TILL 2040 (THOUSANDS OF TONES)



In this respect, the revised RES directive (REDIII) is key. It stipulates that, in 2030, 42 per cent of the hydrogen consumed in industry must be covered by RFNBO. In contrast, the draft Renewable Gases Directive also allows the use of blue hydrogen, which is hydrogen produced from fossil fuels, but with the use of CO2 absorption plants (CCUS).

The process of switching from grey to green hydrogen will accelerate rapidly after 2025. At the regulatory level, the Polish government's launch of a support system for renewable hydrogen production (which should take place in 2025-2027) and the entry into force of the CBAM regulation, which will limit free CO2 emission allowances for industry from 2026 until they expire in 2034, will be key.

CHART 7. PROJECTED GROWTH IN DEMAND FOR GREEN AND LOW CARBON HYDROGEN IN POLAND TILL 2040 (THOUSANDS OF TONES)



Source: Esperis, DISE, Aurora Energy Research, calculations by the author.

At the market level, the prices of natural gas, electricity and CO2 emission allowances will be crucial; an increase in their purchase cost will have a positive impact on the profitability of producing hydrogen from RES and, at the technological level, the purchase cost and availability of electrolysers and CCUS plants

Outlook to 2030:

» **Chemical and coke industry: 295.000 tonnes of green H2.** Apart from refineries and petrochemicals, Polish industry produces about 700 thousand tonnes of grey hydrogen in total. To meet the provisions of the REDI-II directive, Polish chemical and coke plants will have to consume around 295.000 tonnes of green or blue hydrogen in 2030. Producing this amount of fuel from RES will require approximately 18 TWh of electricity.

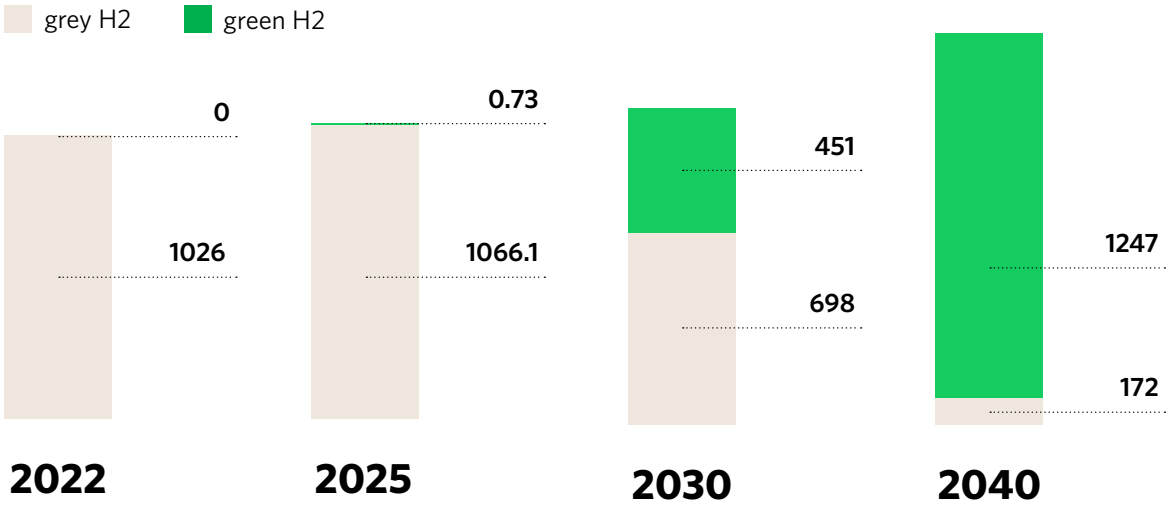
» **Refineries and petrochemicals: 135.000 tonnes of green H2.** To comply with the REDIII Directive, the Polish refining and petrochemical industry will need to produce around 135,000 tonnes of green or blue

hydrogen in 2030. Producing this amount of fuel from RES will require approximately 8 TWh of electricity. Orlen's business strategy calls for the production of around 130.000 tonnes of renewable hydrogen by 2030. This will enable it to cover its refining and petrochemical needs, but not its fertiliser needs.

» **Transport: 18.000 tonnes of green H2.** The REDIII Directive indicates that, by 2030, RFNBO will have to account for at least 1 per cent of final energy consumption in transport in EU countries. In Poland, this will mean replacing 235.000 tonnes of oil equivalent with approximately 78.000 tonnes of green hydrogen. Such a big leap in the use of RFNBO is unrealistic due to electric drives' rapidly-growing competitiveness.

The Alternative Fuels Infrastructure Development Regulation (AFIR) sets more realistic targets. It stipulates that 657 hydrogen refuelling points for cars must be built in the EU by 2030, 49 of them in Poland. This means that the demand for green hydrogen in road transport in Poland could amount to about 18.000 tonnes in 2023, requiring 1 TWh of electricity to produce it.

CHART 8. PROJECTED GROWTH IN DEMAND FOR GREY AND GREEN HYDROGEN IN POLAND TILL 2040

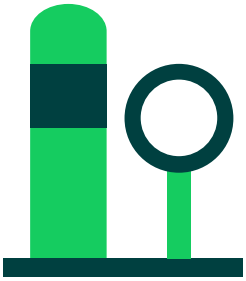


Source: Esperis, DISE, Aurora Energy Research, calculations by the author.

Green hydrogen will be available for use at adapted gas-fired power or CHP plants or at small hydrogen engines operating as peaking sources. However, looking ahead to 2030, hydrogen will mainly be burned for heat production. Demand then could be around 3000 tonnes (Esperis, 2022), which will require around 0.15 TWh of electricity.

THE BOTTOM LINE

Demand for green and blue hydrogen in Poland could rise from zero to 450.000-510.000 tonnes by 2030. The Polish Hydrogen Strategy envisages that 2 GW of electrolysers will be operating in the country by then, enabling it to produce approximately 193.000 tonnes of green hydrogen. To cover the shortfall, Poland will need to revise the Strategy's objectives and increase the capacity of the electrolysers in the country. It will also be necessary to build



CCUS facilities in the chemical and refining sectors, and to prepare the infrastructure for hydrogen imports through dedicated pipelines and seaports. To meet the targets set by the Fit for 55 hydrogen package, the development of off-grid and purely off-grid RES sources for hydrogen production in Poland will need to accelerate, too. These will require around 27 TWh of electricity.

However, Poland will only be able to produce green hydrogen in the power sector on a wider scale if there is a surplus of electricity from RES. In view of the rapidly growing demand for electricity in Poland, there is a significant risk that shortages in the required surplus capacity in the national power system will occur — and grow — after 2025. This could significantly lower the country's renewable hydrogen generation potential. Demand for green hydrogen should surge in the 2030s. By 2040, demand for green hydrogen in the Polish economy should reach 1.3 million tonnes.

03

The major stakeholders in Polish hydrogen sector

Key market players

The entities involved in the development of the hydrogen economy in Poland are mostly state-owned companies focused on the production and consumption of hydrogen. For this reason, the number of companies that can be involved in the creation of supply chains in the hydrogen economy is limited. However, there are also private players hoping for the rapid development of the hydrogen market in Poland.

Orlen

- **Revenue:** PLN 277,5 billion (2022)
- **CEO:** Daniel Obajtek
- **Main H2 specialist:** Grzegorz Jóźwiak, director of the Office of Hydrogen and Synthetic Fuel Technologies
- **Link:** www.orlen.pl/pl

Based in Płock, Orlen is the largest multi-utility company in Central and Eastern Europe, the largest Polish company and the country's largest producer of hydrogen (485.000 tonnes). In 2022, Orlen increased its scale significantly after acquiring Lotos and PGNiG. CEO Daniel Obajtek is the most influential manager at state-owned companies and one of the closest advisors to Jarosław Kaczyński, the chairman of the Law and Justice party. Orlen intends to build electrolysers with a capacity of at least 1 GW by 2030. The plants will produce both renewable and low-carbon hydrogen, which will require CCUS facilities[39]. Orlen plans to build eight hydrogen hubs in Poland by 2030. The first of these, with a capacity of around 50 kilogrammes of automotive-quality hydrogen per hour, started operating in Trzebinia in 2022.

Grupa Azoty

- **Revenue:** PLN 26,4 billion (2022)
- **CEO:** Tomasz Hinc
- **Main H2 specialist:** Henryk Kubiczek, head of the Corporate Strategy and Developmen Department and Rafał Biały, specialist regulatory coordinator
- **Link:** www.grupaazoty.com

Based in Tarnów, the company is the second-largest producer of hydrogen in Poland (420.000 tonnes). It operates in the mineral fertiliser, engineering plastic and OXO product sectors. Grupa Azoty currently ranks second in the EU in the production of nitrogenous and compound fertilisers. It is carrying out R&D related to the production and use of green hydrogen, as well as work related to the development of fuel cells and the launch of a hydrogen quality accreditation laboratory for fuel cell applications in transport as part of the "Green Azoty" project. Grupa Azoty is currently experiencing financial difficulties caused by the high gas prices. These may force it to sell its Puławy plant to Orlen, which would halve the group's capitalisation and financial potential[40].

Zespół Elektrowni Pątnów-Adamów-Konin S.A. (ZE PAK)

- **Revenue:** PLN, 4,2 billion (2022)
- **CEO:** Piotr Woźny
- **Main H2 specialist:** Maciej Nietopiel, CEO of PAK PCE Polski Autobus Wodorowy
- **Link:** www.zepak.com.pl/pl

Based in Konin, ZE PAK is one of the largest private energy groups in Poland, the country's second-largest producer of electricity from lignite and the fifth-largest generator of electricity. The group is in the process of moving away from lignite mining. As part of the Clean Poland programme, ZE PAK has purchased a HyLYZER 1000-30 electrolyser for hydrogen production. The 5 MW installation at the Konin power plant is expected to be operational by mid-2023. The electrolyser will be powered by a biomass power unit. ZE PAK's green hydrogen is meant to power a hydrogen bus charging station in Konin. ZE PAK is owned by Zygmunt Solorz, one of the richest Poles, who also owns Polsat TV.

Sescom

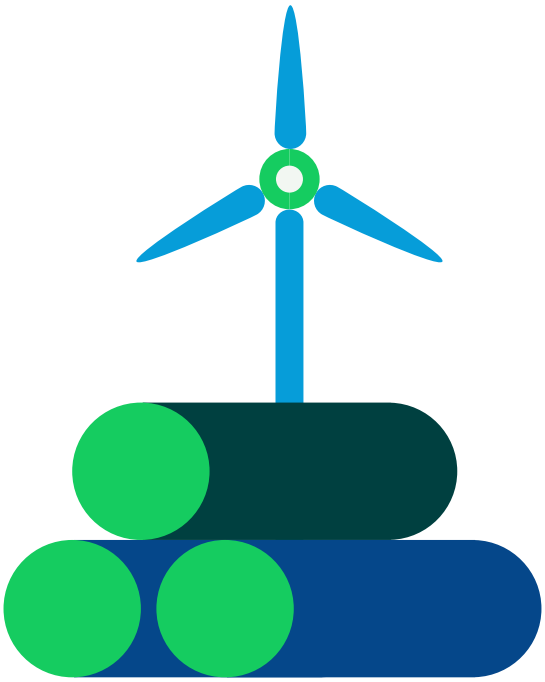
- **Revenue:** PLN 158 million (2022)
- **CEO:** Sławomir Halbryt
- **Main H2 specialist:** Maciej Halbryt, CEO of Sescom Innovation Lab
- **Link:** www.sescom.eu

Based in Gdańsk, this technology company operates in technical facility management services, with a strong focus on new technologies. Sescom holds three patents in the area of hydrogen technology, and has submitted another patent application. In addition, it is involved in the public debate and the exchange of best practices for achieving a zero-carbon economy; for example, within the Hydrogen and Clean Coal Technologies Cluster.

Hynfra P.S.A.

- **CEO:** Tomoho Umeda
- **Main H2 specialist:** Cezary Możeński, head of R&D department
- **Link:** www.hynfra.pl

Based in Warsaw, the company is active in the development of green hydrogen infrastructure. It offers general contracting processes and helps investors operate and maintain technological processes at new installations and sell green hydrogen, and actively develops technologies for the use of green hydrogen in high-efficiency co-generation processes. It is headed by Tomoho Umeda, one of the most recognisable hydrogen lobbyists in Poland, who co-founded the Hydrogen Poland association. In February 2023, Hynfra signed a cooperation agreement with Japanese technology provider Tsubame BHB to develop a solution for small-scale ammonia production[41].



