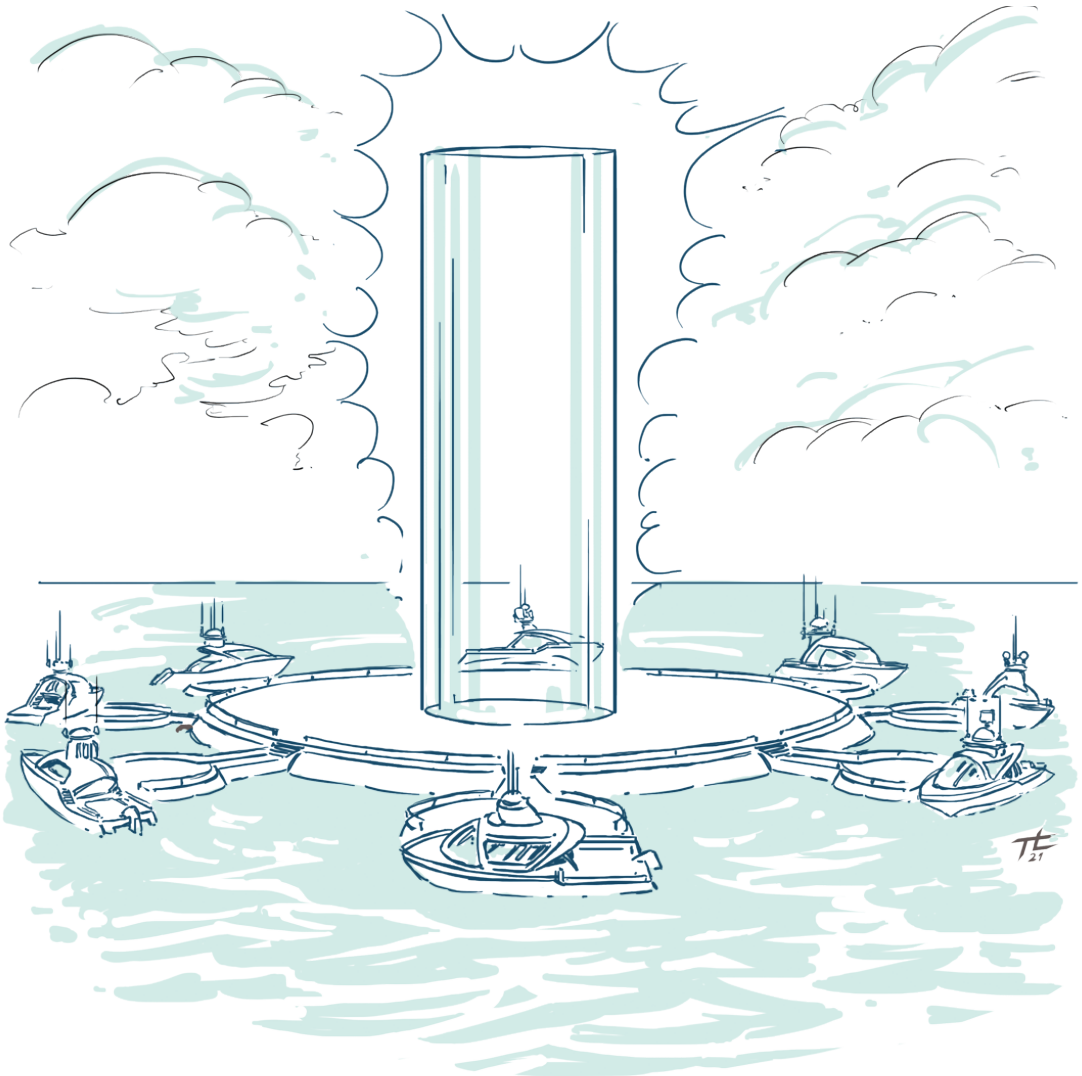
# POLISH HYDROGEN
# WILL WE MAKE IT IN TIME?



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Europe needs to significantly accelerate its energy transition, including energy production, transmission, storage and consumption, in order to achieve climate neutrality by 2050. Green hydrogen as an alternative to fossil fuels can help achieve this.

