1 1.008

H

Hydrogen

REPORT

REGARDING THE HYDROGEN SECTOR AND NEW PROFESSIONS WITHIN THE DEVELOPING HYDROGEN ECONOMY

Co-funded by the European Union

DIALOG of Transformation
Certified Service EDU SMART Training Centre
UKPRN 10066595

FERI

ECRN
European Chemical Regions Network

zielona chemia

KRAJOWY KLASTER KLUCZOWY

CONTENTS

Co-funded by the European Union

INTRODUCTION

Climate change caused by greenhouse gas emissions is forcing humanity to accelerate decarbonization processes in the global economy in virtually all areas. One of these processes is an energy transition aimed at replacing fossil energy sources with renewable ones that provide so-called green energy. This can come from harnessing the power of wind, water, solar, biomass and green hydrogen (Łącka, 2023). The European Union was the first economic grouping to make the fastest decision to start implementing the recommendations enshrined in the UN resolution Agenda 2030 (UN, 2015). The European Commission in 2019, as part of its climate protection policy, announced the tenets of the European Green Deal (EC, 2019). Since then, decarbonization in EU member states has accelerated rapidly. Within the framework of the Green Deal strategy, a number of important decisions and actions have been taken in the following years, first to achieve a 55% reduction in CO emissions in the EU by 20302 , and ultimately to ensure the Community's climate neutrality by 2050. Among these actions were the adoption of an EU hydrogen strategy in 2020. (EC, 2020), as well as the submission of legislative proposals contained in Fit for 55 in 2021. (EC, 2021). It contains provisions to bring EU law in line with ambitious climate protection policies. They require regulatory, organizational and technological changes in all member countries, not only in the energy sector, but also in other areas of the economy, including industry, transport, heating, construction or agriculture.

All countries that have signed the Fit for 55 legislative package are aware that in order to achieve the EU's ambitious climate goals, it is necessary to develop alternative forms of energy generation and storage. One of the solutions turns out to be hydrogen, which can serve to decarbonize, among other things, the metallurgical and chemical industries, where CO2 reduction with currently available methods is difficult for technical reasons.

Russia's attack on Ukraine in February 2022 and the global energy crisis have made everyone in Europe realize that the dependence of their economies on fossil fuels (oil and gas) threatens not only the climate, but also national security. The changed geopolitical and, consequently, economic situation revealed the need to accelerate energy transition processes in EU member states using new green energy solutions, including

INTRODUCTION

those based on hydrogen technologies (Łącka, Wojdyła, 2022). As M. Sobolewski points out, hydrogen "can replace fossil fuels in transportation and industry, as well as be used to store electricity obtained from renewable sources" (Sobolewski 2022). Widespread use of hydrogen in Europe would reduce imports of fossil fuels (oil and natural gas, coal and lignite), thereby improving energy security by stabilizing the energy system. This is particularly important for countries that have hitherto been highly dependent on oil, natural gas and coal imports from Russia. Although they have changed the structure of supply of energy carriers after the start of the war between Russia and Ukraine, their energy mix still shows a strong dependence on hydrocarbons and too small a share of renewable energy sources in total energy consumption. Poland is such a country, hence the need for an energy transition in the country. On the one hand, this is dictated by the need to decarbonize the economy in line with the European Green Deal and the Fit for 55 document, and on the other hand, it stems from the natural need for energy and national security in terms of access to energy in a situation where its consumption is steadily increasing in line with economic growth and development, and the previous long-standing supplier (Russia) has become a threat.

A chance for Poland to free itself from the use of fossil fuels is, in addition to the renewable energy sources from conventional sources (solar, wind, water, biogas) already known and developed in our country for some time, hydrogen obtained in an environmentally friendly way. As the authors of the report Green Hydrogen from Renewable Energy Sources in Poland point out, "However, in order for hydrogen to fulfill its role in the decarbonization of European economies, it is necessary to ensure access to emission-free technologies for its production. In Polish conditions, the key role in the production of clean hydrogen should be played primarily by renewable sources, whose work, thanks to the properties of hydrogen that allow energy storage, will stabilize the National Electricity System in an even better way" (Brodacki et al., 2021, p. 25).

Co-funded by the European Union

INTRODUCTION

In 2020, the European Union adopted a hydrogen strategy. The document, called COM/2020/301, proposes policy actions in five areas: investment support, support for production and demand, creation of a hydrogen market and infrastructure, research and cooperation, and international cooperation. Hydrogen is also an important element of the EU strategy for energy systems integration (COM/2020/299).

By the first quarter of 2022, the EU had implemented and delivered 20 key hydrogen measures:

- Developing an investment programme within the framework of the European Clean Hydrogen Alliance to stimulate the development of hydrogen production and use and build a concrete pipeline of projects.
- You support strategic investments in clean hydrogen in the context of the Commission's recovery plan, in particular through the InvestEU strategic European investment window.
- To propose measures to facilitate the use of hydrogen and its derivatives in the transport sector in the Commission's forthcoming Sustainable and Smart Mobility Strategy and related policy initiatives.
- Explore additional support measures, including demand-side policies in end-use sectors, for renewable hydrogen based on existing legislation and renewable energy directives.
- Work to introduce a common threshold/low-carbon standard to promote hydrogen facilities based on their full-life-cycle GHG efficiency.
- Work to introduce comprehensive terminology and EU-wide certification criteria for renewable and low-carbon hydrogen.
- Develop pilot schemes - preferably at EU level - for a carbon differential contract programme, in particular to support the production of low-carbon and closed-loop steel and basic chemicals.
- Begin planning for hydrogen infrastructure, including Trans-European Networks for Energy and Transport and Ten-Year Network Development Plans including planning for filling station networks.
- Accelerate the implementation of different refuelling infrastructures as part of the revision of the Alternative Fuels Infrastructure Directive and the revision of the Trans-European Transport Network Regulation.
- A project to enable the introduction of market principles for hydrogen deployment, including the removal of barriers to the efficient development of hydrogen infrastructure, and to provide hydrogen producers and customers with access to liquid markets and the integrity of the internal gas market through upcoming legislative reviews (e.g. review of gas legislation for competitive decarbonised gas

INTRODUCTION

- Launch of a 100 MW electrolyser and a call for proposals for green airports and ports under the Horizon 2020 European Green Deal call.
- Establish the proposed Clean Hydrogen Partnership, focusing on the production, storage, transport, distribution and key components of renewable hydrogen to provide priority end-uses for clean hydrogen at a competitive price.
- Steering the development of key pilot projects to support hydrogen value chains, in coordination with the SET Plan.
- Facilitate the demonstration of innovative hydrogen-based technologies by launching calls for proposals under the ETS Innovation Fund.
- Call for pilot actions for inter-regional innovation under the Cohesion Policy on hydrogen technologies in carbon-intensive regions.
- Strengthening the EU's leadership role in international fora dealing with technical standards, regulations and definitions for hydrogen.
- Developing a hydrogen mission as part of the next Mission Innovation (MI2) mandate.
- Promote cooperation with partners from the Southern and Eastern Neighbourhood and the Energy Community countries, especially Ukraine, on renewable electricity and hydrogen.
- Defining the renewable hydrogen cooperation process with the African Union under the Africa-Europe Green Energy Initiative.
- Development of a benchmark for euro-denominated transactions.

The ' Fit -for-55' package presented in July 2021 presents a series of legislative proposals that translate the European Hydrogen Strategy into a concrete framework for European hydrogen policy. This includes proposals to set targets for the use of renewable hydrogen in industry and transport by 2030. It also includes the Hydrogen and Decarbonised Gas Market Package , which sets out proposals to support the creation of optimal and dedicated infrastructure for hydrogen, and the Hydrogen and Decarbonised Gas Efficient Hydrogen Market Package.

The Clean Energy Rebuilding and Resilience Facility has been made available to EU member states to invest in hydrogen projects across the value chain.

Investment support has also been provided by important projects of common European interest (IPCEI) on hydrogen. The first IPCEI called " IPCEI Hy2Tech ", which comprises 41 projects and was approved in July 2022, aims to develop innovative technologies for the hydrogen value chain to decarbonise industrial processes and the mobility sector, with a focus on end-users.

Co-funded by the European Union

INTRODUCTION

In September 2022. The Commission approved " IPCEI Hy2Use ", which complements IPCEI Hy2Tech and which will support the construction of hydrogen-related infrastructure and the development of innovative and more sustainable technologies for the integration of hydrogen in the industrial sector.

In November 2021, the Clean Hydrogen Partnership was established. The main objective of the Clean Hydrogen Partnership is to contribute to the European Green Deal and the hydrogen strategy through optimised funding of research and innovation activities. The Clean Hydrogen Partnership is the successor to the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) and took over its existing portfolio as of 30 November 2021.

The European Commission has launched a pilot mechanism as part of the recently adopted Decarbonised Gases and Hydrogen Package to support the development of the European hydrogen market.

The initiative aims to accelerate investment by providing clearer market insights to both suppliers and consumers of hydrogen. The pilot mechanism will be part of the European Hydrogen Bank and will run for five years, starting in mid-2025.

The primary objective of the Hydrogen Pilot Mechanism is to facilitate the development of the hydrogen market in Europe. By collecting and processing data on the demand and supply of renewable and low-carbon hydrogen and its derivatives, the mechanism aims to create a more transparent market. This transparency is expected to help European consumers match European and foreign suppliers, thereby speeding up final investment decisions and securing offtake agreements.

A key aspect of this initiative is to improve visibility in the market. The mechanism will provide detailed information on hydrogen flows and prices, enhancing the ability of suppliers and consumers to make informed decisions. This improved visibility is expected to lead to faster final investment decisions, thus contributing to the overall growth of the hydrogen sector in Europe. A procurement exercise to find a service provider to develop an IT platform to operate the pilot mechanism has already started and the Commission plans to sign a contract by the end of this year.

While the European Commission's efforts to revitalise the hydrogen market are commendable, it is necessary to compare these initiatives with industry benchmarks to fully understand their potential impact. The first large-scale electrolysers are already being built in Europe and initial offtake contracts have been signed. However, the

INTRODUCTION

success of the pilot mechanism will depend on its ability to attract significant investment and support robust market dynamics.

Hydrogen is expected to play a key role in achieving the objectives of the European Green Deal. It is seen as a key element in phasing out Russian fossil fuels and supporting the decarbonisation and competitiveness of European industry. A hydrogen pilot mechanism, by increasing market transparency and accelerating investment, could make a significant contribution to achieving these goals. However, continuous monitoring and evaluation of the mechanism's operation is needed to ensure that it meets its objectives.

In her speech, Ursula von der Leyen summarised the commitment of a united Europe to decarbonise our environment:
"I want Europe to be a leader, a frontrunner in building a global hydrogen market. Last spring, the European Commission was part of a coalition of countries that committed to creating 100 hydrogen valleys around the world. Of course, we want most of them to be in Europe, so clean hydrogen is becoming part of the conversation with all our global partners, including of course our African partners. Africa has the greatest untapped potential for renewable energy production. Converting clean energy into clean hydrogen could be a solution to store this energy, both to sell abroad and to power Africa's growing industries. With this in mind, I have proposed investing in the African hydrogen sector, thus creating a new market for clean hydrogen between the two shores of the Mediterranean. This could bring clean energy to Europe and sustainable development to the African continent."

Co-funded by the European Union

GREEN HYDROGEN

THE MOST ENVIRONMENTALLY FRIENDLY OPTION

Co-funded by the European Union

What is hydrogen and why is it important for the economy?

Hydrogen, a simple element with the chemical formula H2, plays an increasingly important and complex role in the global economy and in climate protection efforts. As a key resource of the future, hydrogen may revolutionize the sectors of energy, industry, and transport.

Hydrogen, produced through electrolysis using renewable energy, plays a significant role in the energy and climate transformation of European economies and is essential for achieving the goal of a zero-emission economy by 2050, in accordance with the European Green Deal.

The use of hydrogen as an energy carrier in the energy sector, as an alternative fuel in industry, as a substitute for natural gas, and as a raw material for the production of synthetic fuels, is a key element in promoting sustainable energy solutions.

The role of hydrogen in achieving climate balance

In the context of the European Union's strategy, hydrogen is a key component of diverse activities, encompassing production, industry, market, and infrastructure. This strategy aims to develop technology and innovation to increase both the supply and demand for hydrogen. The European Commission emphasizes the importance of hydrogen in moving away from fossil fuels, particularly as an energy carrier for storage and transport, which is crucial given the increasing share of renewable energy.

The "colors" of hydrogen and their significance

Hydrogen production is not uniform and uses varies methods what results in different "colors" of hydrogen, from grey, through blue to green. Gray hydrogen, currently the most widespread, is primarily produced from natural gas reforming, which is associated with high CO2 emissions. Therefore, despite its dominance in production, it is increasingly seen as unsuitable in the context of decarbonization efforts and combating climate change. Blue hydrogen emerges as a compromise option between high CO2 emission hydrogen production and more ecological methods. It is produced similarly to gray hydrogen, but with the use of CCS technology (Carbon Capture and Storage), which allows for a significant reduction in CO2 emissions. Although the production of blue hydrogen still relies on fossil fuels itis more ecological approach. Green hydrogen, produced through the electrolysis of water using renewable energy, represents the most environmentally friendly form of hydrogen.

This production method is characterized by zero CO2 emissions and fully aligns with sustainable development principles. In the context of global decarbonization efforts, green hydrogen is increasingly desired and seen as a key element in a future energy economy. The "colors" of hydrogen not only symbolize different production methods but also reflect the impact of these methods on the environment and climate. The choice of hydrogen production method is crucial for the future of energy sector and achieving climate goals. While gray and blue hydrogen still play an important role in the economy, green hydrogen seems to be the best path for achieving a sustainable energy future.

Co-funded by the European Union
DIALOG of Transformation
FERI
ECRN European Chemical Regions Network
zielona chemia
KRAJOWY KLASTER KLUCZOWY

Low-emission hydrogen production technologies

The need for more environmentally friendly production of hydrogen leads to the emergence of innovative technologies such as electrolysis, steam reforming of biogas or biomass gasification.
For that reason the European Union plans to install electrolyzers with a total capacity of 6GW by 2026, producing one million tons of hydrogen from renewable energy sources. By 2030, electrolyzers with a total capacity of 40GW will support hydrogen energy production in European Union countries.

The role of hydrogen in the global economy

Green hydrogen is gaining importance in the global economy, not only as an energy resource but also through expanding its applications in the energy and transportation sectors, contributing to emission reduction and increased energy efficiency. The European Union places hydrogen at the center of its energy strategy, highlighting its fundamental importance for the global economy.

The article was prepared as part of the project "Professions and competences in the hydrogen sector", no. 2023-1-PL-01-KA220-VET-000159821.

Co-funded by the European Union

THE VALUE CHAIN OF THE HYDROGEN ECONOMY IN POLAND

The complexity of the hydrogen technology field and the hydrogen economy itself, on the one hand, requires that it be properly defined using the hydrogen economy value chain concept. It can be used when describing the processes, technologies and challenges related to the creation and development of this industry in the Polish economy.

Using the definition cited by the experts of the Polish Industrial Development Agency, we can explain that "the hydrogen economy is a value chain related to the production, transmission, storage and application of hydrogen in all areas of human activity, in particular in the main sectors of the economy - transport, energy, heating, and above all in industry" (PARP, 2022, p. 12). Such an approach to the hydrogen economy, together with an analysis of the technologies necessary for the realization of the various stages of the value flow, along with a snapshot of the market position of the various links in the value chain, makes it possible to identify and assess Poland's hydrogen potential.

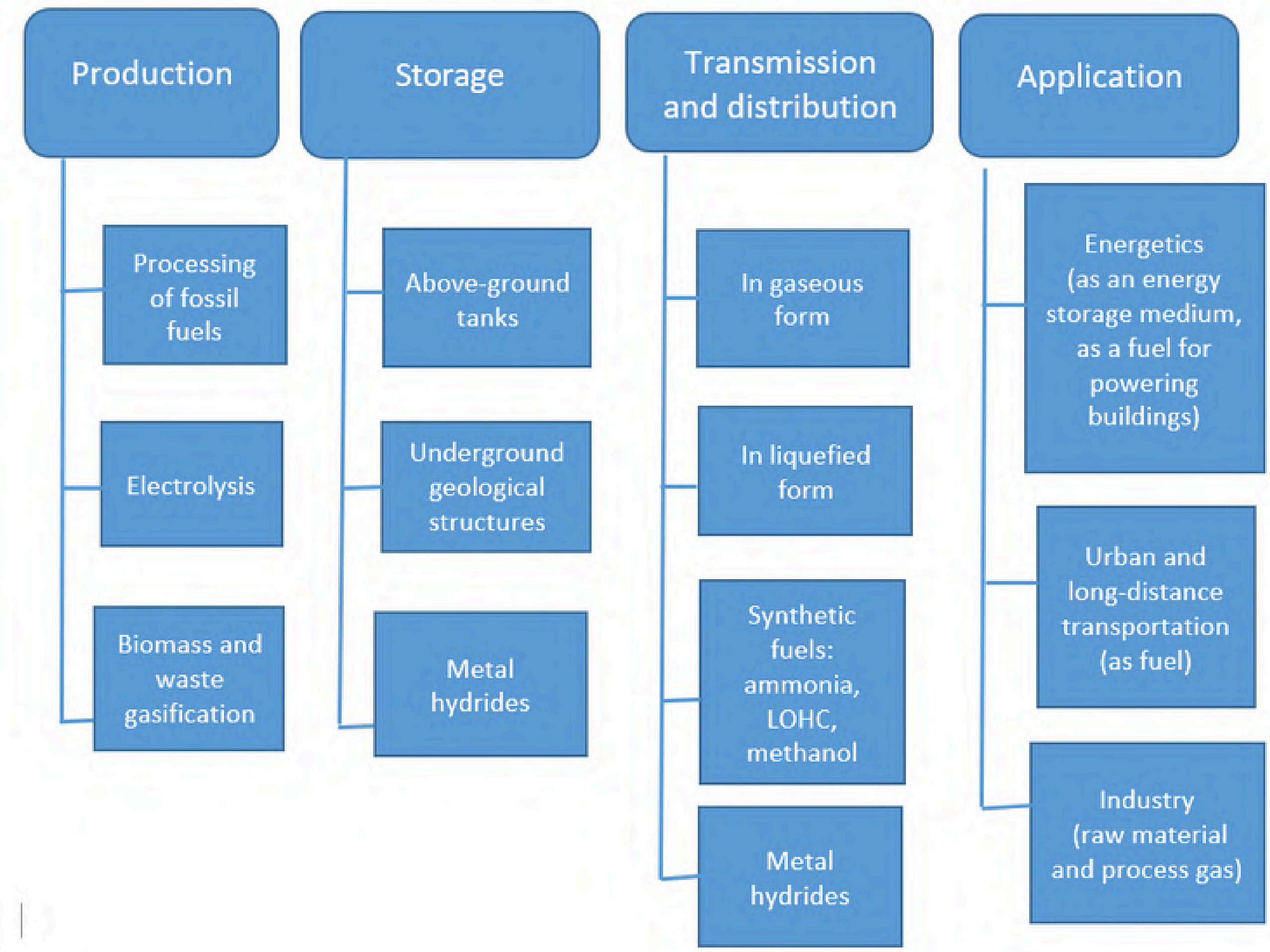
It corresponds to the approach used by a team of experts led by G. Tchorek, who prepared a comprehensive report entitled Value Chain of the Hydrogen Economy in Poland (Tchorek et al. 2023a). Figure 1 shows an example of the hydrogen economy value chain, which can be used for further analysis in this area.

THE VALUE CHAIN OF THE HYDROGEN ECONOMY IN POLAND

As G. Tchorek stated, the European Union has very precisely defined the conditions for the production and characteristics of hydrogen that can be considered low-carbon, and thus determined which hydrogen projects can receive funding. They point out that only hydrogen production based on electrolysis using energy obtained from RES (wind, solar or nuclear) meets the EU taxonomy, i.e. involves emissions of 3 t co2 per 1 t h2 . "Steam reforming of methane (+CCS), steam reforming of biogas and waste processing (+CCS) would require additional reductions at the storage and transport stages to meet this limit.

The other methods: coal gasification (+CCS), steam reforming of methane, waste processing, coal gasification and electrolysis with grid energy would not be considered low-carbon by the Union" (Tchorek et al., 2023a).

FIGURE 1: HYDROGEN ECONOMY VALUE CHAIN



Source: own compilation based on: PARP (2022); Sobolewski (2022).

POLISH HYDROGEN STRATEGY AS A DETERMINANT OF THE DEVELOPMENT OF THE HYDROGEN ECONOMY IN POLAND

Poland has joined the development of the hydrogen economy in Europe by adopting a hydrogen strategy in 2021 entitled Polish Hydrogen Strategy to 2030 with an Outlook to 2040 (Monitor Polski, 2021). This is the most important strategic document referring to the assumptions of the European hydrogen strategy, as well as global, EU and national efforts to create a low-carbon economy. This strategy (referred to as PSW for short) sets out the main goals for the development of the hydrogen economy in Poland, as well as the directions of state intervention that are necessary to achieve these goals. It includes an expanded (compared to the one presented in Figure 1) form of the hydrogen economy value chain. It represents a blueprint for a more complex hydrogen economy value chain, which takes into account in four links of the chain new technologies, not yet operating in the Polish economy, that may develop in the coming years and create opportunities for value extraction.

Table 1 shows this new forward-looking vision of the value chain of a developed hydrogen economy in Poland. Each of the components of the hydrogen economy value chain included in Figure 1 and Table 1 involves the use of different technologies, which are characterized by different measures of CO_2 , the amount of the average cost of producing 1 kg of hydrogen (H_2) and the degree of technological readiness (TRL).

TABLE 1. PROPOSED FUTURE VALUE CHAIN OF THE HYDROGEN ECONOMY IN POLAND

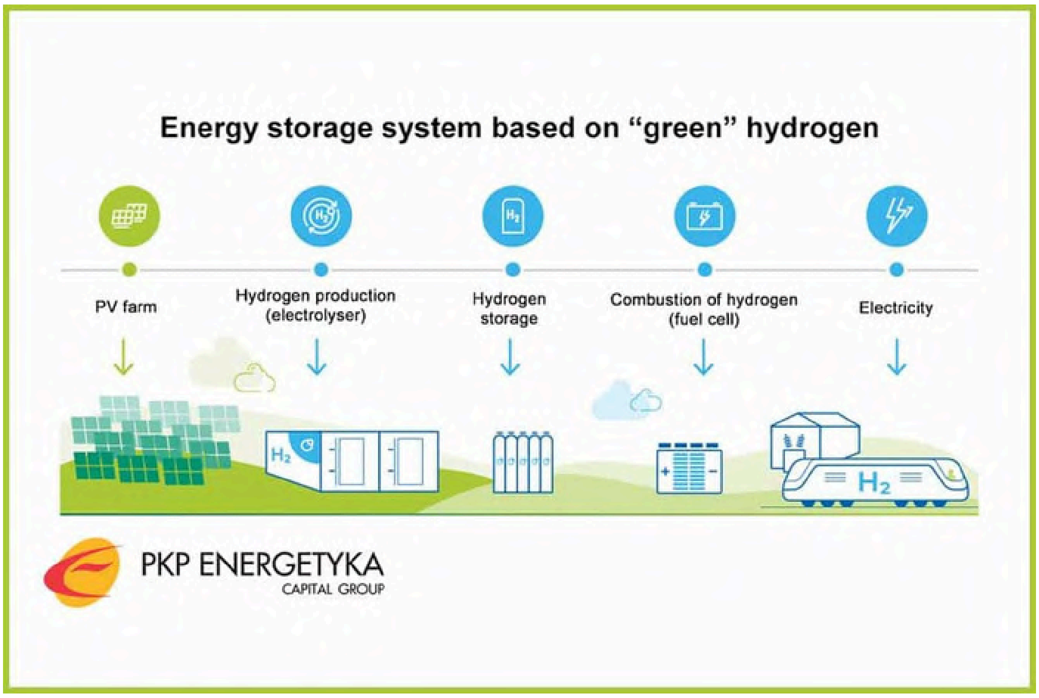
	Cells of the hydrogen economy value chain			
Hydrogen technologies and their applications	**Production**	**Storage**	**Transmission and distribution**	**Application**
	Electrolysis	Underground storage - depleted oil and gas fields, salt caverns	Transmission by means of gas networks	Stabilization of RES and national power grids
	Steam reforming of biomethane	Above ground storage - pressure vessels	Maritime transport	Energy-intensive industries (heavy, chemical, refining, fertilizer)
	Gasification, fermentation or pyrolysis of biomass	Chemical storage	Transportation of gaseous and liquefied hydrogen by tanker trucks	Fuel in cogeneration and polygeneration systems
	Steam reforming of biogas	Liquid hydrogen storage	Hydrogen refueling and bunkering stations	Fuel in road (urban and long-distance), rail, water, air and intermodal transport modes
	Gasification, pyrolysis and thermal treatment of waste	Injection of hydrogen into the gas network		Energy storage
	Steam reforming of hydrocarbons with CCS/CCU			Support for merging economic sectors
	Coal gasification with CCS/CCU			
	By-product of refining processes			
	Coke oven gas separation			
	HTR			

Source: own compilation based on: Monitor Polski (2021).

POLISH HYDROGEN STRATEGY AS A DETERMINANT OF THE DEVELOPMENT OF THE HYDROGEN ECONOMY IN POLAND

The creators of the Polish Hydrogen Strategy assumed that in Poland the hydrogen economy would be developed based on the Power-to-X model. Its concept is based on increasing the use of renewable energy to produce hydrogen, and then using it in further sectors of the economy to decarbonize them. An example of how to use "green" hydrogen in rail transportation is shown in Figure 2.

FIGURE 2: FROM PRODUCING LOW-CARBON HYDROGEN TO POWERING A TRAIN



Source: Elisabeth (2023).

The following specific goals are written in the strategy document for the hydrogen economy in Poland:

- Implementing hydrogen technologies in the power, heating and transportation industries,
- Support for decarbonization of industry, and highly energy-intensive sectors of the economy where electrification is too costly or impossible,
- Hydrogen production in new installations,
- Efficient safe industry, distribution and storage of hydrogen,
- Opportunities to retrain the workforce from sectors at risk of reduction, such as coal and lignite mining, for the development of the hydrogen economy,
- Creating a stable regulatory environment.

POLISH HYDROGEN STRATEGY AS A DETERMINANT OF THE DEVELOPMENT OF THE HYDROGEN ECONOMY IN POLAND

The hydrogen strategy has adopted very ambitious plans to achieve the indicated goals, including, among others (Monitor Polski, 2021):

- Achieving up to 50 MW by 2025. , and 2 GW by 20230 of low-carbon hydrogen plant capacity,
- using 100-250 by 2025 and 800-1000 hydrogen buses in urban transportation,
- Organizing at least 5 hydrogen valleys,
- Creating at least 32 hydrogen refueling stations by 2025.

The PSW was approved and adopted for implementation during the rule of the United Right, which planned to allocate about PLN 11 billion for the purposes listed above (Pilszyk et al., 2023). Potential sources of funding for these investments were to include the National Fund for Environmental Protection and Water Management (NFOŚiGW). For funding research work related to hydrogen technologies, the National Center for Research and Development (NCBiR). In addition to national sources, the strategy indicated the need to use EU funds, including the National Plan, the Horizon Europe program, Important Project from Common European Interest (IPCEI) competitions of the Reconstruction Fund (Next Generation EU) or the Just Transition Mechanism.

The government at the time planned to allocate funds from various public and private sources, including funds from the National Reconstruction Plan (NRP), to implement the PSW's intentions. From this source, €800 million was to be used to provide grants to the private sector for projects related to the use of hydrogen as a fuel in transportation and industry. The United Right government's long-running conflict with the European Commission over the rule of law has made it impossible to obtain EU funds from the NIP and thus allocate some of them for the development of the hydrogen economy.

The indicated level of necessary investment to achieve the goals of the PSW was underestimated from the beginning. Experts indicated that 2 billion PLN should have been invested in the development of the hydrogen economy in Poland by 2025, and about 17 billion PLN by 2030. Due to the changed geopolitical and economic conditions since 2022 (war in Ukraine), the level of public support and private sector investment in such long-term and risky hydrogen projects assumed by the state could not be met in the following years (Kryczka, 2021; Mierwiński, 2022; Łącka, Wojdyła, 2022).

Co-funded by the European Union

POLISH HYDROGEN STRATEGY AS A DETERMINANT OF THE DEVELOPMENT OF THE HYDROGEN ECONOMY IN POLAND

In addition to the problems of financing the development of the hydrogen economy, regulatory difficulties arose from the outset in the implementation of the PSW. In preparation for a stable regulatory environment for the development of the hydrogen economy in Poland, the strategy established that (Wyszkowski et al., 2022):

- A regulatory framework for the operation of hydrogen as an alternative fuel in transportation will be established in Q3 2021,
- The legislative development of the hydrogen package will take place in Q4 2021.

The regulatory package, commonly known as the Hydrogen Law, was to include amendments to such laws as the Energy Law, the Law on Electromobility and Alternative Fuels, the Law on Renewable Energy Sources and the Law on Bio-Components and Liquid Biofuels. On top of this, it was intended to introduce, among other things, a legal framework that takes into account cross-sectoral opportunities for hydrogen application, systemic support mechanisms for conducting research and development activities for hydrogen technology projects, establish a national hydrogen network operator, define regulations on the environmental impact and use of hydrogen investments, and amend the construction law on hydrogen stations, taking into account facilities for their purification (Wyszkowski et al., 2022).

Unfortunately, in spite of the legislative timetable adopted, there have been delays in the introduction of hydrogen technology regulation and support in Poland from the beginning. They hindered, on the one hand, the acceleration of the development of hydrogen technologies, and, on the other hand, the raising of funds for research and development in this field, as well as the development of technologies and their commercialization. As early as 2022, representatives of the private sector pointed to the existence of negligence in the regulatory measures necessary for the development of the hydrogen economy in Poland. They stressed the need to create appropriate definitions of hydrogen, to simplify and shorten the administrative procedures necessary when making hydrogen investments. Entrepreneurs expected that such investments located in hydrogen valleys could count on greater care from the public administration.

Among the barriers perceived since the government's adoption of the PSW, private sector representatives also pointed to the unstable regulatory environment and excessive bureaucracy, the lack of systemic solutions (including training of officials in issuing environmental decisions on hydrogen technologies) and the discretionary nature of official decisions, the lack of precise regulations when planning, implementing or

POLISH HYDROGEN STRATEGY AS A DETERMINANT OF THE DEVELOPMENT OF THE HYDROGEN ECONOMY IN POLAND

operating hydrogen investments. This made it difficult for entrepreneurs to estimate the time and cost needed to implement the project. Problems with connecting RES devices to the power grid, the lack of a coherent certification system for renewable hydrogen, the lack of rules for human safety and environmental protection in connection with the use of hydrogen, and the lack of a description of the hydrogen economy from the technical side were also considered as destimulants for the development of the hydrogen economy in Poland (Wyszkowski et al., 2023).

However, as of 2023, according to the authors of the report The Value Chain of the Hydrogen Economy in Poland, "the Polish regulatory environment for hydrogen and derivatives is gradually beginning to develop in response to very strong regulatory dynamics at the European level" (Tchorek et al., 2023a, p. 24).

The outbreak of war in Ukraine, the sharp increase in gas prices, the energy crisis in the European Union, the adoption of the REPowerEU plan, the increase in EU climate targets and technological developments, have made it necessary to revise the provisions of the PSW. At a February 2024 meeting, the new chairman of the Coordinating Council for the Hydrogen Economy pointed out "the need to revise the Polish Hydrogen Strategy to 2030, with an outlook to 2040 (PSW), due to dynamically changing energy and climate needs, including EU requirements obliging greater use of renewable hydrogen. He stressed that the development of the hydrogen economy is no longer just an alternative, but a necessity, and renewable hydrogen will find application in many sectors, including energy, industry, transportation and heating" (8th meeting of the Coordinating Council for Hydrogen Management , 06.02.2024).

According to experts (Smoleń et al., 2023), the Polish Hydrogen Strategy focuses on the development of the domestic hydrogen market and basically does not take into account aspects related to the global hydrogen market and the international competitiveness of hydrogen production in Poland. Given the very undeveloped Polish market for low-carbon hydrogen, one should consider the need to import this type of energy resource in the initial stages of the development of the hydrogen economy in Poland, while maintaining an appropriate level of supply diversification. One of the goals of the EU's strategic plan prepared in response to Russia's assault on Ukraine, titled REPower EU published in 2022 (EC, 2022), is to diversify energy supplies with the assumption of moving to clean energy as soon as possible. It points to the need to import gas and hydrogen within the EU and from third countries (Energy Community contractors), for

POLISH HYDROGEN STRATEGY AS A DETERMINANT OF THE DEVELOPMENT OF THE HYDROGEN ECONOMY IN POLAND

which the established secure online purchasing platform for LNG and hydrogen imports (EU Energy Platform) is to be used. If the global market for low-carbon hydrogen (or ammonia) really develops, Poland may be inclined to import green hydrogen for economic reasons. As Smoleń and his team point out, it is necessary to establish regional energy cooperation to stabilize and secure the energy system. Depending on the direction of technology development, this could mean developing cross-border hydrogen pipelines that would allow Poland to transport hydrogen in both directions (import and export).

HYDROGEN MANAGEMENT IN POLAND - CURRENT STATUS

HYDROGEN PRODUCTION IN THE VALUE CHAIN

In 2024, Poland, compared to other European Union countries, is at the initial stage of implementation and development of the hydrogen economy, and has failed to achieve the PSW goals intended by 2025. In the third decade of the 21st century. Poland is the third, after Germany and the Netherlands, producer of "gray" hydrogen in Europe in the manufacturing processes of the petrochemical and chemical industries, which comes primarily from the steam reforming process of hydrocarbons. It is produced at industrial plants, where it is also used for the chemical, refining, food and metallurgical industries. In 2022. Poland produced 1.3 million tons of hydrogen, with it generated exclusively from fossil fuels (Sobolewski, 2022; Pilszczyk et al. 2023). This represented more than 13% of the EU's annual production of the resource. In Poland, there are planned investments in the hydrogen economy, which assume the production of "green" hydrogen from RES (only pilot projects are currently in operation), but to a large extent investment activities are also to focus on the production of "blue" hydrogen (obtained using CO capture and storage methods2). On the one hand, the indicated activities can take advantage of the opportunity arising from the high domestic demand for low-carbon ("green") hydrogen. Poland represents a promising market for hydrogen because of its significant potential demand due to its large population, dependence on fossil fuels for power and heating and transportation, and developed industry. On the other hand, current hydrogen technologies leading to the production of "gray" hydrogen are a burden on the economy (Antas et al. 2021) due to the carbon intensity of this type of hydrogen. "Gray" hydrogen will have to be gradually replaced by renewable and low-carbon hydrogen.

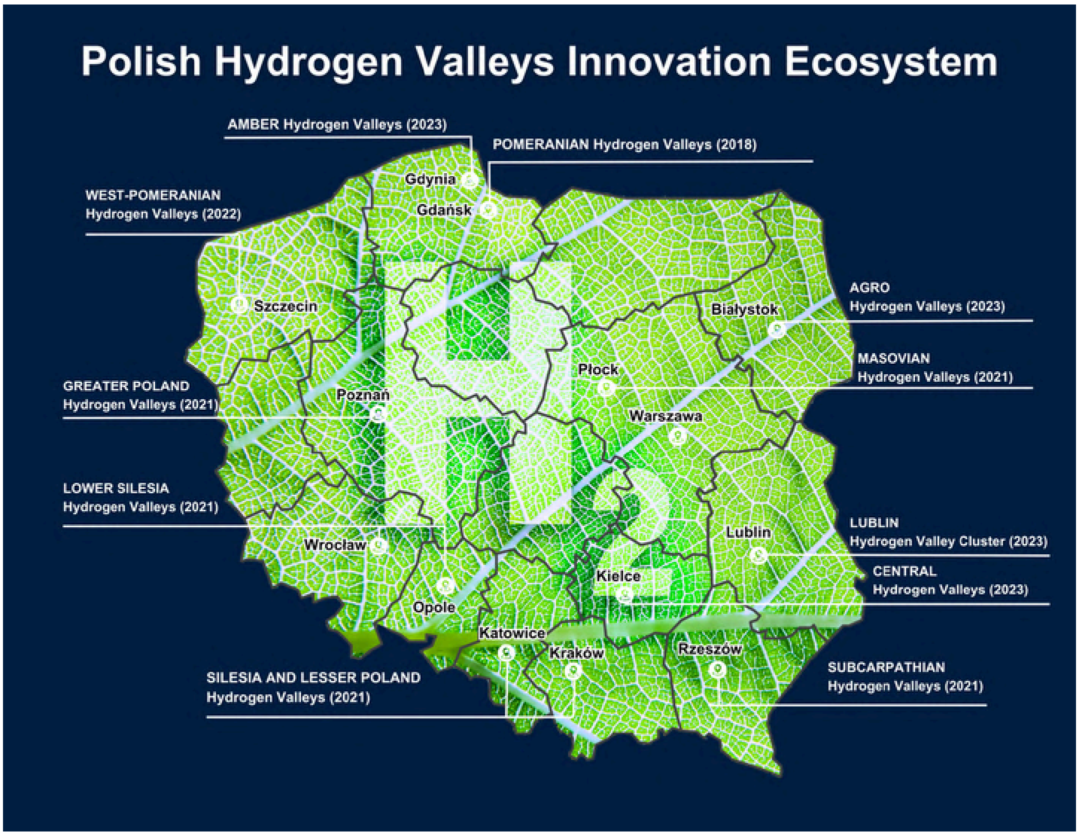
HYDROGEN PRODUCTION IN THE VALUE CHAIN

Data from the European Hydrogen Observer in Poland shows that in 2022, domestic demand for hydrogen was more than 784,000 tons per year. More than 96% of it was consumed in oil refining and ammonia production. Demand for hydrogen for the production of other chemicals was 14 thousand tons per year. In contrast, consumption of hydrogen for the production of industrial heat and for other purposes accounted for 9 thousand and 6 thousand tons per year, respectively. The transportation (mobility) sector used only 13.8 t (about 0.014 thousand t) of hydrogen per year (Pilszyk et al. 2023).

Experts from the Polish Economic Institute reported that in 2023 there were 74 entities related to hydrogen investments. They were characterized by different sizes, forms of ownership and belonging to different sectors of the economy (PIE, 2023). They included small entities with hydrogen refueling stations, research institutes and the largest players in the Polish fuel and energy market. The most numerous were those operating in industry and heating (24), manufacturing (14) and education (14). Entities involved in the development of the hydrogen economy in Poland include automotive corporations, energy companies, ports, gas companies, coal companies, business environment organizations (e.g. clusters, technology parks, chambers of industry and commerce), universities, research institutes and public administration institutions. Their activities are concentrated in the hydrogen valleys that have been created over the past few years. According to information from the Industrial Development Agency S.A., there are eleven hydrogen valley projects in operation in 2024. Eight of them were consulted or created on the initiative of this company, which is actively involved in the development of the hydrogen economy ecosystem in Poland. The idea behind hydrogen valleys is to support the decarbonization of energy-intensive industry, locate technology demonstrators in industrial parks and special economic zones, and build the Polish supply chain with the support of business, science and local administration (IDA S.A., 2024). Figure 3 shows the location of hydrogen valleys in Poland.

HYDROGEN PRODUCTION IN THE VALUE CHAIN

FIGURE 3: HYDROGEN VALLEYS IN POLAND IN 2024.

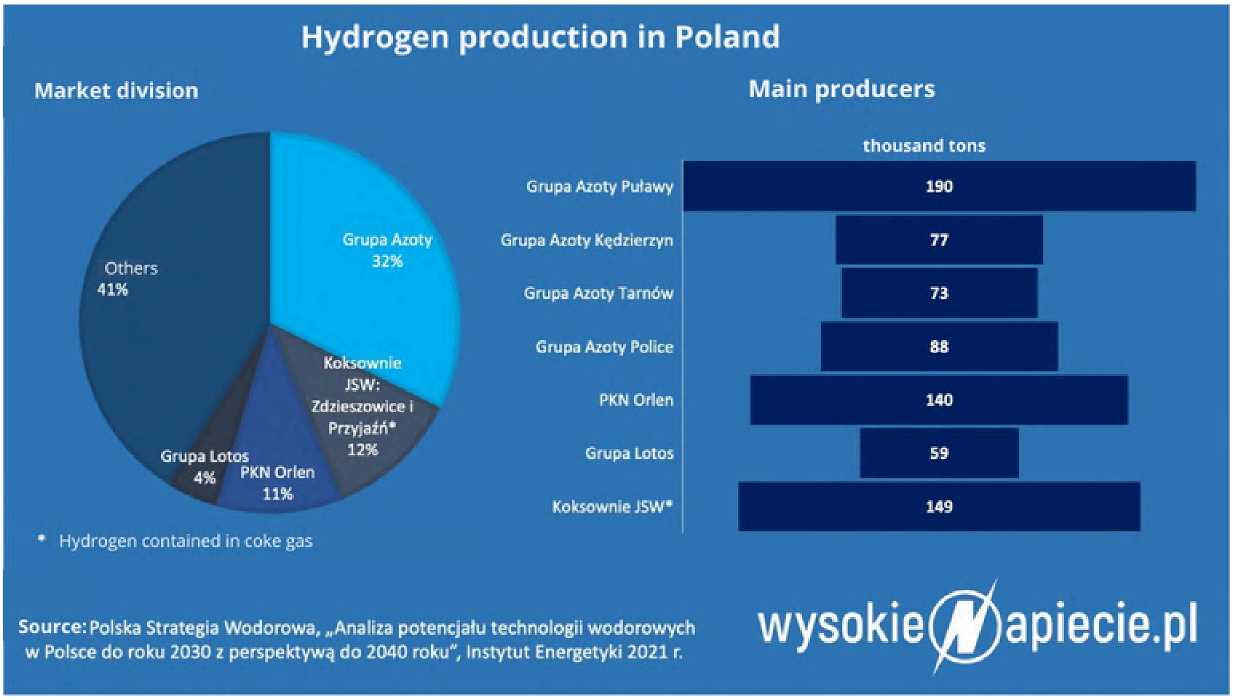


Source: IDA. S.A. (2024).

The largest producer of hydrogen in Poland is Grupa Azoty S.A. (producing mineral fertilizers and chemicals). Significant amounts of conventional hydrogen (from natural gas) are also produced at PKN Orlen, the Przyjazn coking plant, which belongs to Jastrzębska Spółka Węglowa. This shows that hydrogen in Poland is produced by large state-owned companies and consumed primarily for their own needs without much opportunity for resale. As Komorowska et al. point out. (2023) it is difficult to talk about the hydrogen market in Poland today - it has yet to develop. Figure 4 shows the hydrogen production volumes of individual producers in Poland in 2021. Note that in 2022 there was a merger between PKN Orlen and Grupa Lotos, so now only PKN Orlen is on the market as a hydrogen supplier from the fuel and refining sector.

PRODUKCJA WODORU W ŁAŃCUCHU WARTOŚCI

FIGURE 4 HYDROGEN PRODUCERS IN POLAND AND THEIR MARKET SHARES



Source: Elizabeth T. (2023).

Hydrogen produced in Poland is mainly used in the chemical industry to produce ammonia, used in the production of fertilizers. In addition, it is used in the petrochemical industry in the processes of reforming (used to improve fuel quality), hydrotreating (which reduces sulfur, nitrogen and oxygen content) and hydrocracking (converting heavy crude oil fractions into light oils and gasoline). Most of the hydrogen is used by the companies that produce it, and only a small portion is traded on the market. Both the hydrogen plants and the industrial facilities that use them are usually in the same location. This is due to the technical difficulties involved in transporting hydrogen.

TECHNOLOGICAL ENVIRONMENT OF HYDROGEN PRODUCTION IN POLAND

A report analyzing the value chain of the hydrogen economy in Poland (Tchorek et al., 2023a) outlines the low CO recommended by the European Union2 and the methods currently used to produce hydrogen in Poland. Among them were such methods as: electrolysis from RES (wind farms, photovoltaics), electrolysis from the grid, electrolysis from nuclear energy, steam reforming of natural gas, steam reforming of biogas, coal gasification, pyrolysis of natural gas, waste processing, thermochemical processes, biomass gasification, and other methods at the stage of technological development with a commercialization date that is difficult to determine (hydrogen separation membranes, photolysis, dark fermentation of biomass, biological processes, water deoxidation). Their characterization and assessment of their applicability in the light of the provisions of EU policy documents and national acts is based on a comparison of the volume of CO_2 emissions during hydrogen production, the established level of technological readiness (TRL) of a given method and the averaged cost of hydrogen production in EUR/1kg H_2 (Levelized Cost of Hydrogen, LCOH). The various methods are discussed in great detail in the aforementioned report, for this only the most important findings on hydrogen production methods in Poland and their prospects in the coming years will be given here.

The choice of hydrogen production methods used now and in the future is, of course, influenced by the regulatory environment, which consists of strategic documents and directives of the European Union and Polish legal acts, which include:

- RED Directive with Delegated Acts,
- EU taxonomy with delegated act
- New Gas Package
- REPower EU
- Net Zero Industry Act
- others: EU ETS, CEEAG
- selected national acts.

Hydrogen production in Poland and its methods are also affected by factors related to the market environment, which determine such determinants as:

- Natural gas price fluctuations,
- Electricity price fluctuations,
- The cost of producing electricity from RES,
- Electrolysis market development,
- Development of the Carbon Capture Storage (CCS) and Carbon Capture Utilization (CCU) market - technologies that capture CO_2 emissions in gas reforming,
- The existence of exemplary large-scale low-carbon hydrogen production projects,
- The impact of state regulation on the economic efficiency of hydrogen projects.

Co-funded by the European Union

TECHNOLOGICAL ENVIRONMENT OF HYDROGEN PRODUCTION IN POLAND

Synthesizing the assessment of various more and less advanced technologies (technology-ready on a scale of 1-9) for hydrogen production with an indication of their emissivity and average cost of hydrogen production is Figure 5. The TRL level of technological readiness includes a 9-stage classification for determining the technological maturity of a process (possibly a product or service) from basic research (TRL 1-2), through conceptual and laboratory work corresponding to industrial research (TRL 3-6), prototype creation in development (TRL 7-8), to a finished solution (TRL 9) applicable in practice.

Figure 5 has two axes - the vertical axis indicates the amount of CO2 emissions during hydrogen production by a given method, and the horizontal axis indicates the amount of averaged cost of hydrogen production using a given technology. The technology readiness level (TRL) is shown by tri-colored circles. The darker the circle, the more developed the technology is and ready for use in hydrogen production. A very light gray circle indicates a low TRL and a hard-to-find time for a given technology to come to market and be used in Poland for hydrogen production. These methods are currently at the stage of basic research.

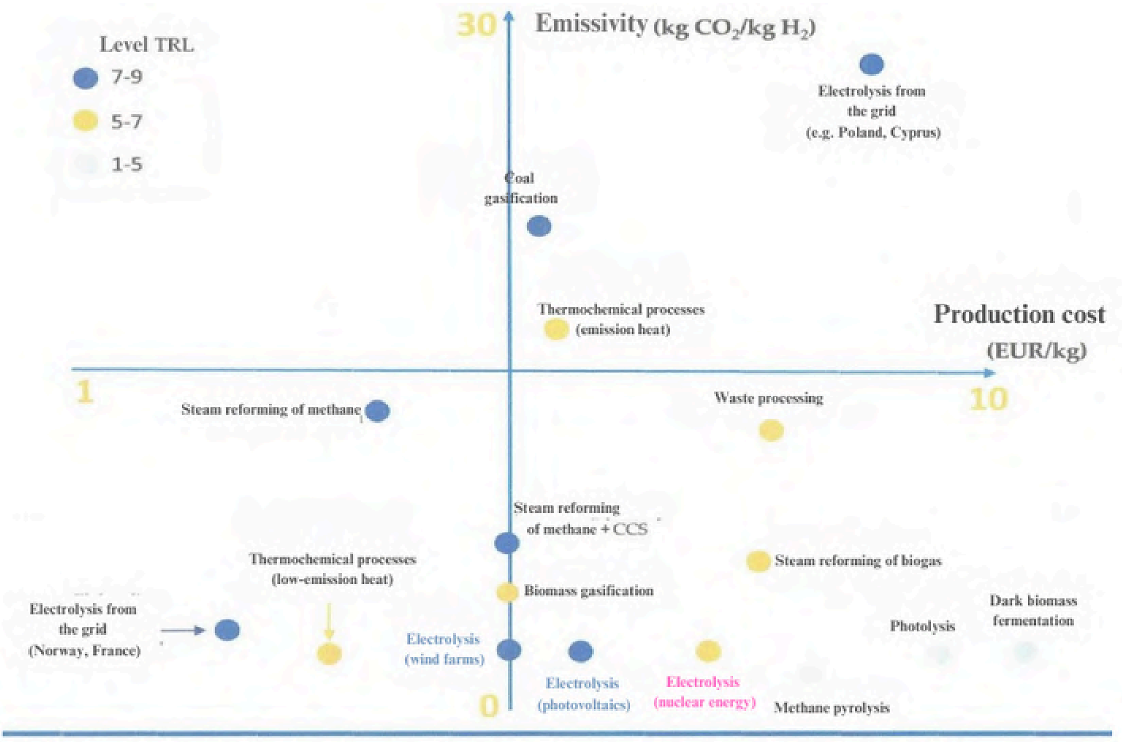
The authors of the report pointed out that the hydrogen economy in Poland should be based on low-carbon and renewable hydrogen production, making it possible to create a low- and zero-carbon economy. However, it should be noted that not every method included in Figure 5 (including those favored by the European Union's strategic documents based on electrolysis) can be applied in Polish conditions in the coming years for environmental (emissions), economic, legislative impediments or problems with the level of technological readiness.

Electrolysis from the grid in the case of Poland is an expensive and highly carbon-intensive method of producing hydrogen. This makes it unsuitable for use. Coal gasification, steam reforming of natural gas are high-technology and not very costly methods, but due to their relatively high emissivity, they should be used together with CO capture facilities2 (CCS/CCU) to meet EU climate policy requirements. The European Commission's recommended method of hydrogen production based on electrolysis from RES (wind farms and photovoltaics) has a TRL of 7-9 and is still developing, with costs still being optimized. It has the advantage of very low CO2 . In contrast, biogas steam reforming and waste treatment are considered promising (still developing) complementary methods, with potentially low cost of hydrogen production. Unfortunately, their use leads to CO emissions2 , which would need to be reduced in the long term.

Co-funded by the European Union

TECHNOLOGICAL ENVIRONMENT OF HYDROGEN PRODUCTION IN POLAND

FIGURE 5: MATRIX OF HYDROGEN PRODUCTION METHODS



Source: Tchorek et al. (2023a), p. 11.

It is difficult to consider today that the electrolysis method from nuclear power for the production of so-called "purple hydrogen" can be used in Poland in the relatively short term due to the lack of large nuclear units and SMRs. Although the TRL level is estimated at 6-7 and the emissivity of the hydrogen production process is close to zero, the lack of developed nuclear power and the high cost of hydrogen production are the biggest barriers to the use of this method in Poland in the coming years.

The authors of the cited report prepared some conclusions and recommendations for policymakers, the implementation of which should support the hydrogen economy at the production stage.