Gaz-System

- **Revenue:** PLN 3,8 billion (2022)
- **CEO:** Marcin Chludziński
- **Main H2 specialist:** Paweł Ernst, head of the Hydrogen Department
- **Link:** www.gaz-system.pl/pl

Based in Warsaw, Gaz-System is a state-owned gas pipeline network operator. It manages gas pipelines and the LNG terminal in Świnoujście. Gaz-System has reached an agreement with transmission system operators from Slovakia, Romania and Hungary to develop ways to reduce CO2 emissions when transporting gas and to transport hydrogen[42]. The company is most likely to become an operator of hydrogen transmission and storage infrastructure.

PERN

- **Revenue:** PLN 1,4 billion (2021)
- **CEO:** Mirosław Skowron
- **Main H2 specialist:** Paweł Jakubowski, CEO of Naftoserwis (a PERN subsidiary)
- **Link:** www.pern.pl

Based in Płock, PERN is a state-owned operator of oil pipelines and oil storage facilities. It is active in the transport and storage of petrochemicals, as well as in fuel handling. It is one of the signatories of the agreement establishing the Mazovian Hydrogen Valley. PERN's subsidiary Naftoserwis is conducting advanced R&D on the construction of a diagnostic piston for testing gas pipelines' readiness to inject hydrogen and hydrogen mixtures[43].

JSW

- **Revenue:** PLN 20,2 billion (2022)
- **CEO:** Tomasz Cudny
- **Main H2 specialist:** Wojciech Kałuża, Deputy CEO for Development
- **Link:** www.jsw.pl

Based in Jastrzębie-Zdrój, this state-owned company is the EU's largest producer of coking coal and coke used in steel smelting. JSW aims to reduce emissions through Ventilation Air Methane (VAM) capture, CCUS technology and green hydrogen production. The company is also planning to build a hydrogen cell factory on the site of the former Krupiński coal mine[44].

PGE

- **Revenue:** PLN 73,4 billion (2022)
- **CEO:** Wojciech Dąbrowski
- **Main H2 specialist:** Piotr Obrycki, director of the R&D Office, PGE Energia Kolejowa (a PGE subsidiary)
- **Link:** www.gkpge.pl

Based in Lublic, this state-owned company is the largest electricity producer in Poland. PGE is investing in green hydrogen production technologies through its subsidiary PGE Energia Odnawialna. In April 2023, PGE acquired PKP Energetyka, the largest electricity distributor for railways, which is developing a system to store green hydrogen from solar farms to power rail traction[45].

Tauron

- **Revenue:** PLN 36,3 billion (2022)
- **CEO:** Paweł Szczeszek
- **Main H2 specialist:** Piotr Apollo, CEO of Tauron Nowe Technologie (a Tauron subsidiary)
- **Link:** www.tauron.pl/dla-domu

Based in Katowice, this state-owned energy company is Poland's largest distributor of electricity. With the Sebastineum Silesiacum Institute of Science and Research, the company is working on an electrolyser, which is expected to power a PEM-type fuel cell[46].

KGHM

- **Revenue:** PLN 33,8 billion (2022)
- **CEO:** Tomasz Zdzikot
- **Main H2 specialist:** Radosław Żydok, head of the Transformation Projects Department at KGHM
- **Link:** www.kghm.com

Based in Lublin, this state-owned company is one of the world's largest producers of copper and silver. The company has production plants on three continents: Europe, North and South America. KGHM is one of the signatories of the "Sectoral Agreement for the Development of the Hydrogen Economy in Poland" and intends to actively invest in low- and zero-emission hydrogen technologies.

Polenergia

- **Revenue:** PLN 7 billion (2022)
- **CEO:** Michał Michalski
- **Main H2 specialist:** Jacek Głowacki, president of Nowa Sarzyna CHP Plant
- **Link:** www.polenergia.pl

Based in Warsaw, this is one of Poland's largest private energy groups. Polenergia is focused on the development of offshore wind farms and other RES projects; it is also implementing a large-scale project to enable the production of clean hydrogen. Its combined CHP plant in Nowa Sarzyna and planned new gas units will be prepared to burn green hydrogen. The company has joined an international consortium working to use hydrogen as a fuel in gas turbines. ENS is working on two Frame6B gas turbines manufactured by Thomassen International, each with a capacity of 40 MW, which could be modified in the future to co-fire hydrogen with natural gas and eventually transition to hydrogen.

Business organisations

Organisations that seek to connect individual actors and realise their common potential have an important place in the development of the hydrogen economy in Poland. The key actors are:

The Hydrogen Poland Association

» **Link:** www.hydrogen-poland.org

The Polish hydrogen sector's main lobbying organisation. Its main task is to represent Polish business interests at home and abroad. The association provides comprehensive legislative support, from promotional activities to preparing and providing an opinion on draft laws or other legal acts concerning hydrogen and fuel cell technologies.

The Chamber of Commerce of the Gas Industry (IGG)

» **Link:** www.igg.pl

This lobbying organisation was founded in 2003. At the end of 2019, it set up a Hydrogen Expert Group to act as a hub for the exchange of experience and expertise. The Expert Group seeks to develop the industry's position for ministries, authorities, and national and foreign organisations, and to promote the most favourable solutions for the use of hydrogen.

The Polish Alternative Fuels Association (PSPA)

» **Link:** www.pspa.com.pl/?lang=en

This association brings together leading brands from across the electromobility value chain. Together, they form a community of 90 vehicle and infrastructure manufacturers, operators and charging service providers, fuel and energy companies, and other entities and institutions working on sustainable transport. With over 150 companies among its members, it is the second largest industry organisation of its kind in Europe.

Scientific institutes

Hydrogen is appearing on university curricula in Poland; for example, as part of Physics, Chemistry or Energy undergraduate and postgraduate programmes. Hydrogen also features in the programmes of postgraduate diplomas; for example, in the section on RES. There are no faculties or study programmes in Poland focusing exclusively on hydrogen. However, over a dozen research institutes and units at the Polish Academy of Sciences (PAN) are involved in research relating to hydrogen to varying degrees. The key units are:

The Institute of Energy – Research Institute

» **Link:** www.ien.com.pl/strona-glowna

One of the largest energy technology research institutes in Poland. The Institute is a modern research centre under the auspices of the Ministry of Climate and Environment. Its activities range from expert work for the electricity sector to the most advanced, future-oriented energy generation technologies, such as fuel cells, clean coal technologies, hydrogen technologies and RES.

The Institute of Physical Chemistry of the Polish Academy of Sciences (IPC PAS)

» **Link:** www.ichf.edu.pl

One of the leading research units in Poland, the Institute has the right to use the logo "HR Excellence in Research", which confirms its commitment to the highest standards when hiring scientists. Each year, its staff publish more than 200 academic publications (including in prestigious journals such as Nature and Science) and are granted many patents. The Institute conducts research on hydrogen production and storage.

The Institute of Fluid-Flow Machinery, Polish Academy of Sciences

» **Link:** www.imp.gda.pl

The Institute conducts research on the operation, design, construction and development of machines for the conversion of energy. Its current research spans fluid mechanics, multiphase flows, thermodynamics and heat transfer, plasma physics, laser technology, machine mechanics, tribology and energy machine diagnostics. The Institute has built a prototype system for the distributed production of hydrogen from biogas.

Ignacy Łukasiewicz Institute for Energy Policy

» **Link:** www.instytutpe.pl/en

The Institute seeks to develop awareness and knowledge in the energy sector in its broadest sense (including hydrogen-generated energy), in particular energy and climate policy, energy security, and the regulatory and economic environment.

Industrial Automotive Institute

» **Link:** www.pimot.lukasiewicz.gov.pl

The Institute conducts R&D spanning motorisation, improving vehicles, enhancing road safety, and alternative sources of vehicle power and fuels, including hydrogen and fuel cells, biofuels and RES. The Institute provides state bodies pursuing strategic objectives relating to transport safety, environmental protection and national energy security with support.

Institute of High Pressure Physics

» **Link:** www.unipress.waw.pl/index.php?lang=pl

Institute is a part of the Polish Academy of Sciences seeks to apply high-pressure methods to research and develop high-pressure technologies. It conducts research on hydrogen storage.

Supporting organisations

The Polish Development Fund Group (GPFR) is a financial and advisory institution for businesses, local governments and individuals that invests in Poland's sustainable social and economic development. It consists of:

The Polish Development Fund (PFR)

» **Link:** www.pfr.pl/en

This state-owned company offers companies and local authorities instruments to develop energy transition projects, including the use of hydrogen in heating and transport. Beneficiaries of PFR funds include PESA, which is building the SM42-6Dn hydrogen locomotive.

The Industrial Development Agency (ARP)

» **Link:** www.arp.pl/en

This state-owned company supports companies' restructuring; it is involved in promoting the use of hydrogen at Polish companies. It is also playing an active role in the establishment and operation of hydrogen valleys.

Bank Gospodarstwa Krajowego (BGK)

» **Link:** www.bgk.pl

This state-owned bank supports investment in hydrogen technology. Since 2019, it has been involved in projects developing of alternative fuels for transport, including hydrogen.

The Polish Investment and Trade Agency (PAIH)

» **Link:** www.paih.gov.pl/pl

This state-owned company seeks to increase FDI flows into Poland and support Polish exporters. It organises hydrogen conferences and foreign economic missions for Polish companies in the hydrogen sector.

The Polish Agency for Enterprise Development (PARP)

» **Link:** www.en.parp.gov.pl

This state entity manages funds to support SMEs. It organises educational webinars on the use of hydrogen, among other things.

The Export Credit Insurance Corporation (KUKE)

» **Link:** www.kuke.com.pl/en/about-us

This state-owned insurance company supports exports by Polish companies.

In addition to the GPFR, the following institutions play a key role in supporting the development of the hydrogen economy:

The National Centre for Research and Development (NCBiR)

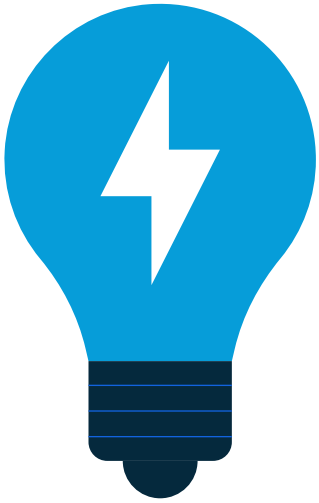
» **Link:** www.gov.pl/web/ncbr

This government agency was established to implement the state's scientific and innovation policy. Its task is to support Polish scientific units and companies in the creation and use of solutions based on scientific research to foster economic development. The NCBiR oversees the call for funds from the European funds. The NCBiR has subsidised the Polenergia hydrogen storage project, among other things.

The National Fund for Environmental Protection and Water Management (NFOŚiGW)

» **Link:** www.gov.pl/web/nfosigw-en

A state entity whose main objective is to provide supra-regional projects relating to environmental protection and water management with financial support. It consists of a head office and 16 independent regional environmental funds, which are subordinate to the regional authorities. It runs the "Hydrogenation of the Economy" programme, which aims to support projects implementing hydrogen technologies, together with the technical infrastructure for the production, storage, transport and use of hydrogen.



The administration

The Department of Electromobility and Hydrogen Economy at the Ministry of Climate and Environment

» **Director: Szymon Byliński**

The Department is tasked with developing the legal and organisational framework for the hydrogen economy in Poland. It is headed by Szymon Byliński, who has been involved in hydrogen issues since May 2020 and served as the director of the Ministry's Department of Innovation in 2018-2020. He was responsible for the creation of the Polish hydrogen strategy.

The Coordinating Council for the Hydrogen Economy in the Ministry of Climate and Environment

» **Chairman: Ireneusz Zyska**

The Council started operating in 2022. Its main task is to coordinate and monitor the provisions of the Sectoral Agreement for the Development of the Hydrogen Economy signed in October 2021. The Council's 45 members come from the public administration, companies and the world of science. It is chaired by Deputy Minister of Climate and Government Plenipotentiary for RES Ireneusz Zyska.

The Government Plenipotentiary for Strategic Energy Infrastructure

» **Plenipotentiary: Anna Łukaszewska-Trzeciakowska**

The Plenipotentiary oversees the operations of state-owned energy transmission companies PERN (oil and fuels), Gaz-System (gas) and PSE (electricity), as well as nuclear energy company Polskie Elektrownie Jądrowe (PEJ). Most of these entities are planning to or thinking about using hydrogen in the future.