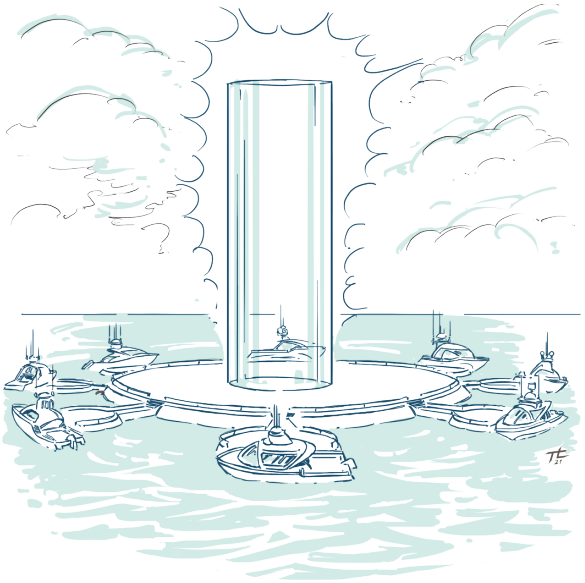
Currently, gray hydrogen derived from fossil fuels is used in oil refining, ammonia, methanol and steel production, among others. There is therefore significant potential for emission reductions from clean hydrogen. In addition, hydrogen can be used in transport, buildings and power generation.

As a result of climate policy and decoupling from Russian fuels, public and private sector players around the world have accelerated research, regulatory and design work to implement hydrogen into the energy mix as soon as possible. Following the planning phase, Europe and other regions are moving dynamically into the implementation of hydrogen projects.

Given Poland's experience and position as a leading producer and consumer of gray hydrogen, green hydrogen is an opportunity to accelerate the decarbonisation of our country.

Currently, Poland has a hydrogen strategy, legislative work is underway on the so-called "Hydrogen Law", clusters and hydrogen valleys already exist. However, this is still only the beginning of the road. It is apparent that we are lagging behind other countries in the European Union and the world.

Most Polish projects focus on transport. Unfortunately, not much is happening in the area of industrial decarbonisation. Will we manage to get on the hydrogen train? This will become clear very soon. In a few years' time, the cards will already be dealt in the market.



## WHAT IS TODAY'S STATUS OF THE HYDROGEN ECONOMY IN THE WORLD AND IN EUROPE?

## WHERE DOES THE POLISH HYDROGEN ECONOMY STAND?

## WILL POLAND'S HYDROGEN ECONOMY BECOME SIGNIFICANT IN EUROPE?

# PROGRESS

Green hydrogen represents only 1% of global energy production.

The EU has adopted a hydrogen strategy, the RePowerEU plan and updated the Renewable Energy Directive (RED III) assuming by 2030: 20 million tonnes of H2 consumption, including 10 million tonnes of imports, the construction of electrolysers with a capacity of 40 GW and an increase in installed RES capacity to 45%.

A regulatory environment, project support and state aid schemes are emerging in the world, including the Inflation Reduction Act in the US or IPCEI in the EU with plans to import 10 million tonnes of green hydrogen by 2030 and build corridors and transmission infrastructure.

More than 1,000 large-scale hydrogen projects have been announced worldwide. Almost 80% are expected to be operational by 2030.

The RED III directive obliges the use of green hydrogen: 5.7% of EU fuel demand by 2030, including: 50% of industrial fuel demand, 1.2% of marine fuel demand. Companies are also to be legally obliged to use green hydrogen in their fuel mix. This is expected to translate into around 9-10 million tonnes of green hydrogen demand in 2030.

35% of global investment is being made in Europe and 15% each in Latin and North America.

Investment in infrastructure, electrolysers and fuel cells is growing. This is dominated by Asian countries.

Consultation on the draft decarbonisation package is ongoing.

The EU approved the first IPCEIs: ”Hy2Tech” (41 projects; €5.4 billion public support); ”Hy2Use” (35 projects; €5.2 billion public support).

The leaders in hydrogen investment are France, Germany, Italy, Spain, the Netherlands and Portugal. In these countries, financial institutions are already financing hydrogen projects.

The European Hydrogen Bank is to help finance hydrogen projects.

A separate (from gas) hydrogen system is to be developed in Europe.

Currently, the EU is already supporting mainly direct investment in production and distribution infrastructure and R&D projects through a dozen aid programmes.