Co-funded by the European Union

TECHNOLOGICAL ENVIRONMENT OF HYDROGEN PRODUCTION IN POLAND

Among them were the following statements (Tchorek et al. 2023a, p. 39):

- it is necessary to launch a support system for the production of renewable hydrogen and derivatives in Poland (RFNBO) - in Poland, only hydrogen produced from RES will make it possible to meet the RFNBO targets;
- It is necessary to enable industrial RES investments using direct lines;
- The state should analyze the possibility of introducing regulatory and/or network fee concessions for hydrogen producers (this would slowly reduce the cost of producing hydrogen by 1-2 EUR/kg);
- the approach should be promoted and supported in energy and hydrogen projects that the RES plant is a component of the hydrogen production system, not an independent asset on which maximum profit must be made (buying electricity for the electrolyzer at wholesale or indexed to wholesale prices will make the renewable hydrogen market unprofitable for a long time to come);
- Industrial companies using hydrogen in technological processes should consider the impact of the revised 2023 EU ETS/CBAM on the unit cost of producing 1kg of hydrogen; these may increase significantly by 2030 due to the increase in the price of CO allowances2 (160 EUR/t CO2 in 2030), the entry of hydrogen into CBAM from 2026 and the gradual move away from free allocation, the tightening of sectoral CO2 benchmarks for hydrogen production in the EU ETS;
- it is necessary for the state to strategically plan the connection and construction of RES installations exclusively for hydrogen production in Poland at the level of the National Energy and Climate Plan 2021-2030 (NERP) and the Energy Policy of Poland until 2040 (PEP2040), rather than for the needs of the electric power industry and wholesale energy sales.

HYDROGEN STORAGE AS A LINK IN THE VALUE CHAIN OF THE HYDROGEN ECONOMY IN POLAND

A number of factors influence the hydrogen storage processes in Poland and the methods used now and in the future - hydrogen hydrogen characteristics and storage requirements, technological, regulatory and economic considerations. As indicated by Folentarska et al. (2016) "Due to the properties of hydrogen, i.e. low energy density compared to conventional fuels, flammability and high explosiveness, hydrogen storage materials should be distinguished by high hydrogen storage capacity, technological simplicity, efficient hydrogen absorption/desorption cycles, low price and safety of use" (Folentarska et al., 2016, p. 125).

Hydrogen storage is subject to regulatory actions determined by EU and national legal acts, such as: delegated acts to the European Union Taxonomy (defining the rules for counting investments in hydrogen storage as compliant with the Taxonomy and making a significant contribution to mitigating the climate effects of global warming), the Package for Decarbonization of the Natural Gas and Hydrogen Market (the so-called New Gas Package), and national legal acts on hydrogen production and their amendments, including the Energy Law and the Geological and Mining Law. New Gas Package), as well as national legal acts on hydrogen production and their amendments, including the Energy Law, the Geological and Mining Law, and regulations on detailed conditions for operation of the hydrogen system (Tchorek et al, 2023a).

Hydrogen is a very common element with a high gravimetric density and a low volumetric density at the same time. It is the lightest element in the universe. This necessitates its storage under room conditions (at room pressure and temperature) over very large areas. As indicated by Siekierski et al. (2023) it has in gaseous form the highest molecule velocity, resulting in a high diffusion coefficient, as well as the highest thermal conductivity and lowest viscosity. Molecular hydrogen has the highest heat of combustion of all fuels known to date, with no direct emission of carbon dioxide.

The volume density of hydrogen gas at ambient atmospheric pressure is about 0.09 kg/m^3. Compression to 350 bar causes an increase in volumetric density to a value of 23 kg/m3 , and compression to 700 bar causes a further increase in volumetric density to a value of 41 kg/m3 . This allows 5 kg of hydrogen to be stored in a 125-liter fuel tank. A 300-liter tank allows storing 13-15 kg of hydrogen at 700 bar. Compressing hydrogen from 20 bar (the output pressure from an electrolyzer or reformer) to a pressure of 700 bar requires up to several kWh of electricity for every 1 kg of hydrogen. The energy consumption of the compression method results in a loss of primary energy of hydrogen of up to about 10-15%. At the same time, it should be remembered that liquefied

HYDROGEN STORAGE AS A LINK IN THE VALUE CHAIN OF THE HYDROGEN ECONOMY IN POLAND

hydrogen has a high volumetric energy density of 71 kg/m3 at an ambient pressure of 1 bar. This value is almost double that of hydrogen compressed to a pressure of 700 bar (Tchorek, 2022). Gaseous hydrogen can be compressed to high pressure to increase its energy density (de Jongh, Adelhelm, 2010).

Hydrogen storage can occur at any stage of the hydrogen economy value chain from the time the hydrogen is produced until before it is used. This link in the value chain plays an important role in ensuring a stable supply of hydrogen to the industrial, transportation, energy sectors and thus a stable operation of the energy system in the event of an increase in the share of renewable energy sources in the grids.

Hydrogen can be stored in gaseous, liquid and solid form, and the storage process can be classified into two categories - underground (geological) and aboveground (reservoir). The gas can be stored directly in the form of a derivative (hydrogen derivative) and in different states of aggregation, as determined by the purpose of storage and what sector the hydrogen is to be used in (Table 2).

TABLE 2. METHODS OF STORING HYDROGEN IN DIFFERENT FORMS OF AGGREGATION

Gas form			**Liquid form**			**Permanent form**	
Compre-sated hydrogen	Synthetic hydrocarbons:		Liquid hydrogen	Chemical Hybrids:	LOHC:	Metal hydrides:	Porous materials:
	Compre-sed methane	*Liquid SNG*		*Ammonia*	*MCH*	*Boro-water*	*Graphene*
		Synthetic gasoline		*Methanol*	*DBT*	*Type-AB alloys*	*Aerogel carbon*
		Synthetic disel		*Isopropa-nol*	*Benzene*	*Aluminum hydride*	*Nano carbon tubes*

Source: Tchorek et al. (2023).

HYDROGEN STORAGE AS A LINK IN THE VALUE CHAIN OF THE HYDROGEN ECONOMY IN POLAND

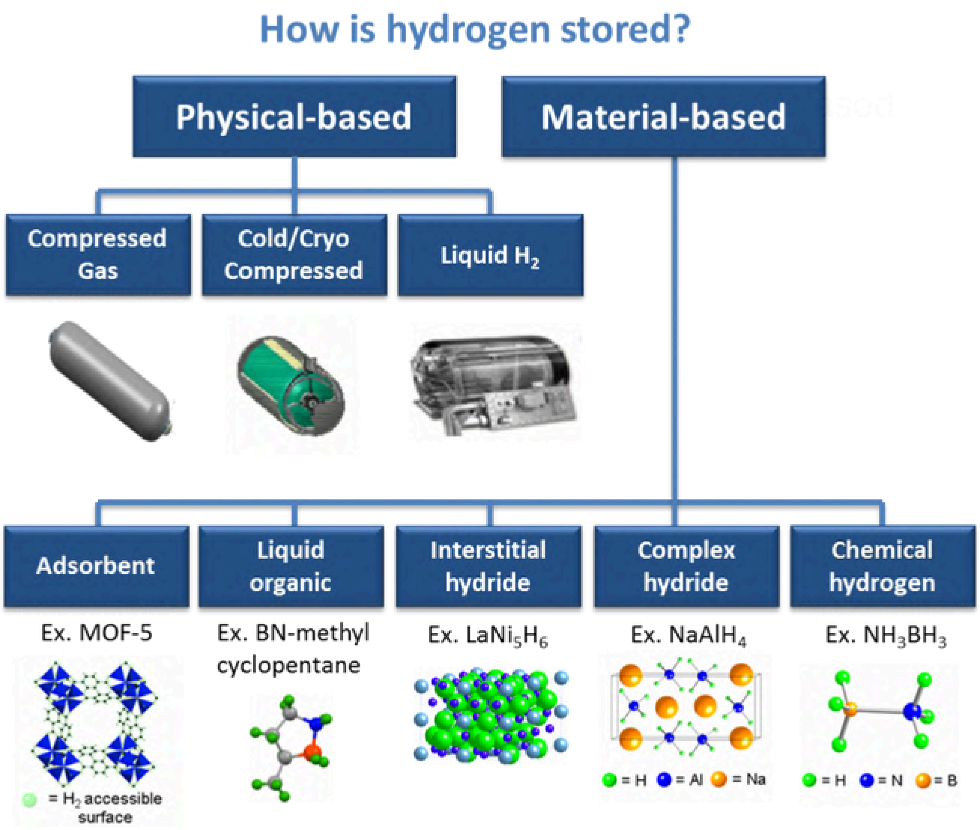
Hydrogen storage methods can also be divided into physical and material methods, as shown in Figure 6. Physical methods include compression and liquefaction of hydrogen. At present, these methods are the easiest to implement and more common, but they have many technical shortcomings, according to experts. In contrast, material methods are based on physicosorption and chemisorption processes and, according to experts, are almost free of drawbacks (Mohan et al. 2018). Unfortunately, research and development processes in this area are still ongoing, which means that they cannot be put into widespread use at present (Kozikowski, Szymlek, 2022).

The aforementioned report on the value chain of the hydrogen economy in Poland discusses the various methods of storing hydrogen in different forms of aggregation and two variants - above-ground and underground (Tchorek et al., 2023a). Hydrogen in gaseous form can be stored underground in salt caverns or rock caverns, at sites left over from depleted gas deposits. On the other hand, pressurized tanks are used for storing this gas on the ground, which is currently the most popular form of hydrogen storage with a TRL of 9, although the storage capacity in tank form is very small (1.1 t of hydrogen). Composite or steel tanks can come in stationary form (e.g., at industrial installations), or mobile form (e.g., for intermodal transport).

Each of the listed methods of hydrogen storage in Poland has different characteristics - a different level of technological readiness and storage capacity, as well as requirements in terms of storage pressure, constant volume of gas in storage, and, in the case of underground hydrogen storage, also the depth of storage.

HYDROGEN STORAGE AS A LINK IN THE VALUE CHAIN OF THE HYDROGEN ECONOMY IN POLAND

FIGURE 6: CLASSIFICATION OF HYDROGEN STORAGE METHODS



Source: Kozikowski, Szymlek (2022), p. 16.

Poland has a large potential for hydrogen storage in the form of salt caverns located onshore, which are characterized by greater flexibility compared to storage after depleted gas fields and saline aquifers. This is due to the possibility of performing several injection and withdrawal cycles in them during the year, making it possible to respond to changes in the market situation. Caverns near the coast (up to 50 km from the shore) could be used as storage facilities for imported hydrogen. The advantages of this storage method include the fact that salt caverns have a high level of technological readiness (TRL is 8-9), a low risk of hydrogen contamination and high storage efficiency (98%), and a large storage capacity (300-120,000 t of hydrogen).

For liquid and solid hydrogen storage, liquid hydrogen (TRL is 7-9) and ammonia (TRL is 9) are considered the most common and developed methods. These are mature tank technologies for small and medium scale storage for liquid hydrogen and large scale for

HYDROGEN STORAGE AS A LINK IN THE VALUE CHAIN OF THE HYDROGEN ECONOMY IN POLAND

ammonia. However, they have some disadvantages, including the flammability of the stored substance and high energy consumption for liquid hydrogen and medium for ammonia. Some advantage of these methods is the medium flexibility of the storage system, which can be useful in situations of changing hydrogen demand. The liquid hydrogen (LOHC) tank storage method has a much greater ability to respond flexibly to market changes. It requires carbon management, low energy consumption, but its disadvantage is also the flammability of the stored substance. Currently, this method has a medium level of technological readiness and commercialization (TRL is 6-8), which hinders its availability in Poland. A similar problem exists with the aluminum hydride method. Although this storage method protects against the flammability of the substance, it has an even lower level of technological and commercial readiness and low flexibility of the storage system.

Medium- and long-term storage of hydrogen and the energy it contains is indicated as one of the most important goals for the development of a hydrogen economy in each EU member country. The growing consumption of hydrogen for energy purposes will force the need not only for its production, but also for storage. This, in turn, contributes to the need for investment activities in hydrogen infrastructure. According to experts, investment in hydrogen storage infrastructure can be as much as 30% of the total infrastructure costs of the hydrogen economy value chain (IEA, 2023). The development of the hydrogen market will encourage the emergence of entities offering underground hydrogen storage services in countries with better geological conditions. This represents an opportunity for Poland, which has significant potential for storage using salt caverns. This method offers the lowest averaged cost of storing 1 kg of hydrogen with high storage potential.

Expert analysis shows that depleted gas fields have the greatest hydrogen storage potential, but this is currently the least mature of the technologies analyzed. It should also be remembered that the use of the various available methods is determined by the planned period of hydrogen storage. For seasonal storage of large quantities of hydrogen, depleted gas fields can be used. For monthly periods, salt caverns and ammonia tanks can be used. For storage of hydrogen on a weekly or daily basis, storage in the form of pressure vessels and liquid hydrogen tanks are proposed. On the other hand, storage in lined rock caverns, which can be used to store hydrogen for several months, but have a medium capacity, is indicated as an intermediate method (Tchorek et al., 2023a).

HYDROGEN STORAGE AS A LINK IN THE VALUE CHAIN OF THE HYDROGEN ECONOMY IN POLAND

Taking into account the pros and cons of various storage methods, the development of technology in this area to date, and the geological potential of Poland, the following conclusions and recommendations can be made for this link in the value chain of the hydrogen economy in Poland (Tchorek et al., 2023a):

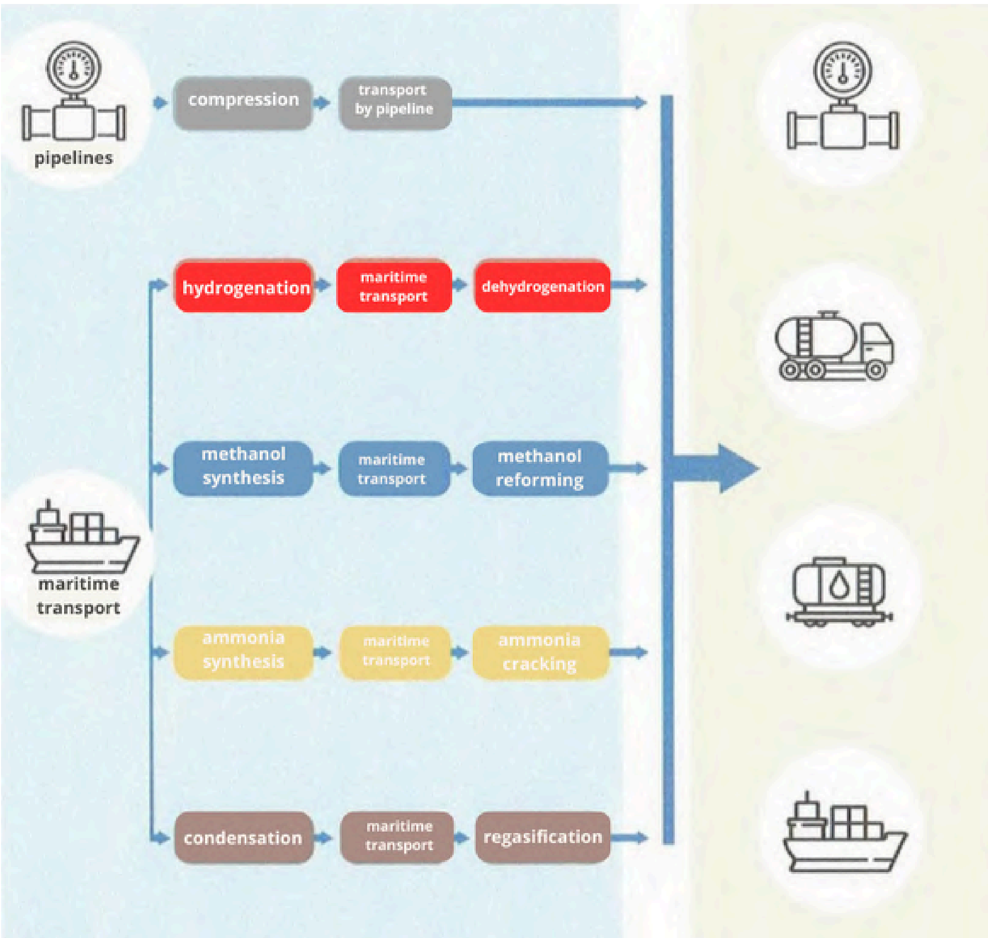
- Barriers to the development of the hydrogen economy in Poland in the coming years will become the need to ensure an adequate number and size of storage facilities for hydrogen, as well as to guarantee sufficient amounts of electricity from renewable energy sources for renewable and low-carbon hydrogen production;
- it is necessary for the state to stimulate the development of both large-scale hydrogen storage in geological structures and smaller aboveground storage facilities; each of these types of storage facilities must perform different roles, so both types are needed for the development of the hydrogen economy;
- important for the development of future transportation infrastructure based on hydrogen energy is the availability and deployment of storage facilities within the country; this is particularly important in the context of the location of high-voltage transmission networks and large-scale storage facilities in geological structures;
- strategic and regulatory policies introduced by the state should take into account, increasing legal obligations for the use of renewable hydrogen from 2030; this will enforce the possession of hydrogen reserves in Poland, while helping to ensure the country's independence and strategic-industrial security;
- it is necessary to take advantage of Poland's favorable geological conditions and its considerable potential for hydrogen storage in salt caverns on a European scale; this will enable greater independence in storing hydrogen in the country, but also provides an opportunity to provide hydrogen storage services for other customers (from EU countries).

HYDROGEN TRANSPORTATION

The next link in the value chain of the hydrogen economy in Poland should be considered in the context of the impact of technological, regulatory and market conditions. These determine not only the choice of a particular mode of hydrogen transportation, investments related to the development of transport infrastructure, but also the efficiency of the process due to the average cost of transporting 1 kg of hydrogen.

The main elements of the hydrogen transportation value chain and their use depending on the distance the hydrogen must travel (above or below 500 km) are shown in Figure 7.

FIGURE 7: TYPES OF HYDROGEN TRANSPORT



Source: Tchorek et al. (2023b), p. 18.

HYDROGEN TRANSPORTATION

Long-distance transportation of various forms of hydrogen - at distances up to and above 500 km - can be carried out either by pipeline, or by sea transport. In the case of the latter method, further processing of the various forms of hydrogen transported must be taken into account in order to continue its distribution over distances of less than 500 km (via pipelines, road transport, tankers, rail and sea transport, intermodal).

The listed hydrogen transportation technologies have different levels of technological readiness, as discussed in detail in the cited report. Its authors (Tchorek et al., 2023b) indicate that the TRL varies depending on the scale of the infrastructure. For large-scale transportation (> 1000 t H2 per day), none of the indicated methods reached TRL 9 across the entire chain. The most technologically advanced method in the case of maritime transport is currently the method of transporting hydrogen in the form of ammonia in the situation of increasing the scale of maritime units for its transportation. The lowest level of technological preparedness is in the case of maritime transportation of hydrogen in the form of LOHC and methanol. The competitiveness of methanol and ammonia as hydrogen carriers is limited by the need for reconversion to obtain hydrogen again, which requires the consumption of significant amounts of energy. However, removing the need for reconversion and using direct liquid forms of hydrogen improves the attractiveness of these transportation methods (Tchorek et al., 2023a).

For pipeline transport, the technology readiness level is relatively high, although it varies depending on the method. In the case of using a dedicated pipeline, the TRL is 8-9, but the existing technology would require an increase in the scale of hydrogen transportation and the use of higher capacity pipes. The same level of technology readiness is present in the case of pipeline retrofits, but if this method were to be used to transport hydrogen, three times more powerful compressors would be required. The ammonia injection technology has a TRL of 8 and requires a larger scale application for transporting hydrogen in large quantities. In contrast, the transportation of ammonia by pipeline alone is a mature technology (TRL is 8-9) and serves the needs of specialized industrial customers.

Compressed hydrogen pipelines (dedicated / retrofit of the gas network) can be used to transport hydrogen over distances of less than 500 km, but also intermodal transport of hydrogen in compressed and liquid form. Taking into account the technological peculiarities and the vulnerability of the infrastructure to various unpredictable events (natural disasters, assassinations, military actions), the transport of hydrogen in liquid form through pipelines is not currently a solution for larger-scale application. However, it can be noted that the greater the distance of hydrogen transport and the increasing needs associated with increasing the volume of hydrogen delivered, the greater the

HYDROGEN TRANSPORTATION

transport. Transport of compressed hydrogen allows for increased transportation flexibility due to the possibility of intermodal solutions through the use of containers. Taking into account the higher density of hydrogen in liquid transport, this method becomes more competitive as the distance and amount of hydrogen transported increases (Tchorek et al., 2023a).

When considering the use of different types of hydrogen transportation in Poland, the cost of transporting or shipping hydrogen should also be taken into account. Experts point out that the methods and costs of hydrogen transportation are related to the scale of the hydrogen market (the annual volume of production, the possible volume and directions of hydrogen imports and the density of sales markets). The larger the scale of this market, the lower the average hydrogen transportation costs. In order to make a detailed calculation of transportation costs for the Polish hydrogen market, it would be necessary to adopt specific data for a selected business case. This is due to the fact that the costs of hydrogen transportation at the early stage of market development vary strongly depending on the size of the investment and its infrastructure environment (Tchorek, 2022).

Researchers involved in the development of the hydrogen economy in Poland believe that at the beginning of the development of the hydrogen market with small volumes of hydrogen production, the cheapest way to transport it for short distances of less than 200-300 km will be to transport hydrogen gas in tanker trucks. With the emergence of a more mature and developed market, such modes of transportation as transportation in tank cars of medium volumes of liquefied hydrogen production over distances of 300-500 km, within several provinces, and pipeline transportation of large volumes of hydrogen over distances of more than 300 km, within several provinces or across borders, will become cost-effective (Tchorek, 2022).

Poland's use of the hydrogen shipping method is currently very expensive. The unit cost of transporting hydrogen by this method is about 6 times more expensive than transporting LNG. If the use of sea transportation is pursued, it will be necessary to increase the scale of operations to take advantage of economies of scale for cost optimization. This will be necessary in the situation of hydrogen imports, but to handle the hydrogen trade Poland needs to create the appropriate infrastructure - build a hydrogen terminal (similar to an LNG terminal). Experts also point out that there are technological possibilities for handling LNG and hydrogen supplies within a single gas port (Tchorek, 2022).

Co-funded by the European Union

HYDROGEN TRANSPORTATION

As part of the development of the hydrogen economy in Poland, in addition to the transportation of hydrogen, it is necessary to remember the need to create a proper infrastructure for supplying transportation means with hydrogen as an alternative fuel. This is regulated by the Regulation of the European Parliament and the Council of Europe on the Development of Alternative Fuel Infrastructure (AFIR) (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2023). AFIR replaces Directive 2014/94/EU of the European Parliament and of the Council of October 22, 2014 on the development of alternative fuel infrastructure. The new legislation will come into force on April 13, 2024. The regulation is part of the Fit for 55 package and sets out specific steps for the creation of charging infrastructure for alternative vehicles, including those powered by hydrogen. It indicates that there should be stations for charging BEV road vehicles with electricity and vessels in ports and aircraft in summer resorts, refueling FCEV road vehicles with hydrogen, and refueling road vehicles with liquefied methane. The TEN-T Trans-European Transport Network, which is considered a comprehensive network and includes major trans-European highways and 424 urban nodes, was taken as the starting point for this regulation. It has been assumed that by 2030 there will be at least 1 hydrogen refueling point at an urban node every 200 km on the main roads of the TEN-T core network. The minimum capacity (efficiency of the point) should be 1 t of hydrogen per day at a pressure of 700 bar. In addition to this, the hydrogen refueling infrastructure should allow ad hoc refueling, electronic payment and clearly inform about payment options. This means that a total of 49 hydrogen refueling stations must be built in Poland by 2030 - 30 stations in urban hubs and 19 stations along the roads of the TEN-T core network. This represents a major challenge for Poland's hydrogen economy.

Taking into account the level of development of available hydrogen transportation technologies, regulatory requirements and market conditions (the relationship of demand and supply in the hydrogen market, the average cost of transporting 1 kg of hydrogen depending on the method of transportation), the following conclusions and recommendations can be made for this link in the value chain of the hydrogen economy in Poland:

- Insufficient supply of hydrogen for domestic demand for this energy source and the inability to ensure self-sufficiency in this area during the transformation of the gas sector, with insufficient renewable energy sources will force the state to determine the size of the necessary hydrogen imports and possible directions,
- Adequate plans for the development of the port infrastructure network will be necessary in connection with the needs of future maritime transport of hydrogen and its derivatives; before that, it will be necessary to determine the national needs for current and projected use of hydrogen, which will directly affect not only the volume of supplies, but also the choice of mode of transportation for importing hydrogen due

HYDROGEN TRANSPORTATION

to the possibility of direct use of the derivative in certain sectors of the economy (e.g., refining, petrochemical, fertilizer);
- The creation of a dedicated support system for the import of green hydrogen and its derivatives is recommended, and the solution used by Germany (H2Global platform) and the Netherlands is cited as an example of good practice in this regard;
- The retrofitting of gas networks and their conversion to hydrogen, despite being the most attractive in terms of cost, may be limited due to the need to adapt infrastructure at customers enabling the use of hydrogen,
- A barrier to the transportation of hydrogen may become its distribution to the end user, which will be determined by the amount of distribution costs; these may be lowered by creating local centers to balance demand with generation capacity;
- The operation of hydrogen valleys should have a positive impact on lowering distribution costs and reducing the price of hydrogen at the hydrogen end-user; they will also contribute to reducing the carbon footprint of the hydrogen supplied.

THE USE OF HYDROGEN IN THE POLISH ECONOMY

Hydrogen is currently used in such sectors as the chemical, refining, petrochemical, steel and metallurgical industries, and the food industry. The chemical sector uses hydrogen in the production of fertilizers (primarily ammonia), methanol, oxidized water, followed by methanol, caprolactam (plastics production) or oxo alcohols (production of detergents, solvents, plasticizers and paints, plastic packaging). The operation of the chemical sector is based on the synthesis of ammonia, which requires a reaction between hydrogen and nitrogen. Ammonia production primarily uses gray hydrogen, which comes from steam reforming of natural gas. In Poland, the chemical industry could significantly reduce CO2 emissions by using less emissive types of hydrogen (blue, purple and green). Experts indicate that the use of RFNBO (green hydrogen) and low-emission fuels could significantly reduce the carbon footprint of the chemical sector in Poland (EY, 2023).

In the case of the refining industry, hydrogen is used, among other things, in processes to remove sulfur, nitrogen and other impurities from crude oil and natural gas. It is also a feedstock in the hydrocracking process, during which it is used to convert heavier fractions of crude oil into lighter products such as gasoline and diesel fuels. For this process, gray hydrogen from steam reforming of natural gas or waste hydrogen from technological processes is used. Hydrogen can also be used in the production of so-called synthetic fuels as new refinery products (Brodacki et al., 2021; Tchorek et al., 2023b). In Poland, the use of RFNBO fuels and low-carbon hydrogen in refinery processes would make it possible to reduce the sector's CO2 emissions and reduce the vulnerability of its players to rising emission allowance prices.

Co-funded by the European Union

THE USE OF HYDROGEN IN THE POLISH ECONOMY

The petrochemical industry uses hydrocarbons to produce organic chemicals and polymers (kerosene, gas, ethane, LPG, natural gas, among others). As indicated by Tchorek et al. (2023), green hydrogen can be used in petrochemicals as a feedstock in steam crackers or as an energy carrier in high-temperature processes (e.g., a cracker burner), reducing the carbon intensity of the process. They suggest that it will be possible to use renewable methanol (a form of hydrogen) during the production of organic chemicals. Besides, the petrochemical sector could also use low-carbon fuels derived from waste hydrogen using CCS technology. The Global Hydrogen Council indicates that the global use of renewable hydrogen in the petrochemical sector could lead to a reduction in CO2 emissions of at least 30% by 2050 (Global Hydrogen Council, 2017). Thus, CO reductions can also be expected in Poland2 after increasing the use of RFNBO fuels.

Nowadays, hydrogen is also used in metallurgy, especially in steel production. Wanting to decarbonize the metallurgical sector would require the use of RFNBO fuels. The process of iron ore enrichment by hydrogen reduction is a potential alternative to traditional methods, which can reduce CO2 emissions by 70-90% compared to conventional steelmaking processes (EC, 2018).

The food industry uses hydrogen for industrial food production processes and as a packaging gas. Among other things, it is used for the hydrogenation of vegetable fats, which makes it possible to create solid fats with certain properties, such as margarine and frying fats. The process makes it possible to obtain products with the desired consistency and a longer shelf life. In addition, hydrogen is often used as a protective gas in food packaging (protecting food products from oxidation and extending their shelf life). It is also used to extend the freshness of certain products, such as meat and seafood (inhibiting bacterial growth).

In the future, hydrogen can be used in Poland as an energy carrier and storage, which will make it possible to stabilize the electricity system and its balancing when the share of renewable energy in the energy mix increases. These tasks will be carried out primarily in a long-term (seasonal) model, and less frequently in a short-term (hourly/daily) model. A competing technology to the use of hydrogen for energy storage will be battery systems, especially for short-term needs.

Another area of hydrogen use in Poland in the future will be such gas unit-based sectors as power generation, heating and cooling. Regulatory requirements for decarbonization will force gas units to use low-carbon and renewable gas blends, or adapt them to work with CCS-based equipment.

THE USE OF HYDROGEN IN THE POLISH ECONOMY

An obvious area of application for hydrogen in the Polish economy is light and heavy wheeled transportation, as well as sea and air transport. Currently in Poland, the use of hydrogen propulsion is being tested in public transport buses in Poznan and Krakow. Hydrogen-powered technologies for small vehicles (passenger or small delivery vans) are already mastered and gradually commercialized in other countries, such as Germany (cabs in Hamburg). The development of hydrogen-based road transportation requires the construction of refueling infrastructure according to the recommendations of the AFIR regulation.

Commercialization of the use of RFNBO fuels for light vehicles could occur as early as 2025. Slightly later , between 2025 and 2030, it is suggested that green hydrogen fueling technology for heavy wheeled transport (trucks, buses, rail) will be introduced to the market. Hydrogen and derivatives are a good source of propulsion for long distances, the need for continuous operation and short refueling times, as well as maximizing the permissible weight of cargo carried.

In the case of the use of hydrogen in maritime and air transport, experts indicate that the commercialization of the application may not take place until 2030-2035. The decarbonization of these sectors of the economy in the medium to long term will be carried out using hydrogen derivatives, i.e. renewable ammonia, renewable methanol, synthetic fuels such as e-kerosene.

Analyzing the potential directions of hydrogen application in the Polish economy, Tchorek and his team (Tchorek et al., 2023) formulated the following conclusions and recommendations:

- it is necessary to include RFNBO fuels in detail in Poland's energy policy (PEP 2040, NERP) as factors for decarbonizing sectors that are difficult to electrify directly (e.g., chemical industry, refining, metallurgy, heavy transport, maritime, aviation).
- the most important factor in ensuring the profitable use of RFNBO fuels will be the optimization of the cost of obtaining electricity; this necessitates carrying out the liberalization of the energy market in Poland (direct line, dissemination of PPAs, reductions in regulatory and network fees for hydrogen valleys, energy storage),
- Supporting the increased use of green hydrogen will be EU policy - its regulations are gradually eliminating fossil fuels from the market while promoting their substitution with RFNBO fuels,
- The answer to increased hydrogen consumption must be a greater supply of low- and zero-emission hydrogen, and this requires the introduction of a regulated support system to cover the financial gap between the cost of the RFNBO fuel and the price of its direct reference carrier (e.g., natural gas or diesel); experts suggest that in the first

THE USE OF HYDROGEN IN THE POLISH ECONOMY

phases of market development (when there is no wholesale market), the support system should ensure the pooling of hydrogen producers and consumers, which will reduce the risk of system imbalance;

- The use of RFNBO fuels in the Polish economy will enable the decarbonization of the Polish economy and reduce Poland's exposure to the EU ETS, including the rising price of CO emission allowances2 .

HYDROGEN SECTOR IN THE NETHERLANDS

As a signatory to the Paris Climate Agreement, the Netherlands has enshrined in law its commitment to a decarbonised future and has agreed ambitious targets in its national climate agreement (see box). For one of the most densely populated and industrialised countries in the world, meeting these targets will pose major challenges. Billions of euros will be allocated in the coming decade to accelerate the energy transition. The Dutch are planning huge investments in renewable energy, especially offshore. Other key policies aim to take advantage of all this carbon neutrality, by electrifying cars at large, home heating and industrial processes.

However, even with these ambitious policies, challenges remain. For example, the country's large industrial sector requires huge amounts of high-temperature process heat, as well as alternatives to fossil fuels. As we become increasingly reliant on intermittent energy sources such as wind and solar power, we urgently need solutions to store large amounts of energy, both on a short-term and seasonal basis. Another challenge is the decarbonisation of the shipping and road transport sectors.

Hydrogen is widely seen as a key technology to overcome the fundamental obstacles to full decarbonisation. Many see it as the missing link required for a successful energy transition. It can be an alternative to natural gas in industrial processes, as a feedstock for chemicals and as a carbon-neutral fuel in virtually all modes of transport, especially those for which electrification is not yet an option. Through electrolysis, hydrogen can be used to store and distribute large amounts of renewable energy, paving the way for further large-scale investments in wind and solar power, creating new opportunities for grid balancing, seasonal storage and even global export of renewable energy.

The Dutch approach to building a hydrogen future has several distinctive features. Firstly, it is clearly driven by the climate policy and commitments described above. Secondly, its scope encompasses the entire value chain.

HYDROGEN SECTOR IN THE NETHERLANDS

Rather than seeing hydrogen production and different applications as separate issues, the Dutch have adopted an integrated approach to developing a 'hydrogen economy'. Dozens of pilot projects with companies and research institutes are building a complete hydrogen economy and hydrogen ecosystem, focusing not only on the technology, but also on demand creation, business models and addressing regulatory and safety issues. This is often done in public-private partnerships and in a very pragmatic way.

The Dutch have an open approach to innovation, which encourages experimentation.

More than 50 years ago, the Dutch discovered natural gas deposits and developed one of the most extensive and advanced gas networks in the world. At gas storage facilities in the northern province of Groningen, hundreds of millions of cubic metres of gas can be stored in underground salt caverns. The same infrastructure - along with thousands of kilometres of gas pipelines across the country - is being mobilised to enable a second gas revolution, replacing fossil fuels with neutral hydrogen.

The easiest way to transport hydrogen is through pipelines. Few countries are as well prepared to build a nationwide hydrogen network as the Netherlands. This is because the foundations are already in place. The country already has a dedicated hydrogen pipeline network of more than 1,000 km, connecting it to industrial sites in Belgium and France.

But perhaps even more significant is that it has one of the densest and most advanced natural gas networks. This network includes 136 000 km of pipelines and more than 7 million connections, reaching almost every Dutch home and business. This infrastructure can already be used to transport hydrogen. Not just by mixing hydrogen with natural gas but by replacing one with the other. Various projects have shown that, with minor changes, existing infrastructure can be used to transport hydrogen. In the province of Zeeland, a 12-kilometre industrial gas pipeline transports around 400 000 tonnes of hydrogen per year, and almost a dozen pilot projects in residential areas to replace natural

HYDROGEN SECTOR IN THE NETHERLANDS

gas with hydrogen, using existing infrastructure. This trend will accelerate in the coming years. One of the key policies of the Dutch climate agenda is that more than 2 million homes must stay on natural gas by 2030. And as the demand for natural gas decreases, a large part of the network capacity becomes available for hydrogen transport, especially as the network includes many 'parallel pipelines. It is estimated that by 2026. The Dutch could develop a national 'hydrogen backbone network connecting the country's five main industrial clusters.

In addition to hydrogen transport, the existing natural gas infrastructure also offers storage capacity to help offset seasonal fluctuations in the availability of renewable energy or to balance the energy grid. In the north of the country, for example, the Dutch are storing natural gas in huge salt caverns with a capacity of hundreds of millions of cubic metres. Pilot projects are underway to demonstrate that hydrogen can also be stored safely here. In addition, Dutch scientists and industry experts are already investigating the technical and economic feasibility of storing hydrogen in empty gas fields, both onshore and in the North Sea. The potential storage and transport capacity is enormous and could easily accommodate the approximately 11 GW of offshore wind energy planned for the Dutch North Sea in the next 10 years.

Building a hydrogen economy requires other and more flexible means of transport beyond pipelines, and in this respect the Dutch are working on a number of innovative solutions. For example, researchers at TNO and industrial partners are developing special hydrogen storage tanks. This includes the development of new materials that make it possible to store hydrogen under very high pressure or at extremely low temperatures, paving the way for safe and cost-effective transport by road, rail or sea.

Other Dutch projects focus on binding hydrogen with other materials such as nitrogen, carbon dioxide or toluene to create a carrier liquid that is much easier to transport, sometimes even in existing tankers.

The country's 136 000 km of pipelines offer unique opportunities for the hydrogen industry.

While such innovations open up new opportunities for hydrogen distribution at the last few stages of the value chain, they can also be applied to large-scale transport over very long distances. There is an urgent need for such solutions, as the potential of the global hydrogen market is enormous.

HYDROGEN SECTOR IN THE NETHERLANDS

Studies indicate that in areas with abundant sunshine and/or favourable wind conditions, the cost of renewable electricity could fall to less than $1 per kWh within 10 years. This will increase the viability of large-scale electrolysis producing carbon-neutral hydrogen for other markets. Europe is expected to become a net importer of clean hydrogen in the next few decades.

Anticipating this, the Dutch are positioning their country as a major hydrogen centre. Again, they benefit from an excellent starting position. Some of the busiest transport corridors in Europe converge in the Netherlands thanks to excellent road, rail and inland waterway infrastructure, road, rail and inland waterway infrastructure, and pipeline connections to most of Europe. The Port of Rotterdam is the largest port for oil and (liquefied) natural gas in Europe and is working with industrial partners to build a similar position for hydrogen.

Several international companies are already building electrolysers in Rotterdam and work has started on dedicated hydrogen pipeline infrastructure. Other companies are focusing on the technology needed for large hydrogen tankers and storage infrastructure not only in the Netherlands, but also in countries that want to realise their potential as a hydrogen exporter.

In 2020, the north of the Netherlands was recognised as Europe's first hydrogen valley by the Clean Hydrogen Partnership and the EU.

Co-funded by the European Union

HYDROGEN SECTOR IN THE NETHERLANDS

In their geographical scope, Hydrogen Valleys encompass many elements of the green hydrogen value chain, from hydrogen production to hydrogen storage and transport and distribution to industrial, mobility and built environment customers via various modes of transport.

Within Europe's first Hydrogen Valley, the following key aspects have been developed in recent years and expansion continues with new announcements. The Valley acts as a business magnet, attracting business and investment and triggering innovation and the creation of educational programmes that match the ambitions of North Holland, while setting an example for other member states in Europe.

Hydrogen in industry

- 32 MW Chloro Alkali Nobian (as a starting point HEAVENN for high green hydrogen uptake)
- CHP upgraded to hydrogen for industrial heat and power.

Education and research

- Waterstof Werkt 1
- HyDelta 1 and follow-up HyDelta 2
- Preparation of a Hydrogen Valley campus in Europe

Hydrogen in mobility

- Dozens of hydrogen passenger cars currently on the market pathway.
- 32 hydrogen buses.
- Many street sweepers, refuse trucks and delivery vehicles vans.
- Five existing hydrogen refuelling stations and five in development.
- Several (small) hydrogen boats.
- First inland waterway transport hydrogen-powered vessel under construction.
- Successful piloting of a hydrogen-powered train.
- Trailer hydrogen refuelling station with HRS for ship refuelling permitted, directly connected to the electrolyser at Delfzijl.
- Development of zero-emission ground-mounted power units at Hydrogen Valley Airport.

Transport

- Chemical Park Delfzijl hydrogen pipeline
- Emmen hydrogen pipeline
- Green hydrogen distribution trailers to HRS I industrial customers
- It was recently announced that the start of development of the hydrogen backbone by Gasunie, supported by the Dutch state
- Several smaller dedicated pipelines (polymer-based) have been announced to connect production and customers.

HYDROGEN SECTOR IN THE NETHERLANDS

Storage

- Successful pilot of HyStock warehouse for injection moulding hydrogen in salt caverns. The next step is the full-scale development of salt cavern storage, which is expected to be operational in 2023.

Hydrogen in the built environment

- Small hydrogen home
- Substantial support from the national government for start-ups Development of 100 new hydrogen homes in Hoogeveen.

Production

- Five electrolysers with a total capacity of 35.7 MW installed power
- Electrolyser capacity 220 MW in FID phase.
- Several electrolysers have received permits
- New announcements have recently been made with a capacity of around 200 MW+, which is already the height of ambition for large-scale offshore projects

HEAVEN Valley success factors

- **First key success factor:** A convincing project concept with consideration of the value chain and selection of technologies that use local resources and meet local needs. HEAVENN is praised for its convincing project concept because it was the most complete valley including every part of the value chain, using local resources and meeting local needs (the region needs the business) - local conditions and more specifically benefits and perspectives have been carefully analysed and are constantly reviewed.
- **Second key success factor:** A viable commercial structure that enables developers to have first real business cases (including any public funding). Mobility helps to accelerate mobility vs. industry), and mobility has a high visibility factor in public society. It is therefore safe to conclude that everyone is familiar with buses and cars. Their constant traffic increases visibility, recognition and acceptance.
- **Third key success factor:** Public-private financing from multiple sources, which includes enough public funding to fill all the gaps. HEAVENN secured funding in the initial phase through a combination of public and private resources. The public contribution included support from the region and the state. In practice, this proved more difficult than anticipated, as regional funding is already available. National funding is in the pipeline. An important element of delay is the excessive complexity of state aid rules. Outdated regulations need to be set aside to revitalise the hydrogen economy.

HYDROGEN SECTOR IN THE NETHERLANDS

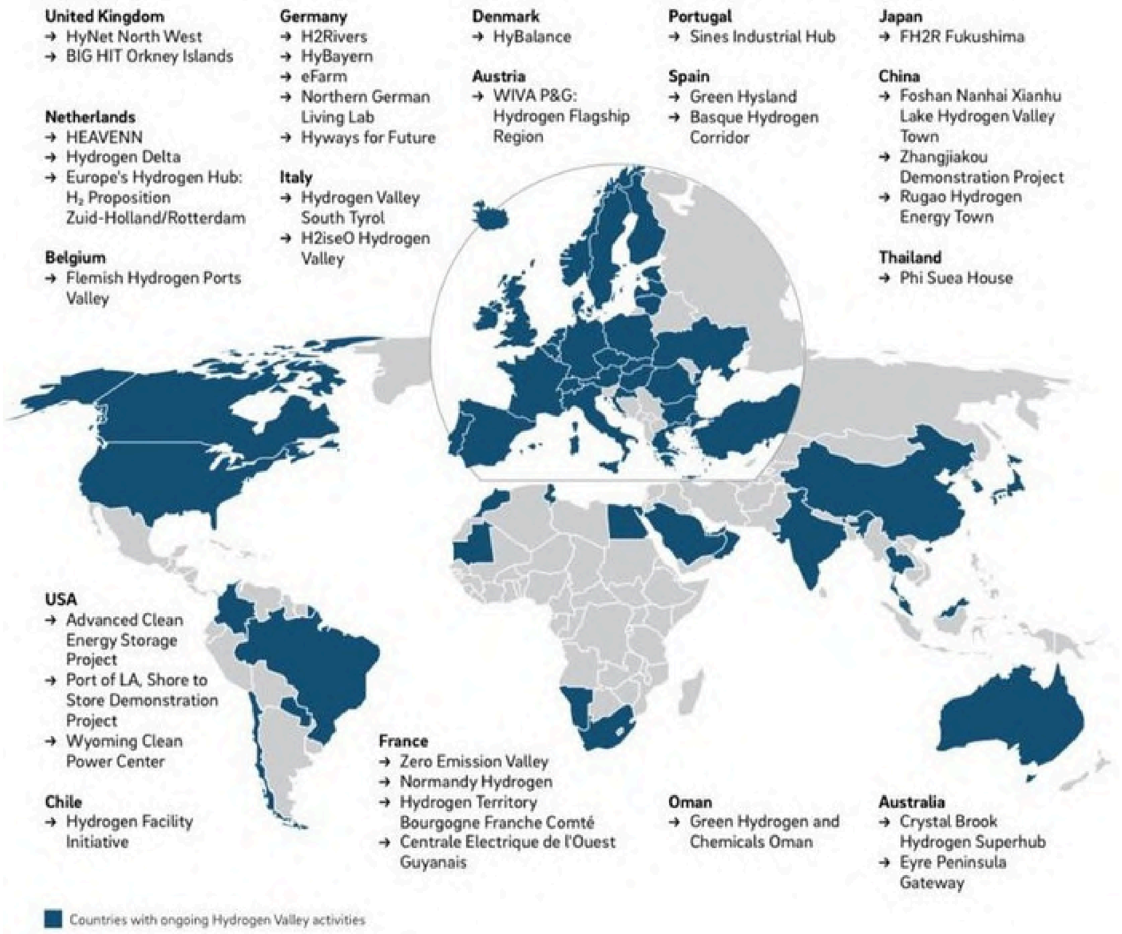
- **Fourth key success factor:** Partner and stakeholder collaboration that spans the entire scope of the project and ensures the ongoing involvement of all parties involved. For a consortium of 30 parties from seven EU countries, stakeholder management and partnership is of paramount importance. HEAVENN has implemented a dedicated governance mechanism and created a project organisation for day-to-day coordination with dedicated project manager(s) and clear rules and allocation of responsibilities within the consortium. It should be noted that the consortium is compact and has a common goal.
- **Fifth key success factor:** Political support and public advocacy for the smooth and continuous development of the project. Perhaps the most influential success factor is political support, advocacy and public support. In the Netherlands, the project is recognised in the National Hydrogen Strategy, and in Europe, the development of the Hydrogen Valley is actively supported by the current European Commissioner Ursula von der Leyen, who refers to HEAVENN and the North of the Netherlands as a leading region. At the regional level, HEAVENN receives a lot of support, while at the national policy level intensification is desirable. Discussions with regulators are conducted on a case-by-case basis; environmental agencies are now showing increasing interest. Local communities are also involved on a case-by-case basis, making it necessary to raise awareness of the overall advantages of hydrogen as a future solution.

The HEAVENN Hydrogen Valley faced the following challenges to becoming a Hydrogen Valley:

- **Renewable energy availability.** Most people support the energy transition and hydrogen, but a large number of solar and wind farms are needed to produce enough renewable energy, but these are not always accepted by the public.
- **Permits.** The initial phase of the Hydrogen Valley is mainly using existing legislation and regulations. However, the limitations of current legislation and regulations and the establishment of additional regulations will take time.
- **Old and new infrastructure.** In a region with an existing business infrastructure, adapting to the required infrastructure (e.g. new processes, procedures, exchange of materials, etc.) can be challenging.
- **Future perspective.** The first period of creating a Hydrogen Valley is not profitable; large investments are needed. It is only profitable when hydrogen is produced on a large scale, which takes time. The challenge is to convince different kinds of stakeholders, because it will take time to get a return on investment.
- **Connections with other Hydrogen Valleys.** Connections with other Hydrogen Valleys bring more business benefits and flexibility in terms of storage and use. Ideally, the Hydrogen Valleys should grow with them. Realistically, however, different regions have different procedures, especially at the beginning when there are several Hydrogen Valleys.

Co-funded by the European Union

HYDROGEN SECTOR IN THE NETHERLANDS



Source: Clean Hydrogen JU, Roland Berger

However, these challenges do not outweigh the fact that Hydrogen Valleys are needed worldwide for decarbonisation, as it is the only alternative to fossil fuels.

The Netherlands traditionally has a strong international orientation and the Dutch economy is largely driven by trade with foreign countries. Furthermore, energy and knowledge are important pillars of the Dutch economy. Dutch companies and institutions have a lot of experience and knowledge about gases, including hydrogen. They are ready to share this knowledge and expertise to unlock the potential of the regions with which they trade.

The hydrogen economy is only at the beginning of what is becoming a major transformation that will continue for many decades. Based on decades of experience with natural gas, the Netherlands has gained a great deal of knowledge in handling particles. This means that the Netherlands was and is in a position to start a hydrogen economy quickly and effectively. From this position, the Netherlands can also share

HYDROGEN SECTOR IN THE NETHERLANDS

nowledge with other regions and countries and help them in their energy transition, as many countries and regions will produce hydrogen and use and/or export it. For the Netherlands, this is a great opportunity to use the knowledge and experience of Dutch companies involved in the hydrogen value chain.

In order to position the Netherlands as a hydrogen expert country, accelerate international trade relations and position Dutch companies as the 'first choice' for exporting countries, it is important to establish so-called 'hydrogen centres' in selected locations. The hydrogen centres function as support points for trade and at the same time provide visibility for the Netherlands in the producing country. Hydrogen centres can also initiate and develop new projects and facilitate business opportunities for the producing region and the Netherlands. The Ministry of Trade and Development and the Ministry of Climate and Energy refer to this suggestion in the National Climate Strategy.

Once hydrogen centres have been established, as suggested above, it is recommended that dedicated offices and functions be established in hydrogen-leading countries. For example, by installing a hydrogen attaché in those hydrogen hubs that work closely with attachés from other areas where hydrogen production will be used (e.g. mining, agriculture, fisheries, etc.). However, a hydrogen hub can also assist in the creation and use of financial instruments to help companies and knowledge institutions position themselves in these strategic countries and regions in the high-risk phase - prior to the conclusion of a commercial agreement.

The Netherlands pretends to play a very important role in the international hydrogen economy, which benefits Dutch companies and/or organisations, contributing to international stability and prosperity.

HYDROGEN SECTOR IN SPAIN

In the race towards a greener and more sustainable future, hydrogen has become a game-changer in the energy landscape. Just three years ago, the concept of hydrogen was met with scepticism, but today it has become the focus of ambitious projects across Spain, each aiming to create its own 'hydrogen valley'.

These public-private business ecosystems aim to promote the production and consumption of hydrogen, and Spain has envisaged 11 such valleys spread across the country, from Puertollano and Huelva to Soria, A Coruña and even Majorca. According to the Spanish Hydrogen Association (AEH2), the collective investment in these initiatives will reach a staggering €21.9 billion by 2030.

The primary objective of these hydrogen valleys is to support the decarbonisation of various sectors, including industry, residential energy and mobility, with a particular focus on air and maritime transport. The potential impact is huge, with the International Renewable Energy Agency calculating that hydrogen production will account for up to 12% of the energy mix by 2050.AEH2 estimates that the development of green hydrogen projects will lead to the creation of around 227,000 new jobs in Spain by 2030. Key players such as Repsol, Cepsa and Enagás are at the forefront of creating business and university ecosystems with the common goal of producing between 1 and 1.7 million tonnes of hydrogen per year. This production will not only meet national demand, but also contribute 10% of the total target hydrogen consumption in Europe.

The European Union recommends the creation of hydrogen valleys because of their many advantages. By bringing together public institutions, research entities and private companies, these valleys enable increased hydrogen production and distribution over larger geographical areas. This configuration facilitates the efficient development of hydrogen sectors while optimising production, transformation and logistics costs.

HYDROGEN SECTOR IN SPAIN

One of the key aspects of these valleys is their involvement in large-scale projects that can significantly boost the local economy. For example, the Andalusian Green Hydrogen Valley alone is expected to create 10,000 jobs and raise the level of economic activity of more than 400 small and medium-sized enterprises (SMEs) in the region. This energy ecosystem provides access to affordable, safe and sustainable energy, driving industrial activity in the area while remaining close to production centres.

From north to south, Spain is witnessing the emergence of significant hydrogen valleys. Puertollano, located in Ciudad Real, occupies a key position and houses the headquarters of the National Hydrogen Centre. As part of the H2Med project, this city will be connected to Germany by a green hydrogen pipeline stretching from Huelva to Barcelona. Iberdrola operates Europe's largest green hydrogen plant for industrial use in Puertollano, capable of producing 3,000 tonnes of hydrogen per year for Fertiberia. Several other infrastructure projects by Repsol and RIC Energy are also underway at this location, with a potential capacity of 30 MW, to be increased to 100 MW in the future. The Castilla-La Mancha hydrogen cluster continues to drive hydrogen initiatives in Puertollano through the collaboration of 41 companies and partnerships with universities and technology centres in Spain and the Netherlands.