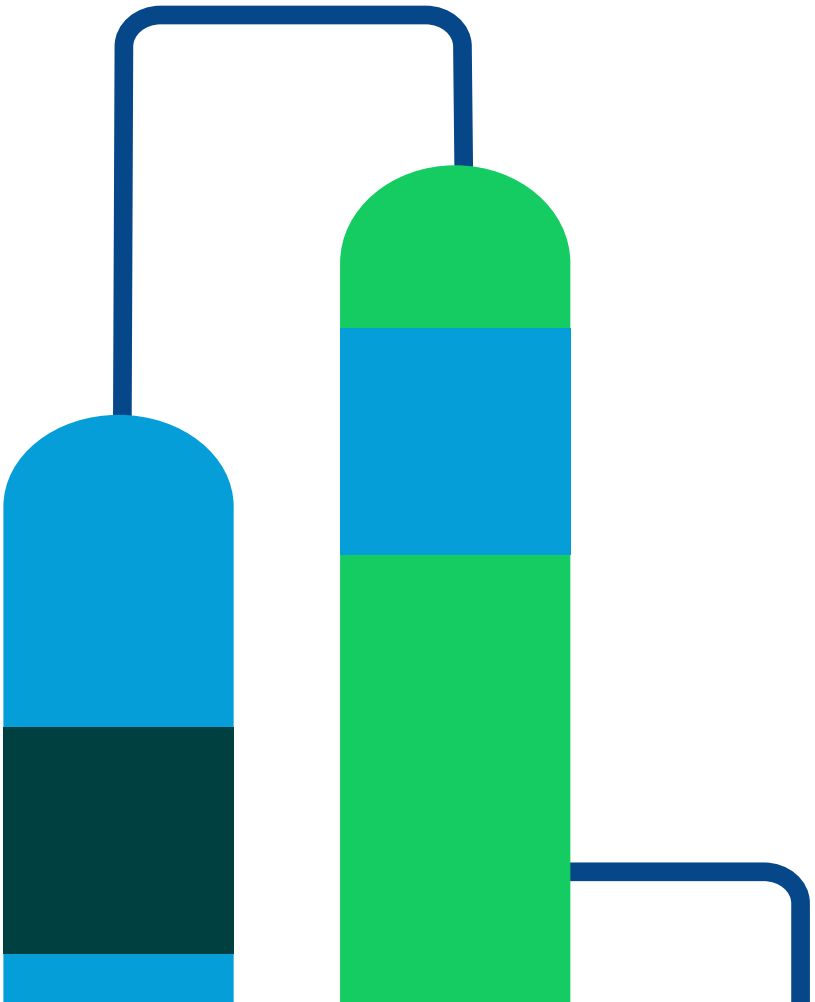
The Departments of Maritime Affairs and Transport Strategy at the Ministry of Infrastructure

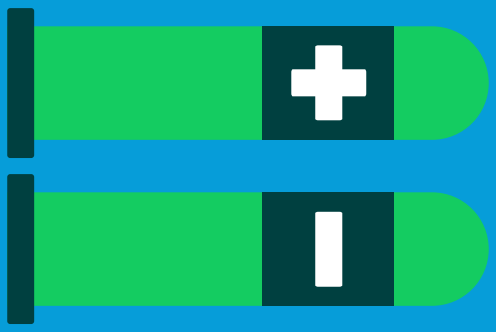
» Directors: Mariola Chojnacka (Maritime Economy), Adrian Mazur (Transport Strategy)

The former is responsible for planning the development of Polish ports, which will include building hydrogen import infrastructure in future. The latter is responsible for monitoring the functioning of the Trans-European Transport Network (TEN-T) and will be involved in planning the construction of hydrogen refuelling stations in the future.

The Plenipotentiary for the hydrogen economy (abolished)

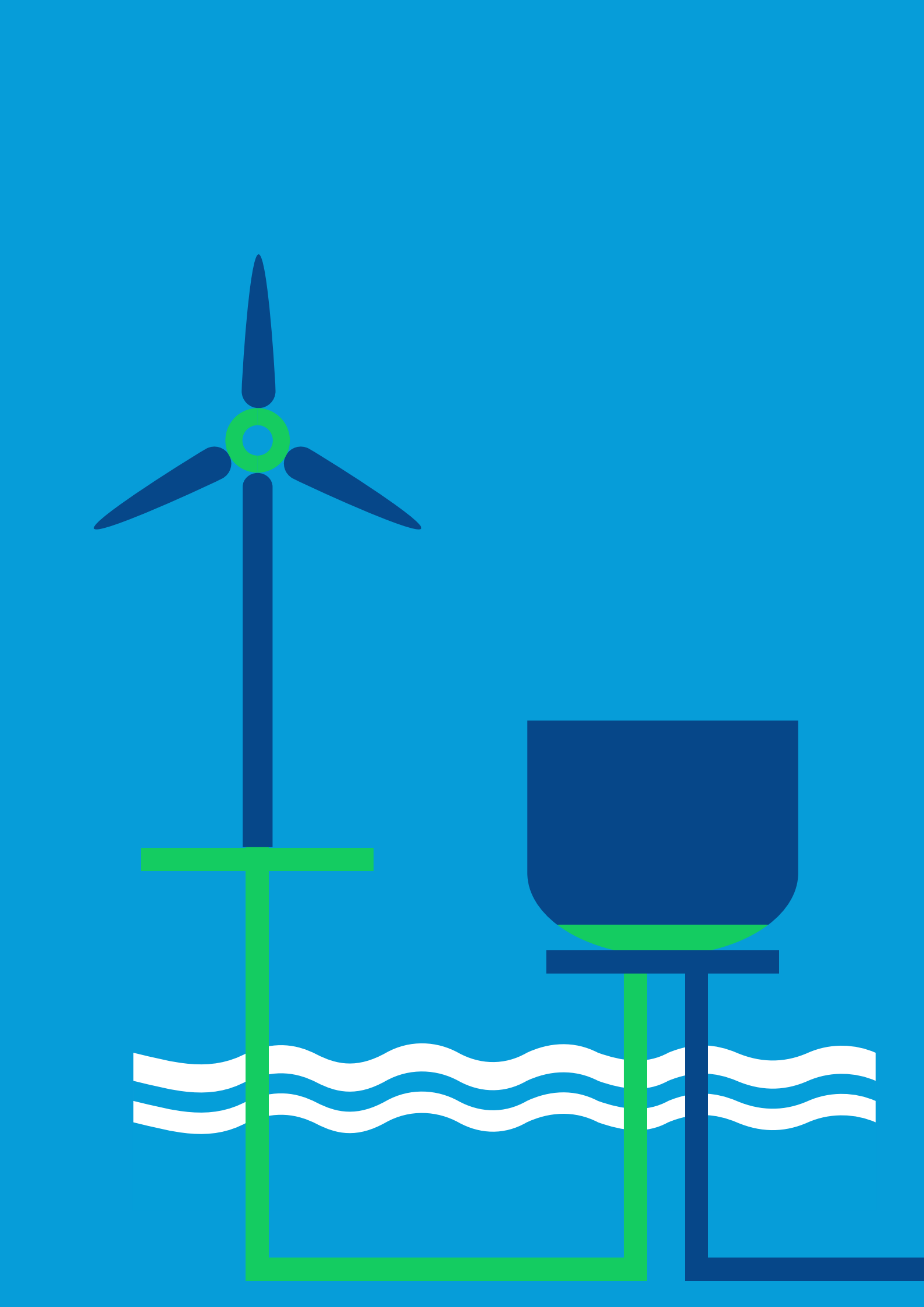
The post was created in July 2020 to integrate work relating to the use of hydrogen in the economy. Krzysztof Kubów, one of Prime Minister Mateusz Morawiecki's closest associates, became the plenipotentiary. The post was abolished in 2022.





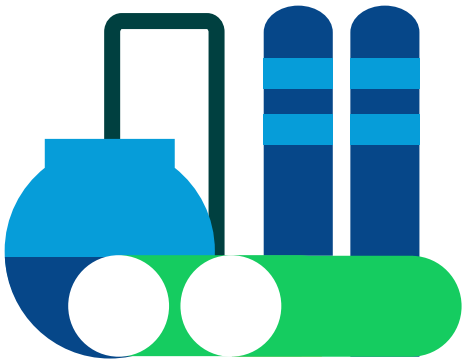
04

The role of hydrogen in the Dutch economy and energy transition



The Netherlands' Hydrogen Strategy

The Netherlands is Europe's second-largest producer of hydrogen, after Germany. Dutch hydrogen is used primarily in the production of steel and iron, or to make ammonia for fertilisers.



Most of the hydrogen is produced at the five largest industrial clusters: Maasdelta (Rotterdam), Zeeuws-Vlaanderen (Zeeland), Limburg, Eemshaven and IJmond. Almost all the hydrogen production is based on the steam methane reforming (SMR) of natural gas, which accounts for 8 per cent of the Netherlands' CO2 output.

The Netherlands announced its Hydrogen Strategy[47] in April 2020. Its objective is to support sustainable hydrogen, primarily based on electrolysis using sustainable electricity, but also based on sustainable biogenic feedstock. "Sustainable" hydrogen includes both green and blue hydrogen. The Dutch government sees it as making an optimal contribution to the development of a broader hydrogen system without impeding the growth of green hydrogen.

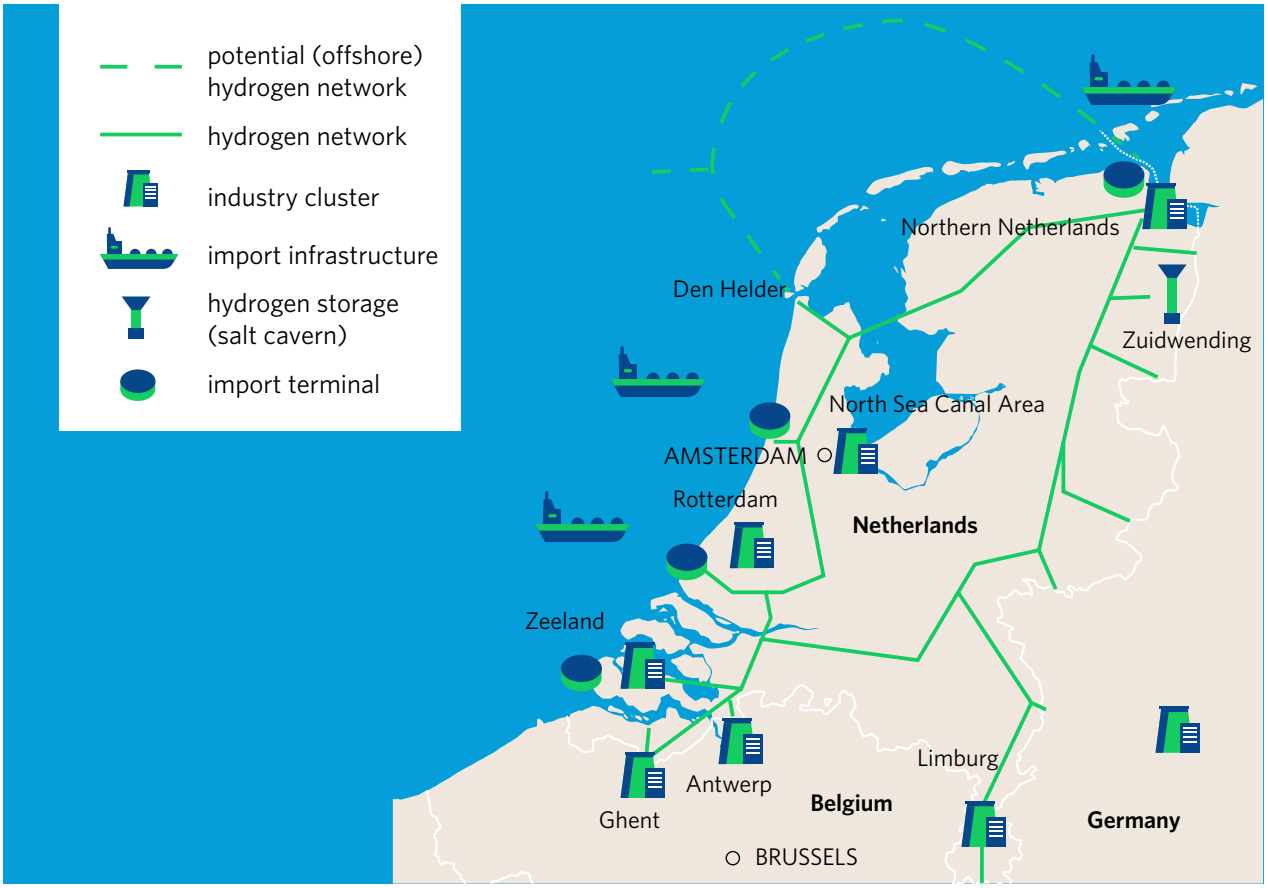
It aims to promote the sustainable development of hydrogen technologies, mainly the production of green hydrogen. Electrolyser capacity is set to increase to 500 MW in 2025 and 3-4 GW by 2030. However, this target is likely to increase to 8 GW[48].