Many European companies have already started large-scale hydrogen projects.

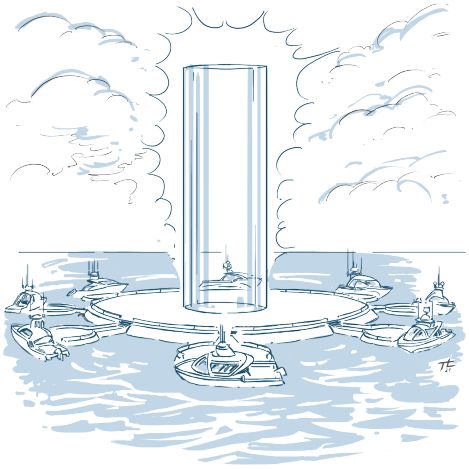
# CHALLENGES

Identify market integrators to build the market architecture and link supply and demand.

Ensuring an adequate amount of renewable energy for the hydrogen industry.

Reducing the cost of producing, storing and transporting green hydrogen.

The effectiveness and pace of development research into reducing production costs, increasing efficiency and reducing energy intensity of hydrogen.



Lowering the risk of hydrogen ventures (increasing the possibility of commercial financing).

Stimulating demand, with particular emphasis on the development of hydrogen infrastructure and the global supply chain.

Timing coordination of the development of the various components of the market.

Need to increase production capacity of electrolysers.

Availability of platinum and iridium required for electrolyser production.

# TRENDS

**Current changes that could significantly affect the future of hydrogen use.**

- The coming years will be crucial in developing a low-carbon hydrogen economy, achieving the energy transition, decarbonisation goals and positioning leading companies as market experts.
- In many regions and countries of the world, there is political support for the development of hydrogen economies and a growing number of financial support mechanisms for hydrogen.
- Developing regions (Africa, Middle East, South America) aspire to become hydrogen suppliers.
- In the long term, Europe will be more of a hydrogen importer due to limited renewable resources, resulting in higher costs for European hydrogen compared to China, the USA, the Middle East or Australia.
- More and more companies are joining the hydrogen economy to position themselves at the forefront of the entire hydrogen value chain and to decarbonise business portfolios.
- The costs of hydrogen production, transmission, distribution, retailing and end-use applications will fall, thanks to increasing investment in the development of hydrogen projects and consequent economies of scale.
- Through cross-sectoral cooperation, new alliances will be formed for the development of hydrogen projects.
- Ammonia is increasingly being used as a hydrogen carrier.
- Innovations to reduce the cost, increase the efficiency and reduce the energy intensity of hydrogen production are underway, including the use of non-ceramic materials and steam instead of water, the use of light in the production of electrolysers, the production of hydrogen from hydrogen sulphide (only requires light, no heat) or the use of seawater instead of fresh water.

# ANTI TRENDS

**Factors of change that may disrupt currently observed trends.**

- The demand for hydrogen by 2050 will depend on the development of hydrogen technologies and technologies supporting energy efficiency, electrification, and carbon capture.
- Limited availability of renewable energy capacity, electrolysers, technologies and components for the hydrogen economy.
- Climate change might hinder further development of investments. High ambient temperatures may, among other things, limit access to water.
- Limited access to rare metals needed for electrolysers due to the geopolitical situation.
- Inability to import hydrogen in the long term (up to the mid-2030s), limited availability of hydrogen for some market players.
- The economic / institutional crisis of the European Union and the resulting lack of access to public funds and commercial financing for the hydrogen economy.
- Changes in energy policy and a slowdown in green energy development due to armed conflicts and social unrest.
- The pace of growth may depend on disruptive innovation, as improvements to existing technologies may not be sufficient.
- Increased influence of sceptics of the hydrogen economy due to technological and infrastructural challenges and the ‚narrow' spectrum of possible applications of green hydrogen.
- Contamination, due to war, sabotage or cyber-attack, could lead to potential hydrogen leaks and phobias in society.
- Inability to achieve price competitiveness of hydrogen with other regions of the world.
- Advances in new technological developments in nuclear energy (over cold fusion) will have a revolutionary impact on the entire energy sector.