In the south of Spain, the Andalusian Green Hydrogen Valley stands out, headed by Cepsa with a substantial budget of €3 billion. This ambitious project comprises two poles: one in Palos de la Frontera (Huelva) in the vicinity of Fertiberia and another in San Roque (Campo de Gibraltar, Cadiz) in collaboration with EDP. The combined capacity of these plants is expected to reach 2 gigawatts (GW), allowing the production of 300,000 tonnes of green hydrogen per year to fuel sustainable biofuels for aviation and land and sea freight transport.

HYDROGEN SECTOR IN SPAIN

In Catalonia, the H2ValleyCat project, led by Repsol, Enagás and Universitat Rovira i Virgili, takes centre stage. This ambitious ecosystem includes more than 260 public and private entities, including the Port of Barcelona, Cepsa, FCC and Vueling. It is well connected to the Aragon Hydrogen Valley, the Green Hydrogen Agenda of Navarra and the Basque Hydrogen Corridor through the Ebro Hydrogen Corridor. The latter initiative is led by Repsol's SHYNE consortium, with the participation of 22 other companies and 11 associations.

The hydrogen revolution is not limited to Spain; the whole of the European Union is actively promoting hydrogen production to achieve energy independence. Spain is a key player in this endeavour, standing shoulder to shoulder with countries such as the Netherlands and Germany. In particular, the Dutch NorthH2 project aims to generate 4 GW of green hydrogen by 2030 using offshore wind power, while the German AquaVentus consortium envisages building 10 GW by 2035. 62 hydrogen initiatives have been selected in Spain with a total investment of €33 billion , potentially receiving €8 billion in public funding.

The European Union's vision is to produce 10 million tonnes of green hydrogen by 2030 and import an additional 10 million tonnes from countries outside the EU. This clean energy movement is attracting significant investment, with a McKinsey report estimating that investment in hydrogen projects across Europe amounts to a staggering €117 billion, representing 35% of global hydrogen investment.

As Spain occupies a central position in the green hydrogen revolution, the Hydrogen Action Plan envisages a hydrogen production capacity of 11 GW by 2030 with an investment of €8.9 billion from companies and the public sector. This surge in hydrogen production is expected to provide between 1 and 1.7 million tonnes of hydrogen per year in Spain and an additional 750,000 tonnes in Portugal, meeting domestic demand while exporting surplus hydrogen to Europe, particularly to high-consumption markets such as Germany. The future of hydrogen valleys in Spain carries the promise of cleaner energy, robust job creation and a sustainable path to decarbonise different sectors and contribute to a greener Europe.

In October 2023, the Spanish government approved the Hydrogen Action Plan, emphasising that green hydrogen is a key element in achieving climate neutrality and a 100% renewable electricity system.

Co-funded by the European Union

HYDROGEN SECTOR IN SPAIN

With an investment of €8,900 million, targets have been set for 2030, which include generating 4 GW of installed electrolysis capacity and ensuring that 25% of the hydrogen consumed in the industry comes from renewable sources.

The Spanish Government's Ministry of Ecological Transformation and Demographic Challenge has given the green light to the 'Hydrogen Action Plan: a commitment to renewable hydrogen', highlighting that green hydrogen is a key element in achieving climate neutrality and a 100% renewable energy system by 2050.

Spain has thus joined other countries such as Japan , China and France , which have decided that the road to decarbonisation requires placing green hydrogen as the central axis of their future energy strategy.

Through the use of green hydrogen, the Spanish authorities want to promote the development of innovative industrial value chains, create jobs and economic activity and contribute to the revival towards a high-value-added green economy.

In the nomenclature adopted in Spain, green hydrogen is an energy vector.Hydrogen is not a primary energy source (like the sun or wind), but an energy vector. This means that the manufactured product is able to store energy that can be released later. When renewable energies are used in the production process, the hydrogen obtained is considered 'green hydrogen' or 'renewable hydrogen'.

The preparation of the Hydrogen Action Plan involved citizens and stakeholders in the hydrogen value chain.

Renewable hydrogen is positioned as one of the main energy vectors , as its production and consumption is climate-neutral and generates no emissions.

It also has a variety of applications, including land, sea, air and rail mobility, industry and power generation. It is one of the important players in the energy transition as it enables the decarbonisation of all sectors and allows for seasonal energy storage.

Co-funded by the European Union

HYDROGEN SECTOR IN SPAIN

SPAIN'S HYDROGEN TARGETS

The roadmap sets national targets for the promotion of renewable hydrogen by 2030 and, based on these, develops a vision for 2050, the year in which Spain should achieve climate neutrality and have a 100% renewable energy system.

In line with the objectives set by the European Commission in its Hydrogen Strategy, Spain has set the following development goals:

- Generate 4 GW of installed electrolysis capacity - a facility to produce renewable hydrogen using clean energy and water - representing 10% of the EU-wide target set by the European Commission.
- By 2030. 25% of the hydrogen used in industry will come from renewable sources.
- In terms of mobility, by 2030, a fleet of at least 150 buses; 5,000 light and heavy vehicles; two commercial railway lines powered by renewable hydrogen have been proposed. Similarly, a network of at least 100 hydrogen generators and hydrogen-powered handling machines should be installed in the first five ports and airports.
- In addition, the document proposes 60 actions, grouped into four areas of action: regulatory; sectoral; cross-cutting (to raise awareness of the potential of renewable hydrogen throughout society) and promoting related research, development and innovation.

The action plan identifies the opportunities for Spain to promote domestic production and the use of renewable hydrogen and is considered in the category of development opportunities for Spain.

Spain joins other countries that believe that the road to decarbonisation requires placing green hydrogen as the central axis of their energy strategy for the future.

The document highlights how the development of renewable hydrogen in Spain will bring environmental, business, economic and social benefits , such as:

- Eliminate emissions of pollutants and greenhouse gases to the environment in sectors or processes that are difficult to decarbonise in order to achieve the goals of a climate-neutral economy by 2050.
- Developing hydrogen economy value chains and positioning Spain as a reference in the technology.
- Enabling the penetration of a higher percentage of renewables in the electricity system, promoting greater manageability.
- Reducing national and European energy dependence.

HYDROGEN SECTOR IN SPAIN

SPAIN'S HYDROGEN TARGETS

- Making Spain one of the European powers of renewable energy generation, due to its favourable climatic conditions and large free areas for the installation of renewable energy plants, both solar and wind.
- Encourage decarbonisation of isolated energy systems, especially in island territories.
- Promoting Spanish energy research, development and innovation as a pillar of sustainable economic growth.

KEY PROJECTS

To draw up the Hydrogen Action Plan, the Ministry of Ecological Transformation and Demographic Challenge held a public consultation to gather feedback from citizens and institutions potentially involved in the hydrogen value chain, which included Enagás. The green hydrogen company, as it is 100% renewable, is heavily involved in specific projects. It also has an infrastructure technically prepared to transport and store hydrogen and other renewable gases such as biogas/biomethane.

In fact, it is one of eleven European gas infrastructure companies that are implementing the European Hydrogen Backbone plan to develop a specific hydrogen transmission infrastructure.

Actions taken by Spain to achieve its objectives:

- Among other things, the Hydrogen Roadmap sets ambitious national targets for 2030 and 2050. Spain expects to achieve climate neutrality and have a 100% renewable energy system.
- published at the end of June 2023, the draft of the first update of the 2021-2030 Integrated National Energy and Climate Plan (PNIEC) overstates the targets for increasing large-scale hydrogen production and use. This sets the installed capacity of electrolysers at 11 gigawatts (GW) for renewable hydrogen production in Spain by 2030, compared to the 4 GW planned in the draft approved three years ago.
- The REPowerEU programme envisages the development of five hydrogen corridors connecting producer countries to demand centres. In this context, Spain is not only a potential major producer, but also has export potential to other EU countries.
- One of the projects that has attracted Spain's attention is Europe's first renewable hydrogen corridor. The project, called H2Med, is a key infrastructure that will enable the transmission of up to 2 million tonnes of renewable hydrogen per year. This is10% of the expected consumption across Europe.

Co-funded by the European Union

HYDROGEN SECTOR IN SPAIN

KEY PROJECTS

- H2Med will transport up to 2 million tonnes of renewable hydrogen per year.
- The corridor, promoted by Enagás in Spain and French transmission system operators GRTgaz and Teréga, as well as Portugal's REN, includes connection points to Portugal and France. Germany is also involved, so hydrogen can travel to the centre of Europe from the south of the continent.
- Together with H2Med, Enagás also presented the first two axes of Spain's hydrogen backbone network to projects of common interest to the European Union. One includes the Cantabrian Coast Axis, the Ebro Valley Axis and the Levante Axis, the other is the Vía de la Plata axis connected to the Puertollano Hydrogen Valley. A proposal was also made to explore possible underground storage facilities in the Basque Country and Cantabria. All received a first positive technical qualification issued by the European Commission to be eligible for EU funding.

One of the largest hydrogen investments in Spain and the most j ambitious project is the Andalusian Green Hydrogen Valley project. The project, which involves investments of more than €3 billion , will involve the construction of two green hydrogen plants in energy parks in Palos de la Frontera (Huelva) and San Roque (Campo de Gibraltar, Cadiz). The plants will have a total electrolysis capacity of 2 GW and will produce up to 300,000 tonnes of green hydrogen per year. Their construction will also increase the production of 2G biofuels and related products such as green ammonia and methanol, helping customers in the manufacturing and heavy road transport sectors in their decarbonisation efforts.

The construction of a hydrogen ring in Huelva (Spain) was announced in 2023. The pioneering engineering achievement resulting from the construction of this piece of infrastructure is to connect hydrogen producers with consumers, provide a more sustainable, efficient, secure and competitive supply and exploit synergies across all adjacent industries.

The development of the Andalusian Green Hydrogen Valley will create 10,000 jobs , including 1,000 direct jobs, and stimulate the economic activity of more than 400 SMEs in the area. It will also stimulate industrial activity in the region by facilitating access to affordable, accessible, safe and sustainable energy near production centres. Andalusia already consumes 40% of the hydrogen currently used in Spain.

Co-funded by the European Union

HYDROGEN SECTOR IN SPAIN

KEY PROJECTS

Important industrial clusters already exist in the Andalusia region, so it is an important objective to promote partnerships and cooperation in order to make the region more competitive. In this sense, the Andalusian Green Hydrogen Valley will be a centre of attraction for other links in the hydrogen value chain , such as electrolyser factories, green fertiliser plants or hydrogen transport technologies.

In addition, the project will make a significant contribution to improving skills and qualifications in the hydrogen industry. The leaders of this project will invest in the training of new professional profiles through training centres in energy parks, as well as other partnerships with universities in the region.

Andalusia is best placed to be one of the most competitive and efficient regions in the world in the production of green hydrogen. It is one of the places in Europe with the most competitive wind and photovoltaic generation capacity: more than 80% of the cost of producing green hydrogen comes from the cost of renewable electricity.

Andalusia consumes 40% of the hydrogen currently used in Spain, so Palos de la Frontera and San Roque, where there is already a significant industrial fabric, are the best locations for large-scale projects. Only such projects, providing access to a wide range of renewables and high end-user demand, can be competitive.

The location of the plant will contribute to a greater integration of renewable energy projects in the Autonomous Community and improve their use by harnessing surplus renewable energy generation during off-peak hours, accelerating the region's and Spain's decarbonisation targets.

Co-funded by the European Union

THE HYDROGEN SECTOR IN IRELAND
SUMMARY OF THE INDUSTRY, PROFESSIONS AND COMPETENCES

SUMMARY OF THE HYDROGEN SECTOR AND MARKET IN IRELAND

Ireland's decarbonisation strategy focuses first on energy efficiency and then electrification; for sectors that are difficult to decarbonise, it then targets low-carbon and renewable fuels, such hydrogen. Compared to several other countries, Ireland has a different starting point for its hydrogen demand. Compared to a few other European countries that already consume large amounts of hydrogen sourced from fossil fuels with high emissions intensity, Ireland currently has a very low end-use of hydrogen.

With a sea area roughly seven times larger than its landmass, Ireland boasts one of the most productive coasts in Europe and some of the world's best offshore renewable energy resources. Ireland has a great chance to become less dependent on imported fossil fuels and possibly even achieve energy independence by using this renewable energy to produce renewable hydrogen.

Hydrogen's high energy density as a gaseous fuel makes it an excellent choice for large-scale seasonal storage applications. These applications can help control the seasonality of demand patterns throughout the year and the variability of renewable energy sources like solar or wind. Today, renewable energy sources are backed up by fossil fuels, but in the future, renewable hydrogen may provide a zero-carbon substitute. In order to support Ireland's energy security going forward, the National Energy Security Framework acknowledged this and called for the creation of a National Hydrogen Strategy.

Ireland will have to develop and expand its existing hydrogen demand uses, which are not very prevalent at the moment. In Ireland specifically, hydrogen is expected to be a major factor in the decarbonisation of industrial processes as well as a fuel for transportation in industries like heavy haulage, shipping, and aviation in the years to come. The development of pure hydrogen applications in these

SUMMARY OF THE HYDROGEN SECTOR AND MARKET IN IRELAND

challenging to decarbonise sectors will take precedence. Resources and policy support won't be directed towards industries where decarbonisation alternatives are more practical and effective.

Although Ireland has the resources to produce substantial quantities of hydrogen from renewable sources, it will take time to install the necessary onshore and offshore renewable energy sources on a large enough scale. Prior to 2030, hydrogen will be produced from grid connected electrolysis from surplus renewables and will focus on small scale decentralised applications such as freight, with small scale production driven by early innovators, research, and demonstration projects.

In addition, a 2 GW target for offshore wind energy to be developed by 2030 for the production of renewable hydrogen will help to reassure investors and generate the volumes required to grow the industry. Ireland possesses large offshore wind resources, and in the long run, it may be able to become a net exporter of renewable hydrogen and establish a decarbonised industrial opportunity close to this resource. Currently, Ireland has 77 offshore wind farm projects of which 1 currently operating, and over 300 land-based wind farms. There is a possibility of the wind and hydrogen sector working together to produce green hydrogen as the sector progresses.

The cost of renewable electricity and the capital costs of electrolysers are the two main factors influencing the costs of producing hydrogen using renewable energy. Because of increased technological advancements, both costs have decreased significantly in recent years and are expected to continue to do so. Ireland has some of the world's most energy-productive renewable energy resources, and the competitiveness of Irish-produced renewable hydrogen will increase significantly as a result of these declining costs.

addition to electricity, a significant amount of water is needed for electrolysis. Ireland should not have any major problems getting the amounts of water needed to make renewable hydrogen. For instance, it is predicted that providing 2 GW will require less than 1% of Ireland's present water supply, leaks included in it. Furthermore, water can be obtained from nearby supplies like streams, aquifers, and rainfall. Desalinating seawater is another option, and this is especially significant when producing hydrogen from renewable offshore sources.

Currently, the hydrogen sector is still at an early stage with many standards still under development, with no hydrogen safety strategy or framework. There is a fear that red tape could halt the progress of the hydrogen sector in Ireland, however many

SUMMARY OF THE HYDROGEN SECTOR AND MARKET IN IRELAND

recommend starting with a voluntary safety framework before progressing onto testing and refinements using feedback, to then create a legally binding regulatory framework.

CURRENT HYDROGEN STRATEGY BASED ON EU REGULATIONS AND IRELAND'S POLICY

Although renewable hydrogen has the potential to present Ireland with many opportunities, it is still an emerging technology with many unknowns regarding future costs, possible applications, and the supply chains, infrastructure, and skills required to make it happen. By offering a long-term strategic vision of the role hydrogen will play in our future economy, the National Hydrogen Strategy seeks to mitigate some of this uncertainty. This will ultimately help to drive investment from the private sector with lowering commercial risk. In the short term, this strategy lays out a number of initiatives that will be implemented over the next few years in order to support the growth of Ireland's hydrogen industry.

These initiatives seek to eliminate any obstacles that might prevent early hydrogen projects from moving forward in the present and to advance our understanding through focused research and innovation along the entire value chain. The National Hydrogen Strategy represents a significant turning point in the industry's growth as Ireland's first comprehensive policy statement on renewable hydrogen.

The National Hydrogen Strategy assesses both the long-term needs and short-term actions to enable hydrogen to develop across the entire value chain, aiming to address multiple questions regarding the Hydrogen industry in Ireland. There are still questions regarding how Ireland will kickstart and scale up production of renewable hydrogen, which end-use sectors will hydrogen be targeted towards (aviation, freight, public

CURRENT HYDROGEN STRATEGY BASED ON EU REGULATIONS AND IRELAND'S POLICY

transport?), or what quantities are likely to be needed (to support specific industries, produce extra quantities to sell on the international market, or carry out a large scale changes in Irish energy?). It is still unknown what infrastructure Ireland needs to support the development of the hydrogen sector (including transportation and storage) and how this development will commence. As discussed in the next section, a large amount of construction workers and engineers will be necessary to carry out this transition. Finally, Ireland must ensure necessary safety, environmental and market rules are in place to enable the sector to grow in a safe and sustainable way, in the country and in Europe.

An edited extract from the 'Summary of Major Policy Statements relevant to the National Hydrogen Strategy' (p.14-15)

Climate Action and Low Carbon Development (Amendment) Act 2021: commits Ireland to a legally binding target of a climate neutral economy no later than 2050, and to a reduction in emissions of 51% by 2030, providing a framework to meet these targets.

Climate Action Plan 2023: sets out how Ireland can accelerate actions required to respond to the climate crisis, putting climate solutions at the centre of development. The Plan sets out that decarbonised gases such as renewable hydrogen will be a critical component for Ireland's energy ecosystem and in minimising the overall cost of decarbonisation across all sectors. The Plan's KPIs include renewable hydrogen in production from surplus renewable electricity by 2030, zero emission gas fired generation commencing by 2030, and renewable hydrogen production via 2 GW of offshore wind under the 2031-2035 measures.

Long-term Strategy on Greenhouse Gas Emissions Reductions: builds upon the decarbonisation pathways set by carbon budgets, sectoral emissions ceilings and Climate Action Plan 2023, to ensure coherent and effective climate policy. It sets out indicative pathways, beyond 2030, towards achieving carbon neutrality for Ireland by 2050.

National Energy Security Framework: prioritised the development of a hydrogen strategy for Ireland.

Government Statement on the Role of Data Centre in Ireland's Enterprise Strategy: highlights the CRU Decision (CRU/21/124) that new data centre connections are required to have on-site generation (and/or battery storage) that is sufficient to meet own demand and assist in full decarbonisation of the power system.

Co-funded by the European Union

CURRENT HYDROGEN STRATEGY BASED ON EU REGULATIONS AND IRELAND'S POLICY

Ireland's Road Haulage Strategy 2022-2031: focuses on improving standards, securing jobs and helping the road freight sector move to a low-carbon future. Under Action 14 of the Strategy, the role that hydrogen can play in the decarbonisation of heavy goods road freight is to be part of the development of the National Hydrogen Strategy.

Shared Island Initiative: Both Ireland and Northern Ireland now have common carbon emission reduction goals and statutory requirements. The cross-border connections provide important opportunities for strategic cooperation on green energy transition on a shared island basis. The revised National Development Plan (2021-2030) includes a priority on exploring potential cross-border and all-island approaches on renewable energy, including on the potential of hydrogen power. Both Administrations are supporting a feasibility study to assess the potential to establish hydrogen refuelling stations along the main road network between Dublin and Belfast.

PROFESSIONS AND JOBS WITHIN THE HYDROGEN SECTOR IN IRELAND

The market for hydrogen mobility is growing, which implies that infrastructure and vehicle costs are coming down swiftly and that there are more and different kinds of hydrogen-powered vehicles on the road. Ireland's hydrogen mobility option will become more affordable thanks to advancements made in other nations. This enables Ireland to move directly to projects at a scale that can be profitable for investors, bypassing small-scale demonstration projects.

As the development of safety legislation for 100% hydrogen begins, the appointment of a safety regulator may occur. This would likely be based on energy health and safety professions with specific details in hydrogen. However, since there is no legislation yet it can be difficult to predict the specificity of this job. Leadership as a competence will be essential from both Governmental entities as well as the private sector to ensure this profession can cope with the hydrogen demand in early infrastructure

Gavin & Doherty Geosolutions Ltd (GDG) was commissioned to critically examine the potential for hydrogen produced by wind turbines to assist in Ireland's transition to a low-carbon energy system. Their report explores and outlines both the challenges – technical, economic, and policy – and opportunities associated with the development of an wind-based green hydrogen industry in Ireland. A sustainable and competitive hydrogen industry is an opportunity for Ireland to strengthen its economy and support

PROFESSIONS AND JOBS WITHIN THE HYDROGEN SECTOR IN IRELAND

future-proofed jobs, where 60% of respondents have already started hiring for hydrogen-specific roles. These stakeholders anticipate hiring across a range of skill levels and skill sets but have already noticed a gap in the available knowledge, training, or skills.

As the green hydrogen industry develops, significant employment opportunities are likely to arise in construction and skilled technical roles. Future hydrogen jobs that are expected (and which will require skills development) include operation and maintenance of the technologies (electrolysers, fuel cells, combustion systems, etc.), transportation and delivery of hydrogen, compression and storage, and gas grid injection among others.

Long term employment opportunities are likely to be found with the provision of services and expertise to the global green hydrogen industry, in addition to the operation of facilities. It's also worth noting that while hydrogen is no more or less dangerous than other fuels, it is very flammable and requires safety concerns that are different from those used today. The future hydrogen workforce will have to be fully prepared and competent to work with hydrogen in a safe manner.

At EU level, green hydrogen could create up to 1 million direct, high-quality jobs by 2030 and up to 5.4 million such jobs by 2050. This works out to be ca. 10,300 jobs per €1 billion invested and includes jobs generated in the renewable electricity sector. In Ireland, this would translate to between 80 and 600 new jobs in the green hydrogen industry by 2030, with a further 170 to 1200 indirectly related to the sector.

However, Ireland is already experiencing a shortage of workers across the economy. One of the hardest hits sectors is the Irish construction industry. Our survey indicated that many of the potential hydrogen jobs will be in the technical/ construction sector, meaning there will be increased competition with the housing construction sector for skilled labour. This is at a time when the new "Housing for all" plan states that up to 80,000 workers, or double today's numbers, are required to meet the new targets it has set, further straining the supply available to any potential hydrogen industry. Therefore, the requirement for a large number of workers may provide a barrier to development. Reskilling of workers in the petroleum and peat industries could play a critical role in addressing any potential shortages.

Ireland's research-performing organisations receive substantial funding from the government to conduct policy-relevant and climate-related research in the humanities and sciences. These organisations actively seek funding for climate-related research from

PROFESSIONS AND JOBS WITHIN THE HYDROGEN SECTOR IN IRELAND

different European fundings. This means many research professions will continue to be available as the hydrogen sector emerges in Ireland, with a focus on international cooperation between research fellows and universities.

HySkills, funded by Erasmus+ and launched in 2020; a Europe-wide project to deliver technical and practical knowledge in hydrogen with Dublin City University as a partner organisation. HySkills highlighted that skills shortages are already evident across most engineering and manufacturing sectors, and the emerging hydrogen sector is at risk of a skilled worker shortage. Over 60% of respondents answered that that it is not easy to find qualified/skilled professionals operatives. The HySkills report found that companies with hydrogen skills needs generally upskill their workers via internal training and various short courses. One of the report's findings is that "all personnel who will be working with or around hydrogen should be adequately trained on hydrogen safety procedures; however, the findings from questionnaires and one to one interview(s) found a range of definitions on the term trained". This shows a lack of knowledge and skill standardisation across professionals working in the hydrogen sector in Europe. Ireland will be key here to establish high but also accessible training standards for hydrogen professionals.

Ireland will need to facilitate the skills development and training necessary for jobs in the hydrogen sector. In the short term, many of the potential new offshore wind and hydrogen economy jobs will be in the construction sector. In the longer-term process, as the hydrogen industry expands, health and safety roles will be a big aspect in the sector. Other key skills needed for the offshore wind and hydrogen economy include technical roles such as civil, electrical, chemical, and geotechnical engineering, alongside support functions in areas like logistics and supply chain management, sustainable finance, and health and safety.

Co-funded by the European Union
DIALOG of Transformation
FERI
ECRN European Chemical Regions Network
zielona chemia
KRAJOWY KLASTER KLUCZOWY

COMPETENCIES REQUIRED BY PROFESSIONALS IN THE HYDROGEN INDUSTRY IN IRELAND

As described above, the range of professions and jobs is very large ergo the range of competencies required by professionals is just as varied. Using various sources mentioned at the end of the document, as well as job postings for a CEO for Hydrogen Ireland and a Research Fellow in hydrogen storage and gas grid analysis at Dublin City University, an overview of general competencies has been created.

General characteristics:

- Accountable
- Professional
- Credible, in terms of references
- Ability to work as part of a team or individually as required
- Ability to create and develop good working relationships
- Ability to set own high standards of performance and delivering desired results
- Strong problem-solving abilities
- Willingness to explore further opportunities as they emerge
- Proven research independence
- Excellent written and oral English
- Proven ability work to strict deadlines
- Proven ability to work under pressure and in an unknown situation

Professional Experience:

- BA/sc, MA/sc, PhD (ie. Level 6 or above) in Engineering or similar areas
- Research grant writing
- Student supervision
- Project management
- Work in industrial settings
- Identification and assessment of internal and external issues that affect the hydrogen sector in Ireland
- Conference planning and organisation of events
- Proven analytical, problem solving and consensus building skills
- Dealing with a variety of stakeholders, including senior management and shareholders, as well as the general public, across a large organisation

COMPETENCIES REQUIRED BY PROFESSIONALS IN THE HYDROGEN INDUSTRY IN IRELAND

Communication skills such as:

- Overseeing the development of a communications plan to utilise across stakeholders
- Collaboration with other energy trade bodies to advocate and represent in discussions and approaches to government, regulatory bodies and trade sectors
- Liaising with industry partners and national as well as global networks and clusters to gather knowledge or insights on best practice
- Presentation of relevant communications to target audiences for project results
- Ability to inform others about internal/external issues affecting the hydrogen sector

General knowledge such as:

- Supply chain aspects
- Develop scenarios in the gas grid (e.g. grid injection)
- Develop scenarios for hydrogen storage technology (e.g. gas grid, tank and geological applications)
- Develop proposed required enablers and solutions to obstacles modelled, focusing generally on management practice, logistics, and supply chains
- Good understanding of the hydrogen and energy space in Ireland & Europe
- Related expertise in current policy and policy formation, specifically clean energy and utilities
- The EU funding landscape, including identification of external funding sources
- Computer skills, including updating websites, social media posting and understanding of communications online

Technical and specialised knowledge such as:

- Supply chain aspects
- Hydrogen production methods
- Hydrogen storage
- Challenges in hydrogen distribution
- Technical readiness of the network to transport hydrogen
- Knowledge and skills of safe transportation and storage of hydrogen on the gas network in the future.
- Asset management for hydrogen blending and injection facilities
- Assist in the writing of grant proposals
- Green hydrogen safety skills
- Logistics: Expanded gas grid, hydrogen storage and logistics, Ireland, UK, EU, gas grid analysis (transmission, distribution, local grid, bottled gas)
- Optimise hydrogen in the gas grid (e.g. grid injection)
- Model demand scenarios (e.g. heat, peaking plants, datacentres)

COMPETENCIES REQUIRED BY PROFESSIONALS IN THE HYDROGEN INDUSTRY IN IRELAND

- Model scenarios for hydrogen storage technology (e.g. gas grid, tank and geological applications)
- Develop itinerary/database of infrastructure obstacles, risks and bottlenecks to the above scenarios
- Develop proposed required enablers and solutions to obstacles modelled, focusing specifically on hydrogen
- Carry out sensitivity testing and alternate scenarios, using management practice as well as computer based scenarios

Leadership and management skills such as:

- Aiding with net-zero transition of the public transport sector, with the idea to help stimulate action from the private sector
- Building a deep understanding of key stakeholder, industry and regulatory pressures and demands, to communicate those to necessary divisions of the organisation
- Leading and executing a strategy for Ireland's hydrogen industry
- Providing strategic future-based guidance for the organisation and its stakeholders
- Forming and executing strategy
- Mentoring and supervising staff
- Directing the implementation of a communications document management platform
- Ability to lead related sub tasks and deliverables in other work-packages or projects

It is recommended to particularity focus on health and safety specific competencies in the hydrogen sector, as there are no specific regulations in the hydrogen sector in the European Union yet, with organisations in Ireland working on recommendations or privately created standards, including the new guidance document published by EHSP. The European Hydrogen Safety Panel (EHSP) has published a new guidance document for the Safety Planning and Management in EU hydrogen and fuel cell projects as well as new guidance document on Hydrogen Safety Engineering. This is based on the same documents published in 2021, with the updated 2023 versions providing further information on safety planning, monitoring, and reporting for hydrogen and fuel cell projects in Europe.

Co-funded by the European Union

COMPETENCIES REQUIRED BY PROFESSIONALS IN THE HYDROGEN INDUSTRY IN IRELAND

This includes specific health and safety competencies such as:

- Identification of safety vulnerabilities and suggesting elimination or control of hazards
- Introduction of mitigation measures to keep the risk at an acceptable level
- Development of innovative engineering solutions

As well as competencies which include leadership and communication skills such as:

- Ability to appropriately communications on safety issues between the project consortium and external parties, as well as describing those in the safety plan of the organisation, including how the plan will be implemented, its monitoring, and reporting as required
- Managing the periodic revision of the codes to reflect new knowledge in the hydrogen sector and best practice

Furthermore, it should be noted that since hydrogen technologies are part of a new and emerging sector, soft skills will be just as important as hard skills during the development of this sector, to appropriately and effectively communicate and manage between stakeholders. Professions within the hydrogens sector in Ireland and EU are varied and some not yet created. Therefore it is critical workers in this sector hold strong interpersonal skills to effectively share and utilise technical knowledge on hydrogen.

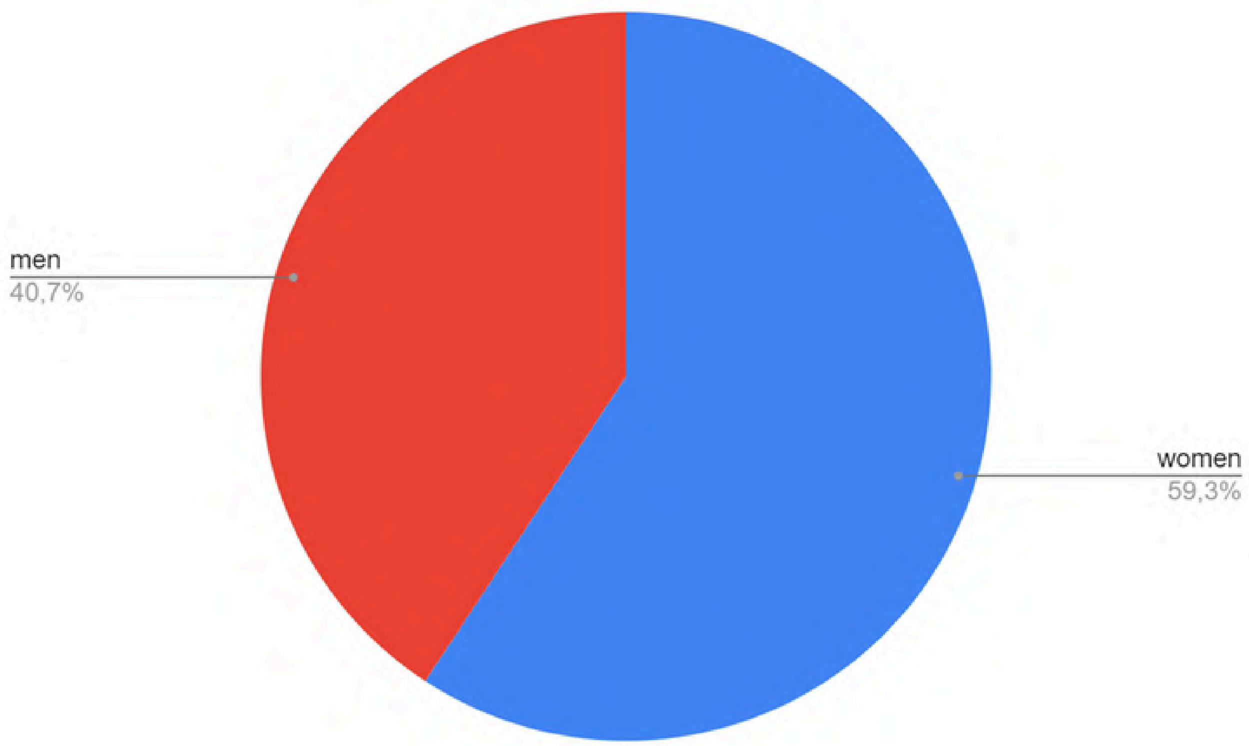
RESEARCH REPORT 1

In order to establish a map of professions related to the hydrogen economy, in accordance with the project, the Partners conducted a survey. The technical aspect of the survey research method is that clearly defined people (respondents) answer questions that create a conscious, logical, consistent and coherent set of answers to solve the research problem. The study was carried out in the period April - May 2024. The measurement used an online survey questionnaire, which was prepared based on the "Google Forms" tool.

The aim of the study was also to outline the trend of which professions will be needed in connection with the development of the hydrogen sector and energy transformation in European countries. The study was also intended to enable the identification of professional profiles and skill needs that would allow for the possible definition of existing gaps in the labor market.

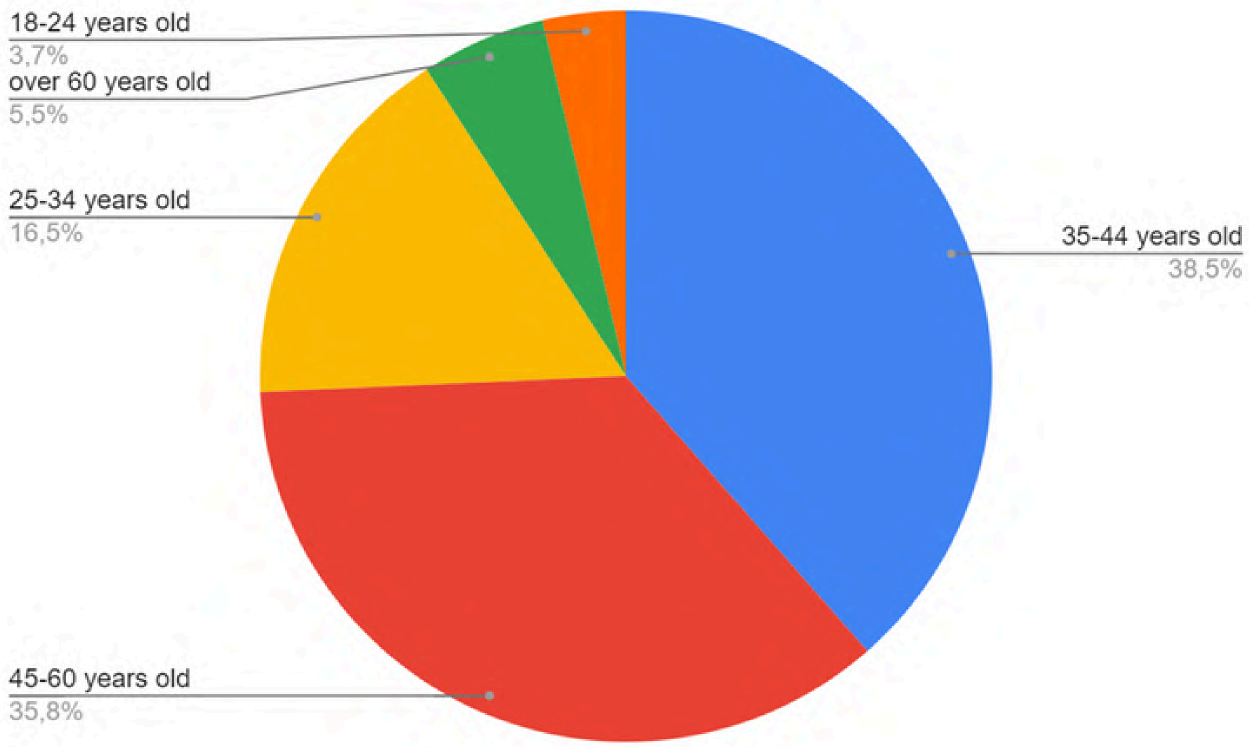
A total of 109 respondents took part in the study, most of whom were men (59.3%) (see Chart 1).

CHART 1 What is your gender?



The respondents were dominated by people aged 35-44 (38.5%), with a significant share of people aged 45-60 (35.8%). A significant percentage of respondents were also people aged 24-34 (16.5%) (see Chart 2).

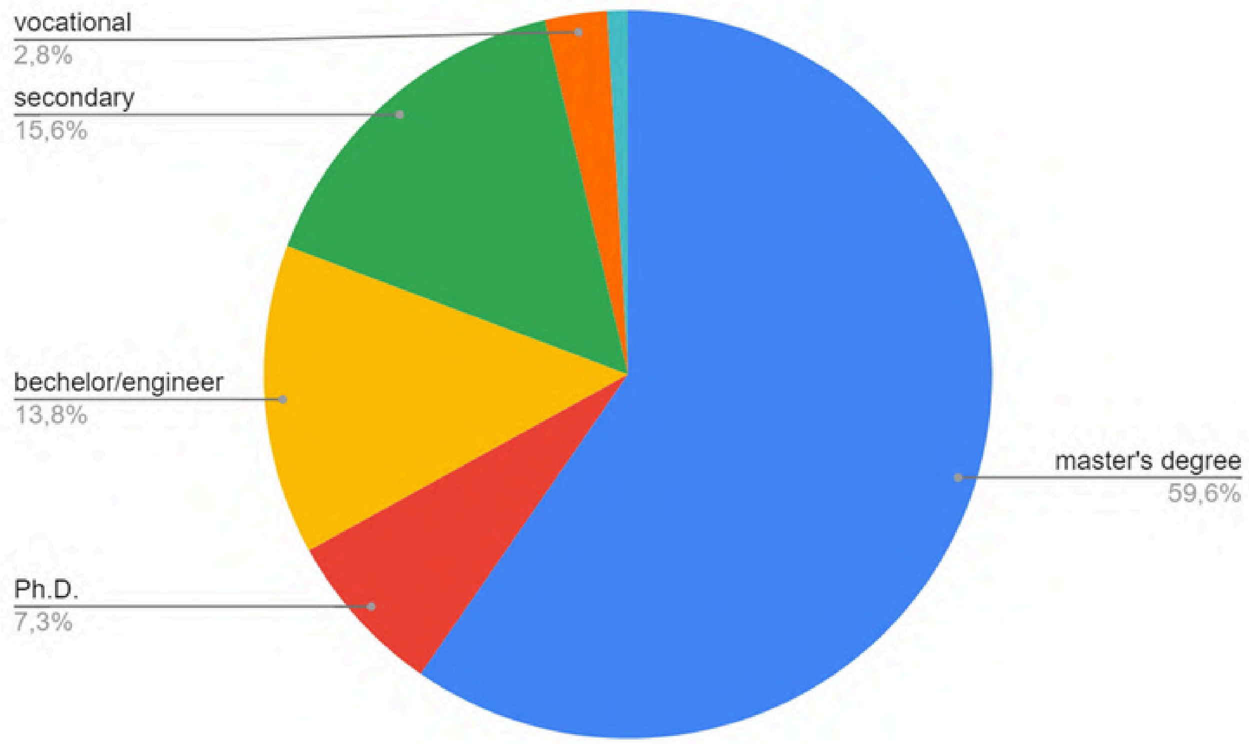
CHART 2 How old are you?



In terms of education, the vast majority of respondents had a master's degree (59.6%), the second largest group were people with secondary education (15.6%), and the third largest group were those with a bachelor's or engineer's degree (13.8%) (see Chart 3).

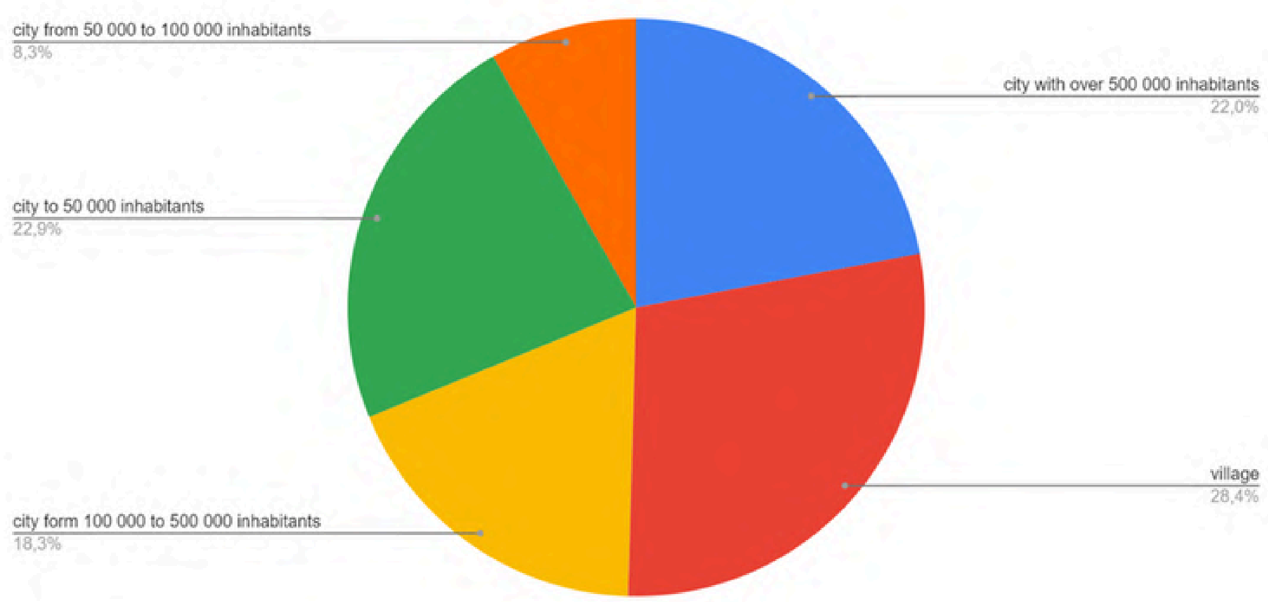
CHART 3

What is your highest completed education?



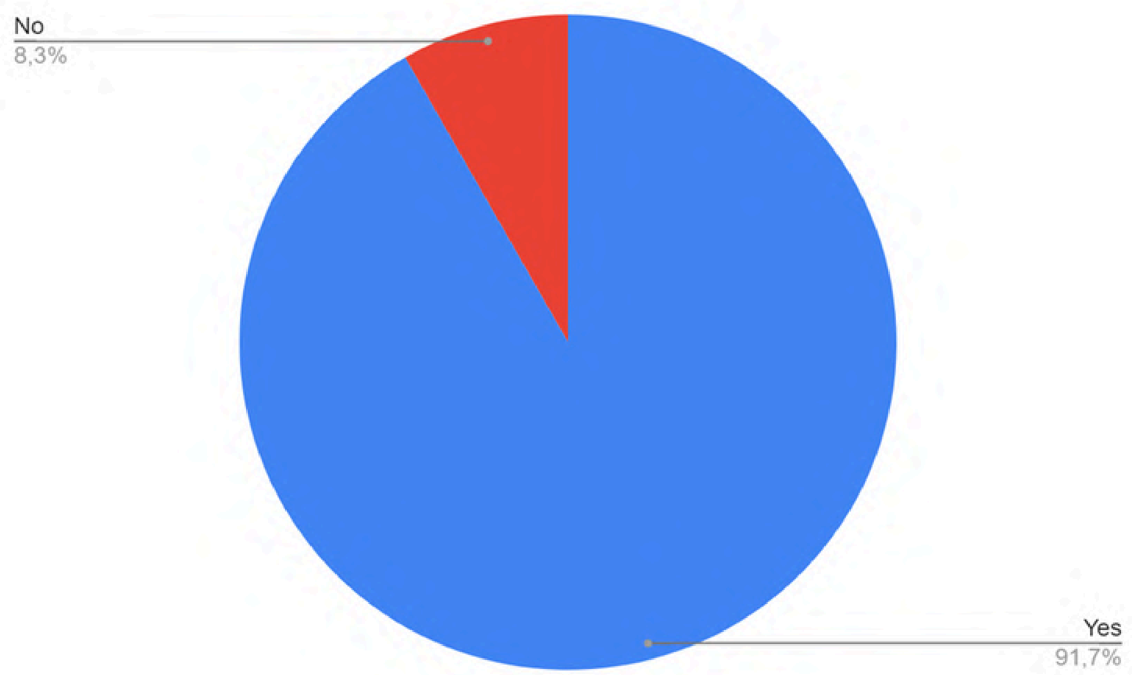
The respondents were mostly residents of rural areas (28.4%) and cities with up to 50,000 inhabitants (22.9%). There was also a large representation of inhabitants of cities with over 500,00 inhabitants (22%) (see Chart 4).

CHART 4 Where do you currently live?



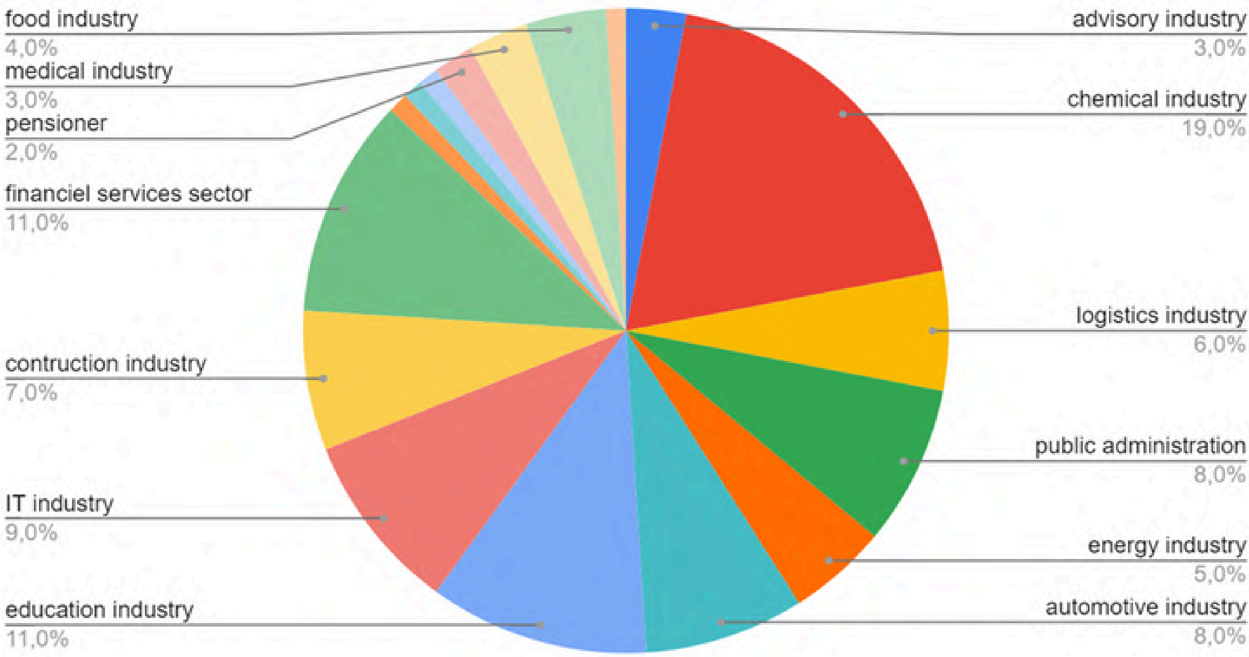
The vast majority of respondents were professionally active (91.7%) (see Chart 5).

CHART 5 Are you professionally active?



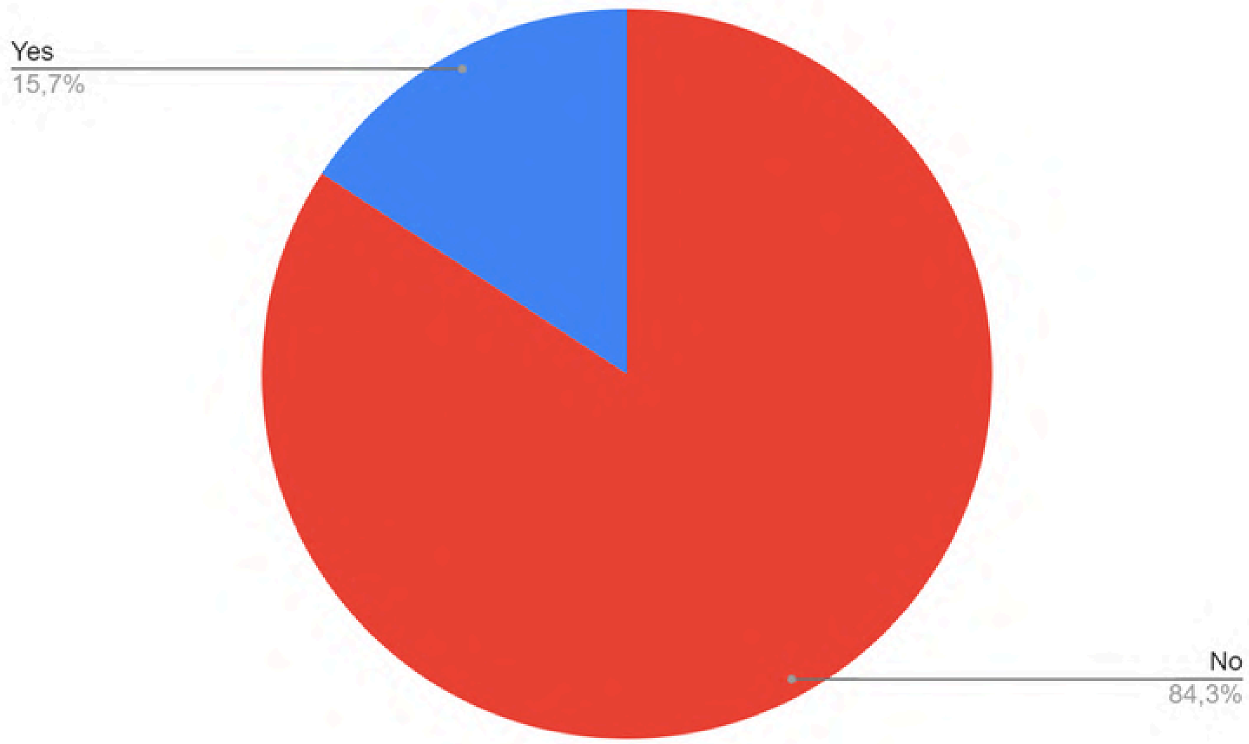
As part of the so-called In the proper survey, respondents were asked to indicate what industry they work in or what industry sector they work in. The majority of respondents represented the chemical industry (19%), which is an important indication of the perspective of the subject of the conducted research. Next, respondents represented the education industry (11%) and the financial services sector (11%). Many respondents were also employees of the IT industry (9%). It should also be mentioned that only 5% of respondents worked in the energy industry. A detailed description of the indications examined in this area is presented in Chart 6.