Offshore wind farms are set to play a key role in the production of green hydrogen. The Netherlands aims to build 21 GW of offshore wind capacity by 2030. This could increase to 40 GW by 2040 and to 75 GW by 2050. The Dutch government is developing coordinated tenders for offshore wind and hydrogen and has provided a subsidy for the world's first pilot project with offshore hydrogen production from seawater (the PosHYdon project[49]). In 2023, The Hague announced plans to have 500 MW of offshore electrolysis capacity connected to an offshore wind farm, which would be operational around 2031[50].

A hydrogen backbone

The hydrogen strategy notes that one way to increase demand for low-carbon hydrogen is a blending obligation for the gas grid. The government indicates that physical blending, with hydrogen accounting for up to 2 per cent of the mix, is already achievable with minor adjustments to the gas network. Further adjustments could make it possible to gradually increase the share of hydrogen to approximately 10-20 per cent (IEA, 2020).

MAP 7. PLANNED DEVELOPMENT OF HYDROGEN INFRASTRUCTURE IN THE NETHERLANDS.



Source: Hynetwork services.

The Netherlands already has a network of dedicated hydrogen pipelines that is 1000 km long. The country's natural gas grid, made up of 136.000 km of pipeline, is also being retrofitted to transport hydrogen for both industry and households. This is the basis of the National Hydrogen Network, which will be ready in stages through 2031.

In June 2021, the Dutch cabinet called on Gasunie, the gas transmission operator, to convert part of the natural gas network into hydrogen infrastructure. HyNetwork Services[51], a subsidiary of Gasunie, is responsible for this task. The infrastructure will be developed in three phases:

1. The first phase, which will run until 2026, involves pipelines in the western part of the country to connect the industrial cluster at the coastline (Zeeland, Rotterdam, Amsterdam, Den Helder, Noord).

2. The second phase, which will run until 2028, involves eastern pipelines running from Eemshaven in the north (Noord) to the Chemelot industrial cluster in the south (Limburg), and connecting the hydrogen infrastructure in the Netherlands with Germany.

3. By 2030, these western and eastern routes will be connected to a southern route that also taps into Belgian hydrogen infrastructure.

The future hydrogen network will be based on the current natural gas network made up of 12.000 km of pipelines, some of which will become available for hydrogen transmission. Ultimately, some 85 per cent of the hydrogen network will consist of existing pipelines and the remaining 15 per cent will be newly built. Investment in Dutch hydrogen infrastructure is expected to reach EUR 1.5 billion in total, with the government providing EUR 750 million.

Transport

The Dutch Hydrogen Strategy sets targets for transport: building 50 refuelling stations, operating 15.000 hydrogen vehicles, 3.000 heavy-duty vehicles by 2025, and 300.000 hydrogen vehicles by 2030. The Netherlands plans to use synthetic fuel additives produced with decarbonised hydrogen in aviation.

Hydrogen imports

The Netherlands will is likely to rely on considerable hydrogen imports to achieve its clean energy targets. The Dutch government therefore considers it important to increase the country's hydrogen import capacity. The Hydrogen Strategy indicates the need to develop diplomatic relations with countries that will have the potential to export hydrogen; for example, Portugal is mentioned in this context.

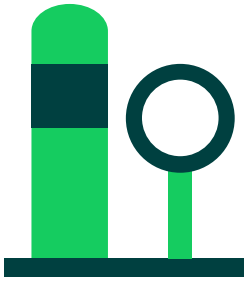
The main Dutch hub for hydrogen imports will be Rotterdam, which has ambitions to become a global hub for green hydrogen trade. The port authority wants to achieve an electrolysis capacity of 2-2.5 GW by 2030[52]. Rotterdam is supposed to be connected to 18-24 GW of offshore wind power by 2040 and become the hydrogen hub of northwestern Europe by 2050, with 18-20 million tonnes of hydrogen per year transported through it.

CCS

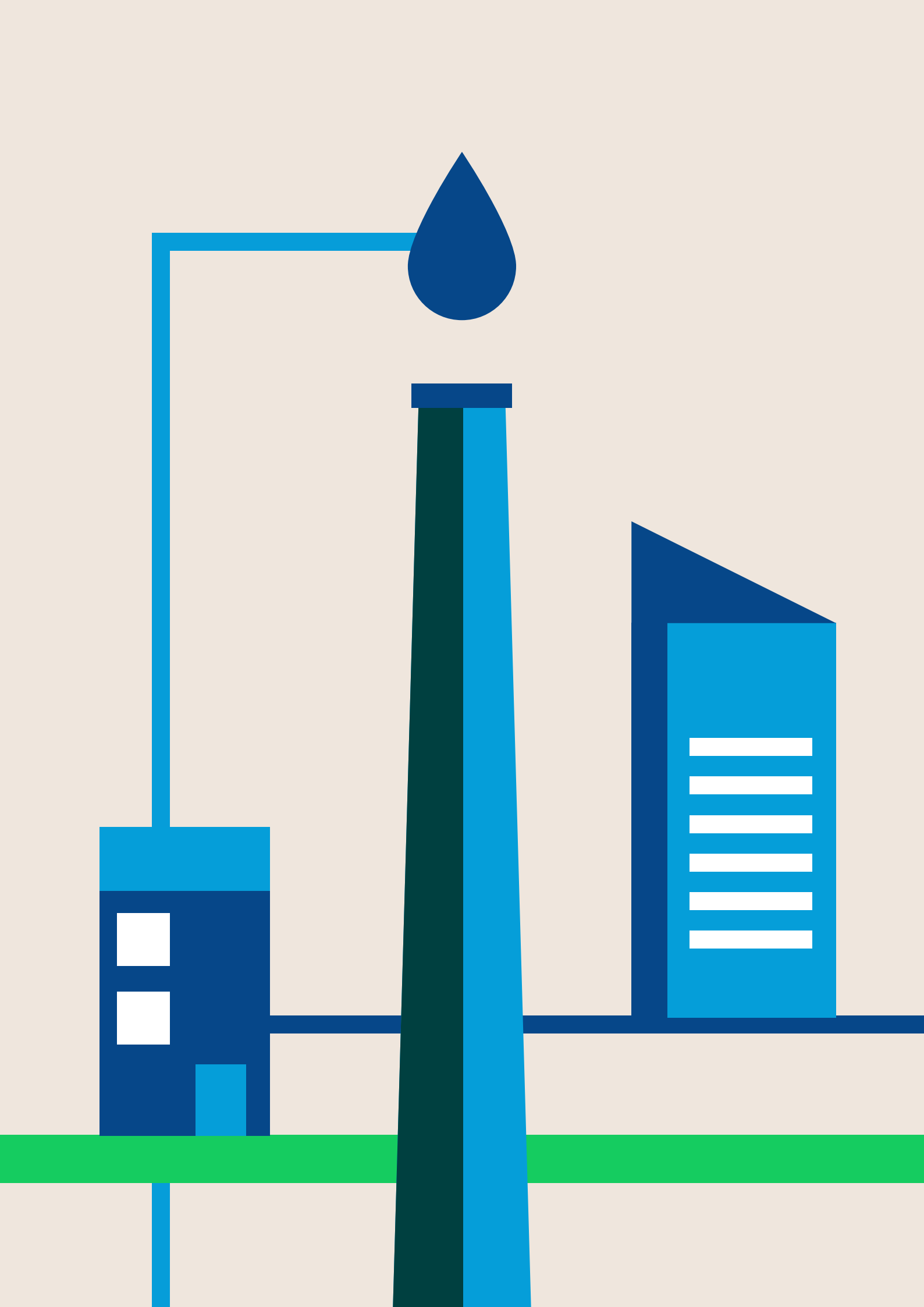
Carbon capture and storage (CCS) is a crucial part of the Dutch Hydrogen Strategy. The Hague's goal is to increase CO2 capture potential to 2-4 million tonnes per year between 2023 and 2025 and to 7 million tonnes per year after 2025.

This CCS infrastructure is set to be built in Rotterdam to enable the production of blue hydrogen. The aim of the Porthos project[53] is to compress around 2.5 million metric tonnes of CO2 per year and store it in empty gas fields under the North Sea by 2024. Four companies (Air Liquide, Air Products, ExxonMobil and Shell) have applied for the subsidy scheme amounting to EUR 2 billion in total over the next 15 years.

THE BOTTOM LINE

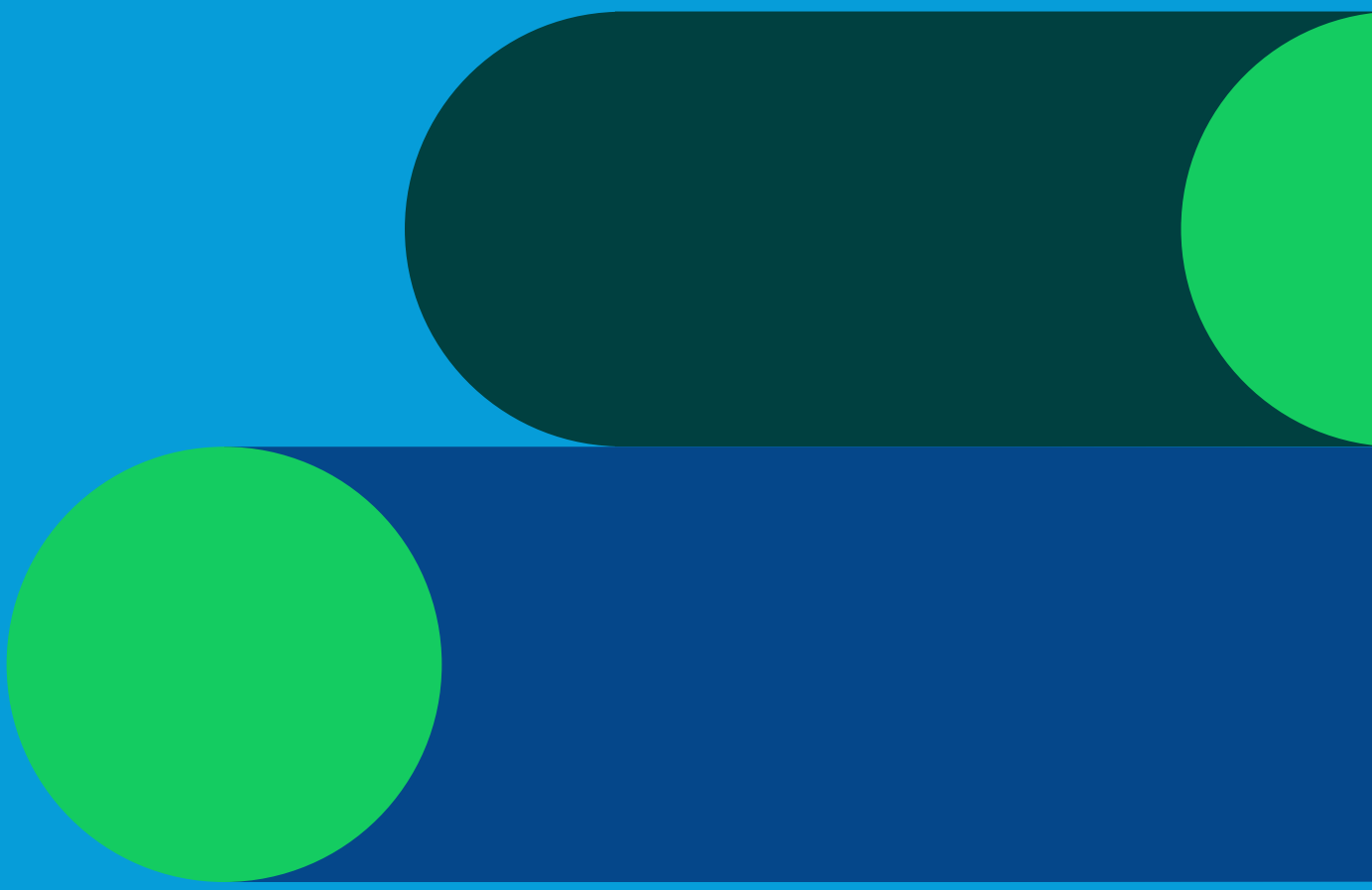


The Netherlands is a key player in European energy markets. It is an important transit and trade hub for natural gas, oil and electricity, and has a large oil refining and chemical industry. The country aims to maintain its role as an energy hub while transitioning to a carbon-neutral economy by supporting the development of a robust market for green and low-carbon hydrogen (IEA, 2020)[54]. This aim will be achieved thanks to the country's favourable location, with its ports, extensive gas network and storage capacity. However, replacing the current hydrogen production with electrolysis would require around 40 TWh of electricity. Even with significant improvement in the efficiency of green hydrogen production, the deployment levels targeted in the Dutch government's policy require a rapid increase in RES generation.