# POLISH HYDROGEN PROJECTS

Compared to other European Union countries, Poland is still at a very preliminary stage of the hydrogen economy implementation. In spite of the adoption of a hydrogen strategy, there is still no clear plan for Poland's energy transition with implementing acts or legislation to reduce the investment risk of hydrogen projects. It is also not known what funds will be allocated to support the development of a hydrogen economy between now and 2030. The question is what will be the share of Poland in the development and production of hydrogen technology or other components for a hydrogen economy? Will we be able to guarantee access to green hydrogen imports? Where will hydrogen transport routes or pipelines be laid? It is also important to answer what we can do to make Polish hydrogen production cost-competitive.

The fact that only the NeptHyne Pomeranian Hydrogen Cluster and the IPCEI Black Horse (Poland, Slovakia and Hungary) are mentioned among the largest 100 hydrogen projects in the European Union confirms the lagging behind of the Polish economy in this area. Apart from these, one hears mainly about projects in the transport sector or the purchase of hydrogen-powered urban transport vehicles initiated by local authorities.

**NeptHyne**
The project concerns the production of hydrogen at an offshore wind farm to allow the storage and conversion of surplus energy or to power service vessels. A transformer substation is to be designed as part of the project, which will also be equipped to desalinate seawater, demineralise it, produce hydrogen, compress it, store it and finally bunker the service vessels with hydrogen.

**IPCEI Black Horse**
It is intended to help decarbonise transport in the Visegrad countries. It includes the deployment of 10,000 HDVs, the production of hydrogen by 40 electrolysers and the construction of 270 hydrogen refuelling stations on TEN-T corridors.

**Hydrogen Eagle (PKN Orlen)**
A project to build infrastructure for the production and distribution of low- and zero-emission hydrogen in Central Europe, funded by the Innovation Fund, Connecting Europe Facility (CEF), the National Fund for Environmental Protection and Water Management (NFOŚiGW) and thanks to the European Commission's notification for the Polish part of the Hydrogen Eagle project under the IPCEI Hy2Use mechanism.

It envisages the construction of nine low-carbon hydrogen hubs - clusters of facilities related to the production and distribution of the low-carbon fuel - in Poland, the Czech Republic and Slovakia. The facilities will operate on renewable energy sources and process municipal waste as part of the company's efforts to achieve carbon neutrality. Its hubs will be powered by photovoltaics and onshore and offshore wind farms, including Orlen's flagship 1.2 GW Baltic Power offshore wind farm, which PKN Orlen will start building in 2024.

**102 hydrogen fuel stations (PKN Orlen)**
By 2030, PKN Orlen plans to build a network of more than 100 hydrogen fuel stations for individual, public and cargo transport, road and rail in Poland, the Czech Republic and Slovakia. About 57 stations will be built in Poland, about 28 in the Czech Republic and about 26 in Slovakia. Hydrogen will be supplied from a network of hydrogen hubs, powered by renewable energy sources and innovative installations converting municipal waste into zero- and low-emission hydrogen. The total assumed capacity of electrolysers in the PKN Orlen Group by 2030 will be around 1 GW of power, which, combined with waste-to-hydrogen projects, will enable the production of more than 130 kt of renewable hydrogen by the end of this decade.

So far, Poland's first mobile hydrogen fuel station is operating in Krakow. Later this year, this new ecological fuel will be available at stations in Poznań and Katowice. The construction of a station in Walbrzych is also planned (2024). In the middle of 2025, stations in Bielsko-Biała, Gorzów Wielkopolski, Kraków, Piła and Warsaw will be put into service thanks to a PLN 60 million grant from the European Climate, Environment and Infrastructure Executive Agency (CINEA) under the EU CEF Transport Alternative Fuels Infrastructure Facility programme. The total value of the project is more than PLN 120 million.

**Hydrogen for glycol production in Trzebinia (PKN Orlen)**
An organic propylene glycol refinery is in operation in Trzebinia. An integral part of the glycol complex is Poland's first hydrogen hub with an annual capacity of 16 Nm3, of which 75% will be used to produce glycol and the remaining 25% will be further purified into hydrogen fuel. The centre's annual production capacity will be 350 tonnes of pure automotive hydrogen.

**Strategic cooperation between PKN Orlen and Alstom**
Agreement on strategic cooperation in the supply of emission-free, eco-friendly trains and hydrogen fuel for public rail transport. PKN Orlen will provide the refuelling infrastructure for the trains produced by Alstom.