CHART 6 Please indicate what industry you work in or what sector of the economy you work in:



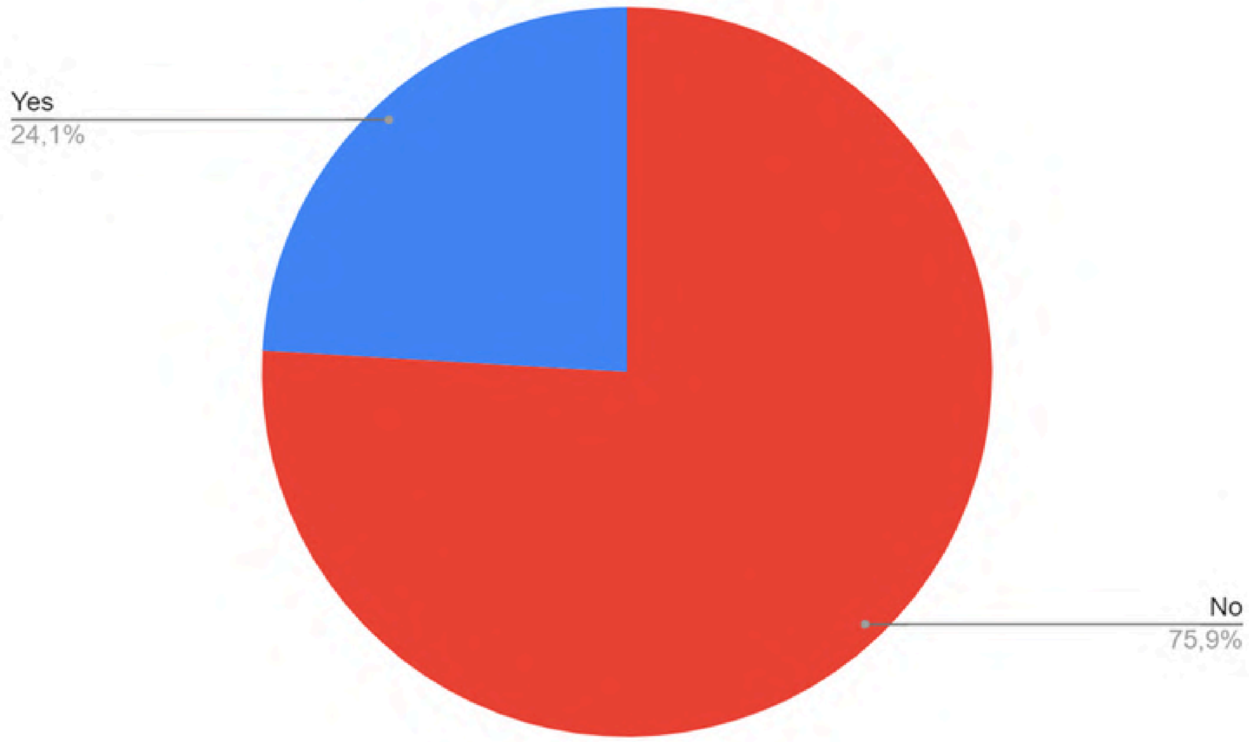
The respondents were also asked to specify whether they had professional experience in the energy industry. The vast majority of respondents (84.3%) stated that they had no experience in this area (see Figure 7).

CHART 7 Do you have professional experience in the energy industry?



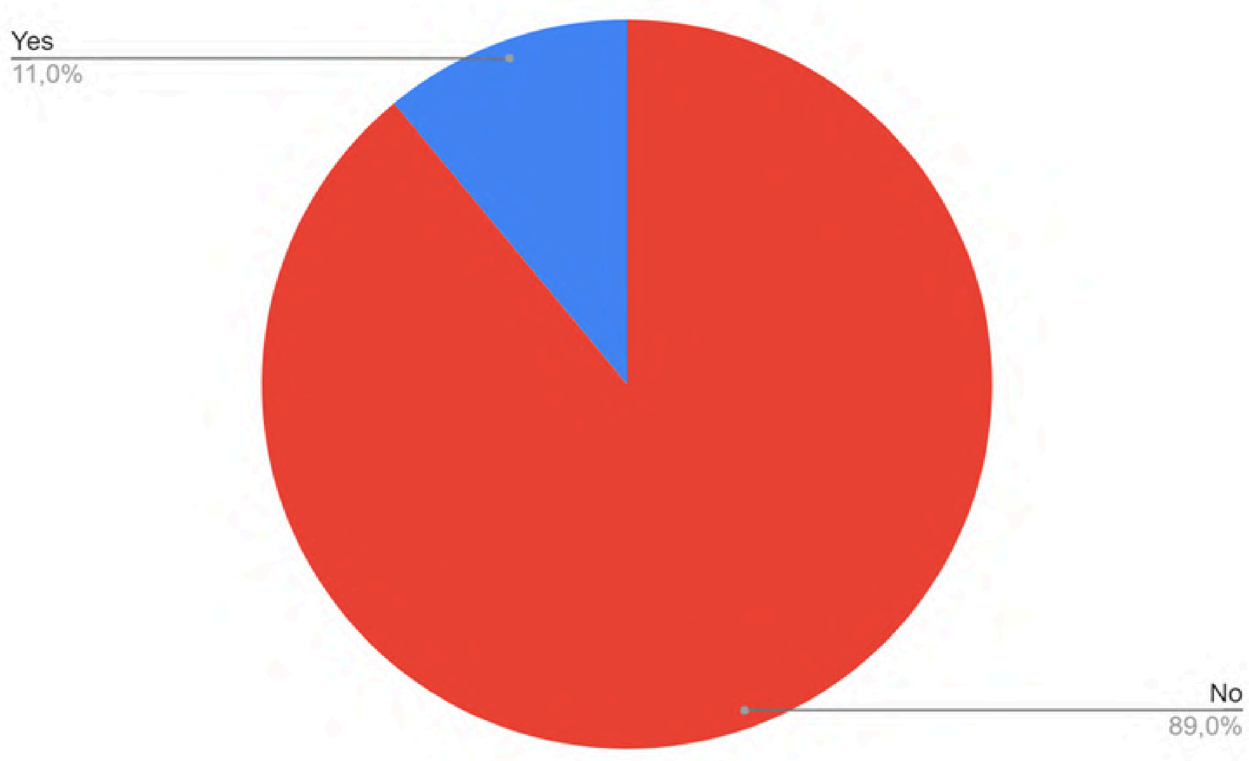
Also in terms of professional experience in the chemical industry, the majority of respondents indicated that they had experience in this area (75.9%), as presented in Chart 8.

CHART 8 Do you have professional experience in the chemical industry?



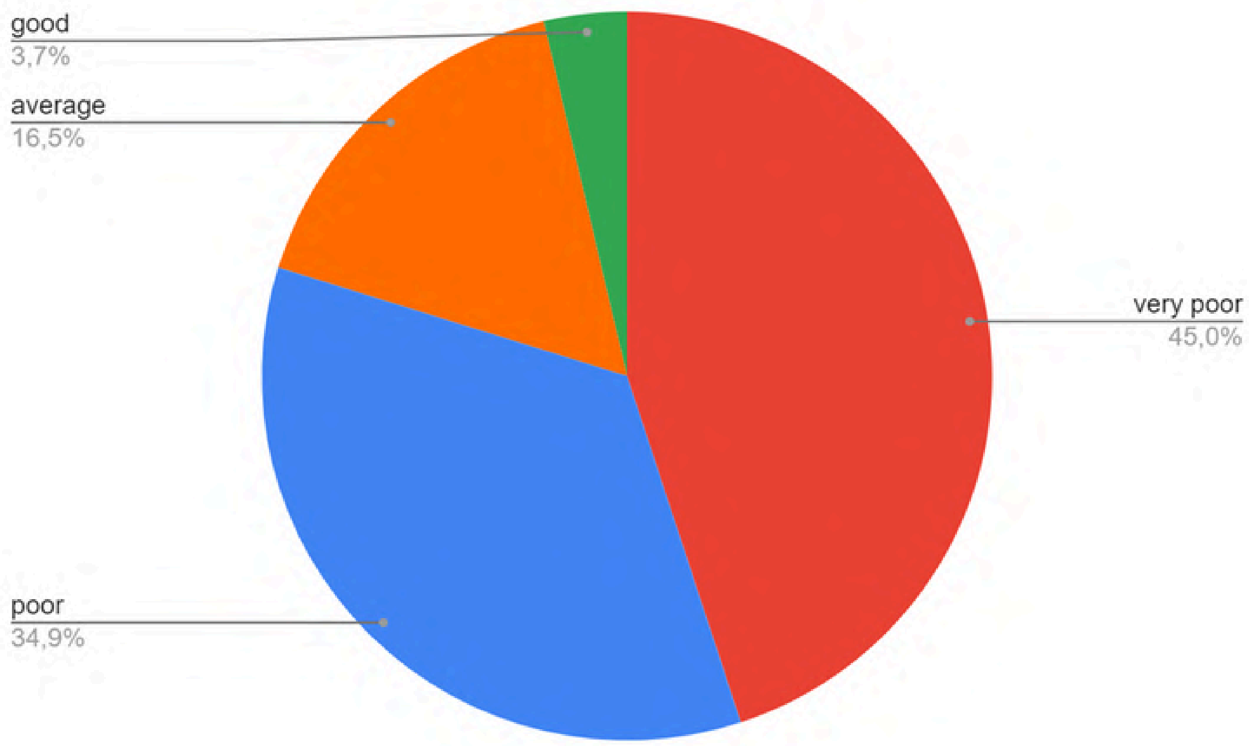
Similar indications were found in the case of the next question regarding experience in working with hydrogen technologies. As many as 89% of respondents stated that they did not have professional experience related to these technologies (see Chart 9).

CHART 9 Do you have experience working with hydrogen technologies?



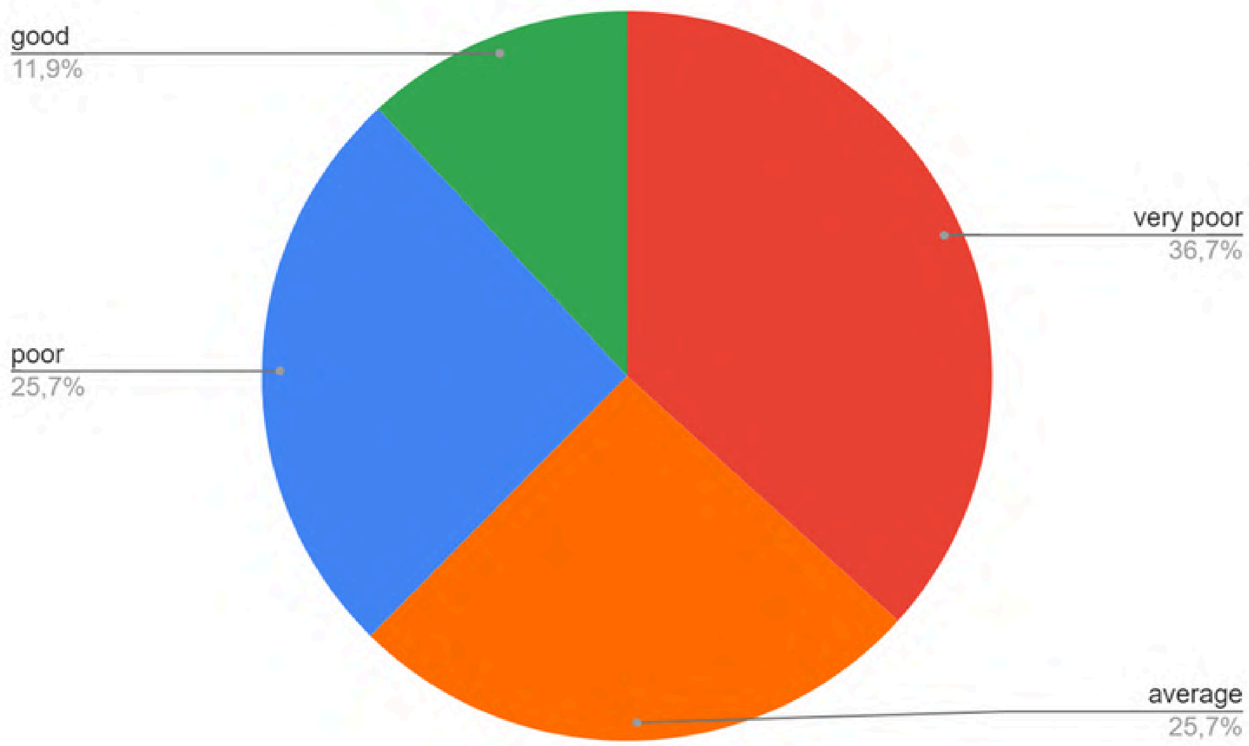
In this context, the respondents' answers were more diverse when it came to the question regarding the assessment of their technical skills in the area of hydrogen technologies. Respondents were asked to respond to it by selecting a specific response category on a scale from "very poor" through "poor", "medium", "good" to "very good". The majority of respondents described their skills as very poor (45%) or poor (34.9%). Only 16.5% described it as average and 3.7% as good. None of the respondents described their skills as very good. (see chart 10).

CHART 10 How do you rate your technical skills in hydrogen technology?



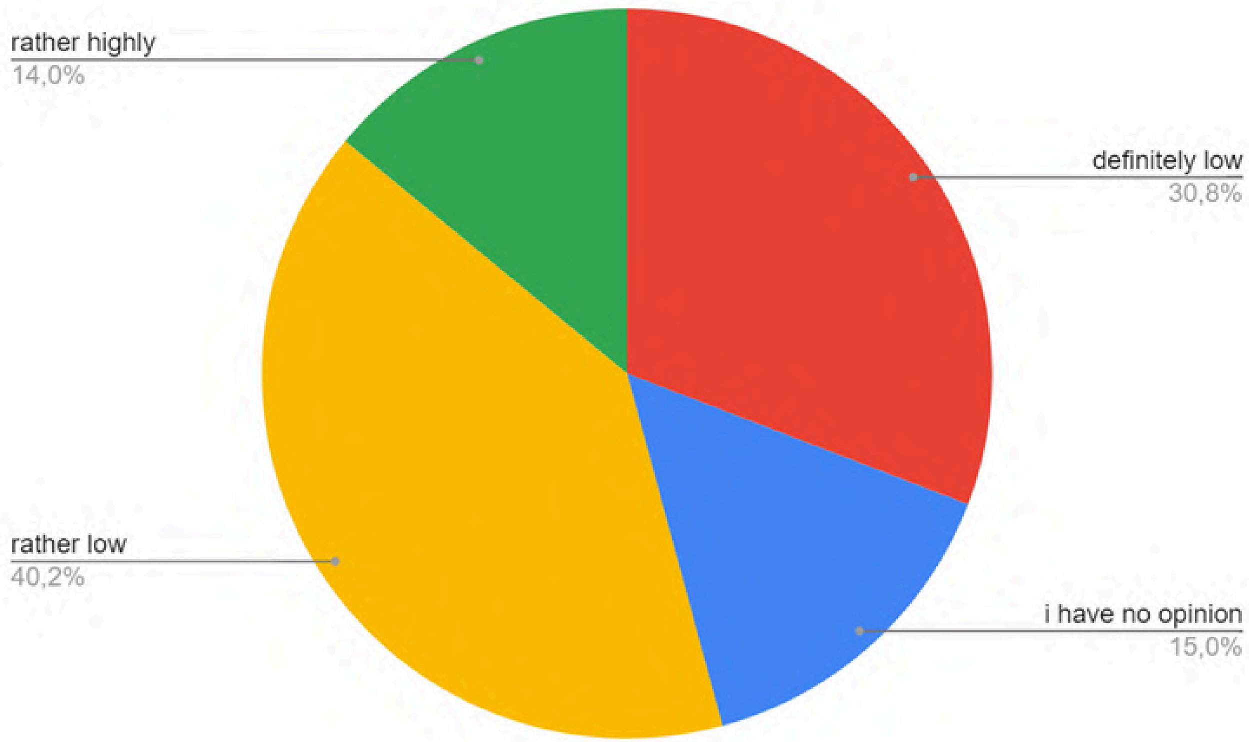
An analogous measurement scale was used in the next question, in which respondents were asked to assess their knowledge of current trends and innovations in the hydrogen sector. 36.7% of respondents described their knowledge in this area as very poor, and 25% as poor, which is more than half of the respondents. On the other hand, 25.7% rated their knowledge as average and 11.9% as good. In this question, none of the respondents rated their knowledge as very good (see Chart 11).

CHART 11 How do you rate your knowledge of current trends and innovations in the hydrogen sector?



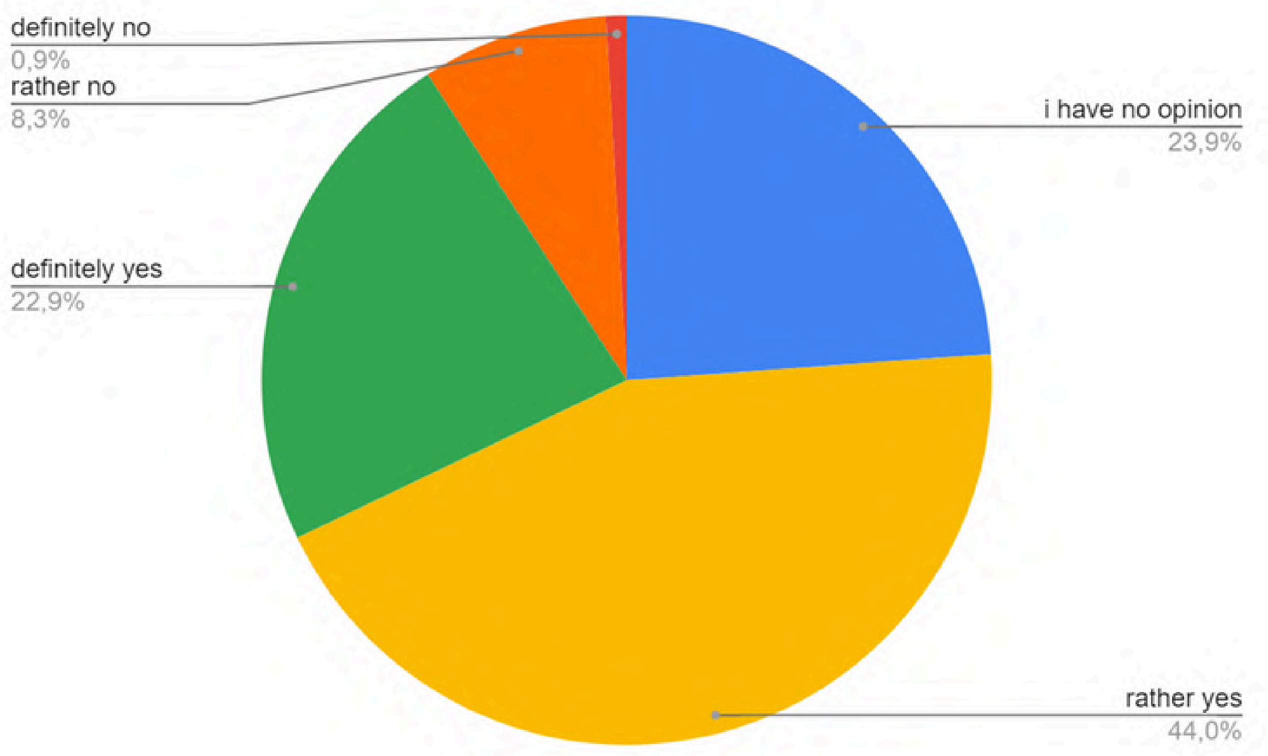
In the next question, respondents were asked to assess their level of knowledge in the field of hydrogen economy. The respondents were asked to respond to this issue by selecting a specific answer category on a scale from "definitely not" through "rather low", "I have no opinion", "rather high" to "definitely high". Most respondents described their knowledge as "rather low" (40.2%) and very low (40.2%). As many as 15% of respondents said they had no opinion on this issue, and 14% of respondents rated their knowledge as rather high. None of the respondents rated their knowledge as "definitely high" (see Chart 12).

CHART 12 How do you assess the level of your knowledge in the field of hydrogen economy?



A five-point scale of response categories was used for the question asking to express one's opinion on whether the hydrogen economy will have an impact on the labor market. Respondents were asked to respond to this issue by selecting the answer from "definitely no", to "rather no", "I have no opinion", "probably yes" to "definitely yes". Most respondents answered "rather yes" and "definitely yes", which proves the great importance they attach to the importance of the hydrogen economy in the context of further development of the labor market (66.9%). However, many respondents (23.9%) stated that they had no opinion on this matter and therefore perhaps they had no knowledge at all about the hydrogen economy and its impact on the labor market. Only 8.3% of respondents stated that the hydrogen economy is unlikely to have an impact on the labor market (see Figure 13).

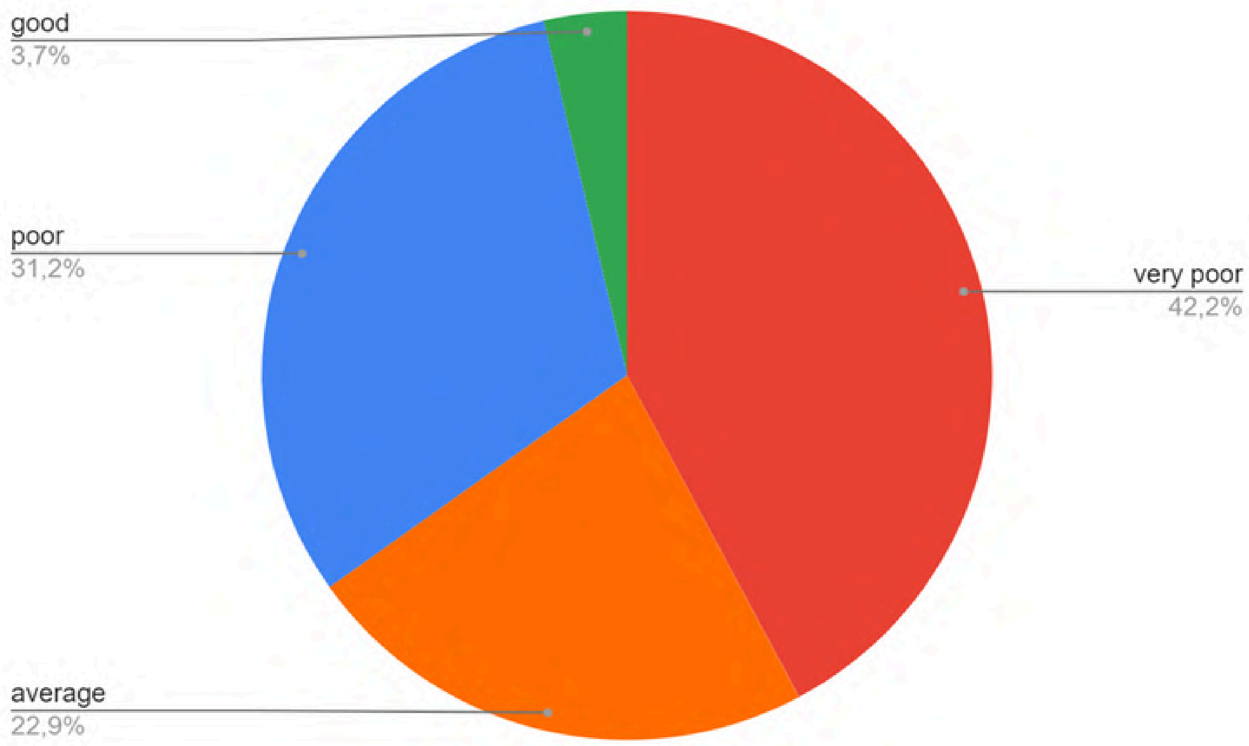
CHART 13 Do you think the hydrogen economy will have an impact on the labor market?



The same five-point scales and response categories were used for questions 14 and 15. Respondents were to respond to them by selecting an answer from "very poor" to "poor", "average", "good" to "very good".

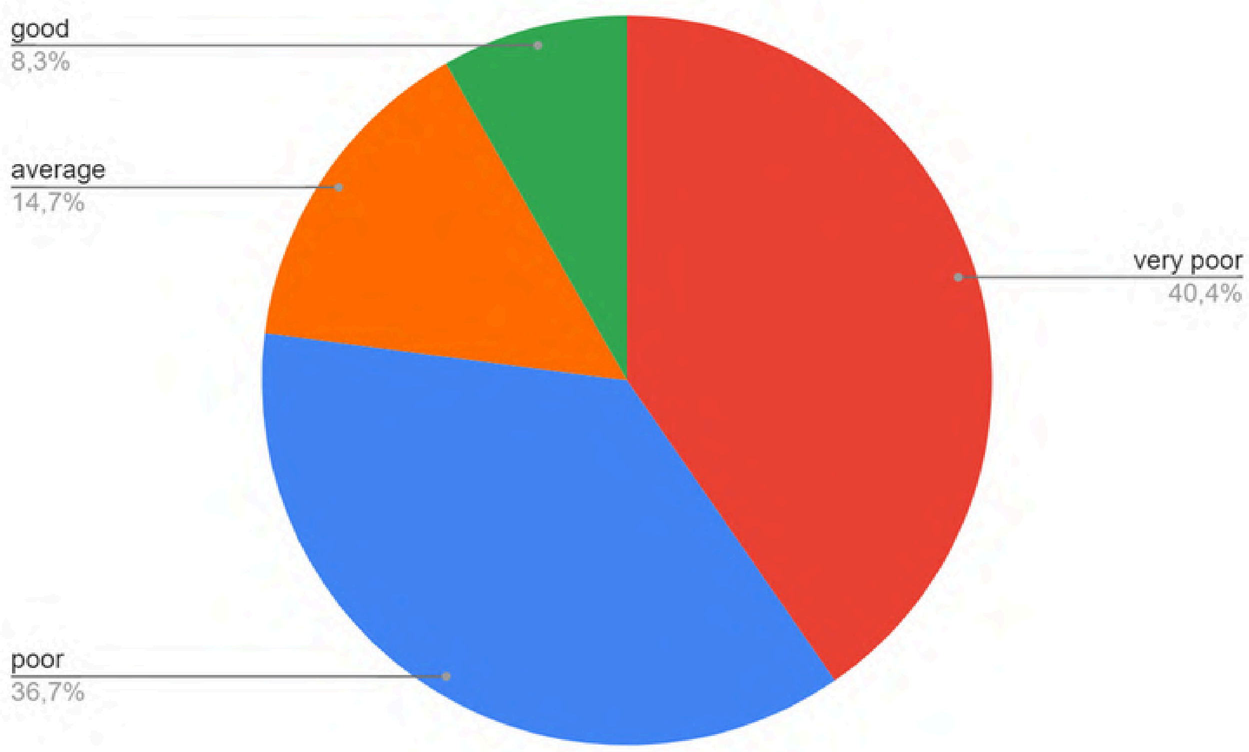
Question No. 14 concerned the respondents' self-assessment of their knowledge of the provisions and regulations of the hydrogen sector. The vast majority of them described their knowledge in this area as "very poor" (42.2%) or poor (31.2%). 22.9% of respondents described their knowledge as average, and only 3.7% as "good". The answer "very good" was not given (see Figure 14).

CHART 14 How do you rate your knowledge of rules and regulations regarding the hydrogen sector?



Similarly, with regard to question no. 15 regarding the respondents' self-assessment of their skills in identifying and solving problems related to hydrogen technology. Most of them described their skills in this area as "very poor" (40.4%) or "poor" (36.7%). 14.7% of respondents described their skills as average, and 8.3% believed that their skills were at a "good" level (see Chart 15).

CHART 15 How do you rate your skills in identifying and solving problems related to hydrogen technology?



In question no. 16, respondents were asked to indicate which professional profiles they believed were important for the hydrogen economy. Participants were offered 25 profiles for evaluation, which they had to rate on a five-point scale from "definitely not" to "rather not", "I have no opinion", "probably yes" to "definitely yes" (see charts 16 to 40).

CHART 16 Managers, senior officials, legislators

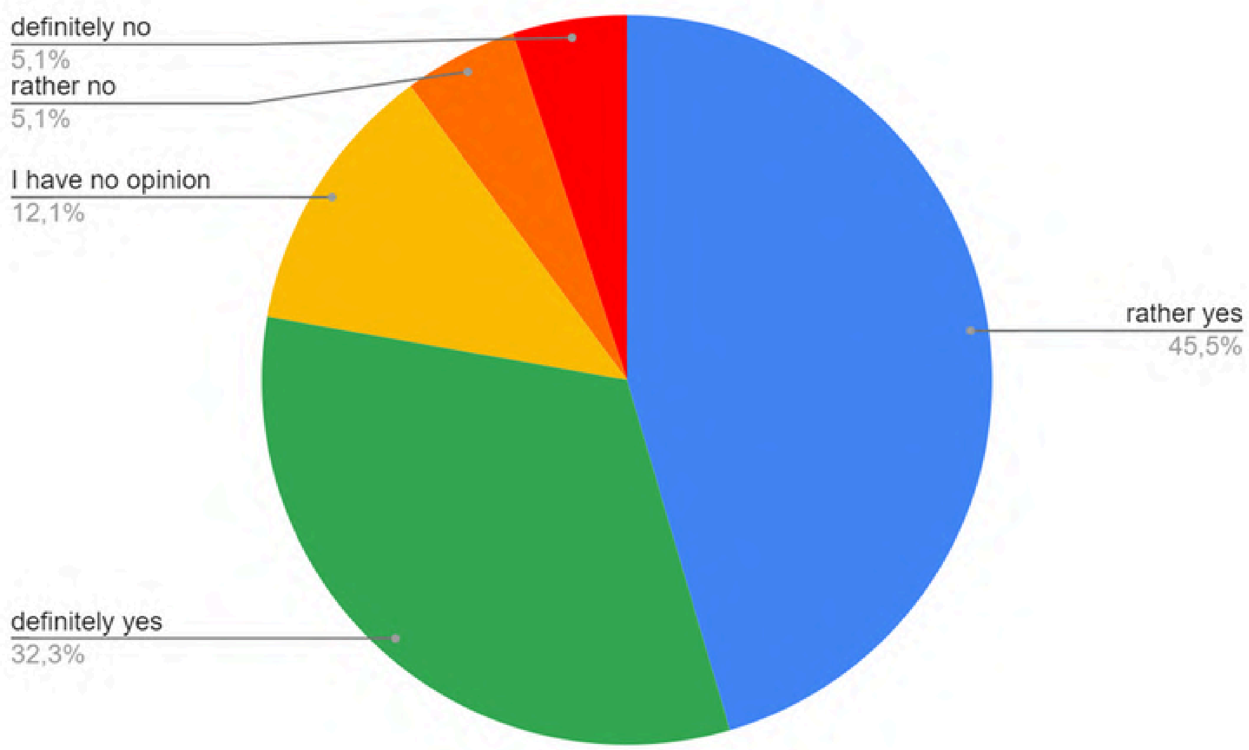


CHART 17

Administrative and commercial managers (business service managers about administration, sales, maketing and development managers)

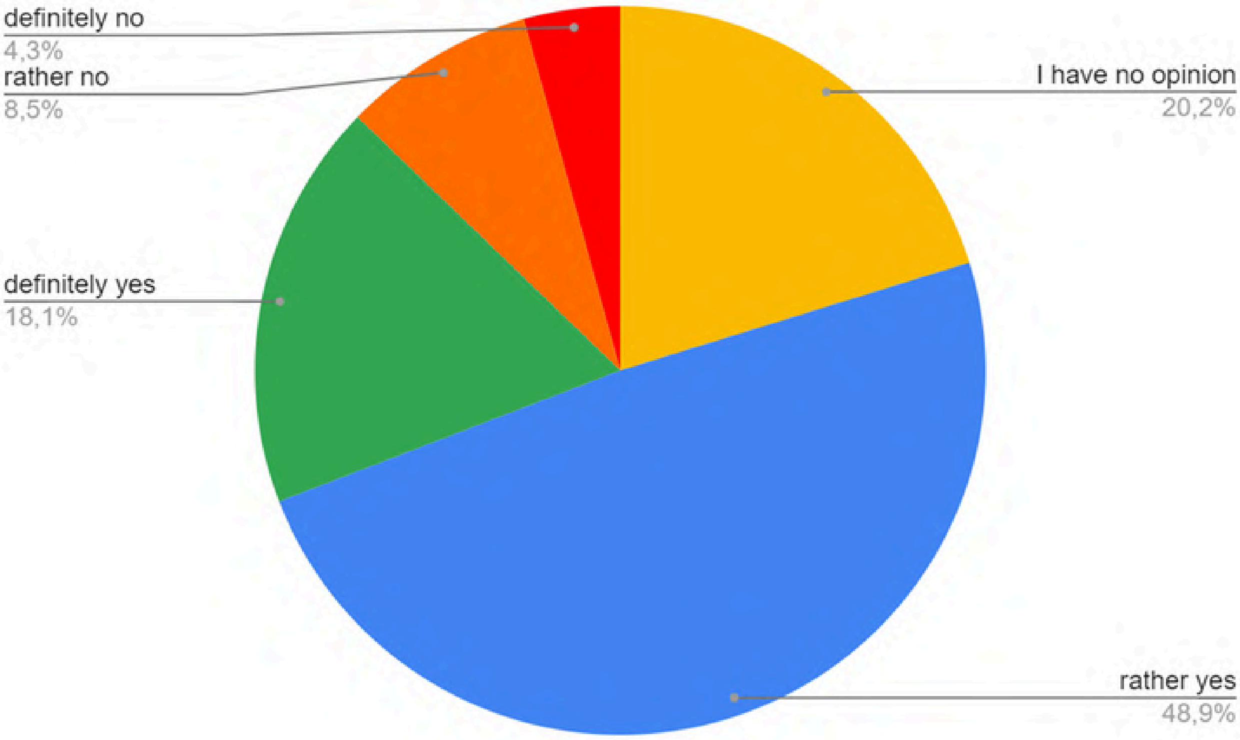


CHART 18

Production and specialist services managers

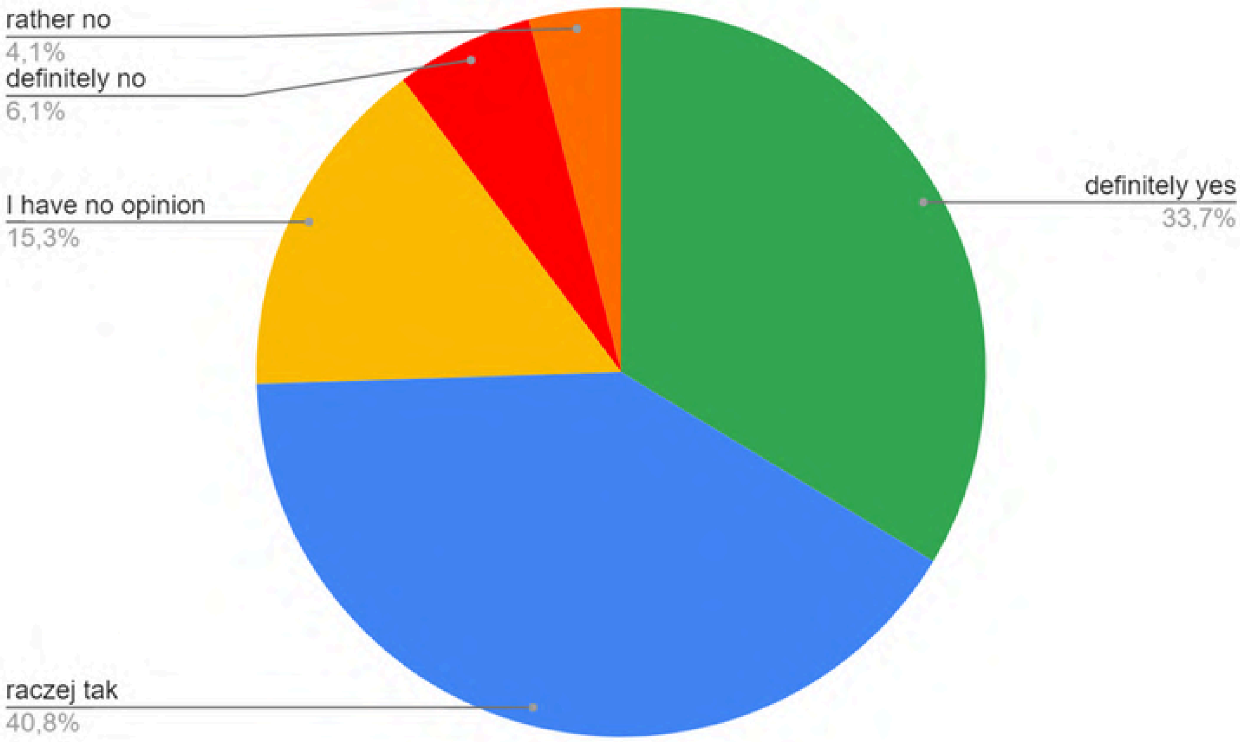


CHART 19

Specialists in science (especially engineering)

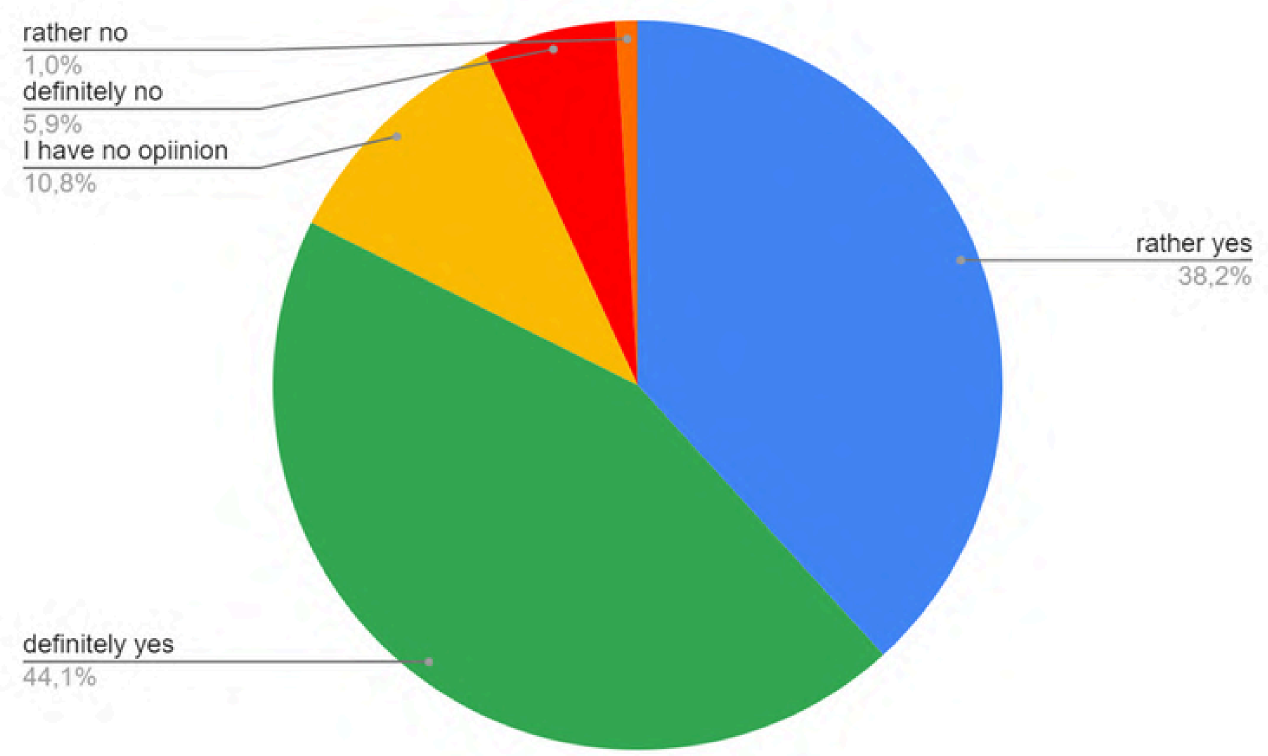


CHART 20

Chemical engineers, chemists

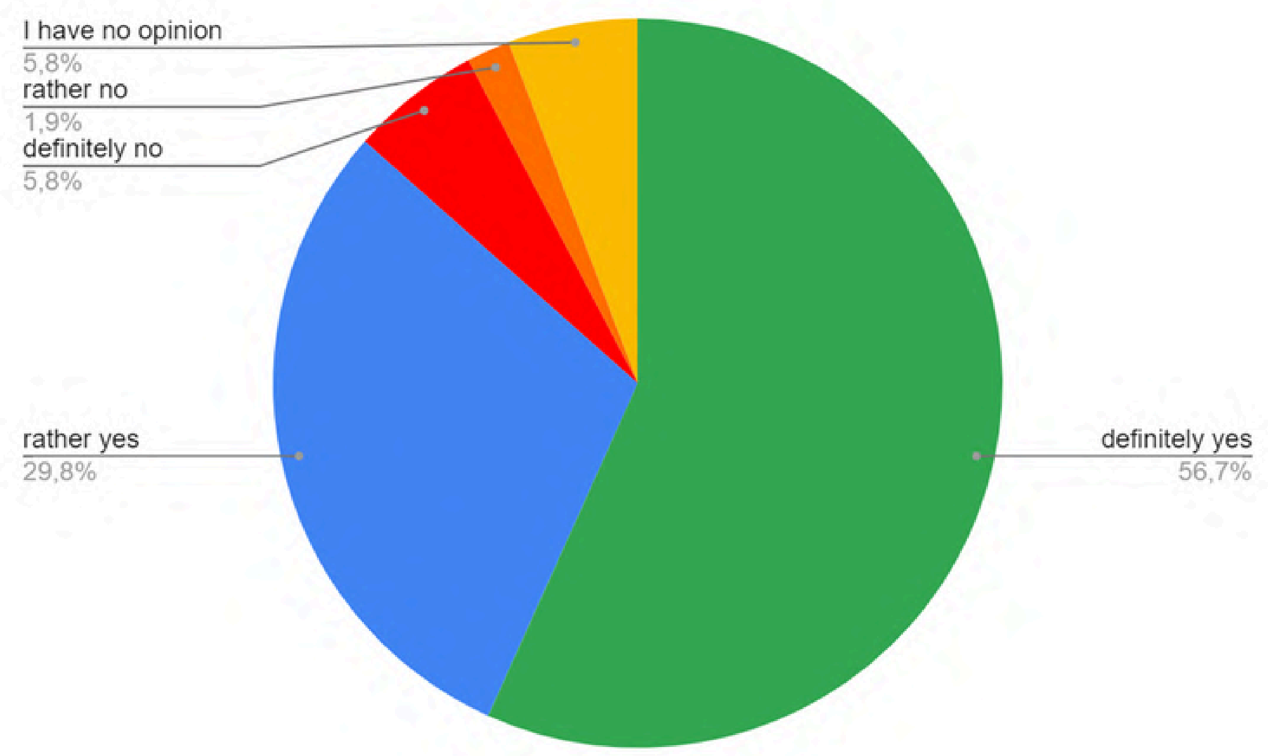


CHART 21

Electrical engineers

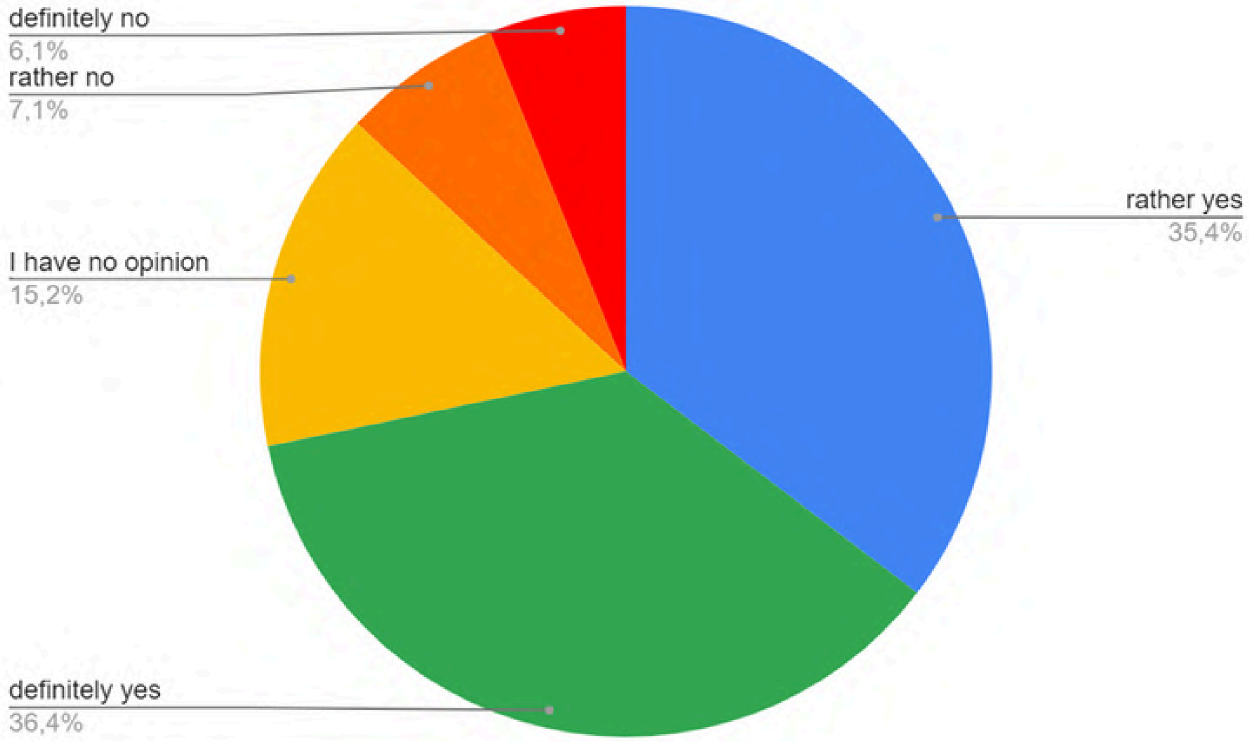
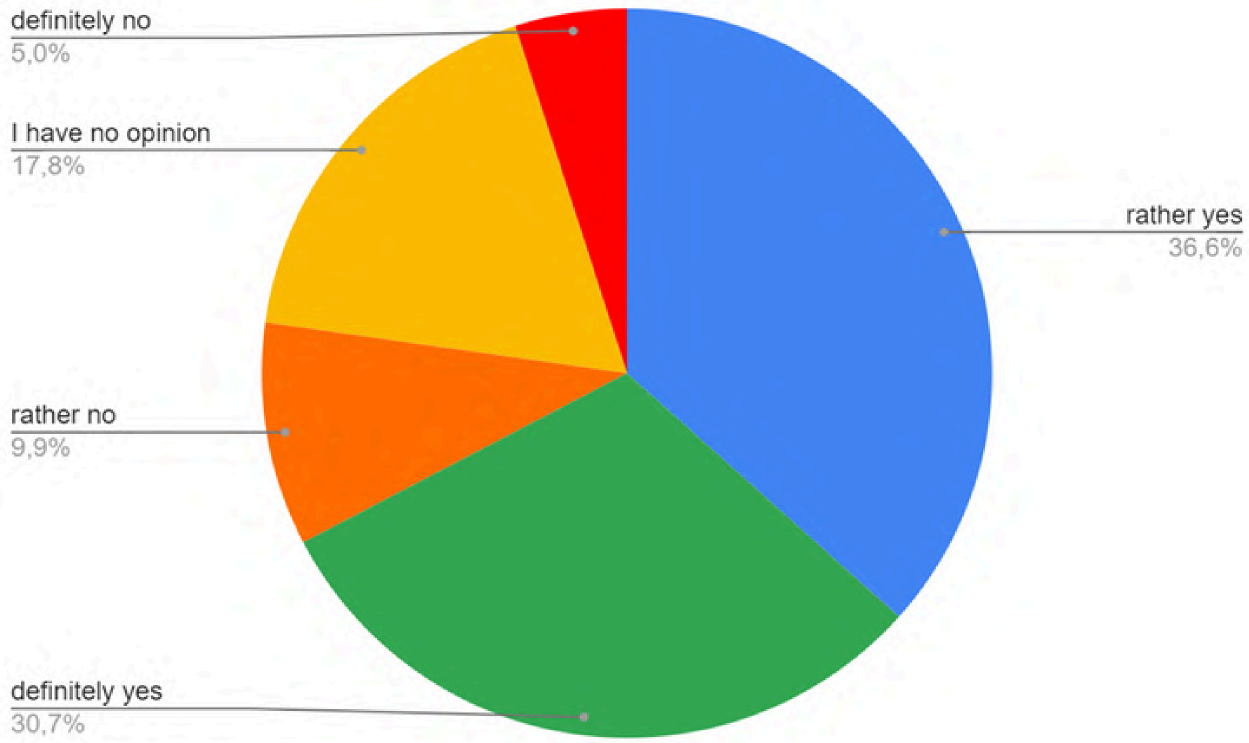