05

Polish-Dutch synergies in the hydrogen sector's development



Dutch and Polish energy policies

The Netherlands and Poland face the challenge of moving away from fossil fuels, towards zero-carbon technologies. The Netherlands is trying to reduce its dependence on gas by accelerating investment in RES. Poland is trying to reduce its dependence on coal by accelerating investments in gas and RES. Both countries want to invest in nuclear power plants.

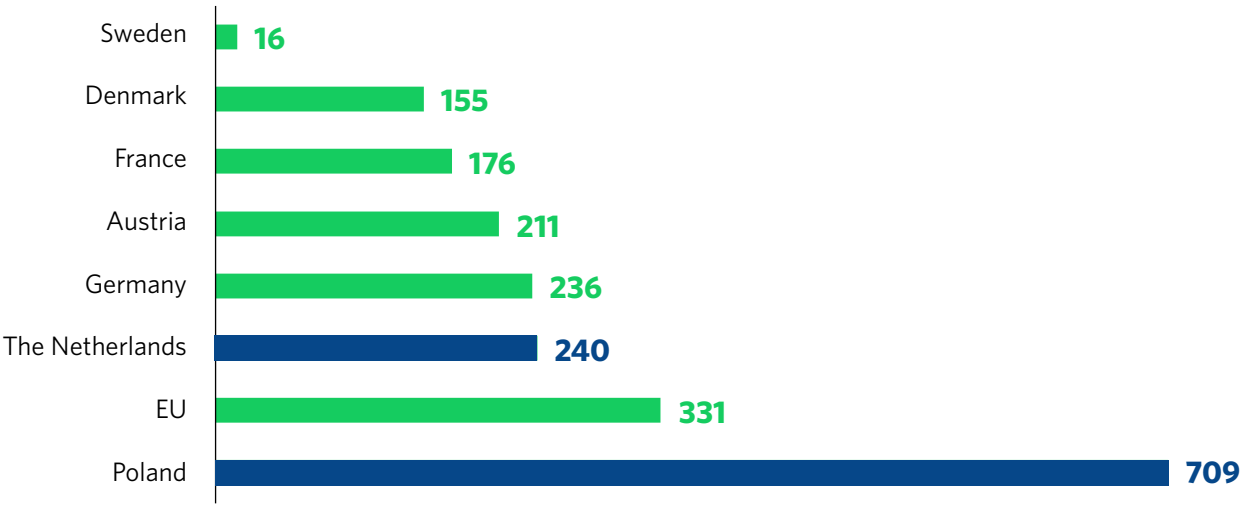
Share in electricity production in 2022 (%)	Poland	The Netherlands
Coal	70	12
RES	20	40
Nuclear	0	4
Gas	7	39,5

Source: Ember.

Both countries are lagging behind in the development of renewable energy. The share of RES in final energy consumption is 13 per cent in the Netherlands and 15.6 per cent in Poland, with an EU average of 21.8 per cent (Eurostat, 2021). However, a different picture emerges if we compare data on the share of RES in electricity production. In the Netherlands, RES account for 40 per cent of electricity production, compared to just 20 per cent in Poland (Ember, 2022)[55]. The high share of coal in energy production (70 per cent) makes the Polish economy's carbon intensity three times higher than that of the Dutch economy.

The energy transition in the Netherlands and Poland has accelerated rapidly in recent years. Since 2019, the share of RES in electricity generation has doubled in the Netherlands and increased by half in Poland due to the war in Ukraine and the energy crisis in the gas market, which has forced the entire EU to accelerate its move away from fossil fuels, among other factors.

CHART 9. EMISSION PERFORMANCE OF SELECTED EU ECONOMIES (THOUSAND TONNES CO2/UNIT OF GDP)



Source: Eurostat.

The impact of the war in Ukraine on the energy transition

The war in Ukraine has changed the perception of Poland's energy transition and its international status. Due to its location, Poland became a key country supplying Ukraine with arms and humanitarian aid, but also fuels. This was made possible by the development of gas[56] and oil[57] receiving infrastructure. In this way, Poland strengthened its position as an energy hub in the eastern part of Europe.

This was reinforced by the suspension of Russian gas supplies to Germany, following the blow-up of Nord Stream 1 and 2 (three of the four branches of the pipeline) in September 2022. As a result, Poland initially found itself in a more favourable position than Germany, with full access to the global LNG market and with contracts signed earlier for cheap gas from the US.

The prospect of the war ending and the start of Ukraine's postwar recovery could further strengthen Poland's position as an energy hub in eastern Europe. The governments in Warsaw and Kyiv launched a new energy link (Rzeszów-Khmelnytskyi) in 2023, which will enable energy imports and exports to Ukraine. There are plans to build another energy bridge (Chełm-Rivne), which could take place in 2026 or 2027. There are also plans to reactivate the construction of a Polish-Ukrainian oil pipeline (the Sarmatia project) and to extend the gas interconnector, which will enable increased gas exchange between Poland and Ukraine from 2030.

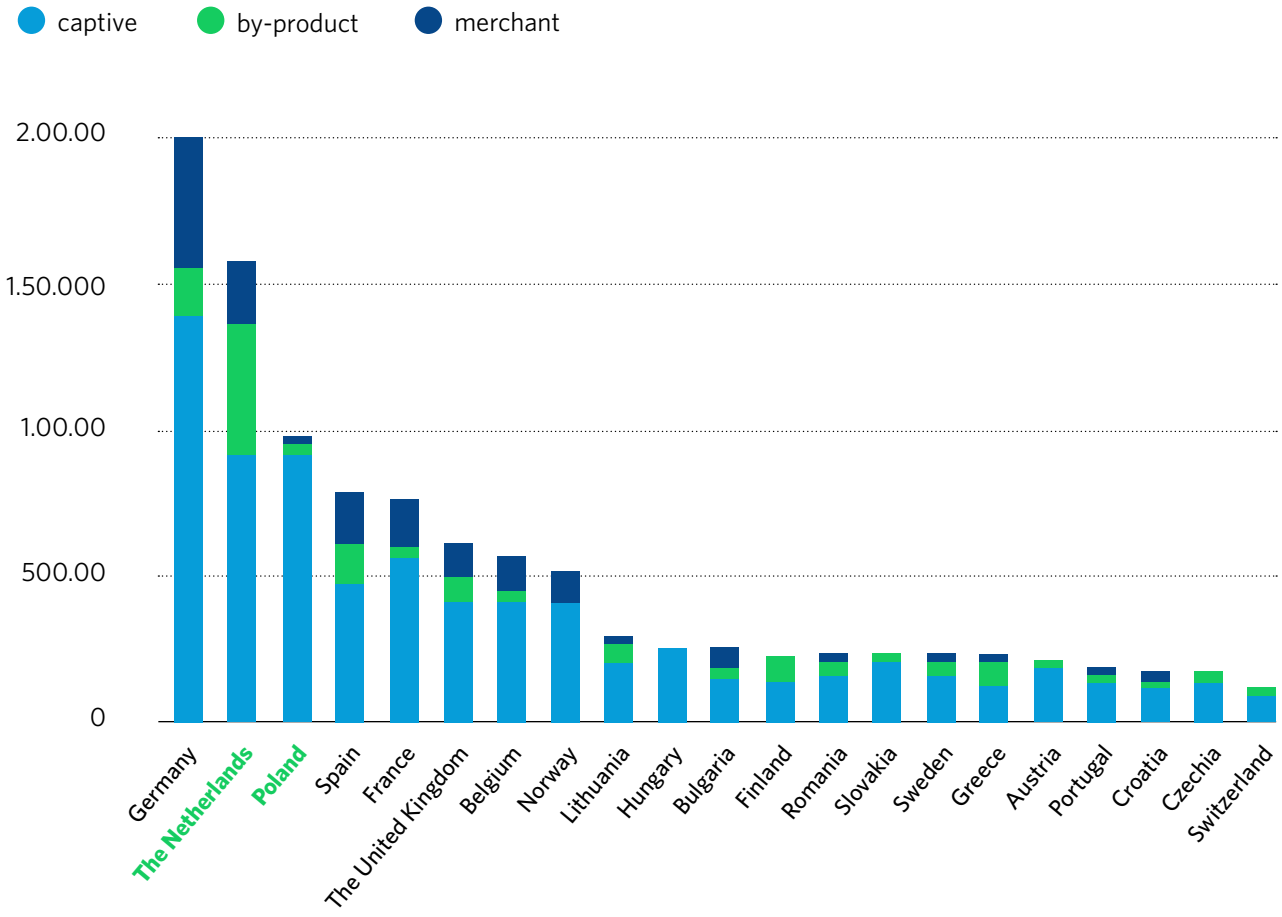
Increased gas cooperation between Poland and Ukraine could have major implications for the development of the hydrogen economy. Both countries are considering the widespread use of biomethane and, in the future, green hydrogen in mutual trade. The risk is the construction of oil and gas infrastructure that later goes unused, becoming a stranded asset. However, plans are already being drawn up on how to adapt the new infrastructure to hydrogen and biomethane transport.

If Poland maintains its status as an energy hub in Central and Eastern Europe, the prospects for new forms of cooperation with foreign partners will be much greater. The Netherlands is already a key player in European energy markets and aims to maintain its role as an energy hub while transitioning to a carbon-neutral economy by exporting electricity from RES and supporting the development of green hydrogen. Poland is yet to become an energy hub and the Netherlands' experience in this area could be very useful.

The Dutch and Polish approach to hydrogen

The Netherlands and Poland are the second- and third-largest producers of hydrogen in the EU (Fuel Cells and Hydrogen Observatory). In both countries, hydrogen is obtained by steam reforming of natural gas. For both of them, green hydrogen is a way to accelerate the energy transition and decarbonise sectors that cannot be easily electrified. Both countries also plan to use blue hydrogen, which would be sourced through the use of CCUS facilities.

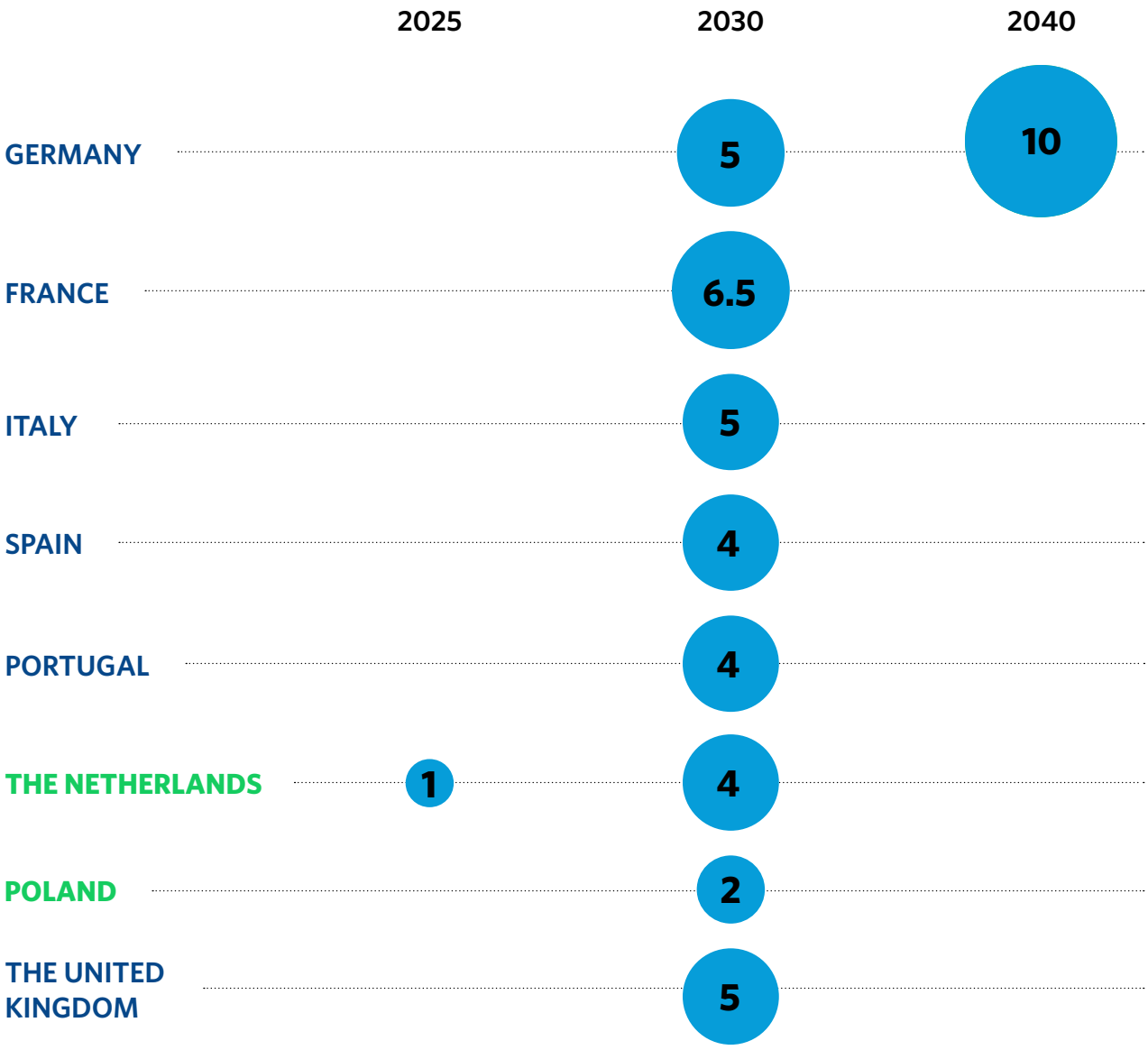
CHART 10. TOTAL HYDROGEN PRODUCTION CAPACITY BY COUNTRY



Source: Fuel Cells and Hydrogen Observatory.