**Hydrogen production installation based on solid oxide cells (Energa - Orlen Group)**
A bi-directional hydrogen production plant based on solid oxide cells is in operation in Elbląg, working with the BB20 biomass unit of the CHP plant. The solution is based on Polish patents, technology and know-how. It is the result of a project carried out for three years by the Faraday Research and Development Centre of the Energa Group and the Institute of Fluid-Flow Machinery in cooperation with the Institute of Energy.

**GreenH2 (LOTOS - Orlen Group)**
A project to produce renewable hydrogen through the electrolysis of water to be used in the refinery's production processes with €158 million in state aid funding to finance the installation of a 100 MW electrolyser, as well as the construction of a 50 MW photovoltaic power plant and a 20 MWh battery energy storage facility. The electrolyser is expected to be operational in 2027 and will gradually increase its production to 13,600 tonnes of renewable hydrogen per year.

**PureH2 (LOTOS - Orlen Group)**
The subject of the project is the construction and launch of infrastructure for the production and sale of high-purity (99.999%) hydrogen meeting the requirements of standards for hydrogen fuel for fuel cells. A hydrogen purification installation will be built in Gdansk on the refinery premises.
A pure hydrogen distribution station will also be built, i.e. an installation for filling so-called battery trucks (compressed hydrogen transport vehicles). The PureH2 project also involves the construction of two installations for refuelling vehicles at 350 bar (e.g. buses) and 700 bar (passenger vehicles). These installations will be built within existing LOTOS Paliwa filling stations.

**VETNI (LOTOS - Orlen Group)**
The aim of the project is to develop and construct a pilot-scale system for the production of hydrogen in solid oxide electrolysers (SOEs), allowing for the highly efficient production of hydrogen (up to 30% better efficiency than currently available) with high purity.

The project will carry out R&D work oriented towards the development, construction and testing under real operating conditions of a system with an electrolyser integrated into the refinery process, which will supply process steam for hydrogen production. The parameters of the electrolyser will allow the production of approximately 16 kg of hydrogen per day with 99.999% purity, making it possible to refuel several hydrogen-powered cars. The project is co-financed by the European Union under the Intelligent Development Operational Programme 2014-2020.

**NesoBus - Polish Hydrogen Bus PAK-PCE**
A 12,000 m2 factory is being built in Świdnik in cooperation with Mostostal Puławy. Production at the new plant will start in autumn 2023. It is expected to produce 100 vehicles per year, some of which will also be exported. NesoBus was developed by Polish designers and engineers in cooperation with partners from Europe and around the world. The tanks have a capacity of 37.5 kg of hydrogen, which allows the vehicle to travel approximately 450 km. Refuelling takes 15 minutes. On average, the NesoBus consumes around 8 kg of hydrogen per 100 km. In the SORT-2 test, it achieved a consumption of 5.5 kg of hydrogen per 100 km. The bus was designed with hydrogen technology in mind from the start, hence it is very easy to change tanks.

**H2 fuel stations PAK-PCE**
The first hydrogen fuel station in a nationwide network of 30 facilities is being built in Warsaw. It will be followed by the construction of a further five. The company will receive PLN 20 million in co-financing from the National Fund for Environmental Protection and Water Management to build a network of hydrogen fuel stations open to the public, located in Wrocław, Rybnik, Lublin, Gdańsk and Gdynia. The total cost of the project is PLN 57.4 million. The stations are to be built by the end of June 2024. The first green hydrogen electrolyser is being installed. It will be able to produce more than 1,000 kg of hydrogen per day. The target production is to reach 40 tonnes per day. In turn, the finished fuel will be distributed to 30 stations scattered in the largest Polish cities by special Wystrach hydrogen trucks. The company currently operates three such vehicles, and one hydrogen vehicle can carry 1,000 kg of hydrogen at a time. The compressors and station installations will be supplied by the Norwegian company NEL. The stations will compress the hydrogen to 700 or 350 bar. A tonne of fuel will be enough for 50 full refuellings of the buses.

**Solaris (CAF)**
The first deliveries of the company's second hydrogen-powered bus model - the 18-metre Urbino 18 hydrogen articulated bus - could take place as early as 2023.