CHART 22

Mechanical engineers



Co-funded by the European Union

DIALOG of Transformation

FERI

ECRN European Chemical Regions Network

zielona chemia

KRAJOWY KLASTER KLUCZOWY

CHART 23
Business and administration specialists

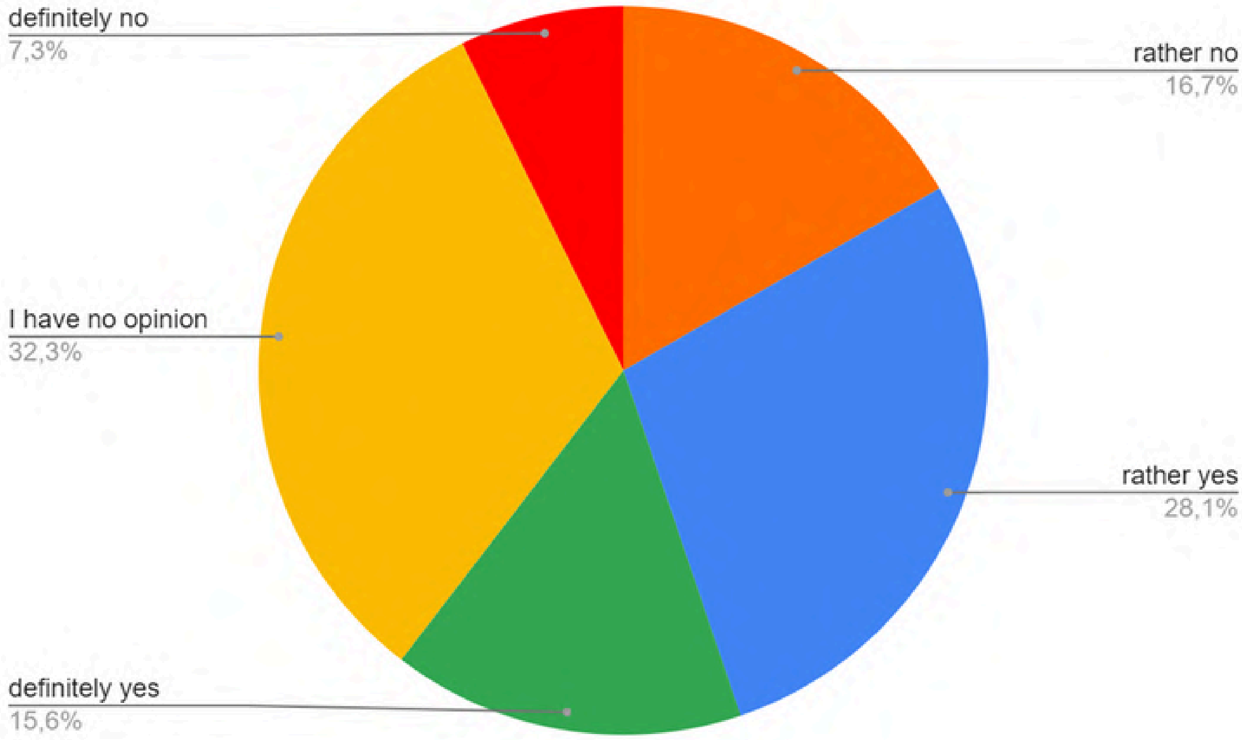


CHART 24
Sales, marketing and public relations specialists

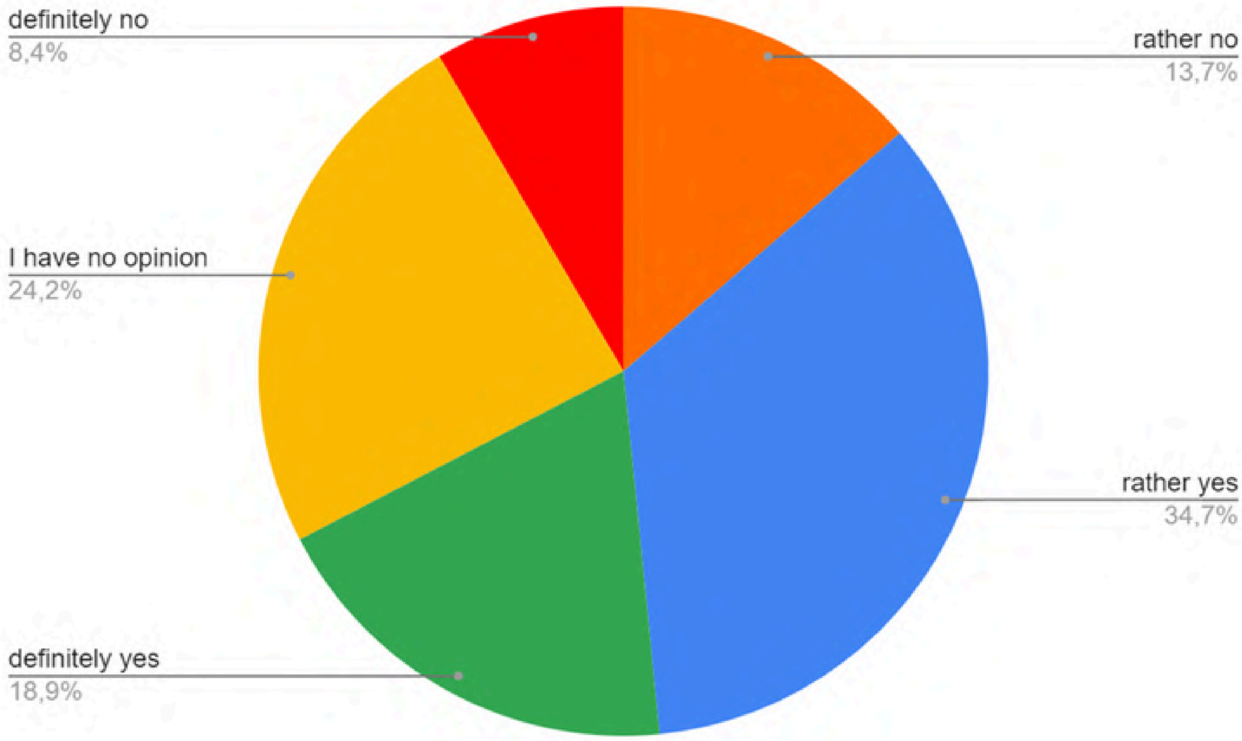


CHART 25 Technicians and specialists in physical sciences and engineering

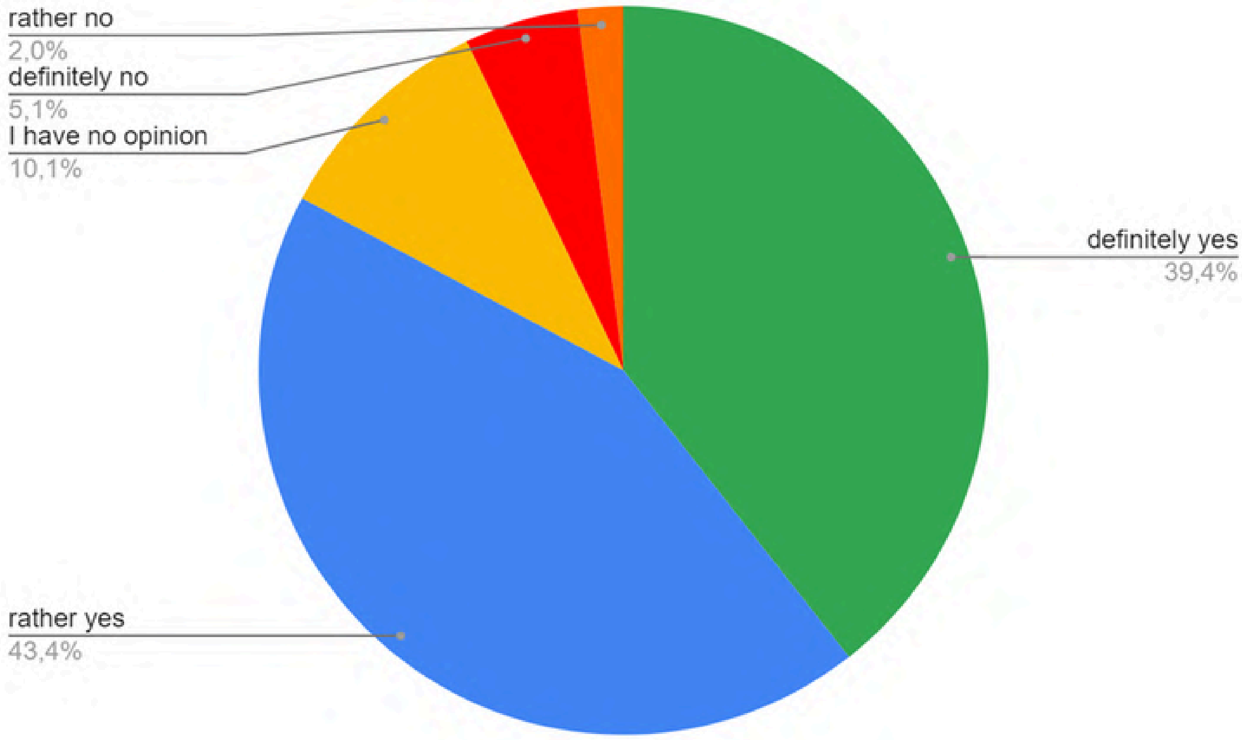


CHART 26 Specialists in mining, manufacturing and construction

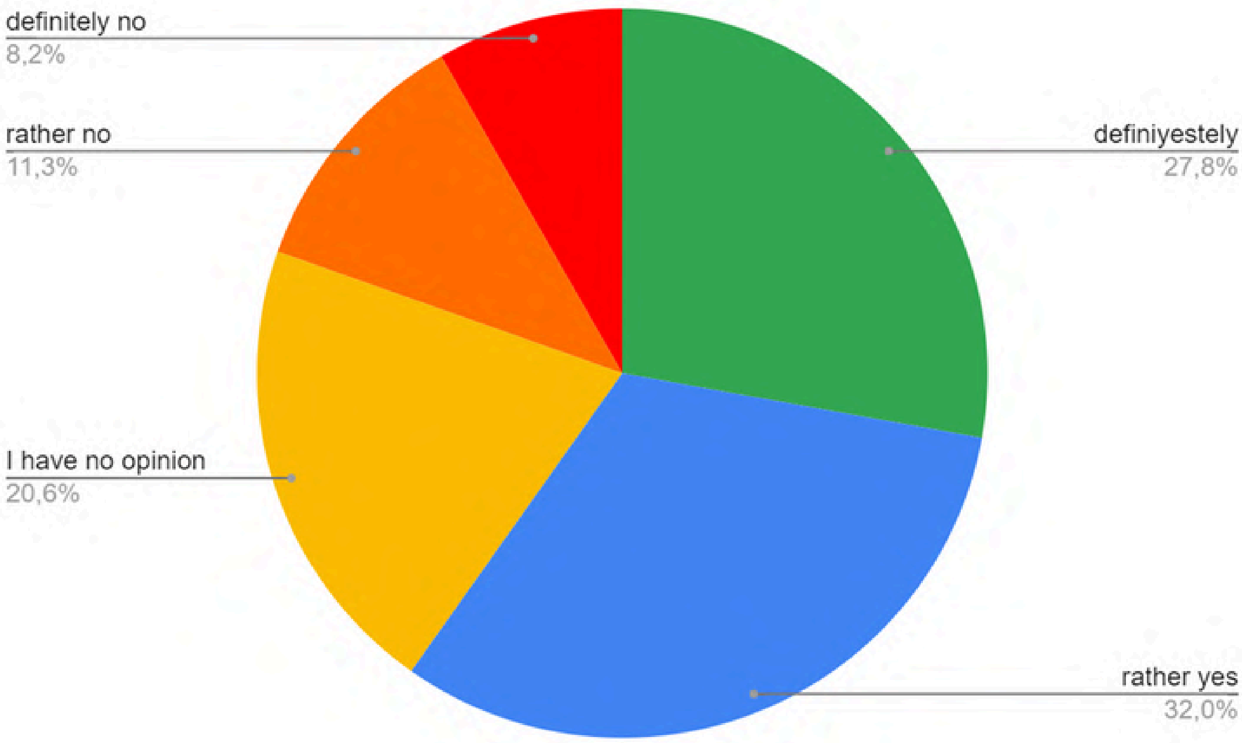


CHART 27 Logistics specialists

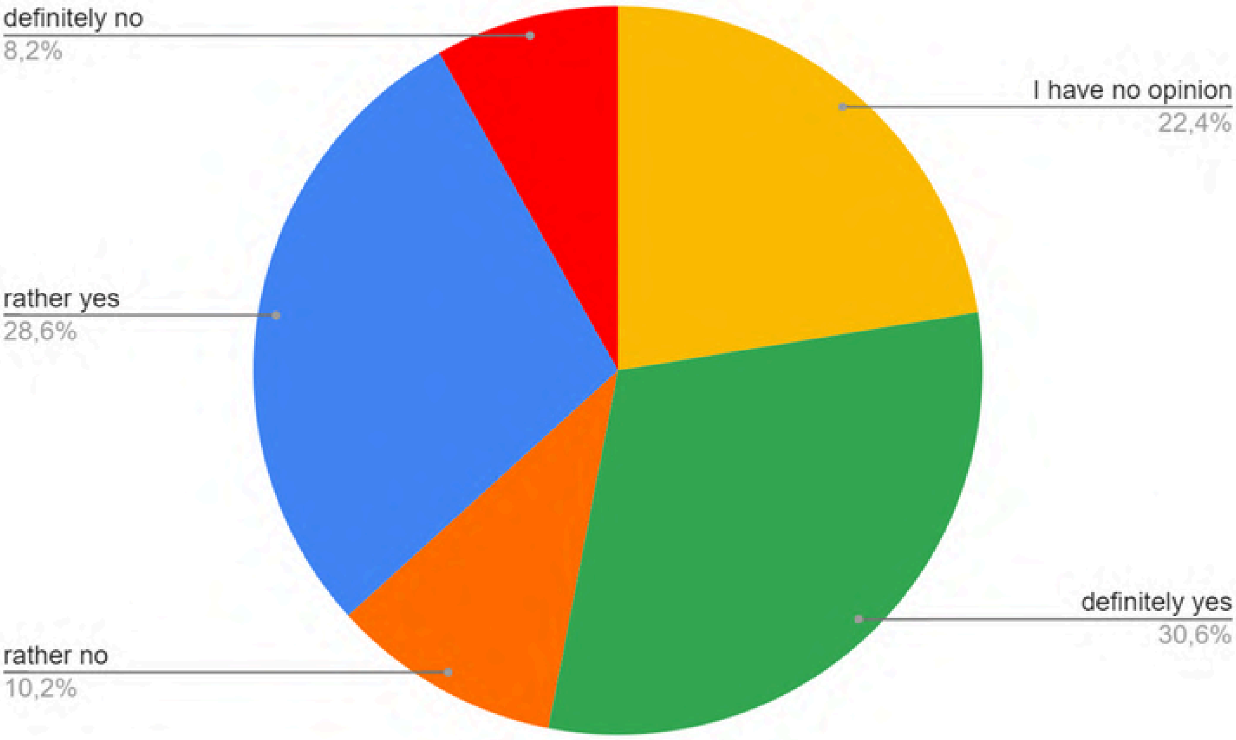


CHART 28 Specialists in transport and storage

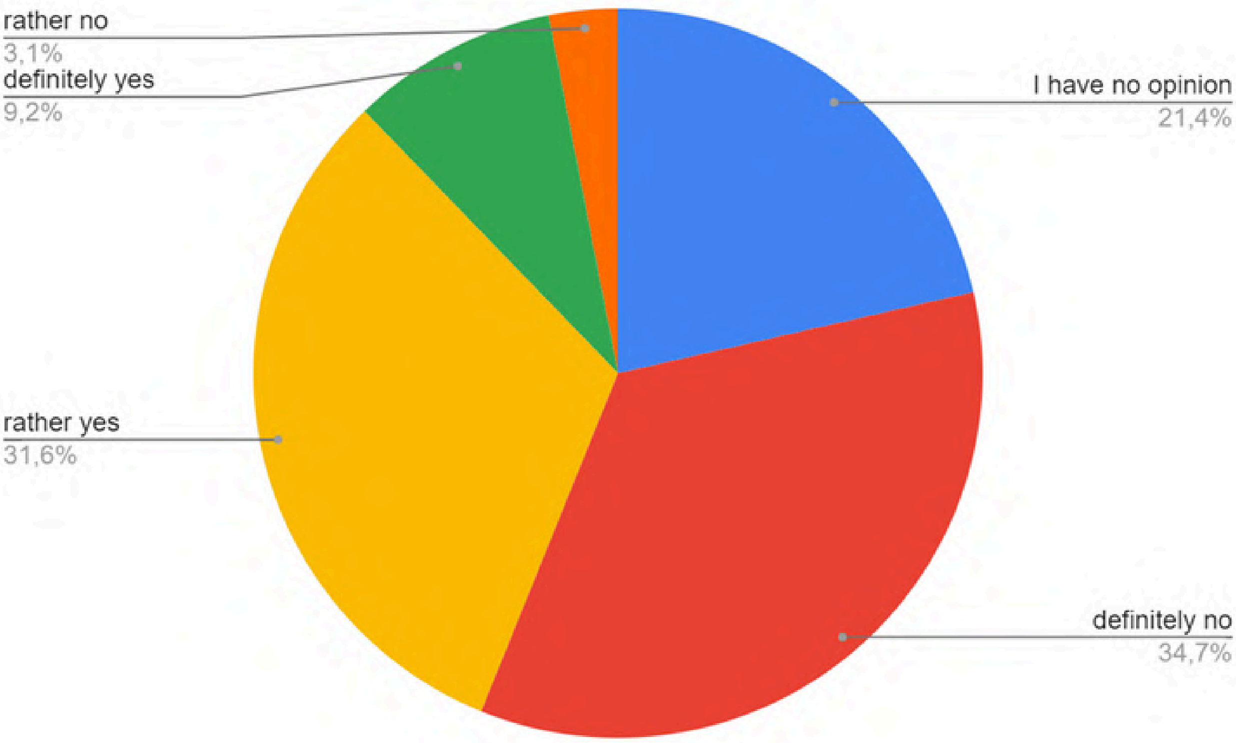


CHART 29

Workers, craftsmen in the metal, machinery and related industries

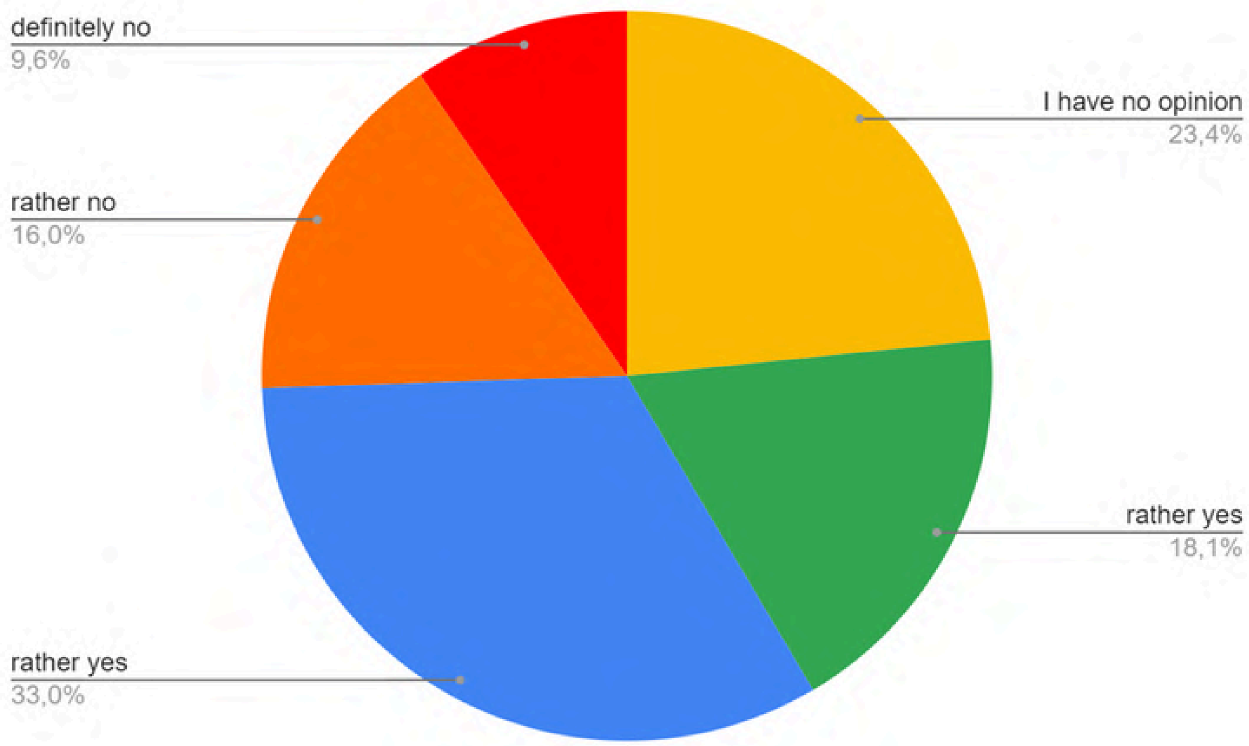


CHART 30

Mechanics and machine operators

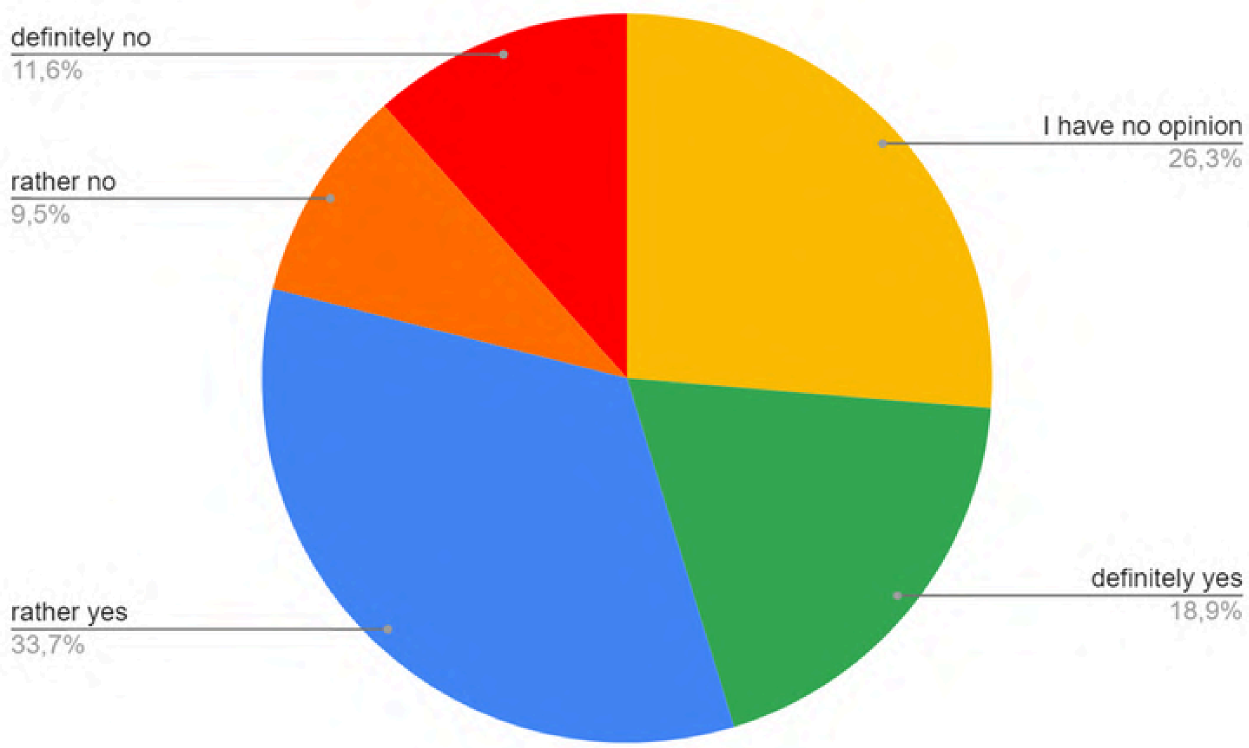


CHART 31 Electrical and electronic industry workers (electronic equipment installers and operators)

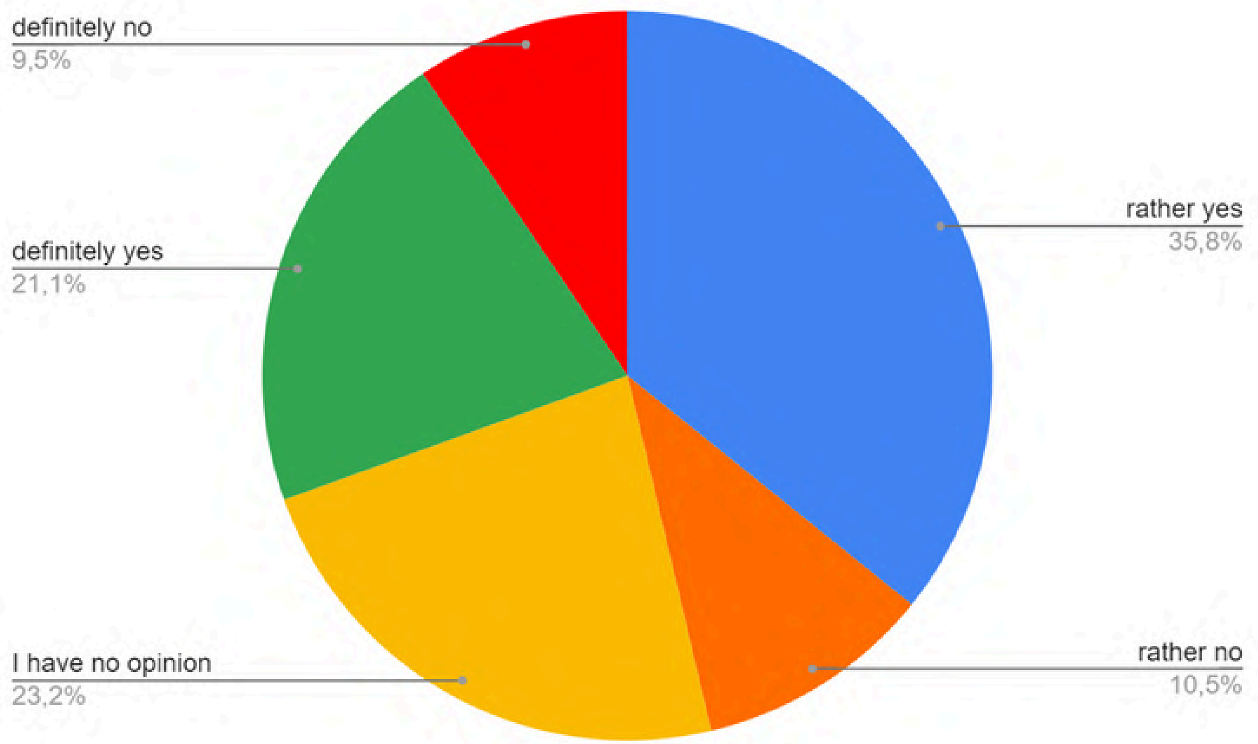


CHART 32 Operators and assemblers of machines and equipment, in particular mining and processing machines; metalworking machines; machines used in the chemical industry

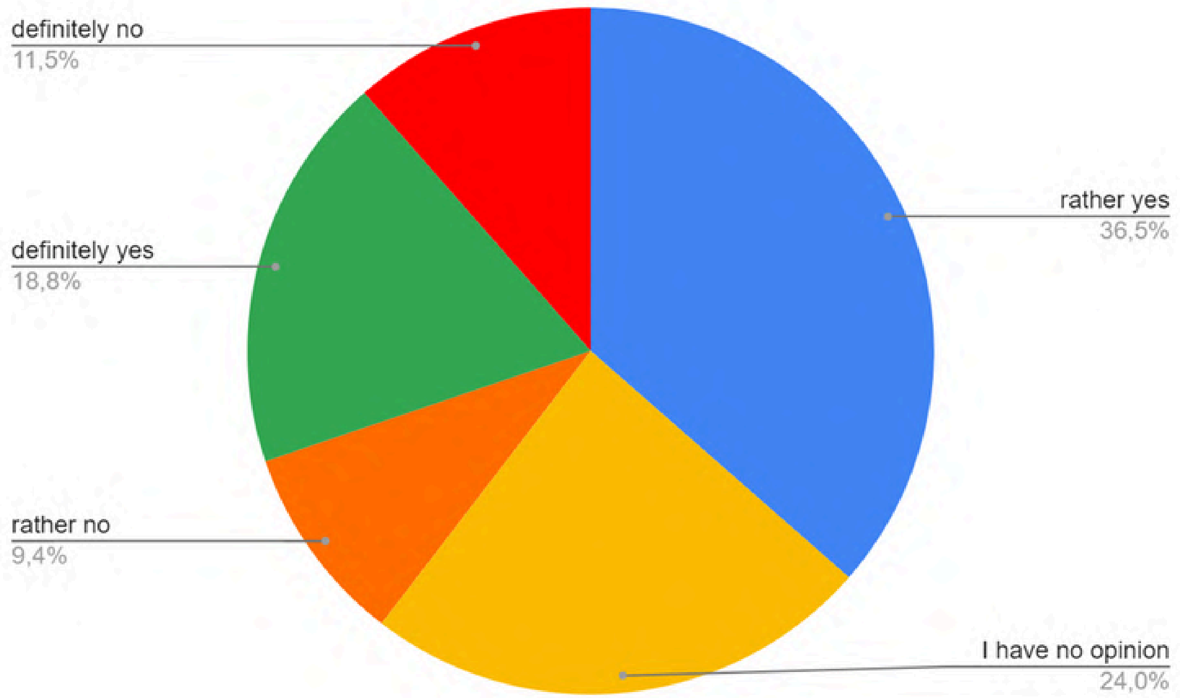


CHART 33 IT specialists and programmers

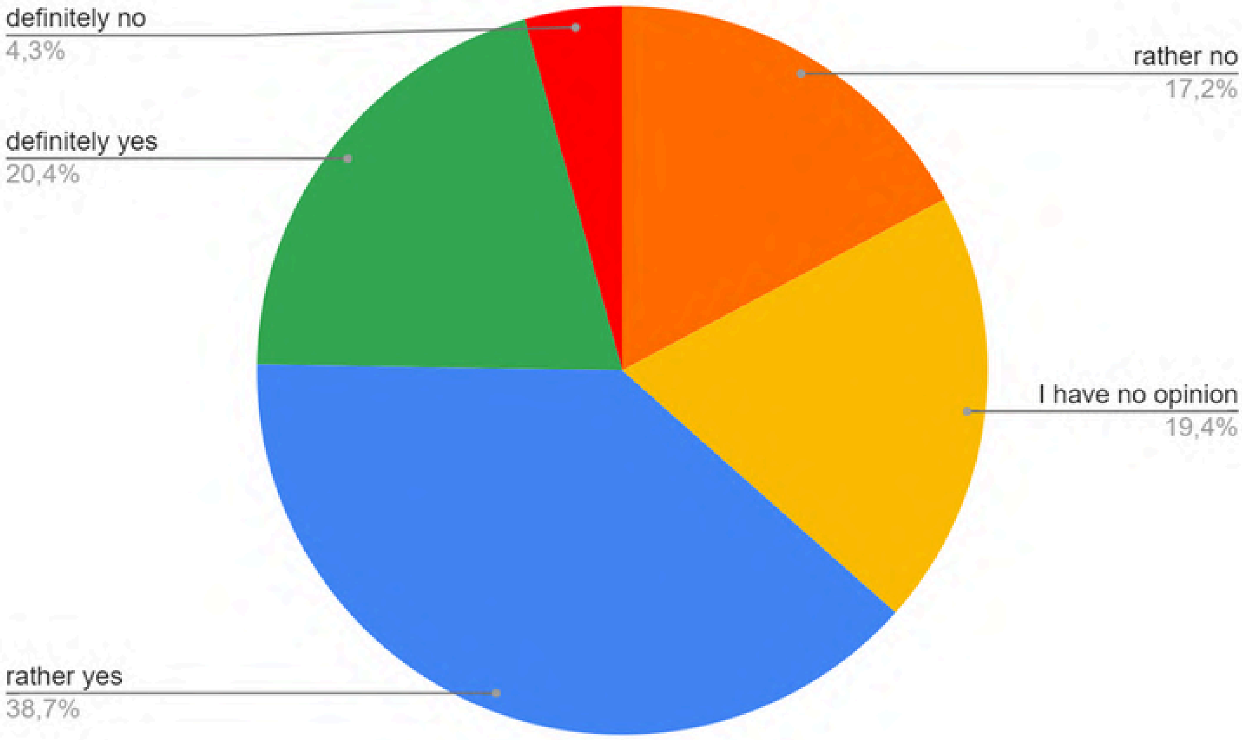


CHART 34 Process safety specialists

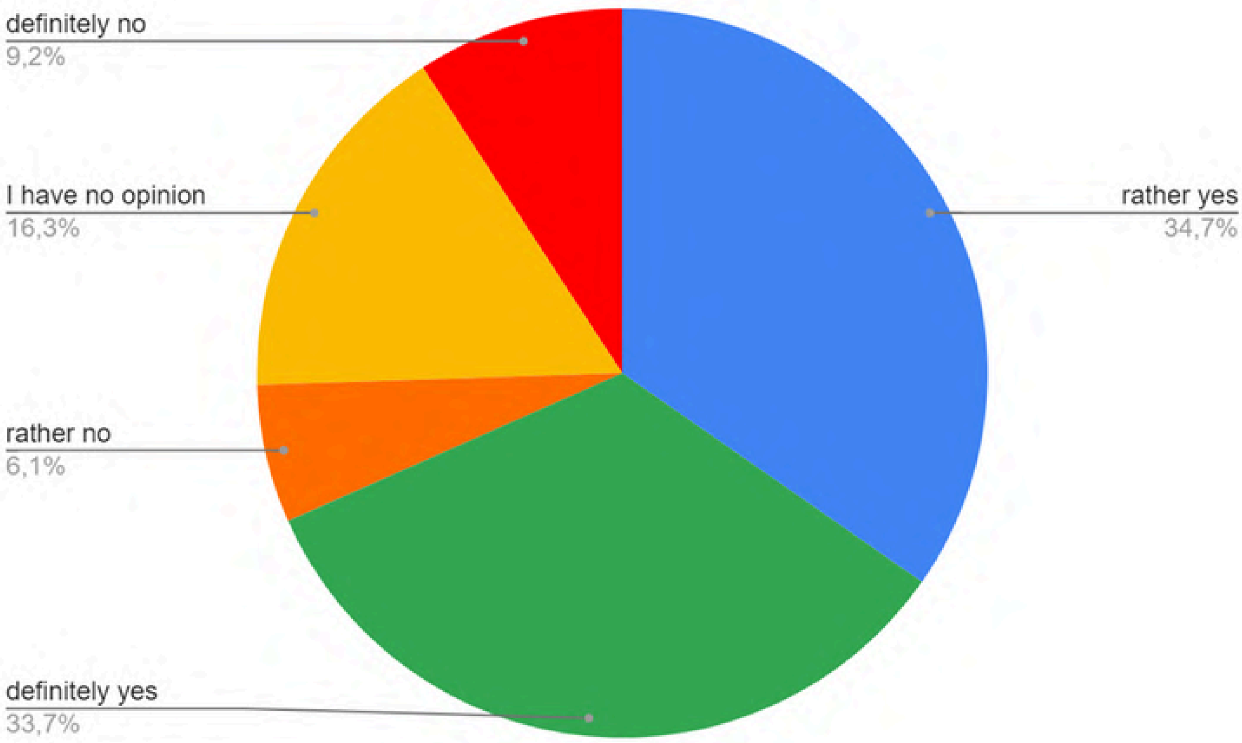


CHART 35 Legal specialists involved in the creation of legal regulations related to the use of hydrogen

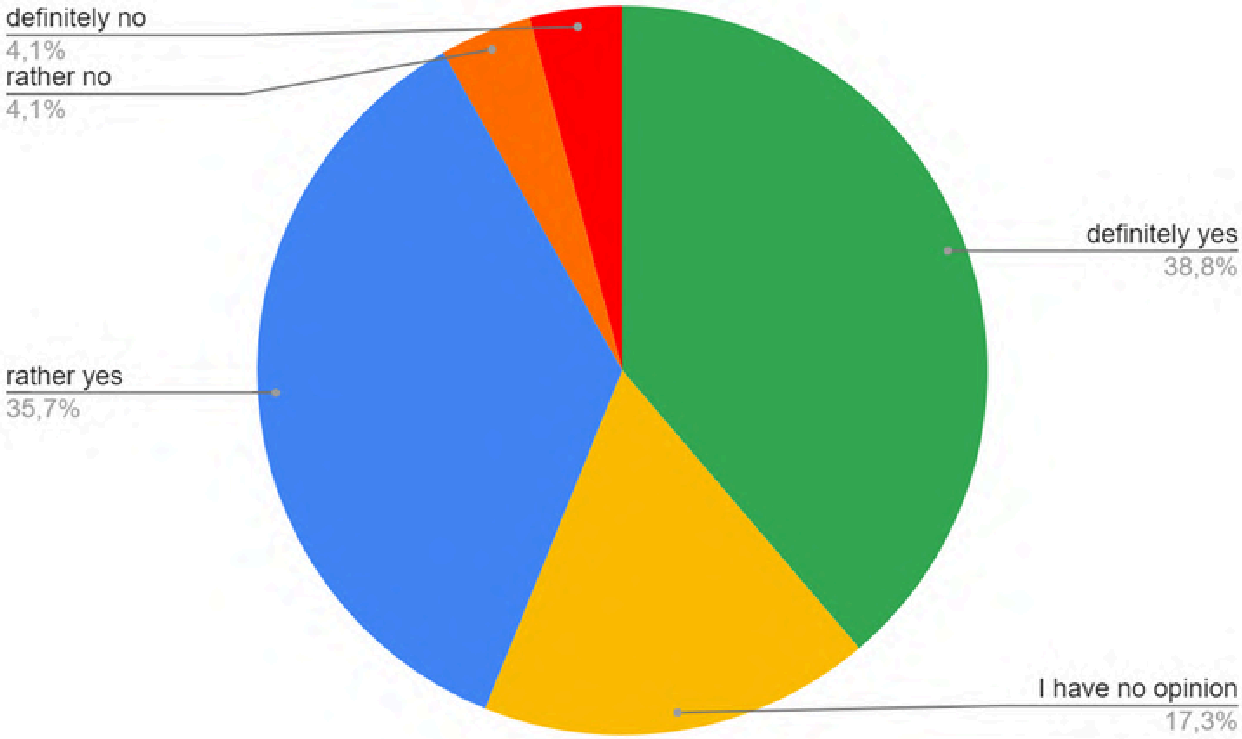


CHART 36 Specialists in energy based on renewable sources

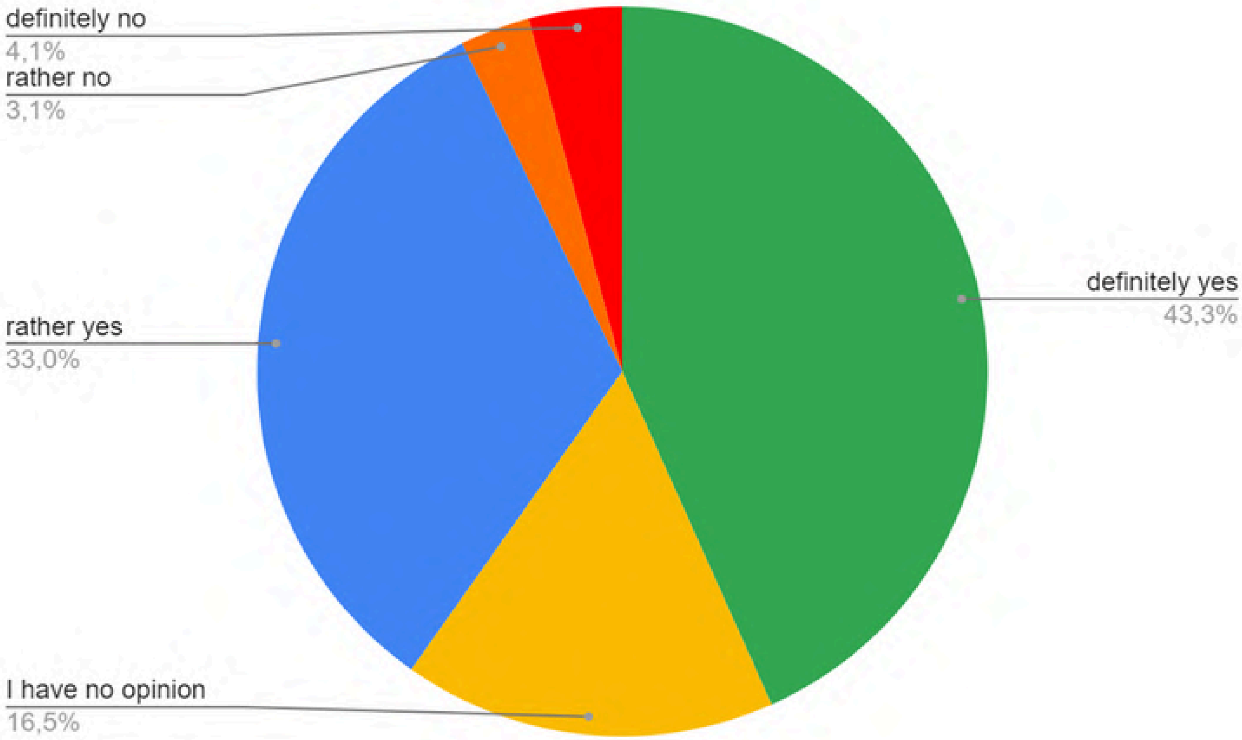


CHART 37 Nuclear energy specialists

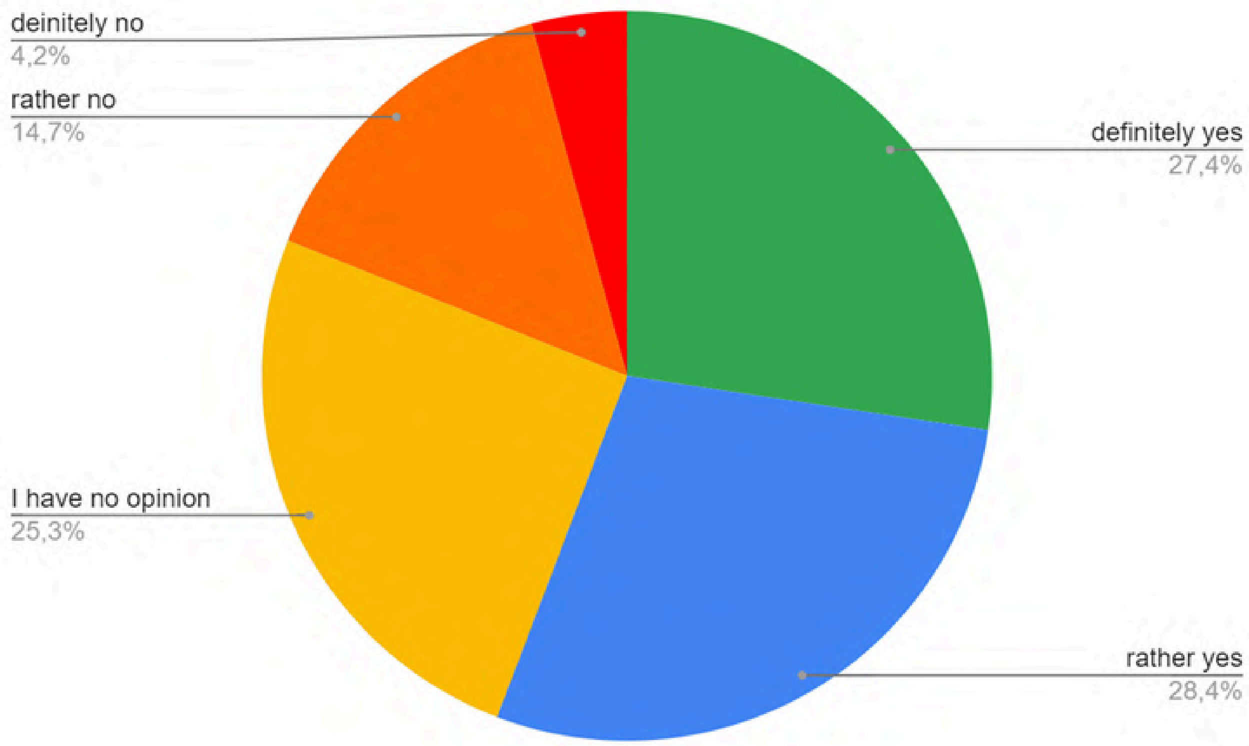


CHART 38 Specialists in vehicle servicing and refueling stations

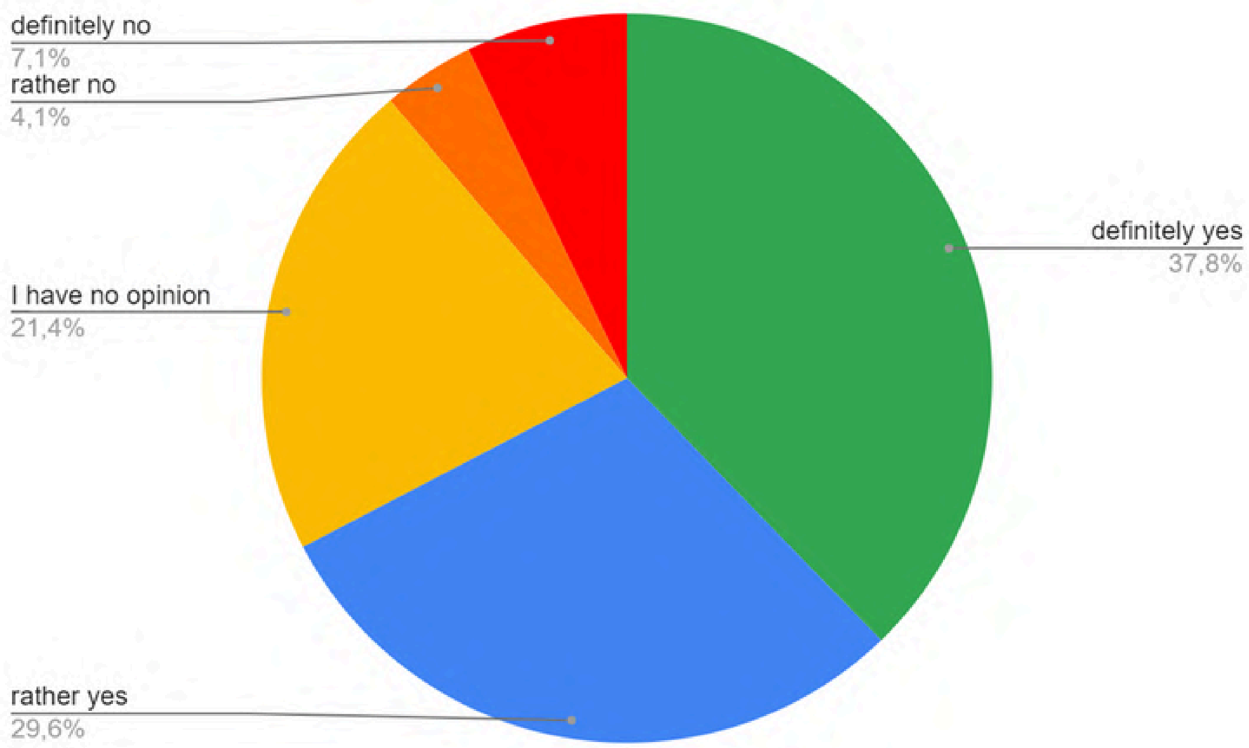


CHART 39 Specialists in materials engineering

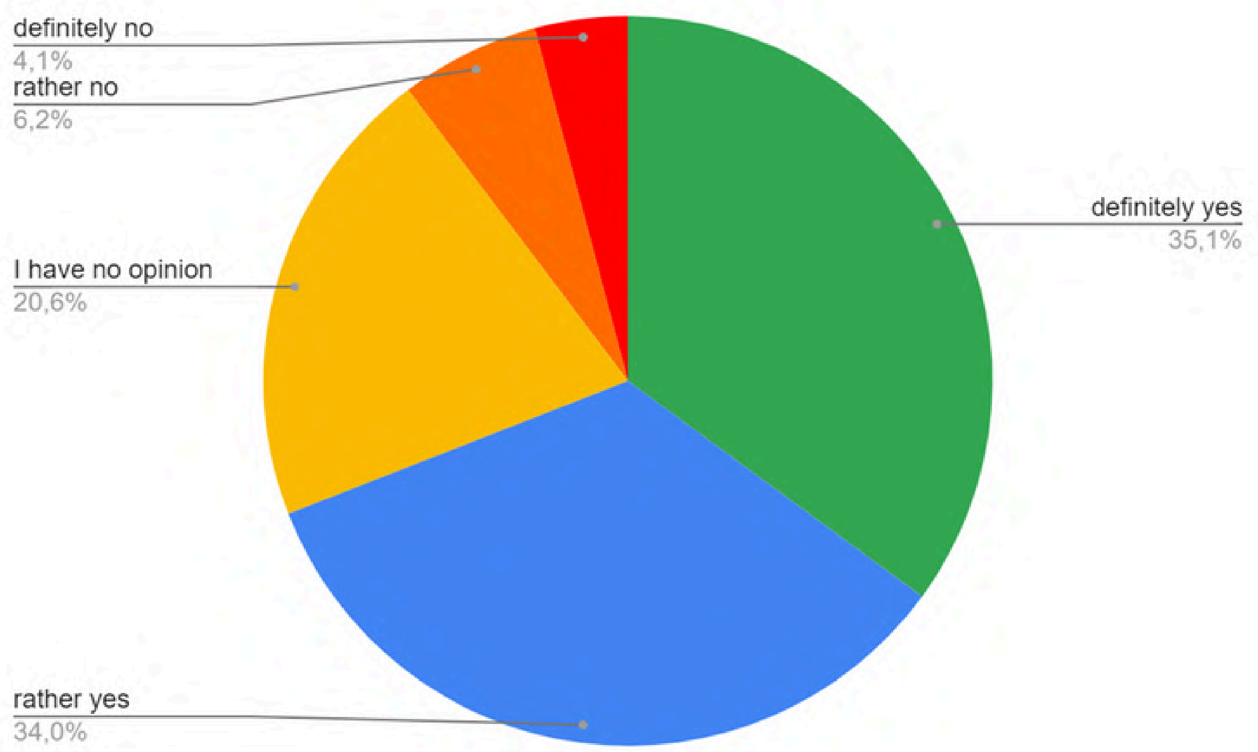
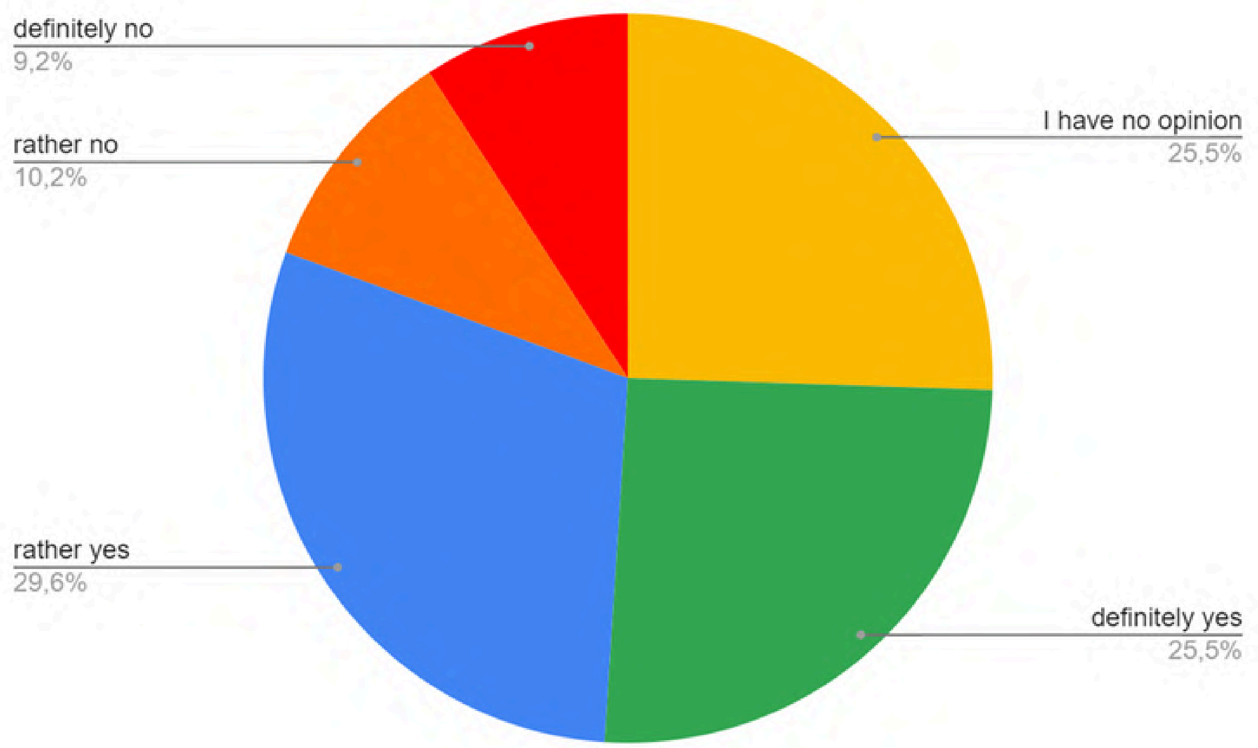


CHART 40 Corrosion specialists



The profile "chemical engineers, chemists" received the most "definitely yes" responses (56.7%). A significant number of responses in this area were also given to the profiles "specialists in energy based on renewable sources" (43.3%) and "specialists in science (especially engineering) (44.1%). Interesting changes occur when the "probably yes" answer is taken into account. Well, in total, the most responses "definitely yes" and "rather yes" were also received by the profile "chemical engineers, chemists" (86.5%), however, the second place was taken by "technicians and specialists in the field of physical sciences and engineering" (82.8%). In total, "specialists in science (especially engineering)" received slightly fewer indications (82.3%). It is also interesting that a lot of responses "definitely yes" and "rather yes" were given to the profile "managers, senior officials, legislators" (77.8%). Therefore, in addition to scientific and technical professional profiles, the respondents also notice the great importance of the legal and organizational environment from the perspective of the development of the hydrogen economy.

On the other hand, the most total responses "definitely not" and "rather not" were received by the profiles "workers, craftsmen in the metal, machinery and related industries" (25.6%), "business and administration specialists" (24%), " sales, marketing and public relations specialists” (22.1%) and “IT specialists and programmers” (21.5%). These indications of the respondents may result from the fact that the above specialties, as a result of ongoing changes in the labor market related to the increasingly intensive automation of individual processes and the popularization of the use of artificial intelligence, in the opinion of the respondents, may be replaced and will not be so important from the perspective of the implementation and development of the hydrogen economy.

A significant number of "I have no opinion" responses were received by the profiles "business and administration specialists" (32.3%), "mechanics and machine operators" (26.3%), and "corrosion specialists" (25.5%) and nuclear energy specialists (25.3%). These indications may have resulted from the respondents' lack of knowledge of the role that specific specialties could play in the hydrogen economy.