The Dutch Hydrogen Strategy is much more ambitious than the Polish one. The Hague plans to build 3-4 GW of electrolyser capacity to produce green hydrogen, twice as much as Poland (2 GW). However, both targets face a likely update and increased ambition in terms of electrolyser capacity. The hydrogen economy in the Netherlands is mature and developed; the sector consists of hundreds of specialised companies with innovative know-how. In Poland, the hydrogen sector is only just emerging, and, for now, there are only a few dozen companies interested in its development, despite its considerable potential.

CHART 11. PLANNED ELECTROLYSER CAPACITY IN EUROPEAN COUNTRIES (GW).



Source: EY

PLANNED ELECTROLYSER CAPACITY IN EUROPEAN COUNTRIES.

The Netherlands' advantage results from its extensive gas sector, among other things. Despite being seven times smaller than Poland, the country has almost three times as many gas pipelines: 136.000 km compared to 55.000 in Poland (Gaz-System, 2023).

The two countries differ in their approach to developing the hydrogen economy. The Netherlands is developing its hydrogen sector in a holistic manner, taking care of the entire value chain, as well as the participation of private entities, local governments, associations and scientific organisations; in other words, a public-private partnership formula. Poland has opted for a top-down approach, in which the government sets goals for the hydrogen sector and — via state-owned companies — is the main driver of its development.

The countries' visions for the development of the hydrogen economy are different, too. For the Netherlands, clean hydrogen is an effective tool for moving away from the Groningen legacy and natural gas, which was the foundation of the country's energy security, while maintaining its status as an energy hub.

For Poland, hydrogen is still a future prospect and a shaky supplement to the energy transition, which will perhaps help decarbonise certain industries.

The differences in the two countries' approach to the development of the hydrogen economy are not only the result of different economic and energy circumstances, but also of different policy models. Dutch energy policy is conducted in a more decentralised manner, open to innovation. Polish energy policy is much more centralised and distrustful of change.

Polish-Dutch hydrogen synergies

Despite the differences in their approach to the development of the hydrogen sector, the Netherlands and Poland share a number of similarities that could become the starting point for building synergies.

H2 production

The growth engine for the hydrogen sector in the Netherlands and Poland will be the same: offshore wind energy. Both countries have big ambitions for offshore projects. The Netherlands already has farms in the North Sea with a capacity of 2.5 GW; this is expected to grow to 21 GW by 2030. Poland does not have offshore farms yet, but it wants to have 5.9 GW by 2030. Moreover, the countries' wind potential is much higher: 75 GW in the Netherlands and 33 GW in Poland (PSEW, 2022).

In the coming decades, both countries will focus on developing the maritime economy, with industry growing at the fastest pace by the sea. For the Netherlands, this is nothing new; the sea has served as the foundation of Dutch economic growth for centuries. For Poland, where the country's industrial heart was in Silesia, this is an economic revolution. In the 21st century, the Baltic Sea will become Poland's new Silesia. The turn to the sea will require investment in ports, building new infrastructure, educating personnel, and creating new development policies. Here, the Netherlands' know-how could be valuable to Poland.

Dutch-Polish synergy: Producing H2 at sea

- Time horizon: 2025-2040
- Projects: PosHYdon (NL) and NeptHyne (PL)
- Type of synergy: transfer of know-how, equity investment, consultancy.

Potential partners:

- Netherlands: Nel Hydrogen, InVesta, Hatenboer, Iv-Offshore & Energy, Emerson Automation Solutions, NexStep, TNO, Neptune Energy, Gasunie, Noordgastransport (NGT), NOGAT, DEME Offshore, TAQA, Eneco, HyGear.
- Poland: Nexus Consultants, Orlen, PGE, Tauron, Enea, Port of Gdynia.

Polish and Dutch companies are developing green hydrogen production projects at sea. The Dutch PosHYdon project, which aims to integrate three energy systems in the North Sea — offshore wind, offshore gas and green hydrogen — is much more advanced. The project is expected to be completed in 2024.

The Dutch experience may turn out to be valuable for the Polish NeptHyne project, which aims to produce hydrogen at sea using offshore farms and transfer electricity and hydrogen to the mainland. It was designed by Tomasz Pelc of Nexus Consultants, which initiated the Pomerania Province Local Government project and the Pomeranian Hydrogen Valley.

NeptHyne is also expected to make it possible to supply service vessels with the hydrogen they need for planned maintenance work on offshore wind farms. An important element of the NeptHyne project is the need to develop the entire technology and processes for desalinating seawater and its chemical adaptation to produce hydrogen.

Key challenges:

- high installation and technology costs of green hydrogen production,
- high energy losses in the hydrogen production process,
- immature solutions using large-scale electrolysers, which, in the case of hydrogen production from offshore wind energy, could be a barrier to the market's development,
- lack of rules and conditions for connecting the electrolyser with the electricity grid and cooperation between them,
- using seawater to produce hydrogen from offshore wind farms is not financially viable.

H2 transport

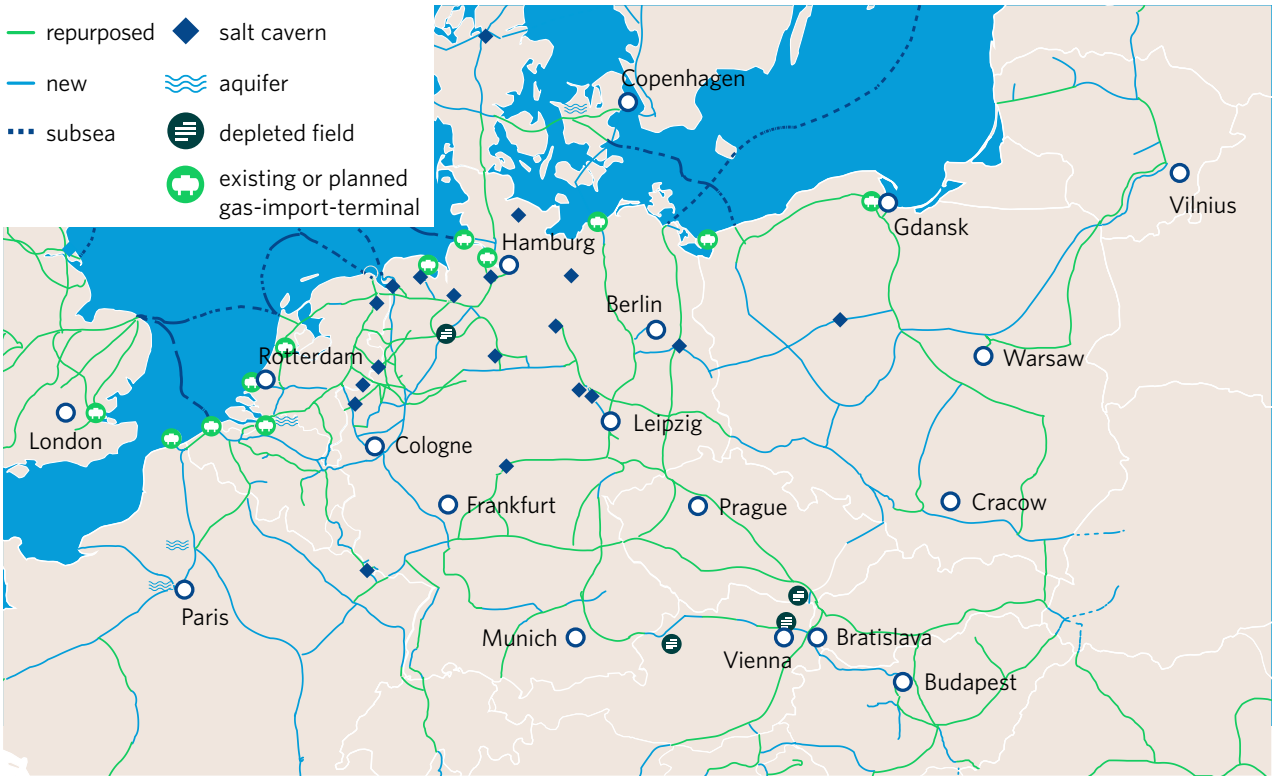
Hydrogen pipelines will be the foundation of the future hydrogen market. The Netherlands already has them (1000 km). The country's natural gas grid, made up of 136.000 km of pipeline, is also being retrofitted to transport hydrogen for both industry and households. This is the basis of the National Hydrogen Network, which will be ready in stages through 2031. In June 2021, the Dutch cabinet called on Gasunie (the gas transmission operator) to convert part of the natural gas network into hydrogen infrastructure.

The future hydrogen network will be based on the current natural gas network, which is made up of 12.000 km of pipelines, some of which will become available for the hydrogen transmission. Ultimately, some 85 per cent of the hydrogen network will consist of existing pipelines and the remaining 15 per cent will be newly built. As a result, the hydrogen market in the Netherlands will be much more centralised and efficient.

Poland does not yet have this kind of infrastructure. Polish gas system operator Gaz-System is only just drawing up plans for the first hydrogen pipelines, which are likely to be built in the late 2020s or early 2030s. In the first phases, the main hydrogen transport method will be tank cars over relatively short distances. As a result, the development of the hydrogen market in Poland will be decentralised.

Poland will need support to build its own infrastructure. In this context, cooperation between Gaz-System and Gasunie — exchanging experience, know-how and best practices in the development of hydrogen transmission infrastructure — will be crucial.

MAP 8. EUROPE'S PLANNED HYDROGEN PIPELINE NETWORK IN 2040



Source: European Hydrogen Backbone initiative 2022.

Dutch-Polish synergy: Developing H2 pipelines

- Time horizon: 2030-2040
- Projects: European Hydrogen Backbone (EU)
- Type of synergy: transfer of know-how, consultancy.

Potential partners:

- Netherlands: Gasunie
- Poland: Gaz-System

The gas pipeline operators of Poland and the Netherlands are part of the European Hydrogen Backbone, a venture to develop the hydrogen economy. It aims to create a network of pipelines dedicated to hydrogen transmission, integrating the markets of individual European countries. An update of the assumptions, set out in the "Extending the European Hydrogen Backbone" document of April 2022, presents the target shape of the hydrogen infrastructure in 2030, 2035 and 2040.

In this system, Poland will be receiving hydrogen from Finland through the Baltic States and transfer it towards Germany. The analysis points to potential hydrogen surpluses in the Baltic States, Sweden and Finland is 46 TWh in 2030 and 84 TWh in 2040. These expected surpluses result from offshore wind development programmes, which exceed the individual countries' energy needs significantly.

Key challenges:

- lack of dedicated networks for hydrogen transmission and distribution. Their development will lead to high construction and maintenance costs,
- underdeveloped technology relating to hydrogen doping capabilities for gas transmission/distribution networks,
- insufficient analysis of hydrogen's long-term impact on the network infrastructure components of existing gas networks in Poland for the transport of the doped gas.

H2 storage

Providing sufficient hydrogen storage will be one of the main bottlenecks in the development of the hydrogen economy. Compressed hydrogen storage in salt caverns has the lowest averaged storage costs (LCOS) per kilogramme. As far as onshore salt caverns are concerned, Poland has the second-largest potential in Europe, after Germany. Caverns close to the Baltic coast could be used to store imported hydrogen and receive hydrogen produced by offshore wind farms in the Baltic Sea. When it comes to hydrogen storage in salt caverns, including offshore projects, the Netherlands has the second-largest potential in Europe[58].

Dutch-Polish synergy: Exploration of salt caverns

- **Time horizon: 2030-2040**
- **Projects: Zuidwending (NL), Damasławek (PL)**
- **Type of synergy: transfer of know-how, consultancy.**

Potential partners:

- **Netherlands: Gasunie (HyStock)**
- **Poland: Gaz-System, Orlen.**

Exchanging experience and know-how on the construction of hydrogen storage facilities in salt caverns could be one of the key synergies between Poland and the Netherlands. Since 2021, HyStock, a subsidiary of Gasunie, has been building up experience with hydrogen storage in salt caverns. By 2030, Dutch company plans to commission up to four caverns for large-scale hydrogen storage in Zuidwending, near Veendam, in the province of Groningen. Ultimately, the caverns will be able to store 20.000 tonnes hydrogen in total.