**PGNiG**
Since 2020, PGNiG is exploring the possibility of storing and transporting hydrogen through the gas network. The Hydrogen - Clean Fuel for the Future programme consists of more than a dozen projects, ranging from the production of "green hydrogen", through its storage and distribution, to its use in industrial power generation. Programme elements include:

**Hydra Tank Project** - a research station for refuelling vehicles with hydrogen,
**InGrid Project** - Power to Gas - hydrogen production using renewable energy. Investigating the feasibility of hydrogen transmission using the natural gas distribution network,
**New Fuel Lab** - hydrogen purity analysis and alternative fuel research,
**Hydrogen Storage** - use of underground gas storage for hydrogen storage,
**Energy** - use of hydrogen in industrial power generation.

**Blue H2**, which involves the development of a blue hydrogen production technology - will include the construction of a pilot production installation in Zabrze. Ultimately, if the research project is successful and a decision is taken to build a demonstration plant, blue hydrogen extracted by reforming will be used by the Company's partners in their production processes.

**Nordic-Baltic Hydrogen Corridor (GAZ-SYSTEM)**
The project aims to build a corridor for the transport of hydrogen from Finland, through the Baltic States and Poland to Germany and a national hydrogen backbone comprising infrastructure connecting domestic hydrogen producers, import sources, the hydrogen storage facility in Damaslawek with end users and possibly local distribution networks.

**Hydro Sanok**
Poland's first city-owned hydrogen company Hydro Sanok has secured an investor, Hynfra, and is embarking on a complete transformation of the city's energy system with RES and renewable hydrogen. The project primarily includes: the construction of its own electricity generation sources (photovoltaic panels), the construction of an energy and heat storage facility, the construction of a hydrogen electrolysis plant, the establishment of a hydrogen refuelling station and a fast charging station for electric vehicles. The city will also invest in a modern heat pump to reduce carbon dioxide and greenhouse gas emissions and other ancillary installations.

**Polish hydrogen technology**
Since 2016, the National Centre for Research and Development (NCBiR) has been implementing 89 hydrogen-related projects for a total amount of PLN 350 million.
The solid oxide cells (SOC) of the Energy Institute are already used in the heat and power plant in Elbląg.
SynGen reactor by mPower Green Tech - a mobile device for processing biomass and waste, as a result of which electricity, heat and green hydrogen are obtained.
The thermoelectrolyzer from Hydromeda Technologies has a hydrogen production efficiency of 96%.

**Poznan Airport**
Poznan Airport has started the decarbonisation process. It signed an agreement with TÜV SÜD to help the airport produce green hydrogen. The photovoltaic panels installed will produce energy that will be turned into green hydrogen through the electrolysis of collected rainwater from the airport's paved surfaces. EU funds will be used for the investment. If the project is successful, Polish hydrogen buses will soon be able to drive around Poznań Airport.

**Poland's first hydrogen locomotive (Pesa)**
The SM42-6Dn locomotive is already approved for operation. It is powered by hydrogen cells. The hydrogen tanks will hold 175 kg of H2. On a single refuelling, the locomotive can run for about 24 hours. The vehicle from Pesa will be zero-emission - if it burns so-called green hydrogen coming from electrolysers powered by energy from RES. The hydrogen locomotive will soon go to PKN Orlen for testing. In the future, PKN Orlen wants to cooperate with Pesa in tenders for these hydrogen machines. Pesa is to supply the vehicles, PKN Orlen the infrastructure and the hydrogen. The next step for Pesa is to introduce a hydrogen locomotive for passenger trains. The project would be completed at the turn of 2025/2026.

**Green hydrogen plant**
Green Capital S.A. will build a green hydrogen plant. The investment will consist of a wind farm with a capacity of about 400 MW, a photovoltaic farm of 800 MW, energy storage, electrolyzers, and accompanying infrastructure. It will produce about 2.2 million MWh per year, hence an equivalent amount of energy in the form of alternative fuels including green hydrogen and heat (subtracting the energy needed for the technological processes). The value of the investment, which will be located in Żuławy, is currently estimated at 1.28 billion EUR. GC has contracted locations for wind turbines with a favourable local spatial development plan, planning and environmental studies, and locations for a photovoltaic farm. It is also in talks with potential technology suppliers, and is analyzing the project from a logistical point of view.