In question no. 17, respondents were asked to indicate the areas whose development, in their opinion, would be crucial for the hydrogen economy. Participants were offered 14 areas for evaluation, which they had to rate on a five-point scale from "definitely not" to "rather not", "I have no opinion", "probably yes" to "definitely yes" (see charts 41 to 54).

CHART 41 Manufacturing technologies

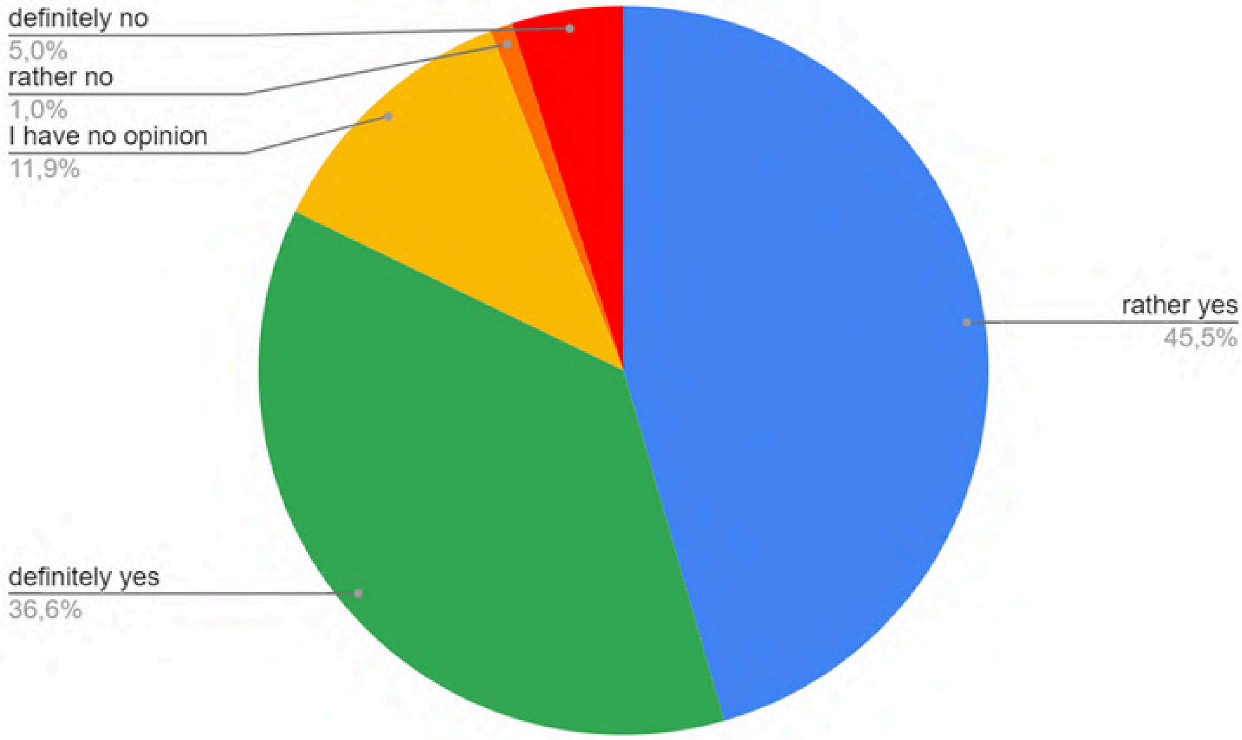
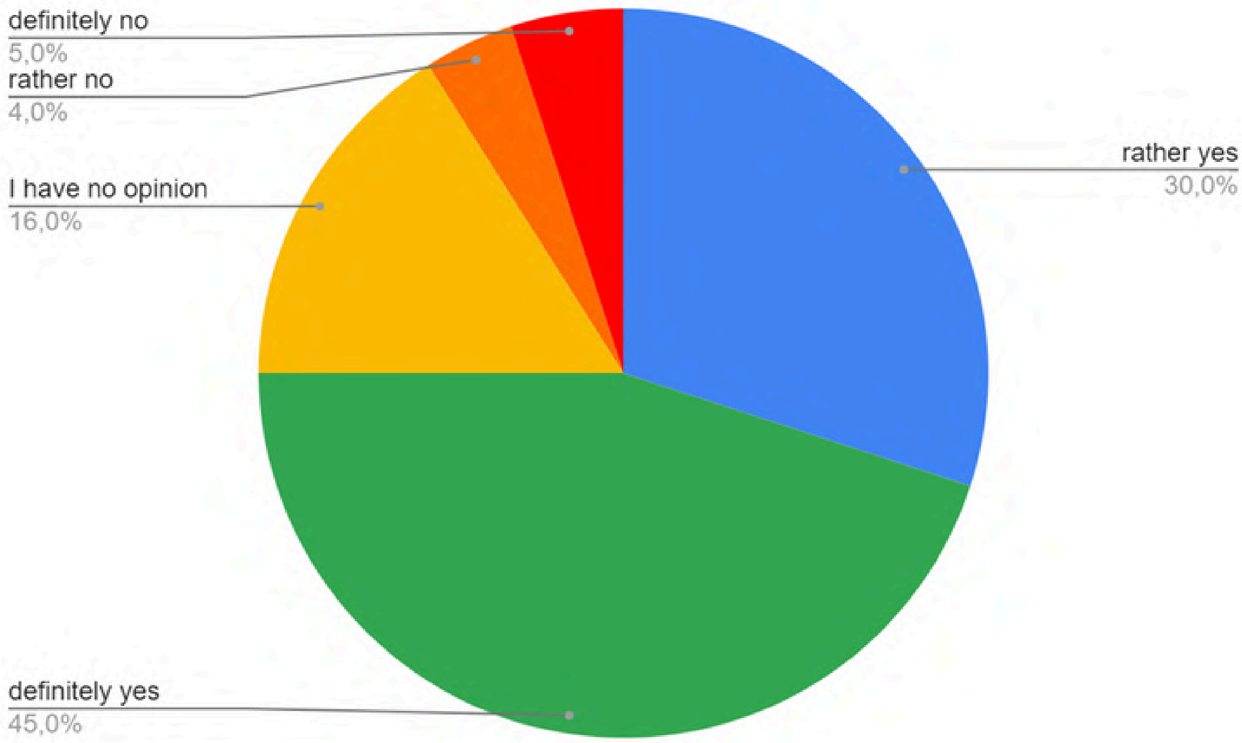


CHART 42 Storage and conversion technologies



Co-funded by the European Union

CHART 43

Distribution technologies

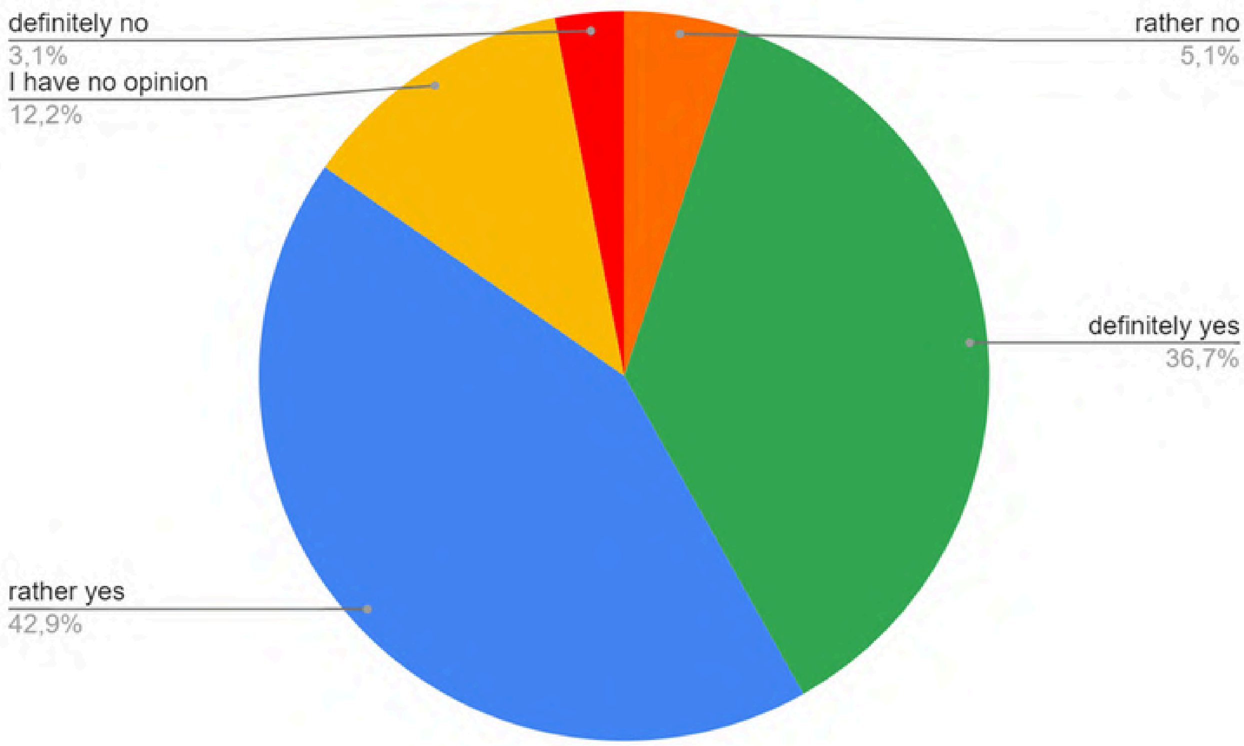


CHART 44

Technologies for the use of hydrogen and its derivatives

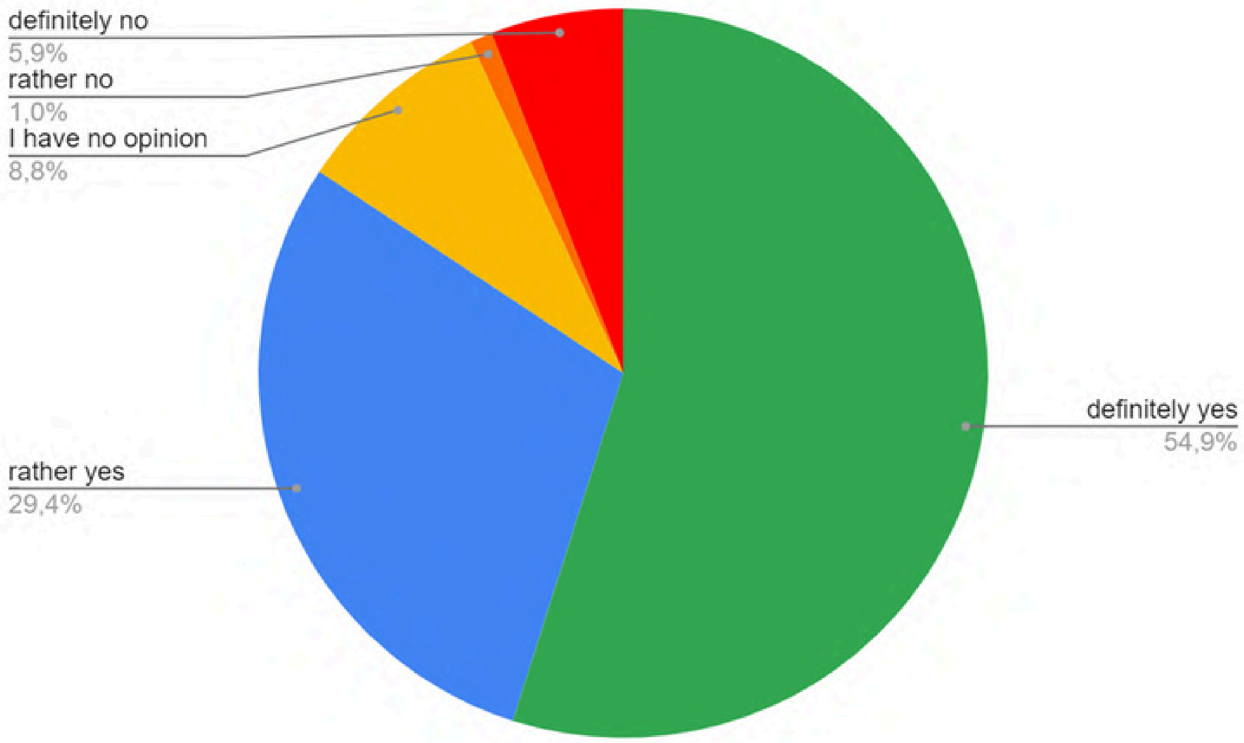


CHART 45

Hydrogen transport technologies

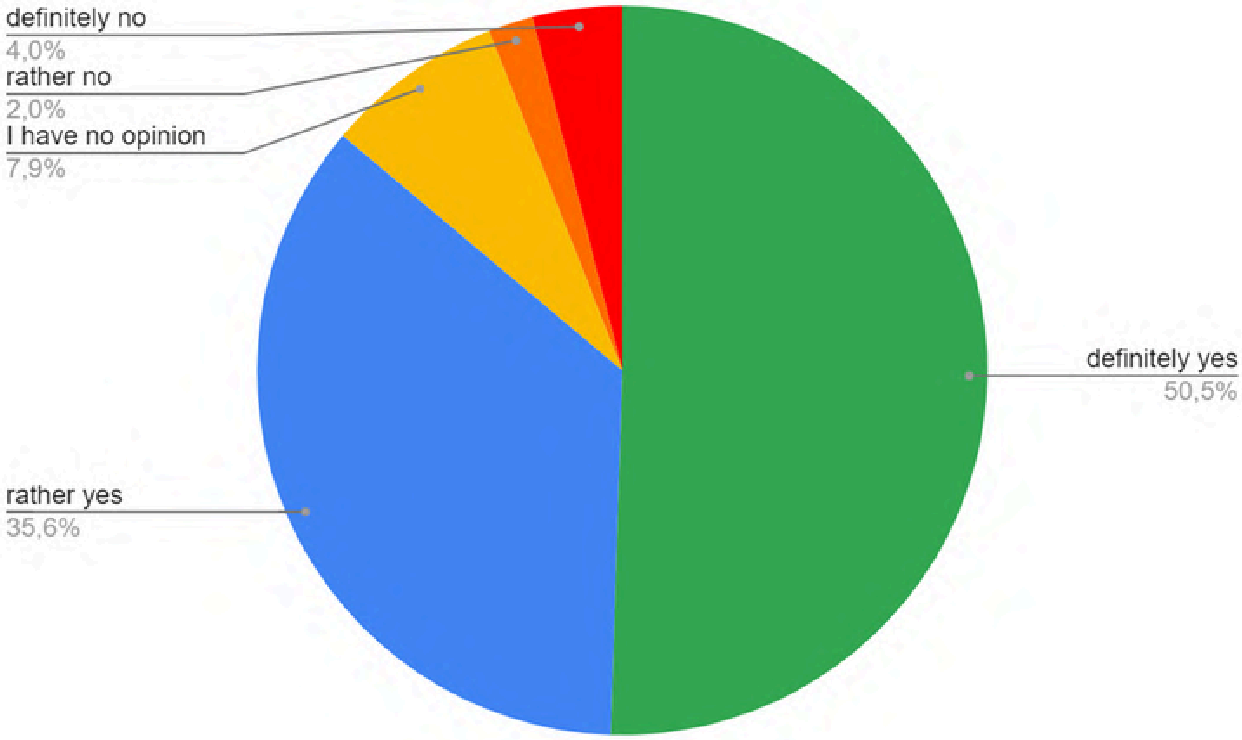


CHART 46

Technologies related to the construction of new renewable energy generating capacity

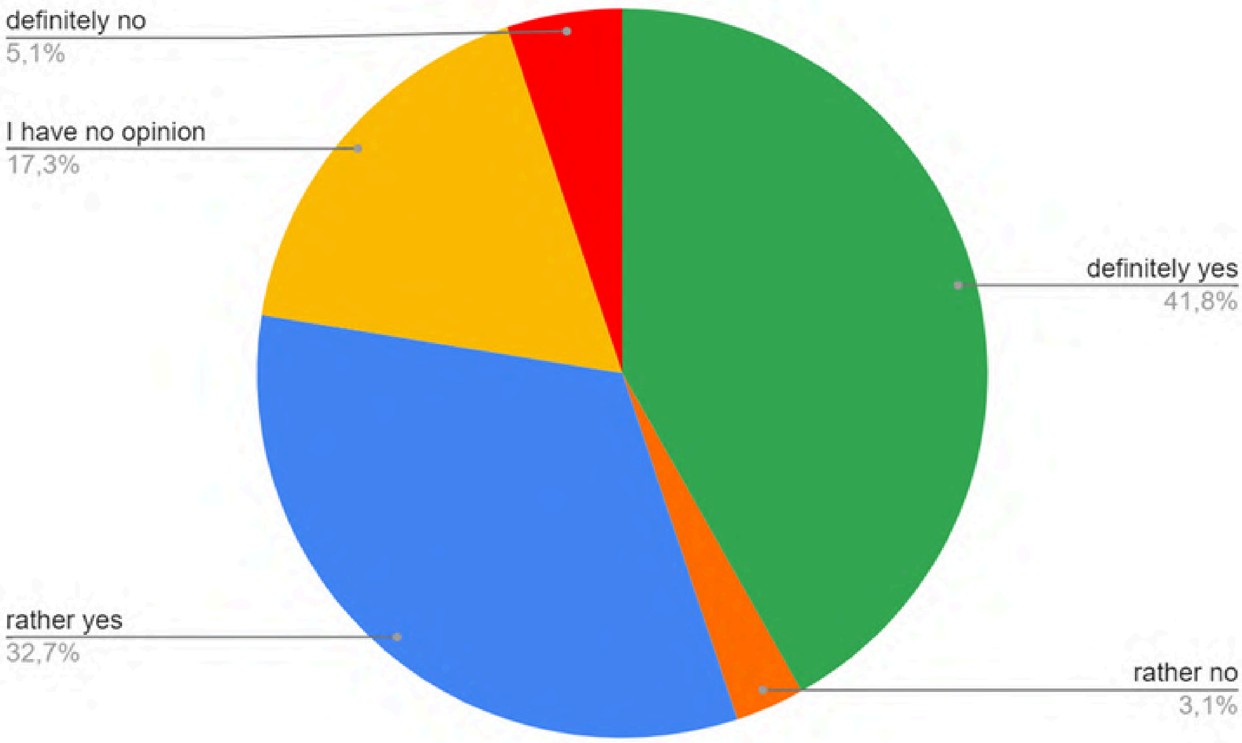


CHART 47

Technologies related to the construction of installations for the production of hydrogen and its derivatives from low-emission sources

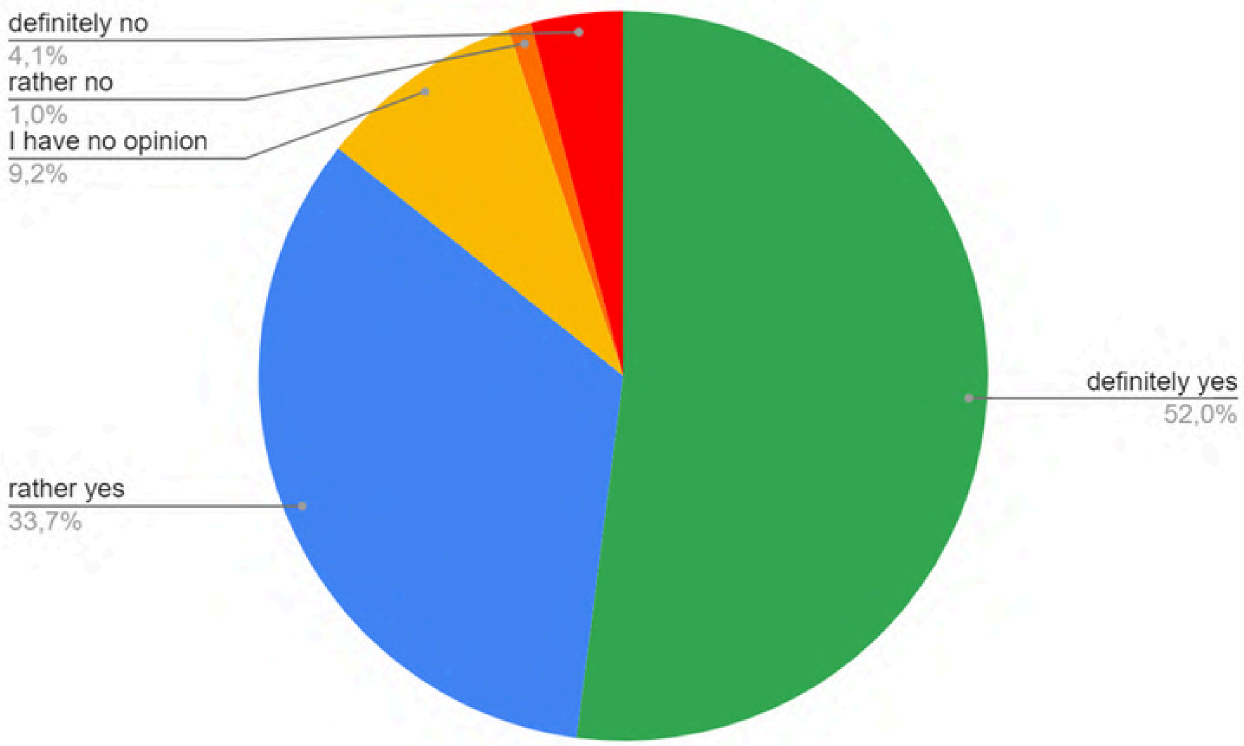


CHART 48

Technologies related to the construction and installation of electrolyzers

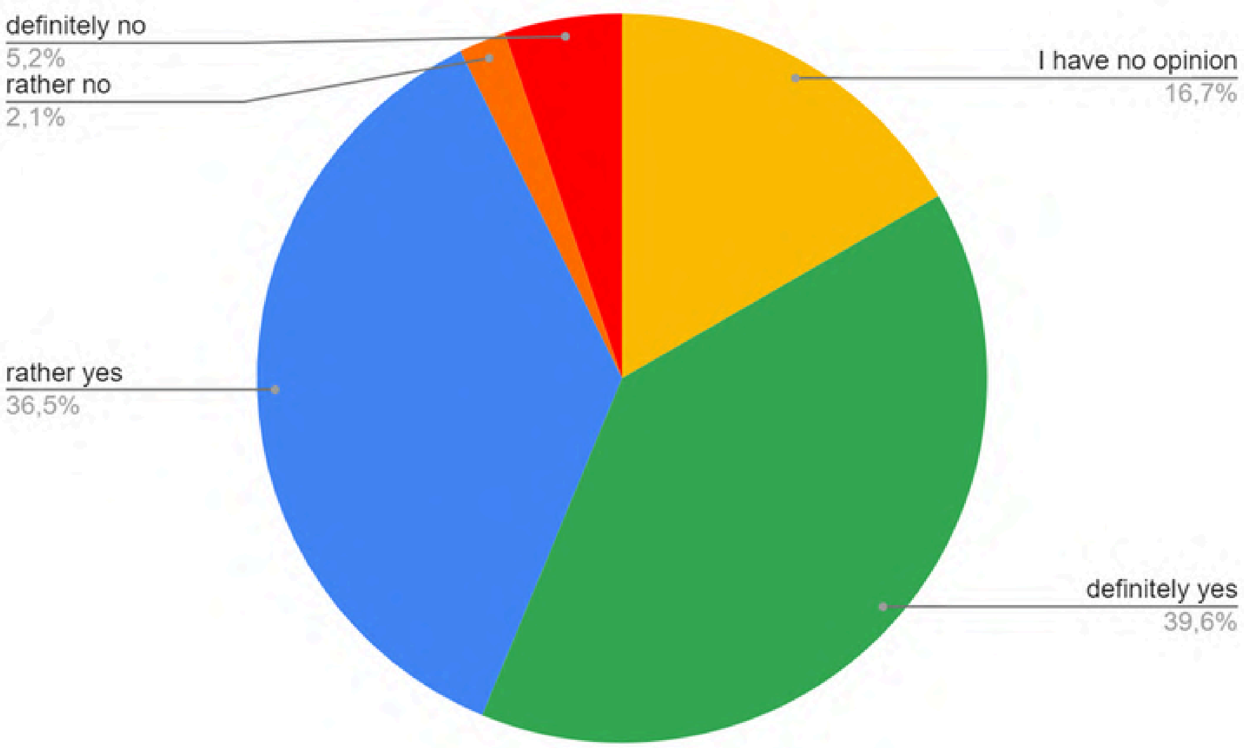


CHART 49 Technologies related to the hydrogen distribution network

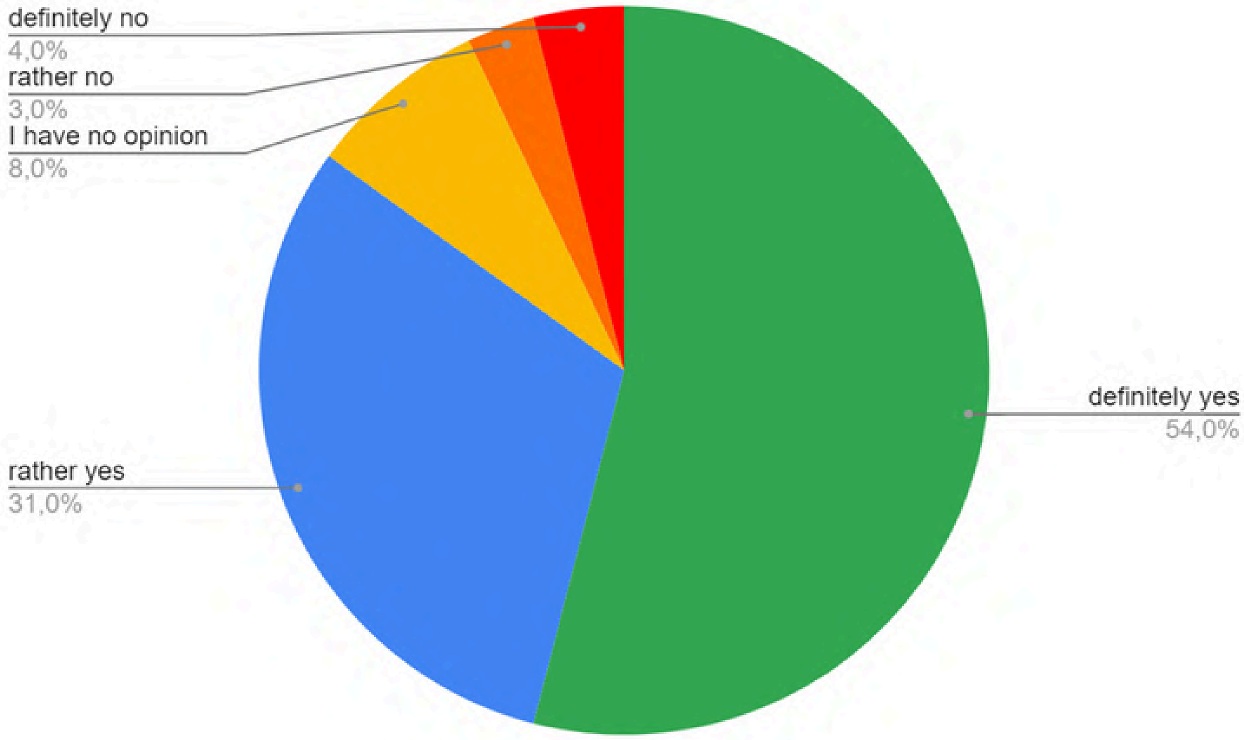


CHART 50 Technologies related to the adaptation of existing industrial and transport infrastructure

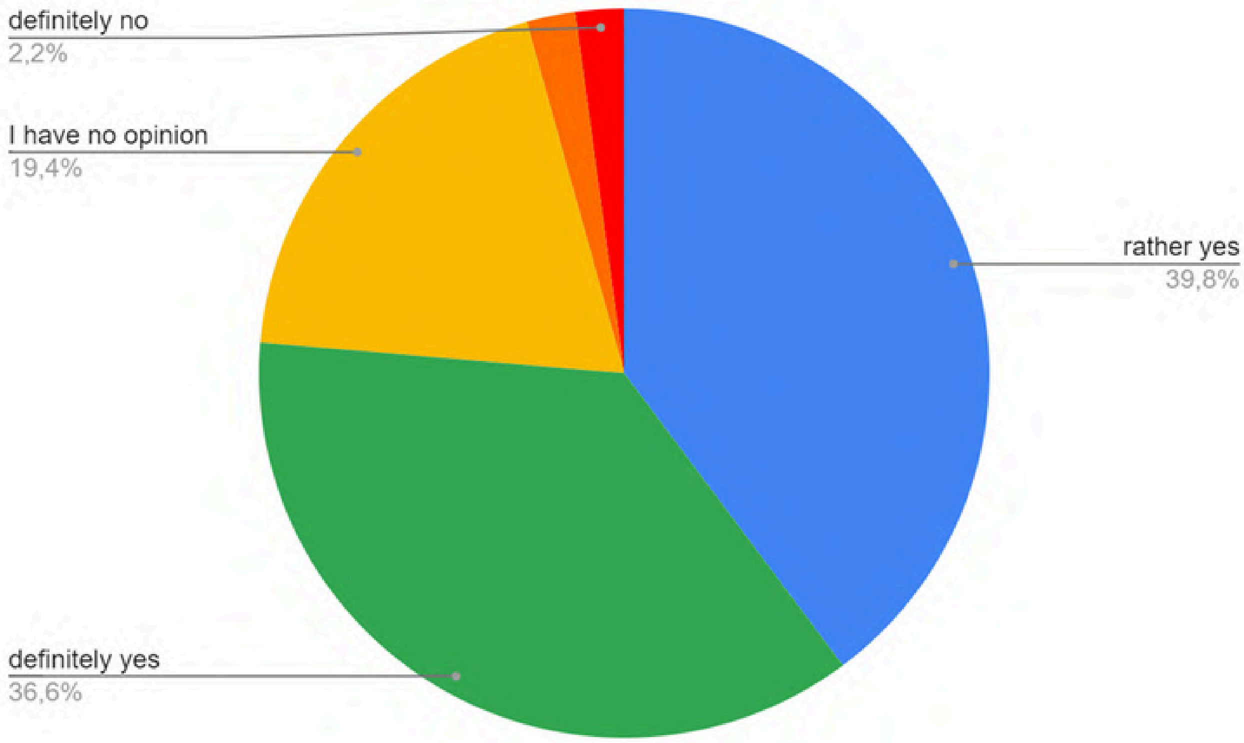


CHART 51 Technologies related to hydrogen refueling infrastructure

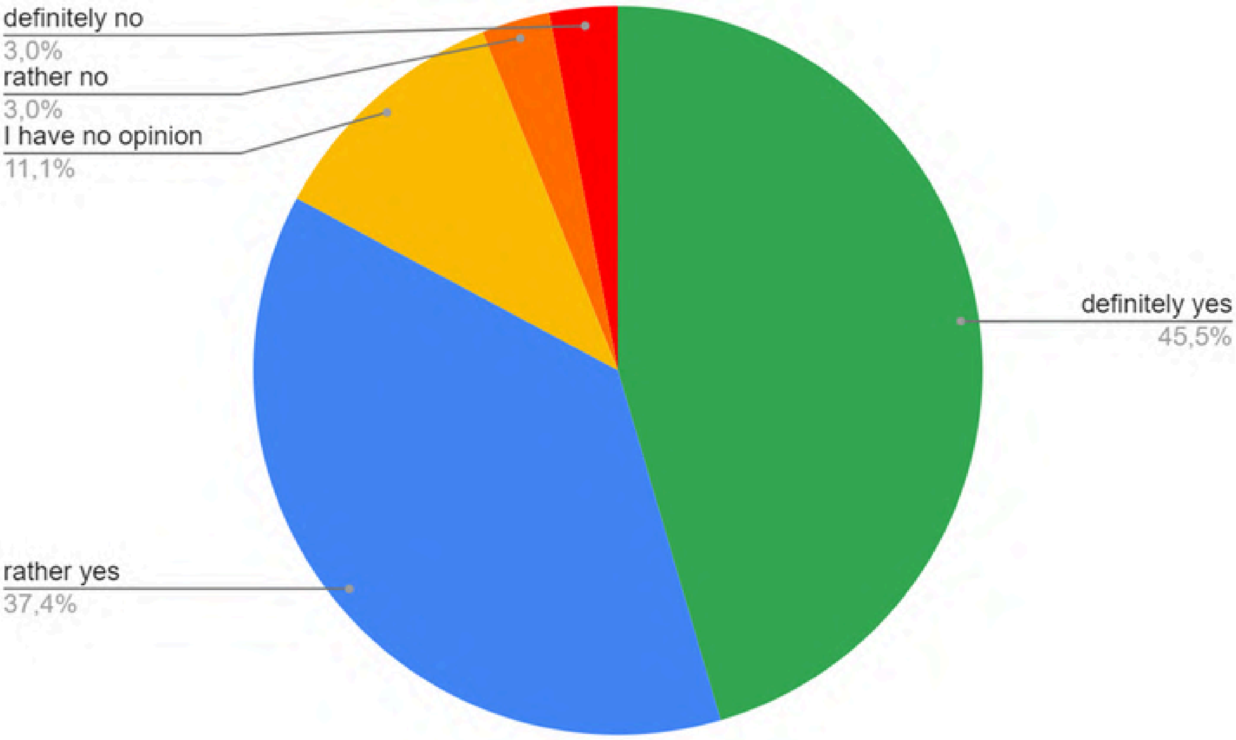


CHART 52 Technologies related to the production of fuel cells used in energy, heating, transport and other sectors

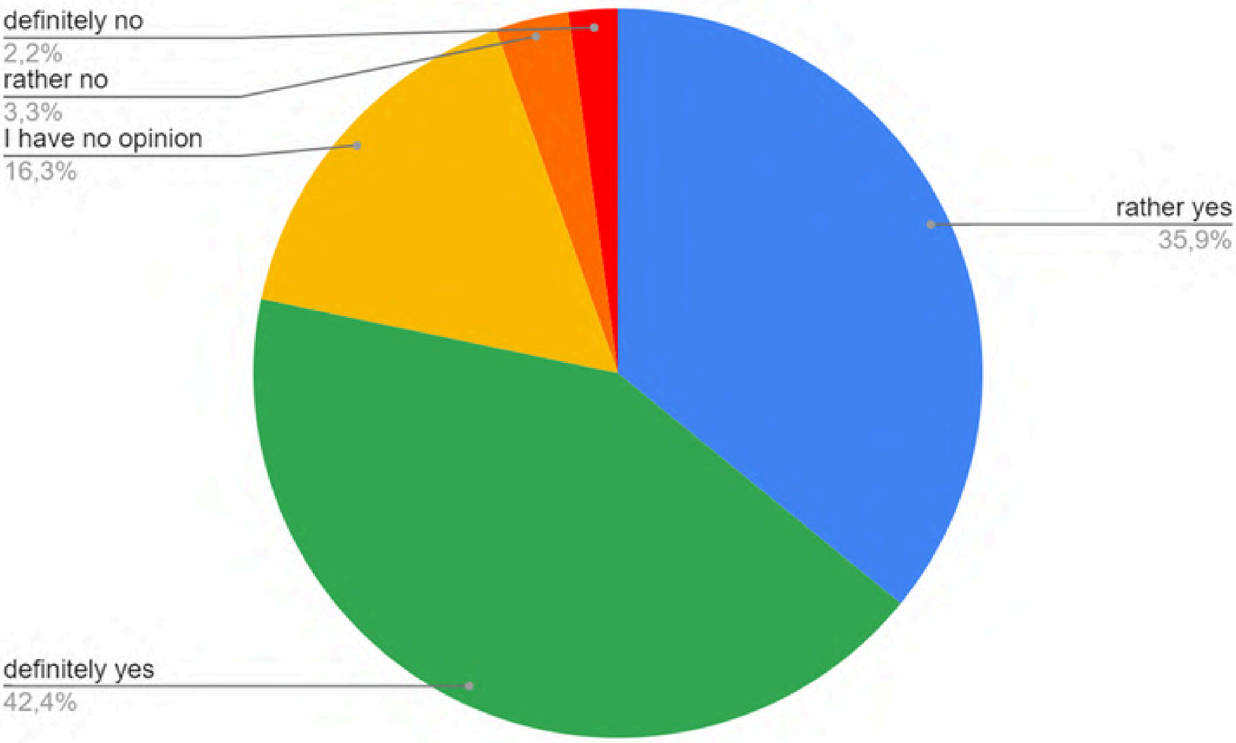


CHART 53 Technologies related to nuclear energy

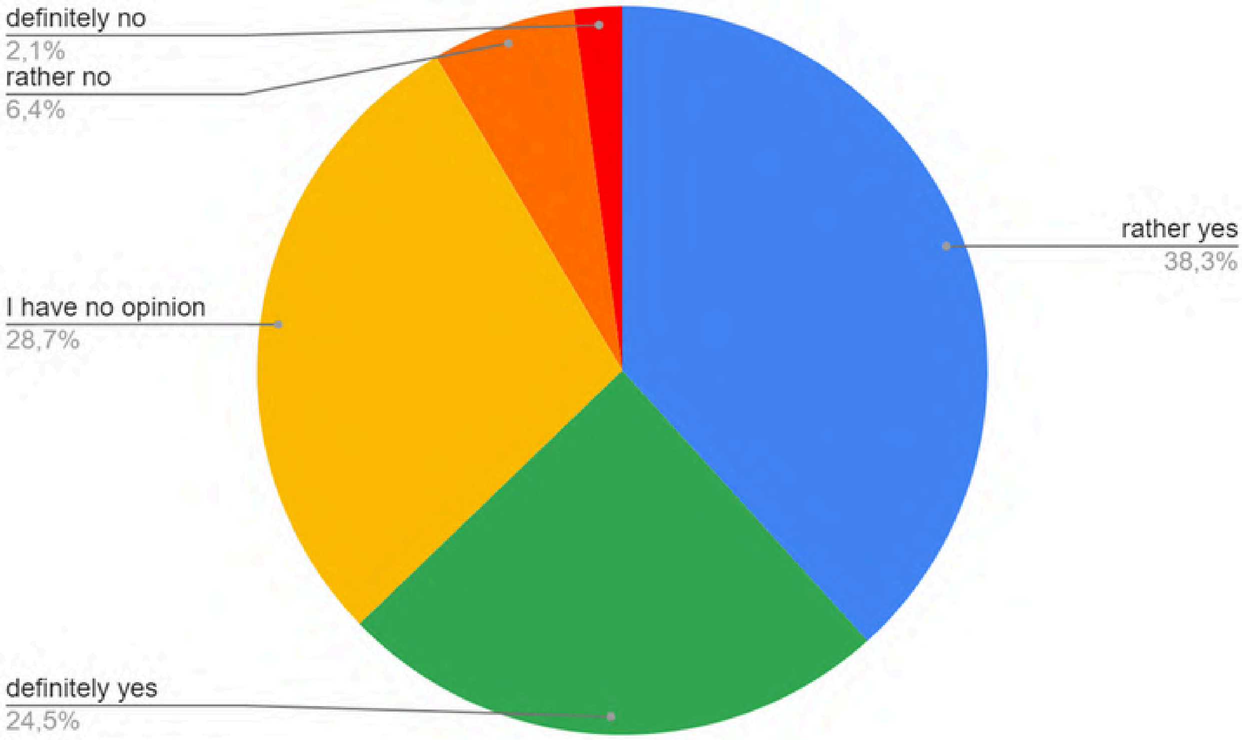
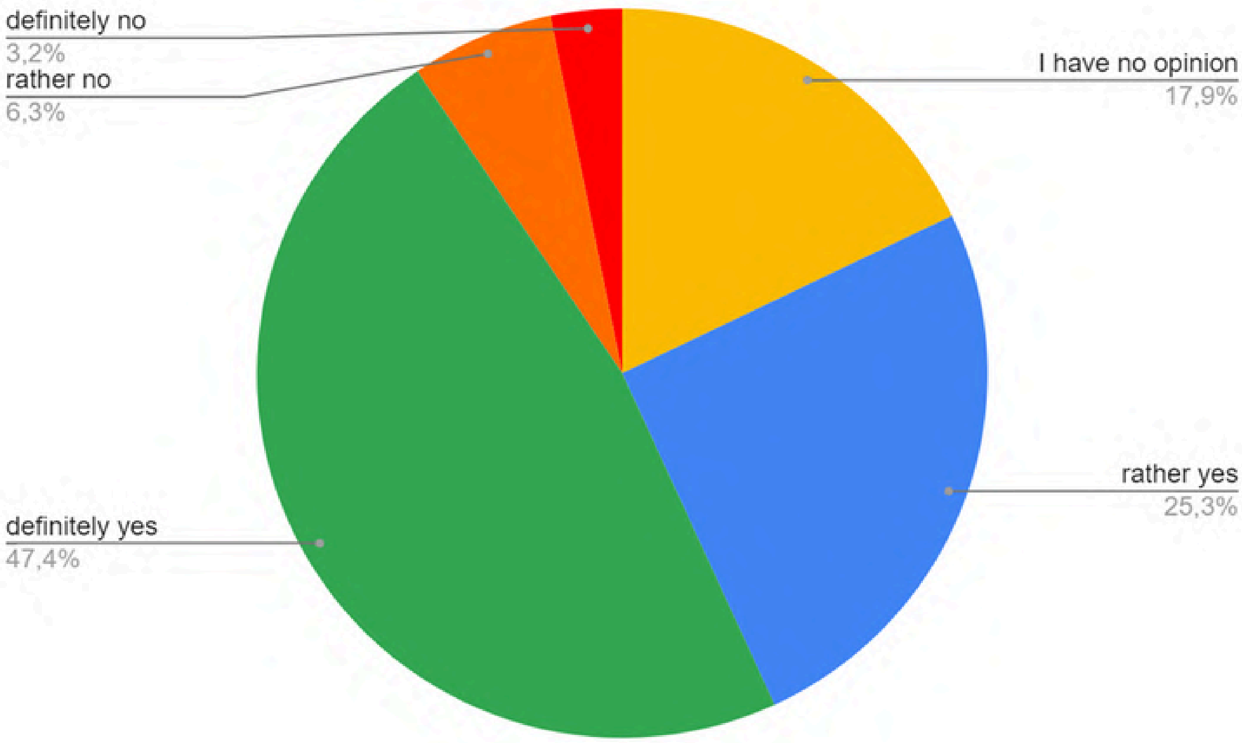


CHART 54 Security technologies



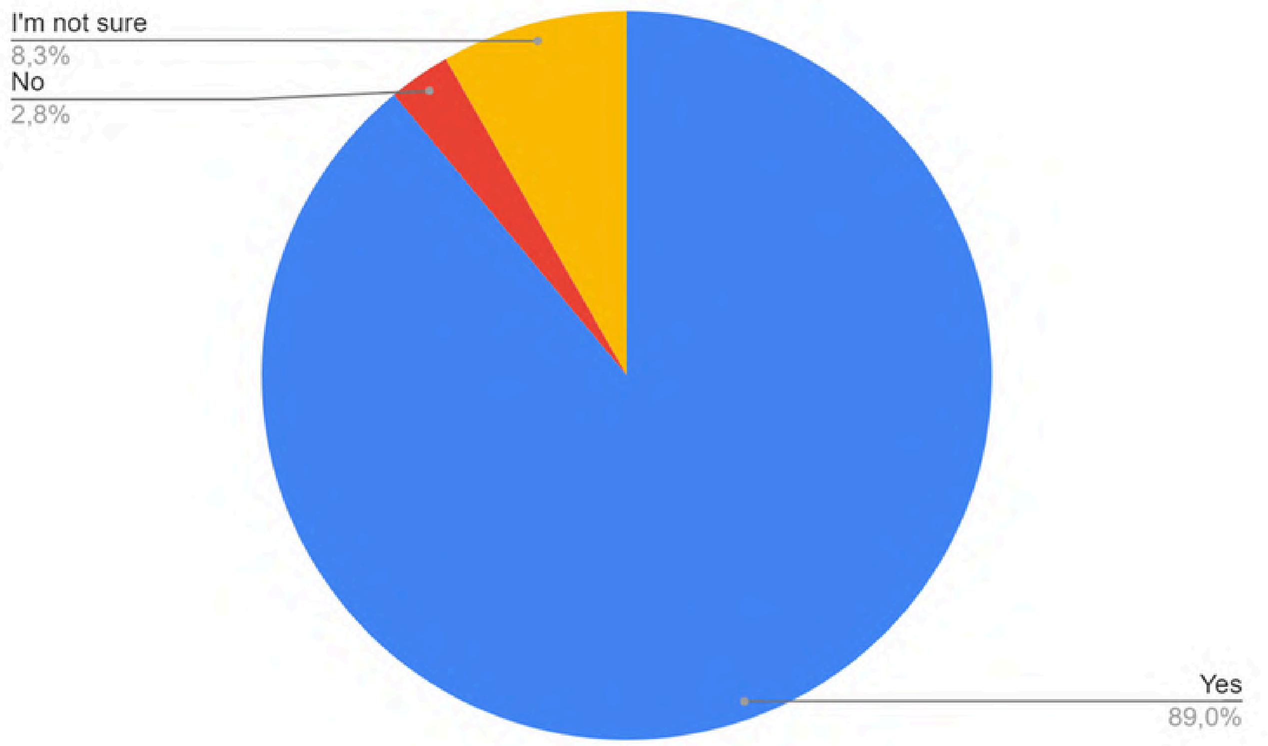
The most "definitely yes" responses were given to "technologies for the use of hydrogen and its derivatives" (54.9%), "technologies related to the hydrogen distribution network" (54%), "technologies related to the construction of installations for the production of hydrogen and its derivatives from low-emission sources ” (52%) and “hydrogen transport technologies” (50.5%). Respondents therefore pointed out the key importance of areas strictly related to the hydrogen economy. The above results are slightly different if we compare two answers, i.e. "definitely yes" and "rather yes". In the case of such a summary, the most indicated areas were "hydrogen transport technologies" (86.1%), as well as "technologies related to the construction of installations for the production of hydrogen and its derivatives from low-emission sources" (85.7%). A large number of responses were also received in the area of technologies related to the hydrogen distribution network (85%) and "technologies for the use of hydrogen and its derivatives" (84.3%).

At the other extreme, the most responses taken together as "probably not" and "definitely not" were received by the areas of "storage and conversion technologies" (9%) and "security technologies" (8.5%). However, as presented above results, there was a very small number of indications, therefore it can be concluded that all areas proposed in the study are important, according to the respondents, from the perspective of the development of the hydrogen economy.

It should also be noted that there were quite a large number of "I have no opinion" responses in the areas of "technologies related to nuclear energy" (28.7%) and "technologies related to the adaptation of existing transmission and transport infrastructure" (19.4%). This seems to indicate the respondents' lack of knowledge regarding the possible possibilities and importance of these technologies in the area of hydrogen economy.

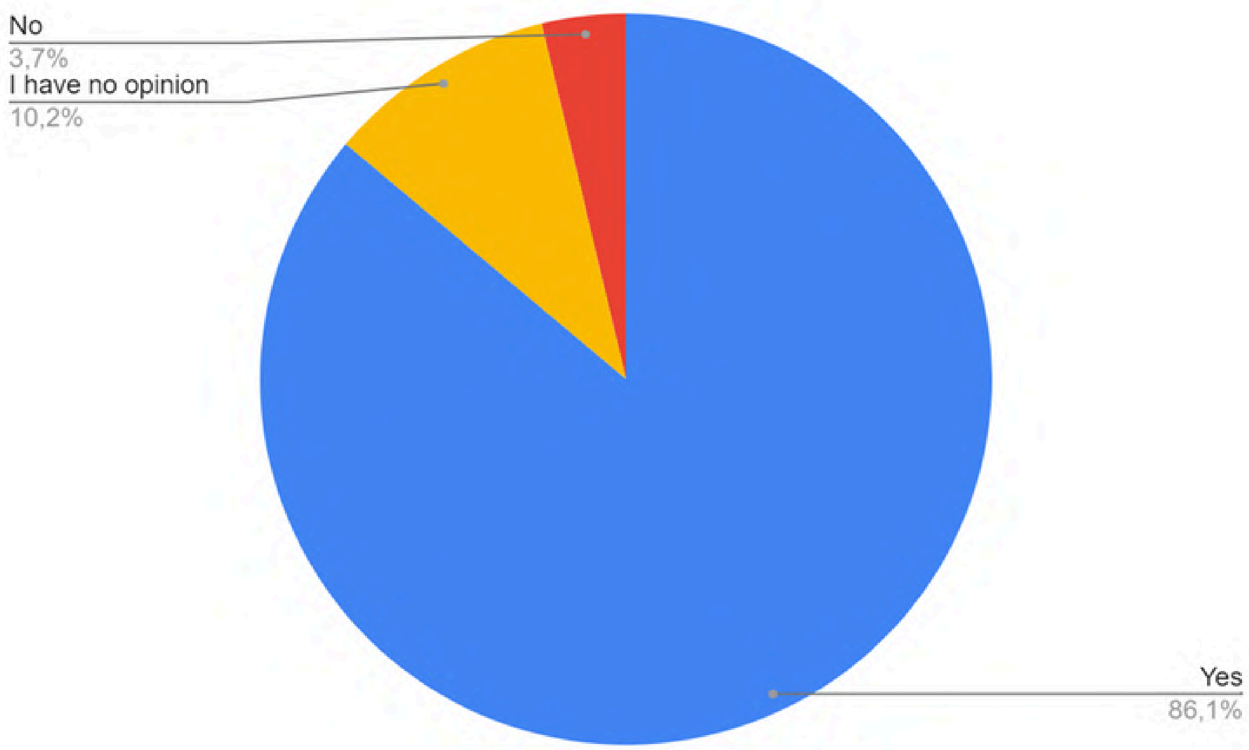
In question no. 18, respondents were asked to express their opinion on the need for specialized education in the context of the hydrogen economy. The vast majority of respondents answered this question affirmatively (89%) (see Figure 55).

CHART 55 Do you see the need for specialized education in the context of the hydrogen economy?



Also regarding the next question regarding expressing their opinion on whether a dedicated training program will be beneficial for current and future employees of the hydrogen sector, the vast majority of respondents answered "Yes" (86.1%). However, only 10.2% said they had no opinion and 3.7% responded negatively (see Figure 56).