Poland's Gaz-System is analysing the possibility of building a hydrogen storage facility in a salt cavern in Damasławek, in the Kujawsko-Pomorskie Voivodeship. In the first stage of the investment, the planned storage capacity could be approximately 1.44 billion m3 of natural gas and 40 million m3 of hydrogen. This location was also mentioned as a potential hydrogen storage site in the European Hydrogen Backbone project.

Gaz-System has added the Damasławek project to the Projects of Common Interest (PCI) list for infrastructure enabling hydrogen transmission, storage, offtake and regasification. The draft PCI list for hydrogen will be published by the European Commission in autumn 2023. Gaz-System will be able to apply for hydrogen project subsidies from the Connecting Europe Facility.

At this stage of work, no business decision on implementing the project has been made yet. However, preparatory work is being carried out in the following areas: geology and concessions, design, business, and the environment. Cooperation with Gasunie and drawing on Dutch experience could accelerate the project.

Key challenges:

- low efficiency of energy recovery from stored hydrogen,
- high losses when converting hydrogen into stored energy,
- high cost of the hydrogen storage facility.

H2 import infrastructure

Changes to the REDIII directive, especially the target of using 42 per cent green hydrogen of total hydrogen used in industry in 2030, will accelerate the development of the hydrogen economy. Demand for green and blue hydrogen in Poland could rise from zero now to 450.000-510.000 tonnes by 2030 (Polityka Insight, 2023)[59]. Meanwhile, the Polish Hydrogen Strategy (PSW) envisages that 2 GW of electrolysers will be operating in the country by then, enabling it produce approximately 193.000 tonnes of green hydrogen. To cover the shortfall, it will be necessary to prepare the infrastructure for hydrogen imports via dedicated pipelines and seaports.

Dutch-Polish synergy: Developing port infrastructure for hydrogen imports

- **Time horizon: 2030-2040**
- **Type of synergy: transfer of know-how, joint projects.**

Potential partners:

- **Netherlands: Port of Rotterdam, Gasunie**
- **Poland: Orlen, Saudi Aramco, Grupa Azoty, Port of Gdańsk, Port of Gdynia, Port of Police, Gaz-System.**

Initially, the Pomeranian Voivodeship will become the largest consumer of green hydrogen in Poland. Gdańsk is home to a refinery for Orlen and Saudi Aramco, which is already one of the largest consumers of this fuel in the country. The refinery's coastal location will enable it to access hydrogen produced from offshore wind farms.

The second hydrogen hub in northern Poland will be the West Pomeranian Voivodeship, in particular Police, the site of the fertiliser plants owned by the Grupa Azoty, which already consume significant amounts of grey hydrogen. From 2023, hydrogen production in Police could increase to 120,000 tonnes per year. Moreover, the town has its own seaport.

From Poland's perspective, it will be crucial to adapt ports to receive hydrogen produced by offshore wind farms in the Baltic Sea and imported hydrogen. Poland will be able to follow the transition of the port of Rotterdam, which is set to become a key hydrogen hub for the Netherlands and Europe. It is estimated that the amount of green hydrogen coming in through Rotterdam could rise to 18-20 million tonnes in 2050.

The Port Authority is developing this pipeline with Gasunie. This will make it easier to distribute hydrogen throughout the port complex and subsequently throughout the Netherlands and northwestern Europe. By cooperating with Rotterdam, Polish ports may be able to accelerate their transition.

Key challenges:

- insufficient development of port infrastructure,
- problems in the construction of port reception logistics for hydrogen.

Blue H2

The transition to green hydrogen will not be immediate. An intermediate step will be the development of blue hydrogen, which will be made possible by using carbon capture and storage (CCS) facilities. The Netherlands and Poland want to develop this type of technology. CCS is a crucial part of the Dutch Hydrogen Strategy. The Hague's goal is to increase CO2 capture potential to 2-4 million tonnes per year in 2023-2025 and to 7 million tonnes per year after 2025. Poland does not have a target. Moreover, the country will not be able to quickly build the infrastructure needed to store large amounts of CO2 in geological formations, so it will be necessary to export CO2 via seaports.

Dutch-Polish synergy: dealing with CCS and CO2

- Time horizon: 2030-2040
- Type of synergy: transfer of know-how, joint projects.

Potential partners:

- Netherlands: Air Liquid, Port of Rotterdam, Gasunie
- Poland: Air Liquid, Orlen, Saudi Aramco, Grupa Azoty, Port of Gdańsk, Port of Gdynia, Port of Police, Gaz-System.

Poland's first CO2 export port is set to be built in Gdańsk by French company Air Liquid[60]. CO2 will be transported to Gdańsk by rail, lorries and water barges, and ultimately via pipelines. Between 2026 and 2030, this infrastructure's capacity is meant to amount to 2.7 million tonnes of CO2 per year, rising to 8.7 million tonnes per year between 2030 and 2035. Ultimately, the refineries in Gdańsk and Płock, as well as the Lafarge cement plants in the Kujawsko-Pomorskie Voivodeship, will be connected to the CO2 port in Gdańsk.

This CCS infrastructure is set to be built in Rotterdam to enable blue hydrogen production. The Porthos project[61] aims to compress around 2.5 million tonnes of CO2 per year and store it in empty gas fields under the North Sea by 2024. The need for Poland to start importing green hydrogen and exporting CO2 could become the flywheel of Polish-Dutch cooperation. In both cases, Rotterdam's experience could be crucial when it comes to planning Polish ports' development.

Key challenges:

- the high cost of storing CO2,
- the lack of appropriate legislation to enable the construction of CO2 sequestration infrastructure.

Individual heating

Polish-Dutch hydrogen cooperation could also develop in individual heating, particularly the prosumer market. Self-generating households are a unique part of Poland's energy transition and one of its driving forces. Polish prosumers are responsible for more than two-thirds of solar energy production; their number has increased by as much as 41 per cent over the past year, to 1.2 million. In 2019, there were just 85.000 prosumers in Poland.

Dutch-Polish synergy: Use of H2 in heat generation for prosumers

- Stage: conceptual work, test deployments
- Time horizon: 2030-2040
- Type of synergy: joint projects, transfer of know-how.

Potential partners:

- Netherlands: Duiker, Hydrogen Powered Solutions, Remeha
- Poland: Sescom, ML System.

Poland's developed prosumer market makes it a good place to develop small electrolysers for the production of green hydrogen; for example, for heating. Polish companies are developing small electrolyser technology. They include Sescom, which is working on its own boiler that would burn a mixture of oxygen and hydrogen derived from RES, and ML System, which has developed a prototype of a high-pressure electrolyser that would mainly be used by small and medium-sized companies and individual consumers. The installation is set to be modular and designed for low-voltage operation, enabling it to be powered using PV panels. The hydrogen produced is expected to be 99 per cent pure.

The Netherlands has a strong ecosystem of condensing boiler manufacturers, who are investing heavily in the transition from natural gas to hydrogen. Several have marketed models suitable for gas mixtures with up to 30 per cent hydrogen and showcased 100%-hydrogen boilers. Others are working on technology that would allow existing gas-fuelled condensing boilers to be retrofitted for use with hydrogen. Polish and Dutch know-how could contribute to the use of hydrogen on a small scale, in households. In the first place, however, this type of solution could be of interest to businesses, including SMEs.

Key challenges:

- high cost of producing heat from hydrogen,
- insufficient development of hydrogen transport infrastructure,
- competitiveness of alternative means of heat production.

The H2 knowledge environment

Compared to other EU countries, Poland has low technological potential when it comes to hydrogen. The choice of educational programmes in Poland for hydrogen industry specialists is still poor. The vast majority of faculties that offer programmes relating to energy, heating and RES do not provide students with adequate courses on hydrogen technology. Currently, just four public universities offer postgraduate diplomas or master's degrees relating to hydrogen energy (three of them from the 2022/2023 academic year onwards). Dutch companies and research institutes could leverage the situation by supporting Polish research and innovation through joint projects.

Dutch-Polish synergy: Flow of H2 know-how

- Time horizon: 2030-2040
- Type of synergy: joint projects, transfer of know-how, scholarship programmes.

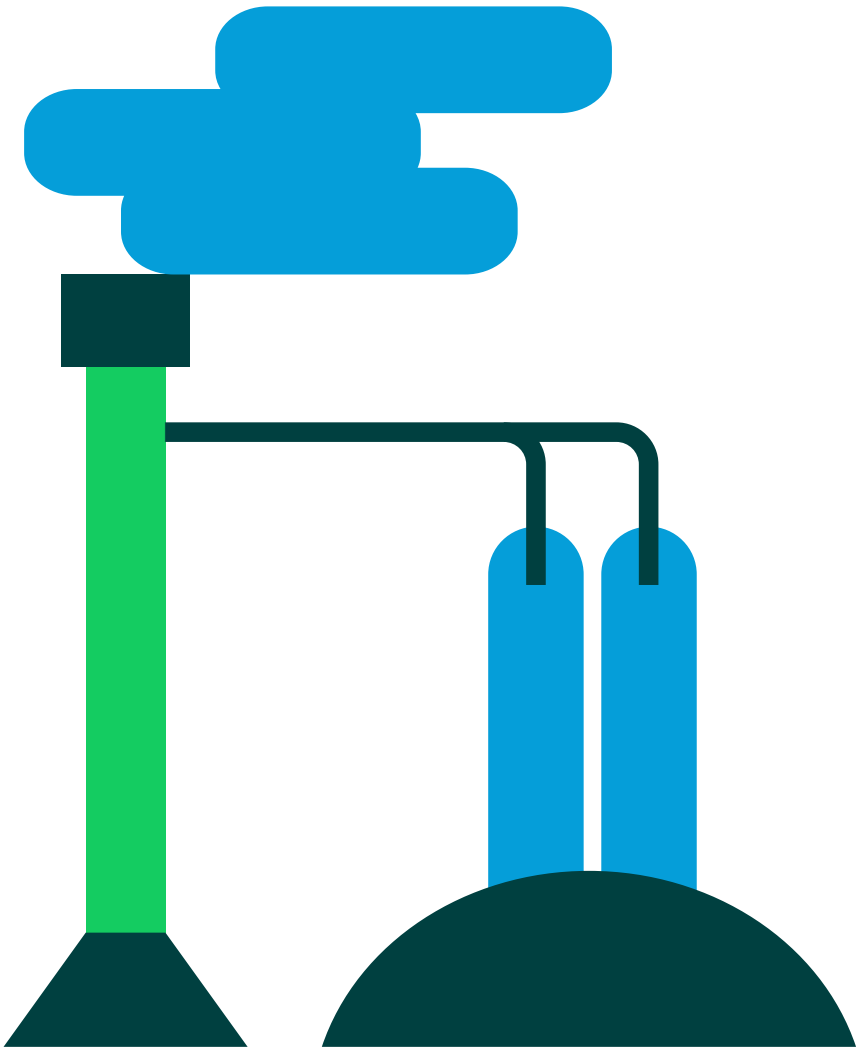
Potential partners:

- Netherlands: TU Delft and University of Groningen,
- Poland: Wrocław University of Technology, Wrocław University, Warsaw University of Technology, Institute of Energy, AGH University of Science and Technology, Silesian University of Technology, Rzeszów University of Technology, Gdańsk University of Technology, Poznań University of Technology.

Working with Polish universities, Dutch institutions such as TU Delft and the University of Groningen could explore the possibility of setting up a Centre of Excellence in Hydrogen Technology in Poland. It could focus on adopting technologies to convert them in marketable products, applying technology, setting up benchmarking, certification, testing facilities for hydrogen technologies, teaching technical professionals new skills, and so on.

Key challenges:

- insufficient development of hydrogen curricula in Poland,
- lack of adequately-trained scientific staff,
- insufficient funding for the development of modern hydrogen research with business opportunities.



Appendix: An overview of the major funding programmes in Poland's hydrogen sector and the future subsidy system

EXISTING SUPPORT SCHEMES FOR HYDROGEN PROJECTS

SUPPORT FOR ELECTRIC VEHICLE CHARGING AND HYDROGEN REFUELLING INFRASTRUCTURTE

The programme aims to support the development of electric vehicle charging and hydrogen refuelling infrastructure to reduce the number of vehicles emitting CO2 and NOx, thereby improving air quality.