**MPK Poznań** has purchased 25 Solaris Urbino 12 hydrogen-powered buses, which will join Poznań's zero-emission fleet in the second half of 2023. Each of the vehicles will be powered solely by hydrogen energy, converted to electricity in a fuel cell.

**The Upper Silesian-Dąbrowa Basin Metropolis (GZM)**
The Upper Silesian-Dąbrowa Basin Metropolis (GZM) has allocated funds for the purchase of 20 hydrogen-powered buses. The buses are expected to arrive in the Metropolis by the second half of 2024. The initiative, named „Hydrogen GZM", co-funded by the National Fund for Environmental Protection and Water Management (NFOŚiGW) in the amount of PLN 81 million, will be implemented as part of the priority program „Green Public Transport". Actions will be carried out in cooperation with energy companies, which will build hydrogen refuelling stations in the GZM area.

**Wałbrzych**
The National Fund for Environmental Protection and Water Management (NFOŚiGW) will co-finance and provide a low-interest loan to Wałbrzych for the purchase of 20 hydrogen-powered buses. The project, worth PLN 80 million, has received a PLN 58 million grant, nearly PLN 7 million in low-interest loans, and PLN 15 million in VAT refund. Vehicle deliveries will take place in 2024 and 2025.

In addition, Wałbrzych has partnered with Hydrogen Utopia International. It announced the establishment of a plastic waste processing plant, a hydrogen refuelling station with a daily capacity of 35 tons, and production capabilities of approximately 2.5-3 tons of hydrogen per day.

**Rybnik, MPK Wrocław**
Rybnik has purchased 20 Nesobus buses. The Municipal Transport Company (MPK) of Wrocław has also announced the purchase of hydrogen buses.

# CONCLUSIONS

The hydrogen economy has significantly accelerated since 2020. However, not every country has equal chances in the race for leading positions in hydrogen production. It is assumed that 60% of hydrogen will be produced by countries with the best conditions for generating wind and solar energy. Although this puts Poland in a somewhat unfavourable situation, there is always potential for our country's participation in part of the production and other components of the hydrogen economy's value chain. Therefore, it is important to provide appropriate conditions for Polish stakeholders to develop the hydrogen economy.

In the short term, it is necessary to amend the law as quickly as possible and create a regulatory framework for the functioning of the hydrogen market in Poland. This will not be possible without a national system of support for hydrogen research and production and ensuring appropriate funds for this purpose by the state. In light of the fact that it is the heavy industry that is the most prospective recipient of hydrogen, it is very important to define the decarbonization path of Polish industry and to mark the role of green hydrogen in it. There is still a lack of concepts for storing and transmitting hydrogen in our country.

The scale of Polish hydrogen initiatives, despite a lot of talk about it, is still very small. Polish entities' participation in trans-European initiatives is also minimal. Without rapid action, Poland will be moving away from its rightful place on the European hydrogen map and will become predominantly just a consumer of foreign hydrogen technologies and a hydrogen importer, depriving itself of potential revenues, employment opportunities, and technological development in this field.

# ABOUT US

## CONTACT US IF YOU ARE INTERESTED IN THE FUTURE OF HYDROGEN!

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4CF is a strategic foresight and long-term strategy building consultancy. For almost two decades, 4CF has been helping its clients prepare for an uncertain tomorrow. The company has completed hundreds of projects for private companies, public and international institutions, including UNESCO, UNDP and WHO.

Using foresight, 4CF supports clients in uncovering future opportunities so that they can make important strategic decisions today and implement solutions to ensure a better future for their stakeholders. We care that our clients are always one step ahead of the competition. The company is the only Polish member of the Association of Professional Futurists, Foresight Educational and Research Network and founder of the Polish node of The Millennium Project.

4CF is at the forefront of global innovation and actively contributes to the development of cutting-edge foresight tools. The company's foresight experts have extensive interdisciplinary knowledge and experience. They are constantly refining the 4CF methodology and actively collaborate with leading international foresight centres.

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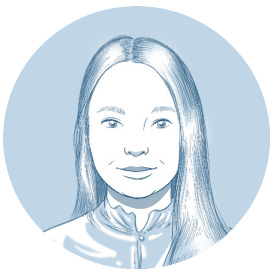

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