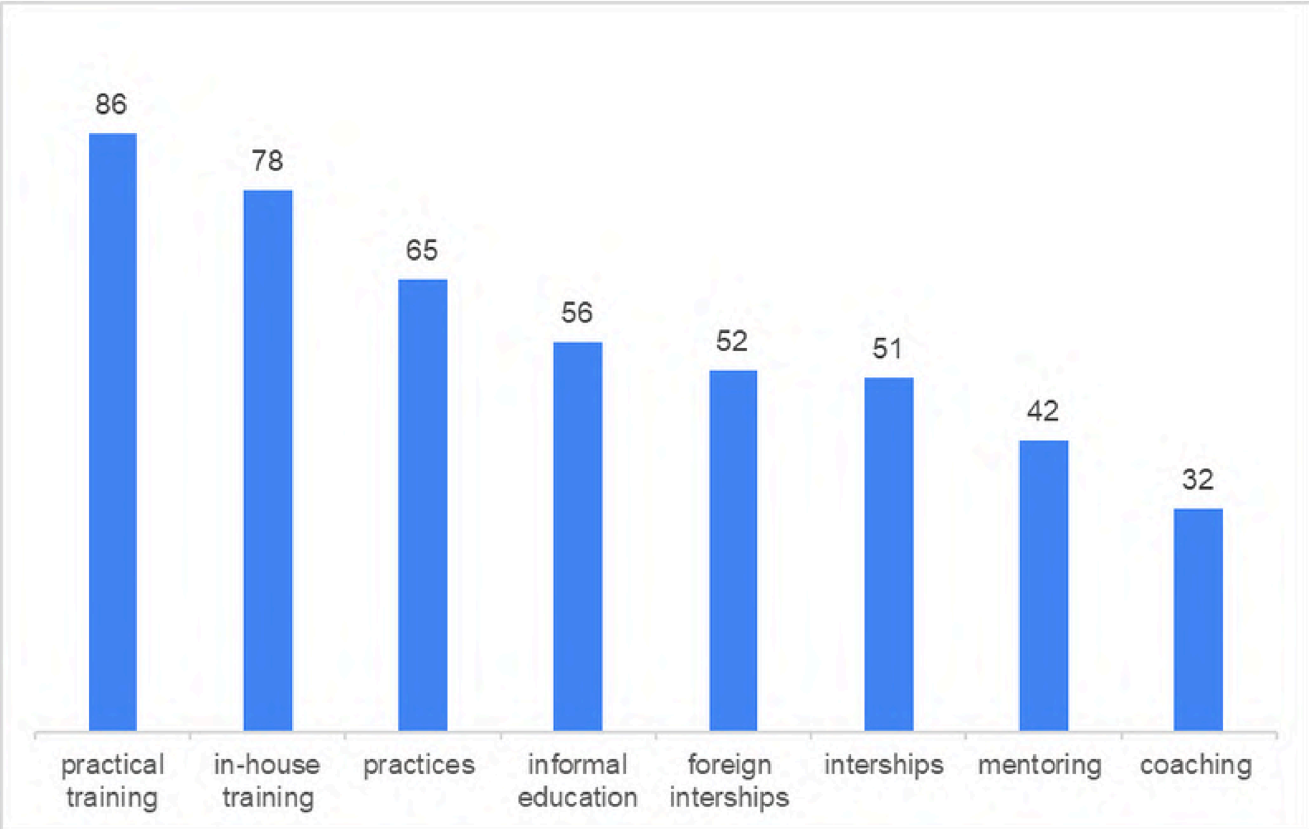
CHART 56 Do you think a dedicated training program will be beneficial for current and future employees in the hydrogen sector?



In question no. 20, respondents were asked to indicate what actions, apart from formal education, should be taken to prepare current and future employees to work in the hydrogen economy.

In this context, respondents most often mentioned in-house training as the most desirable preparatory activities for working in the hydrogen economy. The next answers in terms of the number of indications were internships and informal education. “Coaching” and “mentoring” received the least number of responses.

CHART 57 What actions, apart from formal education, need to be taken to prepare current and future employees to work in the hydrogen economy?



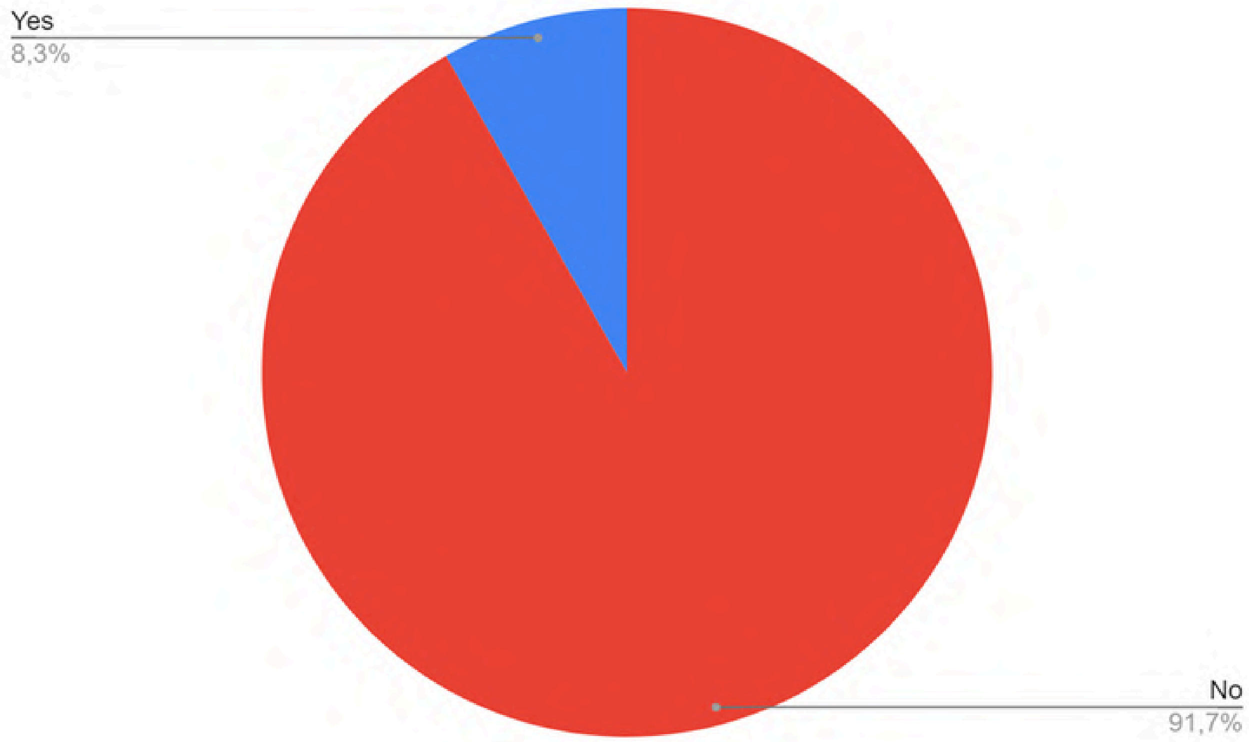
Question 21 was an open question. Respondents were asked to indicate obstacles that, in their opinion, constitute a barrier to access to new qualifications needed in the hydrogen sector. A total of 68 answers were provided, of which as many as 25 respondents concerned the lack of knowledge and awareness among employees and employers. Therefore, the respondents notice problems and barriers in the development of new qualifications at the very beginning, i.e. the lack of awareness and knowledge about the hydrogen sector.

The next most common answer (15 responses) was the lack of qualified staff in this area, which in fact also refers to the general lack of knowledge and awareness about the hydrogen economy indicated by the respondents. Respondents also indicated that the barrier to acquiring new qualifications needed in the hydrogen sector is the lack of training offers in this area (12 indications) as well as insufficient promotion of hydrogen technologies (12 indications).

In addition to the above, respondents pointed out the lack of time and financial resources for developing new qualifications. Respondents also noted that due to the fact that this is a new field, there is a lack of regulations in this area, especially in the area of national legislation, which is associated with not fully specified needs and requirements in relation to employees and employers.

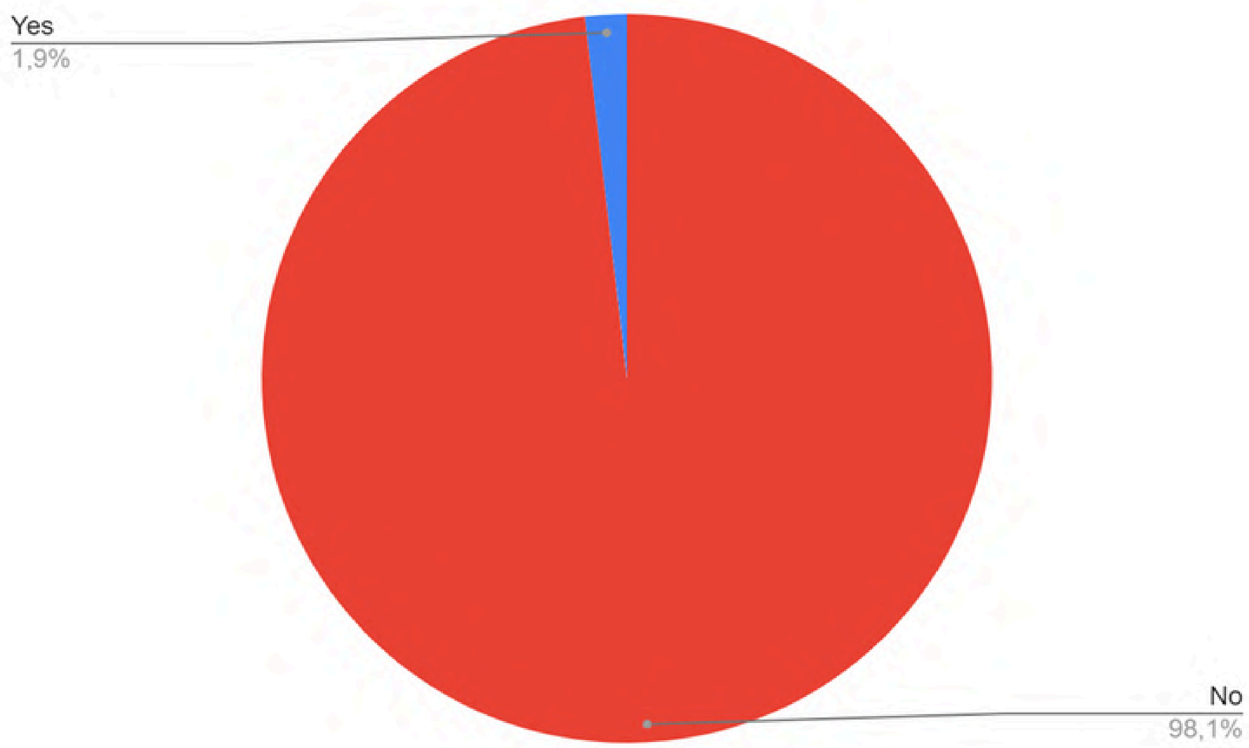
In the next question, respondents were asked to indicate whether they had participated in training or courses on hydrogen technologies in the last year. The vast majority of respondents (91.7%) answered "No".

CHART 58 Have you participated in training or courses on hydrogen technologies in the last year?



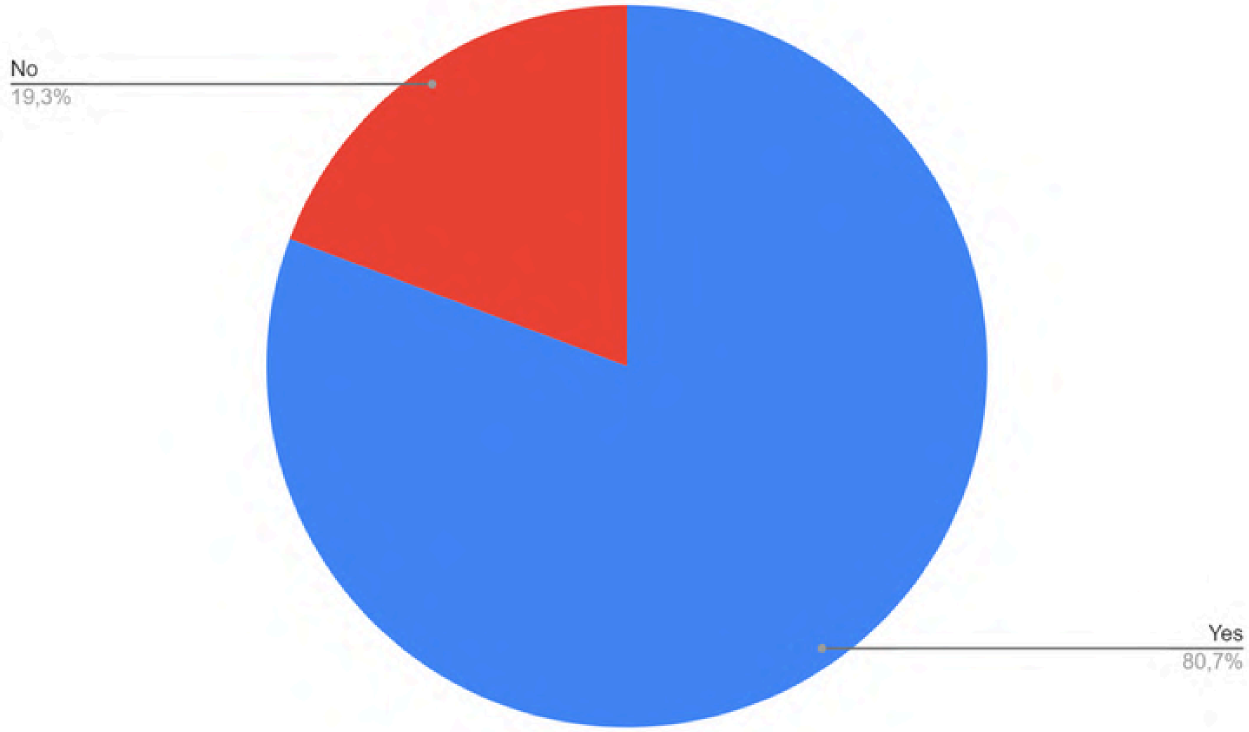
In question 23, respondents were asked to answer the question whether they had certificates or qualifications related to hydrogen technology. In the case of this question, the vast majority of respondents also gave a negative answer (98.1%)

CHART 59 Do you have a certificate or qualification related to hydrogen technology?



In question 24, respondents were asked to express their opinion on their openness to developing their skills and knowledge in the area of hydrogen technologies. The vast majority of respondents answered "Yes" (80.7%).

CHART 60 Are you open to developing your skills and knowledge in the area of hydrogen technologies?



SUMMARY:

The conducted research primarily shows that, according to the respondents, the most important professional profiles for the hydrogen economy are: "chemical engineers", "technicians and specialists in the field of physical sciences and engineering", "specialists in the field of science (especially engineering)" and " managers, senior officials, legislators."

The respondents also indicated areas whose development, in their opinion, would be crucial for the hydrogen economy. These are: "hydrogen transport technologies", "technologies related to the construction of installations for the production of hydrogen and its derivatives from low-emission sources", "technologies related to the hydrogen distribution network" and "technologies for the use of hydrogen and its derivatives".

Co-funded by the European Union

Most respondents declared a lack of knowledge and advice in the area of hydrogen technologies, however, most of them believe that the hydrogen economy will have a significant impact on the labor market.

The vast majority of respondents see the need for specialized education in the context of the hydrogen economy and also believe that a dedicated training program will be beneficial for current and future employees of the hydrogen sector. In addition to formal education, in order to prepare current and future employees to work in the hydrogen economy, according to the respondents, in-house training, as well as internships and informal education, are necessary.

In addition, respondents notice problems and barriers in the development of new qualifications primarily at the grassroots level, i.e. the lack of awareness and knowledge about the hydrogen sector among both employees and employers.
It is also important that the vast majority of respondents are open to developing their skills and knowledge in the area of hydrogen technologies.

RESEARCH REPORT 2

BACKGROUND AND OBJECTIVES

The transition towards a sustainable hydrogen economy is gaining momentum globally, driven by the urgent need to address climate change and achieve energy security. As this emerging industry continues to evolve, it is imperative to understand the evolving workforce requirements and skill sets necessary to support its growth.

The present survey results aim to shed light on the occupational landscape within the hydrogen sector, identify emerging professions, and delineate the competencies essential for these roles.

This research endeavour is a critical component of the broader project titled "Identification of new professions that will emerge in the hydrogen economy" (Project no: 2023-1-PL01-KA220-VET-000159821). The project is spearheaded by a consortium comprising the ECRN European Chemical Regions Network Association, West Pomeranian Chemical Cluster "Green Chemistry," Foundation of Education, Development and Innovation (FERI), EDU SMART Training Centre DIALOG of Transformation Ltd.

The objective of Working Package 2, of which this survey is part, is to map the occupations related to the hydrogen economy and outline the trend of which professions will be in demand due to the development of the hydrogen sector and the energy transition in European countries. The findings will aid in identifying occupational profiles, skill needs, and potential gaps in the labour market.

Furthermore, the results of this work will facilitate the development of a competency framework for hydrogen professions and the preparation of tailored training programs aimed at enhancing the knowledge and potential of the workforce that constitutes the hydrogen economy value chain.

To achieve these objectives, a comprehensive quantitative survey was conducted, targeting professionals and stakeholders in the hydrogen sector across various European countries. The survey aimed to gather insights into the current state of skills and knowledge, perceptions of the industry's impact on the labor market, and the perceived need for specialized training and skill development initiatives.

RESEARCH REPORT 2

SURVEY METHOD

The use of an online survey hosted on Docs Google was likely chosen for several reasons:

- Accessibility and Reach: Online surveys allow researchers to easily reach a geographically dispersed audience, transcending physical boundaries. This was particularly useful for this study, which aimed to gather data from professionals and stakeholders across different European countries.
- Cost-effectiveness: Compared to traditional paper-based or in-person surveys, online surveys are generally more cost-effective, as they eliminate printing, distribution, and travel expenses.
- Convenience for Respondents: Online surveys offer respondents the flexibility to complete the survey at their convenience, potentially increasing the response rate and reducing non-response bias.
- Data Collection and Management: Docs Google streamlines the data collection process by automatically capturing and compiling responses in a centralized database, eliminating the need for manual data entry and reducing potential errors.

The online survey's main details:

- Quantitative Survey: A quantitative survey was conducted by individuals and among micro, small, and medium-sized enterprises (MSMEs) operating in the hydrogen or related sectors across European countries.
- Survey Method: The survey was administered using Computer-Assisted Web Interviewing (CAWI), which is a common technique for online surveys where respondents self-administer the questionnaire via a web-based platform, in this case, Google Forms.
- Verification Source: The encrypted results from the online survey were compiled in an Excel sheet, which served as the verification source for the survey data.

By utilizing Docs Google for the online survey, the research team was able to efficiently collect and manage data from a large number of respondents across multiple geographic locations. The automated data collection and organization features of the form likely facilitated the analysis and reporting processes, enabling the researchers to effectively capture and present the perspectives and insights of professionals in the hydrogen sector.

RESEARCH REPORT 2

SURVEY METHOD

Survey

Ladies and Gentlemen,

We invite you to complete an anonymous survey for research and educational purposes. The survey will take maximum 7 minutes.

Project title: "Professionals and their skills in hydrogen sector"

Project no: 2023-1-PL01-KA220-VET-000159821

Survey: Identification of new professions that will emerge in the hydrogen economy

Consortium in charge of the research:
ECRN European Chemical Regions Network
Association of West Pomeranian Chemical Cluster "Green Chemistry"
Foundation of Education, Development and Innovation (FERI)
EDU SMART Training Centre DIALOG of Transformation Ltd.

Survey description: The main objective of the survey is to map occupations (map of occupations) related to the hydrogen economy. The survey aims to outline the trend of which occupations will be needed due to the development of the hydrogen sector and the energy transition in European countries. The results will allow the identification of occupational profiles and skill needs, which will allow the possible definition of existing gaps in the labor market. In the future, the results of the survey will allow the development of a competency framework for hydrogen professions and the preparation of training programs related to improving the knowledge and potential of the cadres that make up the hydrogen economy value chain.

SURVEY RESULTS

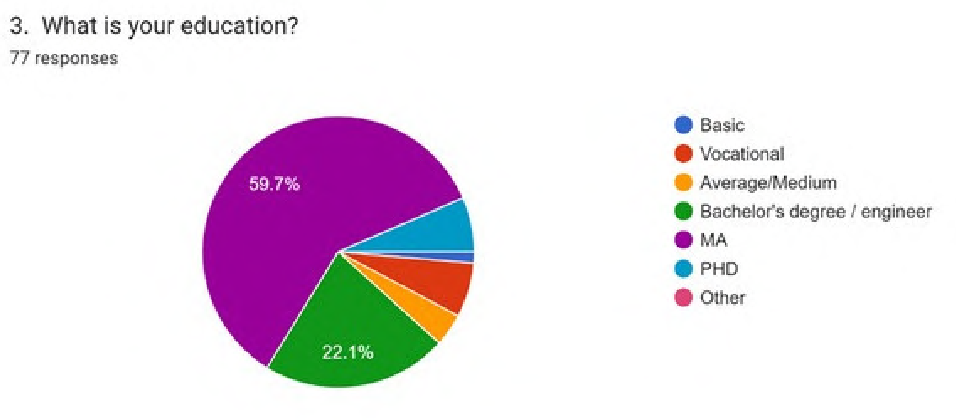
The survey garnered responses from 77 participants, providing valuable insights into various aspects of the hydrogen sector. The demographic breakdown reveals that 57.3% of the respondents were men, while 42.7% identified as women. Regarding age distribution, the majority of participants fell within the 35-44 years (35.1%) and 25-34 years (36.4%) age groups, indicating a substantial representation from the younger and mid-career professionals.

In terms of educational qualifications, a significant portion (59.7%) of the respondents possessed a Master's level of education, followed by 22.1% with a Bachelor's degree. The survey captured a diverse geographical representation, with participants hailing from cities with populations above 500,000 (44%), cities with populations between 100,000 and 500,000 (37.3%), and smaller metropolitan areas. Notably, an overwhelming majority (92.2%) of the respondents identified themselves as active professional persons.

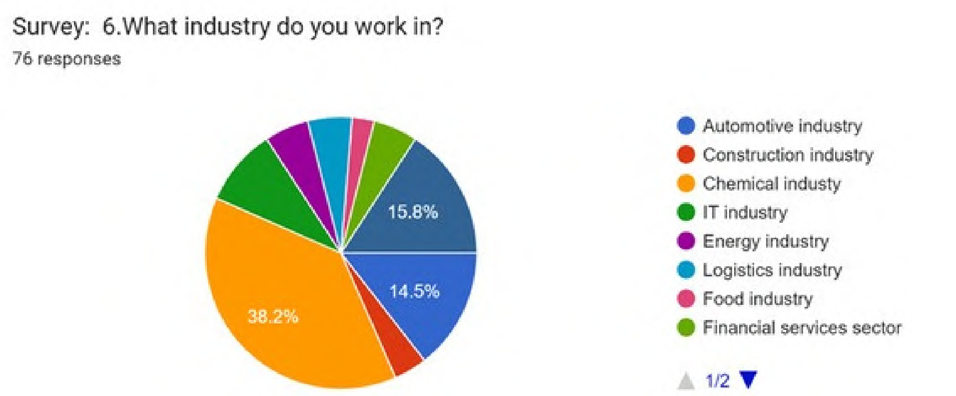
Co-funded by the European Union

RESEARCH REPORT 2

SURVEY RESULTS



The survey delved into the respondents' professional backgrounds, revealing that a substantial portion (38.2%) had work experience in the chemical industry, followed by the automotive industry (14.5%) and the IT industry (9.2%). Furthermore, 31.8% of the participants possessed work experience in the energy industry, while 48.1% had experience in the chemical industry.

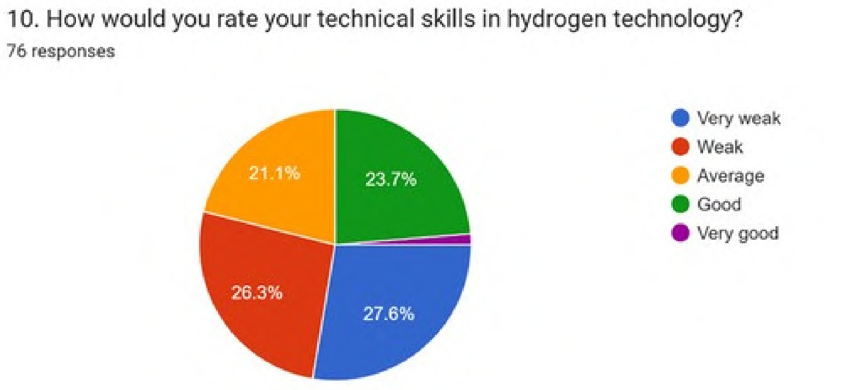


When it came to hydrogen technology, a remarkable 31.2% of the respondents claimed to have experience working with hydrogen systems. However, the self-rated technical skills in hydrogen technology varied, with 27.6% considering their skills as very weak, 26.3% as weak, 21.1% as average, and 23.7% as good. Similarly, the respondents' knowledge of current trends and innovations in the hydrogen sector ranged from very weak (18.2%) to good (28.6%), with the majority (33.8%) rating their knowledge as average.

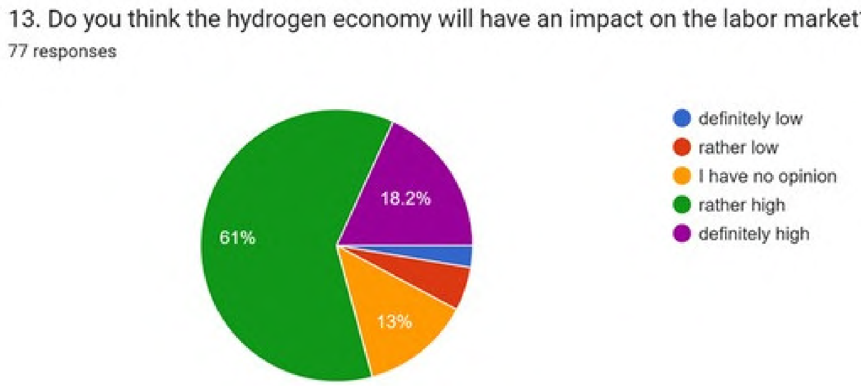
Co-funded by the European Union

RESEARCH REPORT 2

SURVEY RESULTS



The survey results indicated a general consensus among the participants regarding the potential impact of the hydrogen economy on the labor market, with 61% expressing a rather high impact. At the same time, when asked about their knowledge of the hydrogen sector laws and regulations, the responses were more diverse, with 18.7% rating their knowledge as very weak, 22.7% as weak, 34.7% as average, and 24% as good or very good.



Regarding the ability to identify and solve problems related to hydrogen technology, the respondents demonstrated a range of self-assessed capabilities, with 32% rating their ability as very weak, 28% as weak, 18.7% as average, and 21.3% as good.

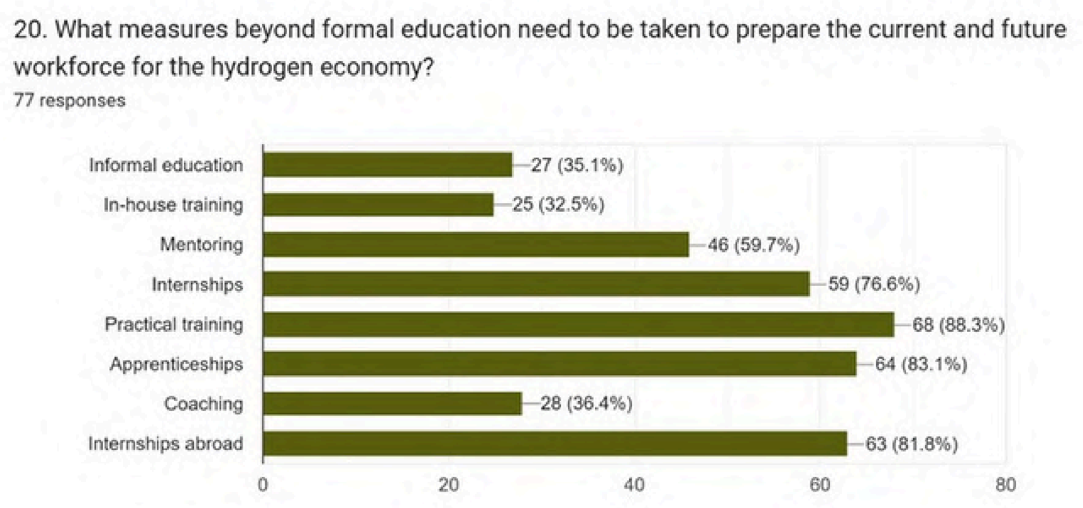
RESEARCH REPORT 2

SURVEY RESULTS

The survey also explored the participants' perspectives on job profiles relevant to the hydrogen economy. The responses indicated a strong emphasis on specialist in the field of science positions, followed by chemical, electrical and mechanical engineers.

When asked about the crucial areas for the development of the hydrogen economy, the respondents highlighted technology development as the most critical aspect, followed by hydrogen transportation, distribution, and storage.

An overwhelming majority (85.7%) of the participants acknowledged the need for specialized training in the context of the hydrogen economy, and 81.8% believed that a dedicated training program would benefit current and future hydrogen workers. The survey identified various measures beyond formal education that could be taken to prepare the current and future workforce for the hydrogen economy, including practical training (88.3%), apprenticeships (83.1%), internships (76.6%), mentoring (59.7%), in-house training (32.5%), and coaching (36.4%).



RESEARCH REPORT 2

SURVEY RESULTS

The respondents also identified several obstacles that could hinder access to the new skills needed in the hydrogen sector, such as a lack of people with a global vision, conservative thinking on lifelong learning, the need for basic knowledge of hydrogen technology, and issues related to the scale effect and awareness of opportunities.

Notably, the survey revealed that only 14.3% of the participants had attended training or courses on hydrogen technology in the past year, and an equal percentage possessed certifications or qualifications related to hydrogen technology. However, a significant portion (59.7%) expressed openness to developing their skills and knowledge in the area of hydrogen technology.

In conclusion, the survey provided valuable insights into the current state of skills and knowledge in the hydrogen sector, as well as the perceived needs and challenges associated with the development of the hydrogen economy. The findings will inform the efforts to develop a competency framework and training programs tailored to the emerging workforce requirements in this rapidly evolving field.

Co-funded by the European Union

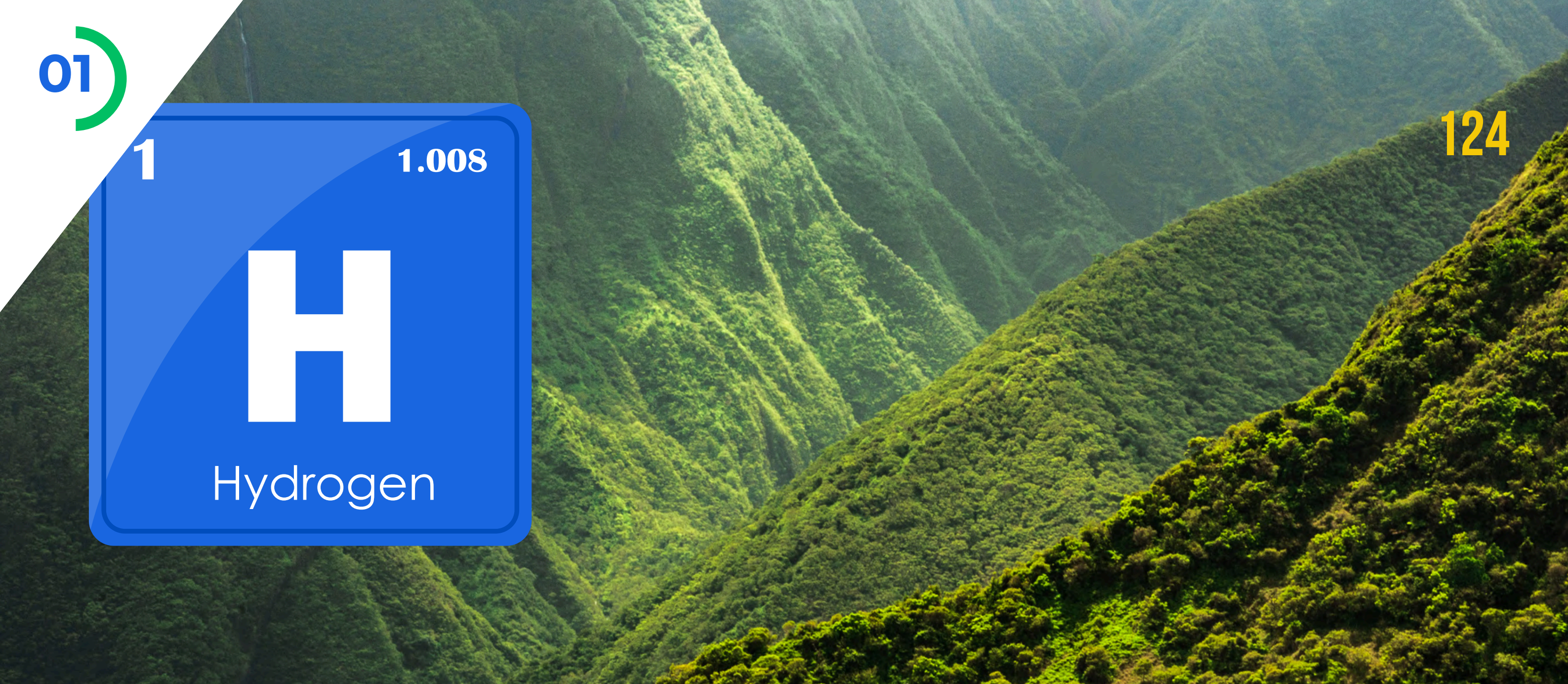
GOOD PRACTICES AND EXAMPLES OF ACTIVITIES IN THE HYDROGEN SECTOR

Co-funded by the European Union

GOOD PRACTICES AND EXAMPLES OF ACTIVITIES IN THE HYDROGEN SECTOR

11. HYDROGEN TRANSMISSION TRAINING COURSE BY DNV
12. INTERUNIVERSITY MASTER OF PERMANENT TRAINING IN HYDROGEN TECHNOLOGIES
13. HYDROGEN: A CRUCIAL PUZZLE PIECE IN THE ENERGY TRANSITION BY UGAIN
14. H2HUB IN SAXONY-ANHALT
15. EXECUTIVE PROGRAMME HYDROGEN BY NEW ENERGY BUSINESS SCHOOL
16. DUBLIN HYDROGEN ‘WHRIGHTBUS’ PILOT SCHEME
17. HYDROGEN IRELAND NATIONAL ASSOCIATION
18. GAS NETWORKS IRELAND PARTNER AND RESEARCH PROJECTS
19. GAS NETWORKS IRELAND TECHNICAL AND SAFETY FEASIBILITY STUDY
20. HYDROGEN MOBILITY IRELAND: DEVELOPING THE USE OF HYDROGEN FOR TRANSPORT

Co-funded by the European Union



Hydrogen Valleys

Hydrogen valleys are becoming an increasingly visible part of the landscape of the European energy sector, symbolising the future of clean, sustainable energy. Norway and Poland, two countries with different geographical and economic contexts, play a key role in developing this new industry. In this article, we will look at hydrogen valley initiatives, both in Norway, which is a pioneer in the field of hydrogen production and applications, and in Poland, where dynamic activities in this area contribute to the development of sustainable energy technologies. By analysing these initiatives, we will be able to understand how the hydrogen revolution contributes to the transformation of the European energy sector and how it can benefit both countries.

Norway, with its abundance of renewable energy sources and a developed energy sector, plays a key role in the advancement of hydrogen-related technologies. Activities in the hydrogen area are aimed at accelerating changes in the energy sector and supporting the country's sustainable economic growth. The H2 Valley in central Norway is an example of a complete value chain covering the production and use of hydrogen in various sectors such as land, maritime and industrial transport. Investments in projects such as H2 Valley are crucial for the energy transition, and public-private

Co-funded by the European Union

partnerships, including the involvement of key industrial players and research institutions, contribute to the dynamic development of this industry. Norway, with its abundant renewable energy sources and developed energy sector, is key to advancing hydrogen technologies. Activities in the hydrogen area are aimed at accelerating changes in the energy sector and supporting the country's sustainable economic growth. In Norway, there are also areas that can be described as "hydrogen valleys" or regions focusing on the development of hydrogen infrastructure. Norway, known for its abundant natural resources, especially in terms of renewable energy, has great potential to use hydrogen as an energy carrier.

The main developer of the H2 Valley project is the ENERGY Cluster, and the partners are, m.in, SINTEF, HYDROGENi, NTE, H2 Marine, ANEO, Statkraft, Meråker Hydrogen, Greenstat, Equinor, Siemens, SalMar, Moen Marin, Moen Verft, Egil Ulvan Rederi, Thor Dal Rederi, Samskip, Salmonor, ASKO, Gexcon and Fremtidens Industri. The main political sponsors of the project are the Trøndelag District, local municipalities and ENOVA (Ministry of Climate and Environment).

The project involves an investment of €150 million, financed from both public funds (including EU, national, regional and local funds) and private sources. As part of the project, it is planned to produce hydrogen through electrolysis of water using PEM and ALK electrolysers, as well as its storage in the form of compressed gas. Hydrogen will be transported via pipelines, trucks and ships. H2 Valley will focus on various end-uses of hydrogen, including mobility (trucks, trains, ships) and industrial (e.g. supply to the chemical and steel industries). The project is to be implemented in the years 2025-2035.

Poland is also setting new paths in the development of hydrogen technologies. There are various regions in the country that are becoming hubs for hydrogen-related investments and projects. From the Łaszczyński Brothers Central Hydrogen Valley to the West Pomeranian Hydrogen Valley, Poland is focusing on various aspects of hydrogen use, such as the decarbonization of transportation, energy production, and industrial applications. These initiatives, based on cooperation between the public and private sectors and support for research and innovation, aim to promote sustainable economic development and reduce greenhouse gas emissions.

- **The Łaszczyński Brothers Central Hydrogen Valley**, located around Kielce, covers the areas of the Świętokrzyskie Voivodeship, the Łódź Voivodeship, the northern part of the Subcarpathian Voivodeship and the southern part of the Mazovian Voivodeship, focusing on the production of clean hydrogen and the decarbonisation of transport and energy.

- **The Lower Silesian Hydrogen Valley**, located around Wrocław, covers the areas of the Lower Silesian, Opole, Southern Lubuskie and Greater Poland Voivodeships, specializing in hydrogen storage, hydrogen energy production and applications in the chemical and metallurgical industries.

- **The Mazovian Hydrogen Valley,** centred around Płock, covers the northern part of the Mazovian Voivodeship and the Kuyavian-Pomeranian Voivodeship, specialising in the production of synthetic fuels, the petrochemical industry, and applications in transport and industry.

- **The West Pomeranian Hydrogen Valley**, in the process of being created, is based in Szczecin and focuses on the area of the West Pomeranian Voivodeship, planning to specialize in the production of green ammonia and the use of hydrogen in maritime transport.

- **The Wielkopolska Hydrogen Valley**, centred around Poznań, covers the areas of the Wielkopolska Voivodeship, focusing on hydrogen applications in housing, air transport and bus production.

- **The Silesian-Małopolska Hydrogen Valley**, located in Katowice, covers the areas of the Silesian and Lesser Poland Voivodeships, specializing in the production of low-carbon hydrogen and applications in industry and transport.

- **The Subcarpathian Hydrogen Valley**, located in Rzeszów, covers the area of the Subcarpathian Voivodeship, focusing on the production of zero-emission hydrogen and its use in heating, transport and industry.

- On the other hand, **the Pomeranian Hydrogen Valley**, based in Gdańsk, focuses on the area of the Pomeranian Voivodeship, planning to specialise in hydrogen applications in public transport, hydrogen storage and clean hydrogen production.

These areas are a key environment for the development of hydrogen technologies in Poland, supporting the country's energy transition and promoting sustainable economic development.

In conclusion, hydrogen valleys are a key element of the future of the European energy sector. By investing in research, infrastructure development and international cooperation, Norway and Poland and other countries on the continent are helping to accelerate the energy transition and build a more sustainable future for our planet. Covering geographical areas with diverse needs and potentials, these valleys focus on the production, storage and use of hydrogen as a clean energy carrier.

Development of the hydrogen sector in Sweden

In Sweden, one of the leading leaders in eco-innovation, we are seeing a dynamic development of the hydrogen sector. Sweden is not only joining the ranks of countries that are adopting hydrogen as a key element in the energy transition, but is also setting new standards in terms of sustainability. Last year's opening of the country's largest electrolyser plant is a clear signal of a change in the approach to energy production and industry.

Sweden's largest electrolyser project has been launched by Ovako, which intends to produce hydrogen for use in the steel production process. The 20 MW electrolyser started operations at the company's plant in Hofors, located 220 km northwest of Stockholm, making it the largest of its kind in the country. Ovako intends to use green hydrogen not to extract iron from ore, but to produce industrial heat, given that the company is primarily focused on recycling steel scrap, which accounts for 97% of its production. The company is already using zero-carbon electric arc furnaces, which has enabled it to reduce its greenhouse gas emissions by 58% compared to 2015 levels.

Co-funded by the European Union

Today, however, the heat required to convert steel into a finished product is still generated by the combustion of natural gas. Ovako predicts that the use of green hydrogen in these processes would enable further emission reductions of 50% or more. In addition, the company plans to supply surplus hydrogen produced in the Hofors electrolyser to Volvo, where it would be used in fuel cell cars. The total cost of the project is SEK 180 million (approx. USD 16 million), of which SEK 71 million is co-financed by the Swedish Energy Agency.

Airswift, a company specializing in the recruitment of personnel for the energy sector, plays a key role in providing skilled workers for the growing renewable energy industry. In the light of her experience, the professions and skill sets that are currently of the greatest interest and are particularly sought after have been identified:

- **Engineers** are key people who design, develop and implement solutions related to the production, storage and use of hydrogen as an energy source. Their work focuses on ensuring the efficiency, safety and sustainability of these technologies.
- In Sweden, there is a sharp increase in the demand for **hydrogen infrastructure specialists** to design, build and maintain the infrastructure for hydrogen production, storage and distribution, including refuelling stations, electrolyser plants, storage facilities and transport networks.

- **Technicians** - these people are responsible for maintaining the proper functioning of hydrogen-related systems and installations, guaranteeing the effective and trouble-free operation of the hydrogen infrastructure.
- **R&D professionals** – the advancement of hydrogen technologies in Sweden requires scientists and innovators focused on research and the development of novel solutions for the production, storage and use of hydrogen.
- The growth of the hydrogen sector in Sweden generates a demand for **project managers/project management and trade professionals** capable of effectively coordinating and supervising hydrogen projects. Commercial experts, on the other hand, play a key role in building partnerships, negotiating contracts and developing hydrogen-related markets.

These sought-after roles reflect the dynamic growth of the hydrogen industry and open up new career opportunities for professionals in the field.

To sum up, the presented practice in the field of development of the hydrogen industry in Sweden is an inspiring example of an innovative approach to the energy transition. The commissioning of the country's largest electrolyser and the pursuit of the use of hydrogen from renewable energy sources in steel production demonstrates Sweden's determination to fight climate change and build a sustainable future. By adopting advanced technologies, promoting innovation, and developing hydrogen infrastructure, Sweden is setting the standard for other countries striving to realize sustainable development.

1 1.008
H
Hydrogen

Hydrogen sector – safety rules

Is the hydrogen economy the future of our energy sector? This issue is becoming increasingly important in the face of the environmental and energy challenges of our time. As we face the challenges of hydrogen production, we are faced with the urgent need to assess its role in the energy future. While hydrogen may seem less practical and more expensive compared to conventional fossil fuels, which have long dominated our energy sector and are easy to use and transport, their negative impact on the environment cannot be ignored. Fossil fuels are harmful, toxic, and contribute to climate change through greenhouse gas emissions. Therefore, there is growing pressure to switch to more sustainable alternatives, such as hydrogen, despite potential challenges such as higher costs and reduced convenience. Investments in environmental protection are becoming essential, even if they involve additional financial outlays.

Understanding and adhering to safety rules is crucial in the hydrogen sector. Hydrogen, being a gas with a high energy content, exhibits highly flammable and explosive properties under specific concentrations and conditions. Therefore, working safely with hydrogen requires in-depth knowledge of its characteristics and potential hazards. Incorrect manipulation of hydrogen

Co-funded by the European Union

can result in serious incidents such as explosions, fires or leaks, endangering the life and health of workers as well as public safety. In addition, although hydrogen as a gas is non-toxic, its emissions into the atmosphere in large quantities can affect local atmospheric conditions, highlighting the need to closely monitor and control leaks.

In the hydrogen sector, there are a number of safety standards and guidelines, the observance of which is crucial both to protect personnel and the environment, and to avoid potential legal and financial consequences for companies operating in this industry. In both Poland and the European Union, the hydrogen sector is subject to regulations aimed at ensuring safety, efficiency and sustainable technological progress in this field. Although regulations for the hydrogen sector in Poland are still being developed, they include provisions for the safe storage, transport and use of hydrogen. They are often combined with general regulations on industrial safety, environmental protection and the energy sector. The Energy Law regulates issues related to the production, distribution and consumption of energy, including hydrogen as an energy carrier. The Hazardous Substances Regulations classify hydrogen as a hazardous substance, which means that the regulations for the storage and transport of hazardous substances apply to it. At the EU level, hydrogen regulations are more extensive and detailed, often with a focus on promoting hydrogen technologies as part of the energy transition, including:

- **The Alternative Fuels Infrastructure Directive (AFID)**, which sets out the framework for the deployment of hydrogen refuelling stations in Member States.

- **Safety and technical standards,** such as ISO and CEN standards for hydrogen, which specify requirements for the safe storage, transport, production and distribution of hydrogen.

- **In 2020**, the European Commission presented the "Hydrogen Strategy for Europe", which aims to support the development of clean hydrogen technologies and create an integrated hydrogen market in the EU.

In addition, across Europe, standards such as ISO 14687 specify specifications for the purity of hydrogen used in fuel cell vehicles, and ISO 22734 standards apply to hydrogen generators using water electrolysis. In the hydrogen sector, it is also important to comply with international regulations, such as those contained in the international codes for maritime and road transport (e.g. IMDG, ADR), which regulate the transport of hydrogen. These regulations are crucial to ensure the safety, environmental protection and efficient development of hydrogen technologies, and compliance with them is essential for companies operating in this sector. Hydrogen technologies are often complex and require expertise to operate them safely.

Understanding technological processes, potential failures and intervention procedures is crucial for safe operation.

PROPOSAL FOR A SAFETY TRAINING AND POLICY PROGRAMME FOR THOSE STARTING OUT IN THE HYDROGEN SECTOR

Purpose of the training: To provide new employees in the hydrogen sector with comprehensive knowledge of safety, operational principles and best practices so that they can perform their duties safely and efficiently.

Learning Outcomes:

- Understanding the properties and risks of hydrogen.
- Ability to handle hydrogen safely and follow safety procedures.
- Knowledge of the regulations governing the hydrogen sector.
- Ability to respond to hydrogen-related emergencies.

Co-funded by the European Union

What to look out for in safety training in the hydrogen sector:

- **Hydrogen storage and transportation:** Know and use appropriate methods for storing and transporting hydrogen, including appropriate containers and safeguards.
- **Leak Detection & Alarm Systems:** Install and maintain hydrogen leak sensors and alarm systems that can quickly warn of potential hazards.
- **Emergency procedures and response plans:** Develop and train employees in emergency procedures such as evacuation, first aid, and what to do in the event of a fire or hydrogen leak.
- **Staff training and awareness:** Regular safety training, not only for new employees, but also as part of the ongoing development and maintenance of safety awareness among all employees.
- **Risk management:** Assess the risks associated with various aspects of hydrogen operations and implement measures to mitigate these risks.

TRAINING MODULES:

Introduction to Hydrogen

- Characteristics of hydrogen and its application in the energy sector.
- An overview of the hydrogen sector and its importance for sustainable development.

Hydrogen safety

- Physicochemical properties of hydrogen relevant to safety (e.g. flammability, explosive concentration ranges).
- Typical hazards and risk scenarios in working with hydrogen.

Regulations & Standards

- National and international regulations for the safe storage, transport and use of hydrogen.
- Review of industry standards (np. ISO, CEN) for hydrogen.

Operational Security Practices

- Safe procedures for the storage and distribution of hydrogen.
- Use of safety equipment and systems in working with hydrogen.

Disaster Response

- Procedures to be followed in the event of a hydrogen leak, fire or other incidents.
- First aid in the event of hydrogen-related accidents.

Hands-on training

- Hands-on exercises on simulators or in a controlled laboratory environment.
- Emergency scenarios and incident response exercises.

TRAINING METHODS:

- Lectures and presentations to convey theoretical knowledge.
- Discussions and case studies to analyze real-world incidents and develop response strategies.
- Hands-on exercises and simulations to allow participants hands-on experience in the safe handling of hydrogen.

The implementation of effective safety rules and appropriate training in the hydrogen sector are an important element in ensuring not only the protection of employees and the environment, but also the sustainable and sustainable development of a dynamically developing industry. By following proper procedures, identifying hazards, and using safe working practices, we can minimize the risk of incidents and increase the efficiency and efficiency of hydrogen operations.

Ultimately, the hydrogen sector faces challenges, but also abounds with opportunities. Through consistent application of safety principles, innovative approaches to technology, appropriate training and cooperation at an international level, we can shape a future in which hydrogen plays a key role in the energy transition, leading to a more sustainable and greener society.

Engineering Institute of Technology.

"Professional Certificate of Competence in Hydrogen Energy" at the Engineering Institute of Technology, Australia.

Engineering Institute of Technology (EIT), as a leading educational institution specialising in engineering, plays a key role in promoting advanced technologies, including hydrogen-related technologies. Nowadays, in the face of changing energy needs and pressure to reduce emissions, hydrogen is gaining prominence as a promising source of renewable energy. The EIT not only plays an important role in educating professionals in the field of hydrogen engineering, but also actively supports the development and implementation of best practices in this field.

Engineering Institute of Technology is headquartered in Perth, Australia. This institution was founded in 2008 by Dr. Steve Mackay, an engineer and educator who wanted to create a specialized institute offering hands-on engineering programs based on hands-on experience and real-world skills that are needed in industry. Initially, the institute focused on providing training courses for engineers and technicians. Over time, the educational offerings expanded to include full academic programs, including diplomas, bachelor's, and master's degrees.

Although the EIT is headquartered in Australia, the institution offers distance learning programmes, which allows students from all over the world to attend its courses. The EIT has been accredited by Australian and international organisations, attesting to the quality and standards of teaching. The institute is recognized as an innovative educational organization that applies the latest technologies such as remote labs and simulations to provide a hands-on learning experience.

The Engineering Institute of Technology is therefore an internationally recognized institute that actively collaborates with industry and academia to deliver up-to-date and practically-oriented educational programs in the field of engineering and technology.

The "Professional Certificate of Competence in Hydrogen Energy – Production, Delivery, Storage, and Use" offered by the EIT is a comprehensive training programme that focuses on key aspects of hydrogen production, supply, storage and use. This course has been designed for engineers, technicians, project managers and all professionals interested in the hydrogen industry who want to expand their knowledge and skills in this fast-growing sector. The course guides the participant through the ins and outs of the hydrogen sector, allows them to understand the processes related to hydrogen production, storage, distribution and energy applications. Thanks to this initiative, participants gain not only theoretical knowledge, but also practical skills needed to work in the hydrogen industry.

The course consists of 12 modules. Initially, participants gain knowledge of the basic principles and concepts related to the production, storage and use of hydrogen energy. The course discusses in detail various aspects of hydrogen technology, ranging from the properties of hydrogen itself, through production and storage methods, to hydrogen applications and infrastructure. One of the key elements of this course is its practical nature, which enables participants to acquire the specific skills and knowledge necessary to work in the hydrogen industry. Through numerous case studies and interaction with industry experts, participants have the chance to understand both the challenges and opportunities associated with the use of hydrogen energy.

Throughout the course, participants have interactive meetings with lecturers and industry experts, allowing participants to gain the latest information and practical skills. The course lasts 3 months, meetings are held online, every two weeks and last about 90 minutes. A number of materials are self-directed by the participant, thus offering flexibility of participation. The course allows you to learn online at a convenient time and place, which is especially important for full-time professionals.

In order to receive a certificate of completion of the course, participants must be present at least every second online seminar (attendance at least 65%). In addition, students must score at least 60% of their assignments. In addition, it is required to score 100% of the points on the quizzes that are available during the course elearning modules. If a student does not receive the required number of points, they will have the option to resubmit the work to obtain the required number of points. Receiving the final certificate confirms the acquired knowledge and skills, which can be a valuable asset on the job market.

In conclusion, this professional course is a great opportunity for engineers and professionals interested in the hydrogen industry. The most important things in the program are:

- **Focus on practical skills** – the course is designed to provide skills that can be directly applied to professional work.

- **Flexibility of learning** – online courses allow participants from all over the world to have access to education without having to relocate or give up their current job responsibilities.

- **Experienced staff** - lecturers are mainly practitioners from the industry, who can provide participants with up-to-date knowledge and experience from market realities.