Organiser: National Fund for Environmental Protection and Water Management (NFOŚiGW)
Budget: PLN 10.383 million (EUR 2.33 million)
Edition: third
Application deadline: from 3 April to 30 June 2023.
Type of support: grant of up to 50 per cent of eligible costs for the construction or reconstruction of publicly-accessible hydrogen stations. Each applicant may submit just one funding application.

Entities eligible to receive a grant:

- **local government units**
- **entrepreneurs**
- **cooperatives**
- **housing communities**
- **individual farmers**

Requirements: to implement the project, the investor should have at his disposal real estate that he owns or that he has the right of use for at least five years after the planned date of completion of the investment.

Detailed description of the programme:

www.gov.pl/web/elektromobilnosc/iii-nabor-wnioskow-w-ramach-programu-priorytetowego-wsparcie-infrastruktury-do-ladowania-pojazdow-elektrycznych-i-infrastruktury-do-tankowania-wodoru--budowa-lub-przebudowa-ogolnodostepnych-stacji-wodoru

THE ENERGY PLUS PROGRAMME

The programme aims to reduce businesses' negative impact on the environment — including by improving air quality — by supporting investment projects. The programme includes the construction or reconstruction of power generation units and their connection to the grid. The units must use one of the following: low-emission gaseous fuels, gas mixtures, synthetic gas or hydrogen; energy from RES; waste heat; heat from cogeneration, excluding heat generated at a coal-fired cogeneration unit.

Organiser: National Fund for Environmental Protection and Water Management (NFOŚiGW)
Budget: PLN 566.9 million (EUR 127 million)
Edition: fourth
Application deadline: February 1, 2023 to December 13, 2024 or until all the funds have been allocated
Type of support: loan
Beneficiaries: Companies registered in Poland

Detailed description of the programme:

www.gov.pl/web/nfosigw/nabor-iv-wnioskow-2023-2024

PLANNED PROGRAMMES

THE "HYDROGENISATION OF THE ECONOMY" PROGRAMME

The programme aims to develop a low-carbon and zero-carbon economy by supporting projects that implement hydrogen technologies, together with the technical infrastructure for the production, storage, transport and use of hydrogen. The programme will be implemented in three parts and help reach the targets set out in Poland's National Recovery and Resilience Plan (KPO), as well as the Polish Hydrogen Strategy.

Note: the start of financing is subject to the availability of funds from the KPO. Due to the conflict between the Polish government and the European Commission over the reform of the judiciary and the threats to judges' independence, the KPO funds still have not been released.

Organiser: National Fund for Environmental Protection and Water Management (NFOŚiGW)
Budget: PLN 1.109 billion (EUR 250 million) in total; PLN 359.7 million (EUR 80 million) for grants and PLN 750 million (EUR 169 million) for loans.
Application deadline: support will be granted in subsequent competitions with three thematic parts. These

are the current dates of the first competitions:

» **From 01.09.2023 to 30.11.2024** – call for projects: Part 1, "Investments in hydrogen technologies, hydrogen generation, storage and transport",

» **From 01.08.2023 until funds are exhausted** – call for projects: Part 2, "IPCEI Hydrogen project support",

» **From 01.09.2023 to 30.11.2023** – call for projects: Part 3, "Support of projects for innovative hydrogen-powered transport units".

Type of support: grants (from at least PLN 10 million of eligible costs) or interest-bearing loans of up to PLN 300 million, granted for up to 15 years (extendable to 25 years).

Entities eligible for support:

» **local government units**

» **companies registered in Poland**

» **Polish public institutions & associations**

Detailed description of the programme:

www.gov.pl/attachment/3be2cffe-2f92-4fef-ae0a-c25e80ac75a3

NEON

A project to support R&D for the refining and petrochemical industries. The competition will cover "Biological and biochemical technologies for obtaining hydrogen", including technologies for producing green hydrogen using biological and biochemical processes (the raw materials should be waste biomass or a by-product of, for instance, agri-food processing, available on the domestic market). The solutions should take into account hydrogen purification, with an indication of the possibility of using it.

Organiser: Nationtal Centre for Research and Development and Orlen

Budget: approx. PLN 120 million (EUR 27 million)

Edition: the second edition has been completed, the third will be announced

Beneficiaries:

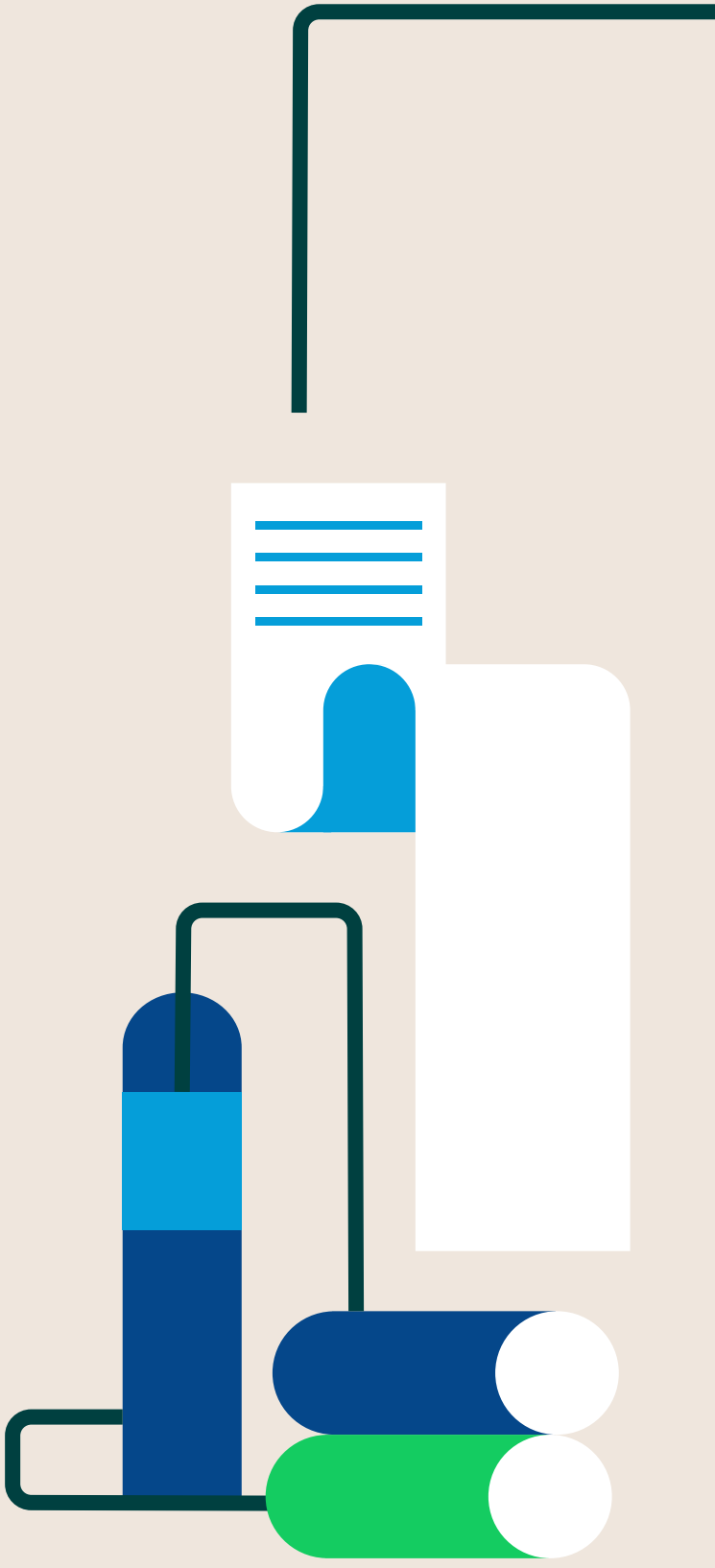
» **scientific entities registered in Poland**

» **companies registered in Poland**

Type of support: for scientific units, the subsidy amounts to up to 100 per cent of eligible costs; for enterprises, it is in accordance with state aid.

Detailed description of the programme:

www.gov.pl/web/ncbr/neon-ii



The support scheme for hydrogen production

Poland lacks a support mechanism for hydrogen production, but the Ministry of Climate is preparing legislative solutions that would enable one to be introduced. The most likely support model will be a hydrogen contract for difference (CfD). This was the recommendation made by the Esperis consultancy in a study commissioned by the government in 2022[62].

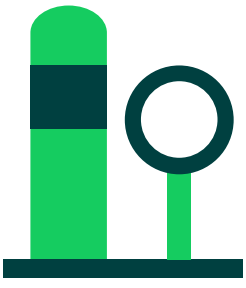
The hydrogen CfD model would be implemented based on two auction baskets, depending on the sector in which hydrogen consumers operate. These will be:

- Basket 1: industry, power and heating,
- Basket 2: transport.

Bids from hydrogen generators and consumers in the auctions will be based on reference prices. It is assumed that the reference prices on the supply side will depend on the weighted average cost of producing low-carbon or renewable hydrogen (LCOH) set by the Energy Regulator Office (ERO) based on market data. For industry, power and heating, the relevant reference will be the price of natural gas; for transport, it will be the price of diesel. The auctions will be split according to the hydrogen plant's capacity.

In the hydrogen CfD model, generators and consumers will participate in the auctions together through business partnerships created in advance. Entities in the same capital group will be allowed to participate in the auctions, so that companies that both produce and consume hydrogen can join in, and so that participation supports their decarbonisation targets relating to the regulations at the EU level. The concept of combining a generator and a consumer in a partnership formula is expected to reduce the significant risk of the lack of hydrogen supply and demand coverage.

Partnerships that have submitted an auction bid will compete with each other for the lowest possible spread between the hydrogen generation price and the purchase price. The partnerships with the lowest spread will be supported for ten years, on the basis of a bilateral Hydrogen Purchase Agreement (HPA).



THE BOTTOM LINE

There is currently no competitive hydrogen market in Poland. For it to emerge, it will require support through a public aid mechanism to cover the financial gap between the price of renewable and low-carbon hydrogen and the price of substitutes with a high carbon footprint. The launch of the support scheme must be in line with regulatory and market needs to ensure efficiency. The scheme's implementation will require notification to the European Commission. The hydrogen CfD scheme is most likely to launch in 2025-2027. The prospect of the first hydrogen auctions being held after 2025 (for example, in 2027) could result in investors postponing the construction of hydrogen generation facilities while waiting for financial support.

Key hydrogen events in Poland

H2Poland

» **Link:** www.h2poland.com.pl/pl/
Date of event: most likely May 2024
Venue: Poznań

The Central European Hydrogen Forum H2POLAND has been organised since 2022 with the aim of spreading knowledge about hydrogen technologies. The event takes place in Poznań and provides a platform for sharing knowledge and debate.

PCHET

» **Link:** www.pchet.klasterwodorowy.pl
Date of event: 4-5 October 2023
Venue: Pomeranian Science and Technology Park, Gdynia

The conference has been organised since 2018. It aims to spread knowledge about hydrogen technologies and connect different groups of stakeholders in the hydrogen technology value chain. The main theme of this year's event will be large-scale green hydrogen production and innovative ways to produce it.

Expopower International Energy Exhibition

» **Link:** www.expopower.pl/pl/aktualnosci
Date of event: April 23-24, 2024
Venue: Poznań

Expopower has been bringing together representatives of the Polish and foreign power industry in Poznań for years. The event covers a wide range of issues relating to industrial power engineering, but also automation systems, control and low-voltage installations, and renewable and alternative energy sources, such as hydrogen.

Enex Nowa Energia

» **Link:** www.targikielce.pl/enex
Date of event: most likely March 2024
Venue: Kielce

A trade fair where representatives of the energy industry from all over Europe meet every year. Most of them present solutions in the areas of solid and liquid biofuels, biogas, renewable electricity and heat generation, and hydrogen technology.

Impact

» **Link:** www.impactcee.com/impact/2024/pl/start
Date of event: May 15-16, 2024
Venue: Poznań

Held in Poznań, Impact is one of the largest economic and technological events in CCE. Energy, including hydrogen, is one of the 18 themes.

Smart City Expo

» **Link:** www.smartcityexpo.pl/en
Date of event: October 18-19, 2023
Venue: Łódź

An annual event dedicated to urban technology topics such as e-mobility, renewable energy, and low-emission urban transport, including hydrogen solutions.

European Economic Congress

» **Link:** www.eecpoland.eu/2022/pl
Date of event: May 8-10, 2024
Venue: Katowice

The largest economic congress in Poland, the EEC is a three-day series of debates, meetings and accompanying events with guests from Poland and abroad. It aims to bring together European entrepreneurs, building an awareness of community values. The event covers key issues relating to Europe's economic and social development.

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Source: www.wz.uw.edu.pl/files/2023_04_Hydrogen_Conference_konferencja_raport_21_DRUK.pdf

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