- **Support for students** – the EIT is known for its good support for its participants, offering access to learning materials, online labs and opportunities to interact with lecturers and other participants, allowing for a wide exchange of experiences.

Completing the course and earning the certificate will allow graduates to validate their knowledge and skills, opening the door to new career opportunities in the growing hydrogen sector.

Professions in the French hydrogen economy

The hydrogen sector in France is playing an increasingly important role as a key element of the energy transition and the fight against climate change. The applications of hydrogen as a clean energy carrier have a significant impact on a variety of economic sectors, from transport to industry, and represent an important step towards achieving a sustainable future. France's entry into the decarbonization of industry and transport requires the development of the hydrogen sector as an effective alternative to traditional, high-emission energy sources, enabling the reduction of CO_2 emissions and improvement of energy efficiency.

The government's plan to decarbonize the industry with the intention of significantly reducing CO_2 emissions by 2050 poses new challenges and opportunities for the sector. The implementation of decarbonized hydrogen responds to these challenges while opening new economic, strategic and technological perspectives for the country. The increase in investments in the hydrogen sector indicates the need to develop new qualifications and skills for work in this industry. Both new, emerging and traditional professions are identified that need to be adapted to new technologies and the challenges of decarbonization. In the context of emerging professions, there is a need to

Co-funded by the European Union

to educate gas engineers and technicians involved in the design of gas networks with thermoelectricity. However, traditional industrial professions such as welders and mechanics remain important players, although they require updating of skills in line with new technologies and procedures. The development of the hydrogen sector also creates a need to strengthen the competences of technicians, such as electronics, electromechanics and maintenance technicians. Their specializations must be tailored to the requirements of the hydrogen sector, which may include mechanics, pipeline installations and the operation of specialized equipment. Appropriate preparation and support for employees who will participate in the energy transformation process is also important. Internal and external training and business incubator programs can support the development of skills and qualifications necessary for employees in the hydrogen industry.

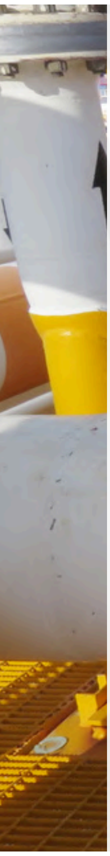
The growing role of the hydrogen sector in France is crucial to achieving the Sustainable Development Goals, fighting climate change and creating a greener and more efficient economy. Investment in this sector is essential to ensure the future stability and competitiveness of the French economy, while contributing to global efforts to protect the environment and climate.

Professions of the future in the hydrogen sector.

As the hydrogen sector develops and becomes an increasingly integral part of the global energy transition, promising new job opportunities are emerging in a variety of fields. One of the main challenges for the labor market in France is the adaptation of traditional industrial professions to new technologies related to the hydrogen sector. The existing skills and experience of industrial employees may prove to be insufficient given the changing requirements of the hydrogen sector. It is therefore necessary to retrain and adapt the skills of employees to operate new technologies, such as hydrogen electrolysers, hydrogen storage systems or hydrogen fuel stations. This also requires adapting safety standards and work procedures to the specificity of the hydrogen sector.

On the other hand, the development of the hydrogen sector in France also creates new employment opportunities through the creation of new professions related to this industry. With the growing demand for hydrogen technologies, there are staffing needs that must be met. The development of the hydrogen sector can therefore contribute to the creation of new jobs and career opportunities for workers in France. Below are the various professions that are gaining importance due to the development of the hydrogen sector in France:

- **Gas Engineers:** Gas engineers play a key role in the design, construction, and maintenance of gas infrastructure, which is an essential component of the hydrogen sector. Their tasks include the design of hydrogen distribution networks, the development of storage and transport facilities, and the supervision of the operation and maintenance of existing installations.
- **Electrolyser technicians:** Electrolyser technicians are involved in the operation, maintenance, and repair of electrolysers, which are a key equipment for the production of hydrogen by electrolysis of water. Their tasks include diagnosing faults, carrying out repairs, monitoring the operation of electrolysers and maintaining appropriate safety standards.
- **Hydrogen storage specialists:** Hydrogen storage specialists are involved in the planning, design and supervision of hydrogen storage facilities that enable the storage and distribution of this energy carrier. Their tasks include identifying appropriate storage technologies, assessing the efficiency and safety of storage facilities, and developing strategies for managing hydrogen stocks.
- **Hydrogen fuelling station operators:** Hydrogen fuelling station operators are responsible for the day-to-day operation and operation of charging stations where customers can refuel hydrogen-powered vehicles. Their tasks include monitoring station operation, ensuring the safety of refueling operations, serving customers, and maintaining and upholding equipment.

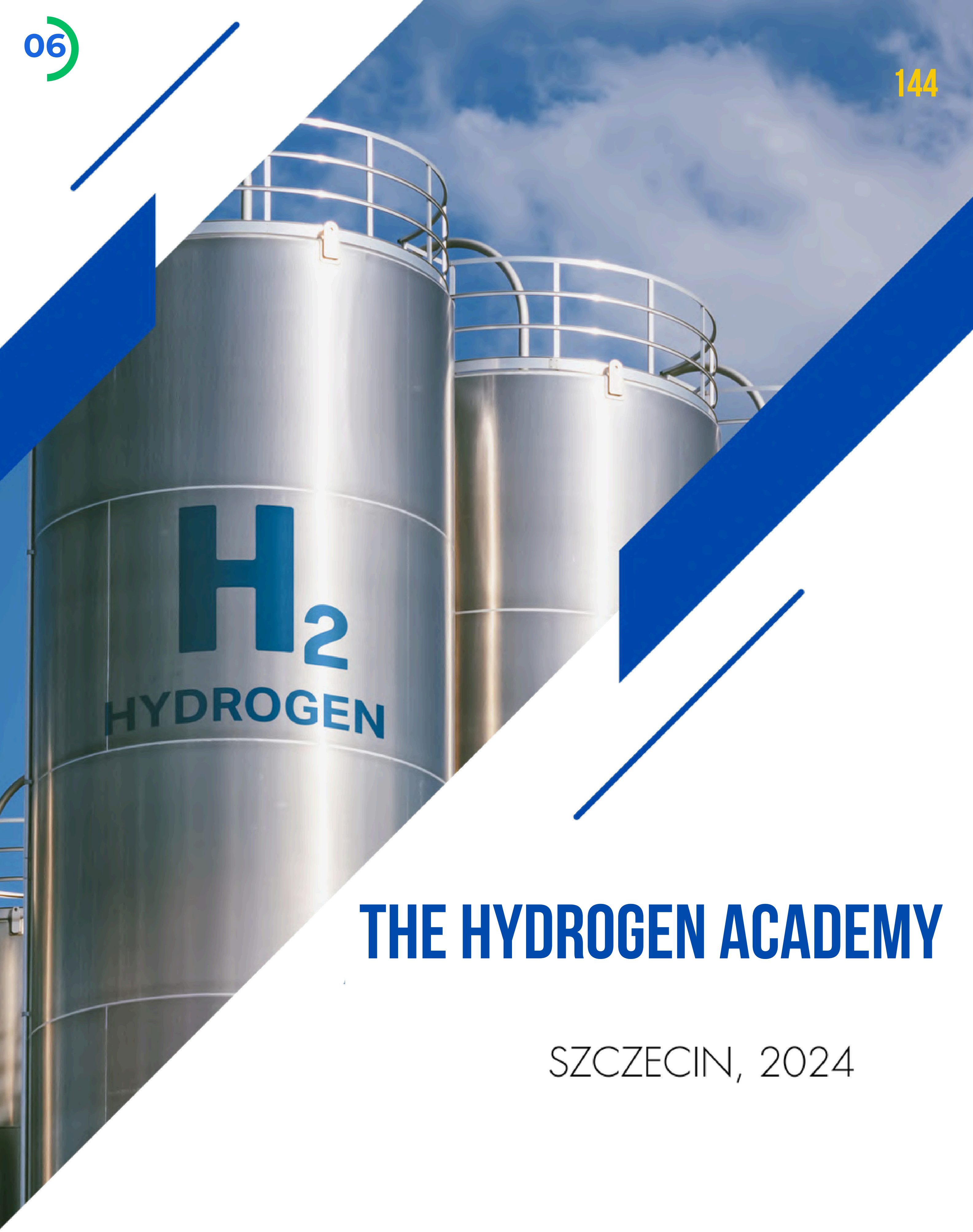


The jobs of the future in the hydrogen sector in France include a variety of specializations, from engineers and technicians to filling station operators. The development of these professions is crucial for the successful implementation of hydrogen technology and achieving sustainable development goals.

Appropriate training and qualifications are essential for employees to effectively contribute to the development of the hydrogen sector in France. Career prospects in the hydrogen sector are broad and varied. People with the appropriate qualifications can find employment in various areas, such as engineering, research and development, design, production, installation and operation of hydrogen infrastructure. Moreover, the growing demand for experts in fields related to electrolysis, hydrogen storage, fuel technologies and environmental protection opens a wide range of career development opportunities for specialists. As the hydrogen sector in France develops, wages for employees related to this industry can also be expected to increase. The high demand for specialists in the field of hydrogen technologies and the growing competition on the labor market contribute to increasing the attractiveness of the offered remuneration and benefit packages for employees. In the context of the global energy transformation, the demand for hydrogen technology specialists will continue to grow. The hydrogen sector is a key part of the decarbonization strategy and the fight against climate change, and hydrogen specialists will play an increasingly important role in supporting the transition to greener and more sustainable energy sources.

In conclusion, the hydrogen sector in France offers promising career prospects for those seeking a career in the booming energy industry. The increase in investments, the growing demand for specialists and the prospects for further development of the sector make working in the hydrogen industry an attractive option for people with appropriate qualifications and interests.

Co-funded by the European Union



THE HYDROGEN ACADEMY

SZCZECIN, 2024

Co-funded by the European Union

THE HYDROGEN ACADEMY

The Hydrogen Academy is an initiative organised by Grupa Azoty Zakłady Chemiczne "Police" S.A., the Faculty of Technology and Chemical Engineering at the West Pomeranian University of Technology in Szczecin and the West Pomeranian Hydrogen Valley to train and develop highly specialised personnel in hydrogen technology.

The mission of the Hydrogen Academy is to communicate the benefits and challenges of using hydrogen and to promote innovative solutions based on this rapidly developing technology.

The initiative is aimed at individuals who are under 30 years of age on the date of enrolment, - is a student studying S1 or S2, in a technical or agricultural field of study, who has achieved a grade point average of 4.0 or higher in the last semester of study, or is a graduate of a technical or agricultural field of study S1 or S2, who has achieved a grade point average of 4.0 or higher, or is a doctoral student in the Doctoral School who is the author or co-author of at least one publication in a journal indexed on the Journal Ciatation Report list.

A key stage to qualify candidates for participation in the Hydrogen Academy was to produce a description of a solution related to hydrogen innovation and technology.

The description should fit in with the Azoty Group's strategy covering, for example, the following aspects:

a. development of the hydrogen market,
b. implementation of the European Union's hydrogen strategy, taking into account the potential of Grupa Azoty,
c. raw material diversification in a "green direction",
d. implementation of technical solutions related to hydrogen technologies,
e. use of hydrogen technologies in decarbonisation and reduction of environmentally harmful emissions,
f. Developing the market for 'green hydrogen',
g. the production and use of 'green hydrogen',
h. hydrogen transport.

As part of the Hydrogen Academy programme, the programme authors have planned a series of free training courses, workshops, lectures and meetings with experts and scientists whose professional and research activities are related to hydrogen technologies.

THE HYDROGEN ACADEMY

The Hydrogen Academy consisted of two stages:

Stage I - Implementation of the Hydrogen Academy
Free training, workshops, lectures and meetings with experts and scientists whose professional and research activities are related to hydrogen technologies. Participants in the Hydrogen Academy will carry out independent projects. Project topics will be announced at the first lecture session. The projects developed were the basis for the selection of Candidates for internships in companies participating in the Hydrogen Academy.

Stage II - Internships
Selected participants of the Hydrogen Academy had the opportunity to realise paid internships in enterprises - partners of the West Pomeranian Hydrogen Valley. The selection was based on an evaluation of the projects that the participants in the Hydrogen Academy were required to prepare during its duration.

The substantive summary of the Hydrogen Academy's activities was the Conference entitled "ENERGY CRISIS AND THE GROWTH OF HODORIUM", which took place in Szczecin from 26 to 27.09.2023 at the Radisson Hotel.

Its key message was to demonstrate the helicity and commitment of all relevant partners within the very dynamic new Hydrogen industry.

The conference was attended by representatives of the Ministry of Climate and Environment, the West Pomeranian Governor, the National Centre for Research and Development, the Rector of the West Pomeranian University of Technology in Szczecin, representatives of the Poznań University of Life Sciences, representatives of the Jagiellonian University and representatives of Grupa Azoty and other companies involved in the development of Hydrogen Technology. Key participants at the conference were alumni of the Hydrogen Academy who presented their projects prepared and developed during the two days of the Hydrogen Academy. A total of 21 alumni presented their studies.

THE HYDROGEN ACADEMY

THE HYDROGEN ACADEMY

The Hydrogen Academy is a very good example of how business and science can work together to solve new problems. Unfortunately, the formal vocational education system is not flexible enough to keep up with the high dynamics of change on the labour market, especially when a new sector of the economy is being created and emerging before our very eyes. Initiatives of this kind require great social recognition and are worth recommending and following in the name of developing the future and securing appropriate professional staff with a high level of qualification and competence.

Co-funded by the European Union

DIALOG of Transformation

FERI

ECRN European Chemical Regions Network

zielona chemia

KRAJOWY KLASTER KLUCZOWY

GAZ-SYSTEM S.A.

SZCZECIN, 2024

Co-funded by the European Union

DIALOG of Transformation

FERI

ECRN European Chemical Regions Network

zielona chemia

KRAJOWY KLASTER KLUCZOWY

GAZ-SYSTEM S.A.

Gaz-System S.A. is an operator of gas transmission pipelines. The company is a strategic company for the Polish economy. It is responsible for the transmission of natural gas, manages the most important gas pipelines in Poland and the Baltic Pipe undersea gas pipeline, and is the owner of the President Lech Kaczyński LNG Terminal in Świnoujście.

As part of the 2015-2025 investment programme, the company is developing more than 2,000 km of new gas pipelines in the western, southern and eastern parts of Poland. Interconnections with Lithuania and Slovakia have been completed, as well as the design of onshore gas pipelines that will connect the planned FSRU floating terminal in the Gulf of Gdansk to the national transmission system. An extension of the LNG Terminal in Świnoujście is also underway, which will increase the regasification capacity of this facility by more than half.

Gaz System, taking into account its potential and following good practices from the Netherlands, intends to become involved in the energy transition process aimed at decarbonising the economy. The company has launched a study to develop a Hydrogen Map of Poland. It will identify the locations of hydrogen demand and supply and the potential route of hydrogen pipelines across the country. The company is working on the concept of a Nordic-Baltic Hydrogen Corridor together with Finland, the Baltic States and Germany, and a pre-feasibility study is currently being developed.

The above data will allow a timetable to be set for further activities and, ultimately, a tentative date for the first hydrogen infrastructure. This work is being carried out in parallel with analyses of the potential for hydrogen production from RES.

Nordic-Baltic Hydrogen Corridor
EU Member States are currently in a phase of dynamic change related to the energy transition and decarbonisation of the European economy. Hydrogen is expected to be one of the key fuels in the EU's energy transition.

On 14 December 2022, European gas transmission system operators from six EU countries - Gasgrid Finland (Finland), Elering (Estonia), Conexus Baltic Grid (Latvia), Amber Grid (Lithuania), GAZ-SYSTEM (Poland) and ONTRAS (Germany) - signed a cooperation agreement to develop cross-border hydrogen infrastructure from Finland through Estonia, Latvia, Lithuania and Poland to Germany to meet the REPowerUE 2030 targets.

The operators have initiated a project called the Nordic-Baltic Hydrogen Corridor, which will strengthen the region's energy security, reduce dependence on imported fossil fuel energy and play an important role in decarbonising societies and energy-intensive

GAZ-SYSTEM S.A.

industries located along the corridor. The project also has significant potential to contribute to the EU's goal of reducing greenhouse gas emissions by replacing current fossil fuel-based production and use of fossil fuels in industry, the transport sector, the electricity sector and heating.The Nordic-Baltic Hydrogen Corridor also fits into the strategy of diversifying energy supply and influencing the acceleration of renewable energy development, specifically achieving the EU goal of domestic production of 10 million tonnes of hydrogen from renewable sources by 2030. The corridor makes it possible to transport environmentally friendly hydrogen produced in the Baltic Sea area to industrial customers located along the entire corridor, including primarily in Central Europe.

The project also fits in with the EU Hydrogen Strategy and the REPowerEU Plan. Furthermore, the Nordic-Baltic Hydrogen Corridor will support selected regional and EU climate targets, such as the Green Deal and the Fit for 55 package.

In addition, the project has been recognised as an investment contributing to the emergence of an integrated European hydrogen infrastructure under the TEN-E Regulation (Regulation (EU) 2022/869).

28 November 2023. The European Commission has published a list of investments that have been granted the status of Projects of Common Interest (PCIs) in the energy sector in the first PCI list for hydrogen transmission and storage, as well as regasification of hydrogen or hydrogen derivatives.

The Nordic-Baltic Hydrogen Corridor project has been included in the PCI list under the 'Baltic Energy Market Interconnection Plan in hydrogen' (BEMIP Hydrogen) and has been given priority investment project status in the European Union.

Given the complexity of the project, the project partners are taking proactive steps towards project implementation.

In December 2022, the project partners signed a cooperation agreement for the joint implementation of the project. Following a tender process carried out during 2023, in 2024 GAZ-SYSTEM, together with the partners, signed an agreement with AFRY Management Consulting to carry out a pre-feasibility study for the corridor. The purpose of the pre-feasibility study is to investigate the feasibility of a Nordic-Baltic Hydrogen Corridor and to define the project parameters (such as the route, scope and capacity of the corridor), to prepare a financial analysis, to develop a roadmap for project

GAZ-SYSTEM S.A.

implementation and to define the main risk factors. The study will be prepared by mid-2024.

On the basis of the recommendations of the pre-feasibility study, a decision will be taken on further actions leading to the implementation of the project.

ZE PAK SA CAPITAL GROUP

SZCZECIN, 2024

Co-funded by the European Union

DIALOG of Transformation

FERI

ECRN European Chemical Regions Network

zielona chemia

KRAJOWY KLASTER KLUCZOWY

ZE PAK SA CAPITAL GROUP

At present, ZE PAK SA's activities are mainly focused on the segment of conventional electricity generation through the combustion of lignite, but the Company is aware of the challenges that await the power industry in the near future. Changing legal and environmental conditions, rising CO2 emission allowance prices, tightening emission standards for other substances, are all requirements that conventional generators must meet, and this process is inevitable for ZE PAK as well.

The ZE PAK SA Capital Group is pleased and satisfied to see the initiative of its dominant shareholder Zygmunt Solorz in establishing the association "Czysta Polska Programme", which assumes evolutionary changes to existing business models.

The company has already significantly reduced its share of coal in PAK's energy mix. In 2019, CO2 emissions fell by more than 30% compared to the previous year. One reason for this was the cessation of operations by the Adamów power plant, but even in absolute terms, i.e. per unit of electricity generation, the Group's CO2 emissivity fell by nearly 8%.

As declared on 30 June 2020, two coal-fired units at the Pątnów power station, each with a capacity of 200 MW, were decommissioned. Units 3 and 6 were commissioned in 1968/69 and operated a total of 631,117.1 hours. The capacity of the Konin power station was also reduced by 93 MW as a result of the decommissioning of the coal-fired units.

The decommissioning of coal units at ZE PAK SA is not the first time this has happened. Over the last 30 months, a total of 1293 MW of coal-fired capacity has been decommissioned at ZE PAK SA, comprising 600 MW at the Adamów power plant, a total of 600 MW at the Pątnów power plant and 93 MW at the Konin power plant. The reduction in generation potential has translated over recent years into a reduction in both lignite energy production and emissions of CO2, SO2, Nox and dust.

The 493 MW of coal-fired capacity decommissioned on 30 June 2020 was responsible for 1,442,000 tonnes of emissions, CO2 in 2019, which means that ZE PAK SA Group's emissions should fall by this amount in the following years. Reducing both the carbon footprint and emissions of other substances is in line with the declarations made as the Company's response to the initiative of ZE PAK SA's main shareholder Mr Zygmunt Solorz called the 'Czysta Polska Programme'.

The Konin power plant, which has operated a 50 MW biomass unit since 2012, will soon be expanded with another biomass unit of similar capacity. Thus, the Konin power plant will become the first coal-fired power plant converted to biomass in the country. It should be mentioned that the city of Konin is already assured of a 100% renewable heat supply from the aforementioned biomass unit.

Co-funded by the European Union
DIALOG of Transformation
FERI
ECRN European Chemical Regions Network
zielona chemia
KRAJOWY KLASTER KLUCZOWY

ZE PAK SA CAPITAL GROUP

In the past year, the Group also reported on a photovoltaic project to be located on land previously used for mining activities. A number of other ideas have been developed in the fields of renewable energy generation, energy storage or, for example, the production and use of hydrogen.

Some of these projects are already submitted to a special programme within the framework of EU support for regions heavily dependent on coal exploitation (the so-called 'Coal Platform'). The company has also joined the "Agreement for equitable energy transformation of Eastern Wielkopolska", whose signatories, i.e.: representatives of local authorities, non-governmental organisations and entrepreneurs, have expressed their willingness to cooperate in order to maximise the use of common potential in the process of transforming the region.

The implementation of these investments is fraught with risk, and the investment horizon in this type of project is strongly stretched over time. The shareholders of ZE PAK SA must therefore be prepared for a period when the Company faces challenges related to the coal segment on the one hand, and a period of capital-intensive, drawn-out investments on the other. Their effectiveness will largely depend on the shape of future regulatory conditions and the adaptation of new technological solutions.
Hydrogen production at ZE PAK Spółka Akcyjna is a new fuel source for passenger vehicles and buses.

9 April 2020. ZE PAK Spółka Akcyjna (ZE PAK S.A.) has signed a contract with Hydrogenics Europe N. V. concerning the purchase of a HyLYZER 1000-30 electrolyser for hydrogen production together with the necessary instrumentation, i.e. a 350 bar compressor station (2x750 m3) and a mobile storage filling station, as well as commissioning and maintenance services. The hydrogen will be produced through energy produced from biomass (RES) from water.

Hydrogenics Europe N. V. of Belgium is a world leader in the design and manufacture of solutions for industrial and commercial hydrogen production. Hydrogen will be produced by water electrolysis using PEM (proton exchange membrane) technology The ongoing project will use PEM (Proton Exchange Membrane) technology, which means that the hydrogen produced will be created without harmful by-products.

The production of hydrogen using this technology is based on the fact that pure demineralised water is decomposed into hydrogen and oxygen by means of an electric current, which takes place on the surface of special membranes that enable the catalytic process of water decomposition. The hydrogen produced in the PEM with a pressure of approx. 30 bar is compressed to a pressure of approx. 350 bar (in the compression

ZE PAK SA CAPITAL GROUP

station) and pumped into mobile storage (via a filling station).

The mobile storages will make it possible to supply hydrogen to passenger vehicle and bus refuelling stations located in many parts of the country. The electrolysis process will use electricity generated from Konin Power Plant's biomass-fuelled generation units - RES units, including from a new biomass unit resulting from the conversion of a coal-fired boiler to a biomass-fuelled boiler.

In the first stage of the hydrogen plant, the electricity demand will be 2.5 MW, and after equipping the module with a second electrolyser, 5 MW, which will allow the production of 2 tonnes of hydrogen per day. One electrolyser will allow the operation of approximately 50 buses per day, each travelling approximately 250 km per day.

With the contract signed, ZE PAK SA will join the ranks of pioneers in hydrogen production by electrolysis, which already include Austrian, German, Japanese or Australian plants.

The above-described example of the activities of the ZE PAK SA Capital Group shows the model transformation of a company that originally operated on the basis of fossil fuels and, thanks to the strategy adopted, transformed to a model incorporating the use of renewable energy sources and climate-neutral fuels.

H2IDEA

SZCZECIN, 2024

Co-funded by the European Union

H2IDEA

H2idea is a nationwide competition aimed at secondary school students (secondary schools, technical schools, vocational schools), in which students in groups of 2-5 under the supervision of a teacher/mentor prepare a project (technical, IT or process), the result of which will be part of the hydrogen economy or will have a direct impact on the development of this sector of the economy. H2idea is a community initiative that aims to promote hydrogen energy among young people.

The main organiser of the competition is TÜV SÜD Polska Sp. z o.o., based in Warsaw, as well as partners Local Government of the Wielkopolska Voivodeship, the Energy Institute, the Hydrogen Technology Cluster and the Empiria and Knowledge Foundation and the company Polowiec i Wspólnicy Sp. J.

The main objective of the competition is:

a. development of self-confidence, indispensable in adult life
b. development of imagination, perceptiveness
c. sensitivity to market needs (new products, services)
d. acquiring the ability to work as part of a team
e. stimulating technical imagination, developing ingenuity and fostering creative thinking
f. seeking innovation and fresh ideas, inspired by green technologies.

During their work on the Project, teams should demonstrate their skills in particular in:

a. looking for ideas - what can be changed, improved, invented across the supply chain and value of the hydrogen economy,
b. gathering information - how it can be done, with what material, with what tools, in what order,
c. analytical work - on the basis of the information gathered, carry out an analysis of the market, competition, technology, SWOT analysis,
d. conceptual work - the design of a technical, IT or process solution, by definition innovative,
e. preparing presentations and, if invited, presenting their work to a panel of experts,
f. learning to apply their knowledge in practice, developing their ingenuity and resourcefulness.

H2IDEA

The elements of the Project should be:

a. an introduction outlining the design issue with justification,
b. basic market analysis (customers, competitors), available technical solutions,
c. presentation of the project (technical, IT or process) with justification of the innovativeness of the solution, its impact on the economic sector, on the environment.
d. What changes have been made and why, or why the presented concept was invented. A comparison with existing products with a related application.
e. The presentation of the project should be as detailed as possible and the project itself should be ambitious and feasible in the formula proposed by the team. It should be innovative, have a positive impact on the environment and produce tangible results once implemented.
f. a brief description of the workflow (division of tasks, barriers and how to mitigate them).

TÜV SÜD Polska's initiative, gives young people the opportunity to actively participate in the country's energy transition.

The multidisciplinary nature, encompassing physics, chemistry, mathematics and computer science, is key to developing innovative solutions for RES. It is an excellent opportunity for students to develop their skills and competencies in these areas, as well as to understand and put into practice ideas related to the hydrogen economy. The competition provides an excellent platform for creative thinking, problem solving and teamwork.

It is also an opportunity for young people to gain knowledge, skills and experience in green hydrogen. By participating in this competition, participants have the opportunity to actively engage in creating the future and influence the shaping of sustainable energy development. Building competencies in the hydrogen economy is key to achieving the Sustainable Development Goals, and H2idea provides a platform where young people can develop their skills and contribute to this important process for future generations.

The H2idea initiative is a vitally important action for our future and for building an informed society that is capable of taking innovative solutions in the field of energy and, further, climate and curbing galloping climate change. By engaging young minds and their ability to think critically, we are able to accelerate the development of the hydrogen economy and achieve a sustainable and zero-carbon future energy system.

H2IDEA

H2idea is not only a competition, but also an educational platform that promotes and develops knowledge about the hydrogen economy. It gives students the opportunity to learn about this dynamic sector, as well as to be inspired and collaborate with other participants. It is an investment in a future in which young people play a key role as innovators and leaders of change.

Building competences in the hydrogen economy is essential to address the challenges of the energy transition and ensure sustainability. H2idea is an initiative that encourages young people to get involved in building a hydrogen future. By developing skills and creativity, participants become key players in shaping the hydrogen economy and contribute to building a better future for us all.

CASE STUDY I
HIPOWER ENERGY

SZCZECIN, 2024

Co-funded by
the European Union

CASE STUDY I HIPOWER ENERGY

Polish scientists have developed a technology that solves the problem of hydrogen loss during storage, transport and transmission. It is also being implemented by a Polish company - hiPower Energy - which estimates the hydrogen tank market to be worth $1.5 billion.

Polish researchers at the Wrocław University of Technology have developed technology to solve the problem of losses in hydrogen storage and transport.

Its commercial implementation has also been taken up by the Polish company hiPower Energy, whose company, hiPower Institute of Materials, has developed technology to protect the penetration of hydrogen particles through the tanks and pipes in which hydrogen is stored and transported.

The effectiveness of the Polish technology was confirmed in a certified hydrogen tank testing laboratory in Germany. The result confirmed an almost 100 per cent efficiency of hydrogen gas retention in the tank.

Hydrogen is set to be the fuel of the future, especially for industry, for which it may be the most effective way to decarbonise. However, we are still at the beginning of the development of the hydrogen economy. In particular, investment is needed in generating sources of green, or the most desirable, emission-free hydrogen, which today accounts for only 1 per cent of global production. As much as 70-80 per cent of this gas is still produced globally by reforming petroleum-based fuels, mainly methane.

The storage and transport of hydrogen remains a challenge. Due to its characteristics, the particles of this gas penetrate practically every barrier, so hydrogen losses due to permeation are currently measured in the tens of billions of dollars. The annual hydrogen loss for a single transport platform, consisting of several tanks, can be as much as 1 000 kilograms of this valuable gas.

With a solution to this problem come Polish scientists, working with Polish business within the hiPower Institute of Materials. The hiPower Institute of Materials, which specialises in the development and commercialisation of functional surface layers derived from sol-gel technology, joined the hiPower Energy group in 2024. The innovative materials, with efficacy proven by laboratory tests, increase the tightness of tanks for the storage and transport of hydrogen and other problematic substances. The advantages of the new generation of coating materials enable their wide application also in medicine, industry and the construction industry.

CASE STUDY I HIPOWER ENERGY

It is a company of the NewConnect-listed hiPower Energy Group (formerly Areny.pl SA), which has developed a technology that protects the penetration of hydrogen particles through the tanks and pipes in which hydrogen is stored and transported.

The technology of Polish scientists being implemented by a Polish company could revolutionise the hydrogen industry worldwide.

Developed by researchers from the Wroclaw University of Technology working with the hiPower Institute of Materials (IoM), the innovative barrier coating, together with a comprehensive application and validation system for any surface, including geometrically complex and large-format surfaces, is set to revolutionise the hydrogen industry.

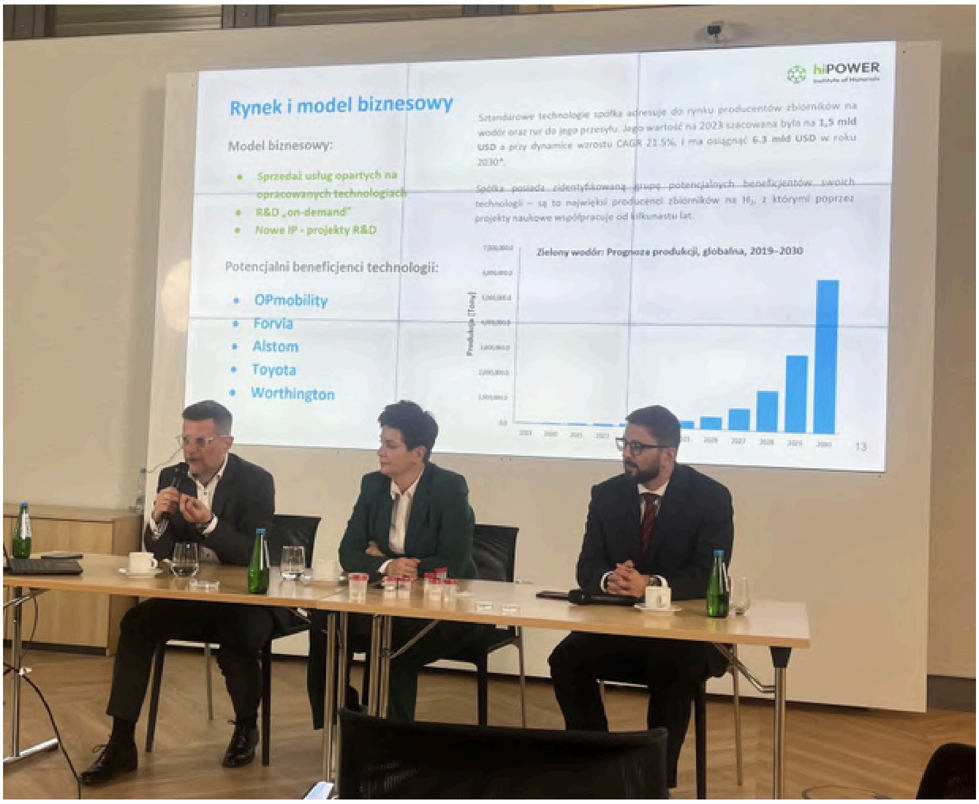
This technology - according to the assurances of its authors - solves the problem of hydrogen loss during storage, transport and transmission, due to the hitherto unattainable tightness of the sol-gel coating developed by hiPower IoM.

The company has exclusive rights to the know-how reservations, which are the basis for the creation of innovative barrier layer technologies that minimise hydrogen loss. It also owns the 'FineCoat4PressureVessel' multilayer coating system, the use of which guarantees the preservation of the unique properties of the functional layers.

The effectiveness of the Polish technology was confirmed in a certified hydrogen tank testing laboratory in Germany. The result confirmed an almost 100 per cent efficiency of hydrogen gas retention in the tank.

Thanks to the work of the research team, it has been possible to obtain a layer that virtually fully protects the hydrogen from penetrating the Generation IV tanks currently used for hydrogen storage.

CASE STUDY I HIPOWER ENERGY



Sol-gel coating technology can also have much wider applications than just the hydrogen industry.

The innovative barrier coating is based on the sol-gel method, which allows multicomponent materials to be obtained directly and therefore without the need for intermediates or costly processing technologies. Sol-gel technology offers a wide range of possibilities in the area of surface refinement coatings for a variety of materials. Thanks to its use, our research team has already developed, among other things, insulating mats based on aerogels and recycled PET, a range of anti-corrosive, adhesive and self-healing coatings, as well as nanometric and submicron powders that will find application in various industries.

These coatings can be used to cover metals, polymers, glass, virtually any surface, so the Polish technology can have a really wide range of applications. An example is the coating of a windmill mast, which will make the structure resistant to the harmful effects of weather conditions, for example. In the medical industry, coatings with biological activity will allow various types of medical implants to be coated, e.g. for the controlled release of medication into the body.

CASE STUDY I HIPOWER ENERGY

The technology developed provides a technological foundation on which specific functional solutions can be built for various industries, ranging from the hydrogen management industry to the construction, textile, medical and metallurgical sectors.

The hiPower IoM company is mainly targeting manufacturers of hydrogen tanks and pipes for hydrogen transmission. The company estimates that this market is worth US$1.5 billion and could be as high as US$6.3 billion by 2030.

Ultimately, the company wants to offer its own kind of R&D on demand, meaning that it will adapt its technologies to the needs of its customers.

HYDROGEN TRANSMISSION TRAINING COURSE BY DNV

DNV is an international accredited registrar and classification society headquartered in Norway. It provides services for several industries, including maritime, oil and gas, renewable energy, electrification, and healthcare. It organizes the 'Hydrogen Transmission Training Course' at the DNV's Technology Centre Groningen.

Scope

The training provides a comprehensive overview of hydrogen transmission and blending with natural gas within the context of natural gas service. Participants will delve into topics such as hydrogen production, transmission, and utilization, along with key considerations for retrofitting or repurposing existing infrastructure for hydrogen use. Safety and operational challenges in future operations are also addressed. Additionally, the three-day program includes a tour of DNV's Technology Centre Groningen, featuring demonstrations of various hydrogen applications to offer practical insights into the training concepts.

DNV unveiled its new Technology Centre in april 2023 at Groningen's Zernike campus, a dynamic hub of educational, commercial, and research endeavors. This state-of-the-art facility, designed with sustainability in mind, is outfitted with cutting-edge testing apparatus to bolster DNV's investigations into the decarbonization of energy infrastructures.

Competences

Upon completion of the course, attendees will acquire comprehensive competences in several crucial areas:

- Technical understanding of retrofitting natural gas infrastructure for hydrogen transportation.
- Familiarity with regulatory frameworks and policies governing pipeline conversion.
- Assessment of economic feasibility for pipeline conversion projects.
- Proficiency in safety considerations associated with hydrogen pipeline conversion.
- Knowledge of hydrogen properties and their impact on infrastructure and end-use equipment.
- Expertise in blending hydrogen with natural gas and transitioning to pure hydrogen across various sectors such as built environment, industries, and transportation.
- Understanding of network management and energy capacity implications when transitioning to hydrogen.

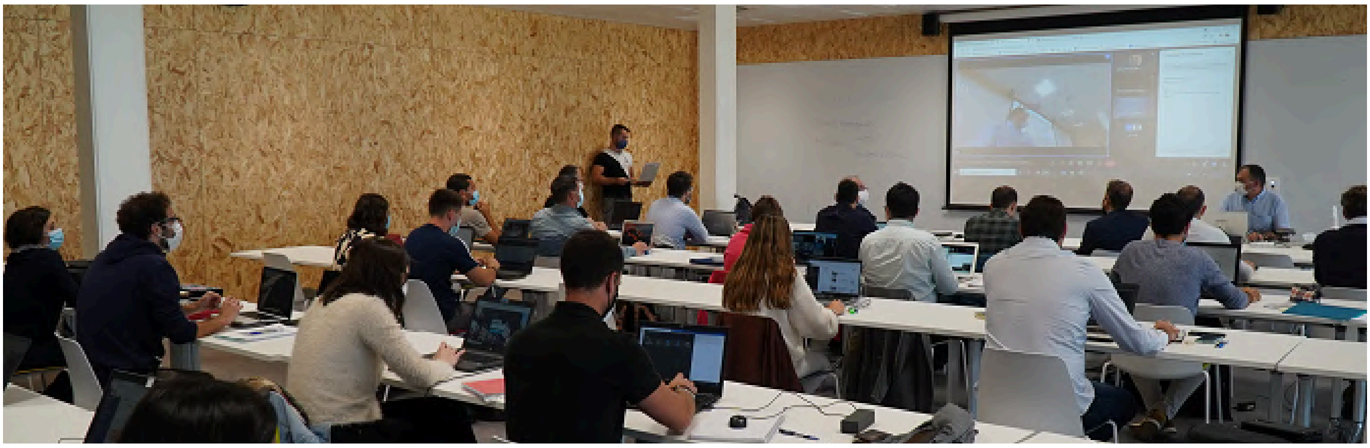
Target audience

The training course caters to a diverse audience, including:

- Pipeline operators seeking to transform energy systems for hydrogen.
- Government decision-makers and regulators involved in energy transition policies.
- Engineers and asset managers responsible for evaluating and implementing repurposing initiatives.
- Professionals from industries reliant on natural gas, aiming to understand the implications of transitioning to hydrogen.
- Stakeholders involved in the built environment, industrial sectors, and transportation, preparing for the integration of hydrogen into their operations.

INTERUNIVERSITY MASTER OF PERMANENT TRAINING IN HYDROGEN TECHNOLOGIES

The Interuniversity Master in Hydrogen Technologies is organized by several training centres and universities in Catalonia. Petronor-Repsol promotes this master's degree, designed and endorsed by 5 universities: Mondragon Unibertsitatea, the Universitat Politècnica de Catalunya, the Universitat Rovira i Virgili, the University of the Basque Country/ Euskal Herriko Unibertsitatea and the University of Zaragoza, along with 6 other training centers and research: the Somorrostro Integrated Vocational Training Center, the Comte de Rius Vocational Training Center, the Institut Escola del Treball, the Pirámide Integrated Public Vocational Training Center, the Hydrogen Foundation in Aragon and the School of Industrial Organization.



Scope

The Master's objective is to equip professionals with expertise across the entire hydrogen value chain, encompassing generation, storage, transportation, distribution, transformation, and applications. The training methodology includes theoretical classes covering the various processes and transformations involved in each stage of the value chain. Practical application of concepts is ensured through hands-on laboratory sessions, simulations using specialized software, and technical visits to companies employing hydrogen in their production processes.

Competences

It provides comprehensive skills in hydrogen technologies. The Master's covers hydrogen production, combustion systems, fuel cells, and their operation and maintenance. It also includes the economic and environmental impacts of these technologies. The course addresses hydrogen storage, transportation, and distribution systems, and prepares individuals to apply these technologies at an industrial level, mobility, and urban/residential use. Lastly, it covers risk and safety management in compliance with current regulations. Overall, it prepares individuals for various roles in this emerging field.

Target audience

The Master is aimed at professionals interested in training in hydrogen technologies and their applications, a specialty aligned with European decarbonization strategies and the promotion of the industrial hydrogen sector:

- Project managers and technicians from companies that are introducing or plan to introduce Hydrogen technologies in their products or services in the future.
- Professionals from the industrial or technological sector interested in the potential of this new emerging technology to open new professional opportunities.
- Supplier companies in the energy sector that in the future intend to offer their products and services to the hydrogen sector and that need to begin preparing their technicians.

HYDROGEN: A CRUCIAL PUZZLE PIECE IN THE ENERGY TRANSITION BY UGAIN

UGain, UGent Academy for Engineers, organizes intensive training courses that reflect the current state of technology and science, it bridges the gap in knowledge with young graduates and offers employees with years of experience the opportunity to orient their careers in a new direction. 'Hydrogen: a crucial puzzle piece in the energy transition' training contributes to the professionalized training offering on hydrogen, tailored to the companies.

Scope

This post-academic training program focuses on hydrogen, highlighting its pivotal role in the energy transition towards a sustainable and climate-resilient society and economy.

It covers various aspects of hydrogen technology, including production, conversion, storage, transport, usage, safety, and business cases. The program aims to equip participants with the necessary competencies to navigate the entire hydrogen value chain.

Sources: https://www.ugain.ugent.be

Competences

Participants will develop competencies across the entire hydrogen value chain, including but not limited to production, conversion, storage, transport, and utilization in diverse sectors. The program emphasizes theoretical knowledge combined with practical insights gained through industry visits. Safety considerations and certification for hydrogen-related processes and applications are also addressed.

Target audience

This program primarily targets individuals working in companies seeking to transition to hydrogen, such as those in the steel or chemical sectors, or those involved in developing, designing, or implementing hydrogen technology for specific applications like transportation or industry. It is specifically tailored for technical professionals seeking to enhance their expertise in hydrogen technology. A minimum prerequisite for participation is at least a technical bachelor's degree level of prior knowledge.

Co-funded by the European Union

H2HUB IN SAXONY-ANHALT

Since February 2023, collaborative efforts with the Merseburg University of Applied Sciences, the Otto von Guericke University Magdeburg, and the Anhalt University of Applied Sciences have been ongoing to establish a central H2HUB for training and further education.

Scope

The objective is to delineate the intersections between company requirements and the prescribed curriculum of training and further education, while also pinpointing synergies and harnessing their potential. Future specialists will need both specialized expertise and a comprehensive understanding of the hydrogen economy.

Previously conducted separately, the training and further education formats of network partners will now be consolidated and enhanced with complementary options. The coordination of tasks and competencies in developing knowledge transfer formats will be synchronized among network partners and transformed into collaborative project offerings.

Objectives of the learning environment:

- Learn how to set up a hydrogen system and understand how the individual components work in a playful way;
- Visualization of the specialists in a hydrogen plant and their tasks;
- Expandable content through module system, “quests” and scenarios;
- Visualization and virtual application of current R&D in the field of hydrogen.

Goal of the learning environment:

- VR serious game for students;
- Modelling parameters of energy transfers between different infrastructures;
- Development of a generic prototype in the style of an economic simulation;
- Parameter modelling taking into account permanent and discontinuous resources and different consumption values.

Development of further training on selected topics of the hydrogen value chain for a wide range of target groups, e.g. for plant manufacturers and operators, planners and project developers, decision-makers in companies or municipalities, etc.

Target audience

Students, specialists, and executives will be trained for the knowledge areas of the hydrogen economy in accordance with their needs (bachelor or master level, part-time further education).

Co-funded by the European Union

EXECUTIVE PROGRAMME HYDROGEN BY NEW ENERGY BUSINESS SCHOOL

New Energy Business School, established in 2002 by Gasunie, Gazprom, and the University of Groningen, later joined by Shell and Enagás, evolved over time. In 2017, it merged with Energy Valley and Energy Academy Europe to form New Energy Coalition.

This coalition aims to bring together researchers, entrepreneurs, and policymakers to boost innovation, achieve breakthroughs in technology and knowledge, and drive changes in mindset and behavior regarding the energy transition. The business school is responsible for the organization of 'Executive Programme Hydrogen' course.

Scope

The school's 'Executive Programme Hydrogen' focuses on key topics driving the hydrogen revolution, including geopolitical considerations, financing models, infrastructure development, and safety protocols. This program equips participants with strategic foresight, technical expertise, and leadership judgment needed to drive meaningful change in the hydrogen sector.

Competences

The program comprises three modules. The initial module, spanning two days, is held at Rotterdam School of Management in the Netherlands. This segment concentrates on hydrogen value chains, market developments, and leadership.

Following this, the second module, also spanning two days, will be hosted at Nyenrode Business University in Breukelen, the Netherlands. This module explores the role of harbors, hydrogen import strategies, and incorporates a workshop on design thinking. This methodology aids in implementing innovation and fosters early engagement with stakeholders' perspectives.

The third module, situated in Norway, shifts the focus towards hydrogen production and implementation. During the interim period, participants will be tasked with crafting a New Energy Essay, to be presented during the second module.

Target audience

This masterclass is designed for high-profile individuals within the hydrogen sector who are motivated to shape the future of energy. It caters to leaders, innovators, and visionaries committed to driving transformative change through the strategic integration and advancement of hydrogen technologies. It is a program designed for those with knowledge and experience in the energy sector.

DUBLIN HYDROGEN ‘WHRIGHTBUS’ PILOT SCHEME

The first hydrogen buses were purchased in the summer of 2021; the world’s first double decker hydrogen buses found themselves in Ireland’s capital city of Dublin. The project saw joint efforts between the Bus Éireann and the National Transport Authority, as well as the company Wrightbus which created the buses. The buses were the first hydrogen fuel-cell buses to be used on Irish public transport, marking a significant advancement towards a fleet of zero-emission vehicles, with the investment totalling more than €2 million (approximately €2.4m) to purchase three zero emissions vehicles. The bus models used are the ‘Wrightbus Streetdeck H2 FCEV’ manufactured by the Bamford Bus Company, and assembled in Galgorm, in Northern Ireland.

As part of a pilot programme for alternative fuel technology, the NTA and Bus Éireann evaluated the buses while they were in operation. BOC Gases Ireland initially provided the hydrogen for the buses, which was refuelled at its Bluebell facility in Dublin.

The Hydrogen Whrightbus in collaboration with TFI

Source: https://council.ie/new-hydrogen-buses-for-initial-use-on-commuter-route-105x/

The minister of transport at the time of unveiling, Eamon Ryan TD, explained that “Reducing carbon emissions from transport is critical to reaching our climate goals and will also improve air quality for all... other technologies such as battery-electric, are very well suited to bus services in urban areas, but on longer commuter and inter-urban routes, hydrogen fuel cell technology is an innovative zero pipe emission alternative to diesel... I’m especially pleased that the Wrightbus Streetdeck, which is the first such bus in the world, is assembled in Northern Ireland and that Bus Eireann are piloting these buses on their commuter route between Dublin to Ratoath.”

Three of the above-mentioned zero-emission buses entered service on Bus Éireann Route 105x between Dublin and Ratoath, County Meath in July 2022. Following its launch, just after one year the buses completed over 60,000 kilometres of emission-free travel, saving over 50 tonnes of CO_2 from tailpipe emissions and 20,000 litres of fuel. It is comparable to making three and a half trips from Dublin to Sydney, to put things into perspective.

The hydrogen buses function similarly to battery-electric buses in that the vehicle can travel farther than conventional EVs thanks to the electricity produced by the fuel cell and hydrogen storage tanks on board. These buses only emit water vapour, released from the exhaust at the back of the vehicle. This has a great environmental benefit as it reduces city pollution. Traditional diesel buses expel pollutant gases, which only increase in traffic. Water vapour, although a greenhouse gas, only stays in the atmosphere a couple of days, compared to carbon dioxide or methane and is less damaging to public health.

Source: https://www.irishexaminer.com/news/arid-40336385.html

Apart from the eco-friendliness of the vehicles, Dublin Bus Éireann consumers have greeted the models with great enthusiasm. A single bus is capable of carrying up to 79 passengers, and the vehicles are fully accessible to individuals with mobility impairments. Moreover, the absence of a conventional combustion engine in the diesel models results in significantly lower noise pollution in both urban and suburban areas.

HYDROGEN IRELAND NATIONAL ASSOCIATION

A national association known as HydrogenIreland (H2IRL) serves as a platform for the island of Ireland's hydrogen community in both the Republic of Ireland and Northern Ireland. H2IRL aims to increase awareness of hydrogen and influence policy changes under the general purview of the European Hydrogen Association and Hydrogen Europe, assisting in securing sustainable, renewable energy across both the north and south of the island of Ireland.

Together, company operations, academic institutions, research centres, and policymakers constitute H2IRL, which serves as a forum and voice for the hydrogen community. It offers a hub for hydrogen knowledge on the island, encourages the production and sale of hydrogen and associated technologies, and establishes hydrogen as a sustainable energy source going forward. Increasing the widespread use of clean energy and renewables through connecting organisations together is a key aspect of H2IRL.

The Association acts on behalf of its members to deliver help and expertise so that hydrogen and fuel cells become a key component of a low carbon economy on the whole island; therefore communication and organisational expertise is crucial.

Hydrogen Ireland

The H2IRL exists to provide value to its members by:

- **Advocating** strongly for a positive social, political and economic environment: developing renewable hydrogen energy and fuel cells on as the island of Ireland developing a zero and low carbon economy.
- **Representing** the shared interests of its members: a collective approach to maximise impact and effectiveness.
- **Providing** a common voice: addressing concerns about hydrogen energy and fuel cells.
- **Sharing** non-commercially sensitive information: facilitating knowledge transfer.

- **Promoting** the development of best practice: developing safety guidance and standards in the deployment of fuel cells and hydrogen.
- **Influencing** government and company policies in Ireland: supporting hydrogen energy and fuel cell development, demonstration and procurement.
- **Influencing** the policies of public and private sector organisations: supporting hydrogen energy and fuel cell deployment on the island of Ireland.
- **Representing** members' interests: within European and International organisations.

Hydrogen Ireland: GENCOMM Project Summary

The GENCOMM project, carried out between 2017-2023 aimed to address the energy sustainability challenges of North-West Europe through the implementation of smart hydrogen-based energy matrixes. The project aimed to implement three pilot plants that link the three main northwest European renewable sources (Solar Power, Wind Power, and Bioenergy) with forms of energetic demand (Heat, Power and Transportation fuels). Belfast Metropolitan College, as the lead organisation, worked with the National University of Ireland Galway, as well as other organisations from the UK, Ireland, Denmark, Luxemburg, France, and Belgium, utilising € 7.07M of EU funding, to a total budget of € 11.79M for the three pilot plants.

Based on the above pilot plants, GENCOMM integrated technical and financial simulation models into developed. These models helped to form the Decision Support Tool (DST) which provides a roadmap for communities to transition to renewable, hydrogen-based energy matrixes. The DST gives hydrogen stronger future market viability.

Interreg
EUROPEAN UNION
North-West Europe
GenComm
European Regional Development Fund

Specific Objectives of the GENCOMM project:

1. **Empower** communities to implement hydrogen-based energy matrixes to sustainably satisfy their energy demand.
2. **Stimulate** the uptake of renewable hydrogen-based technologies by successfully running three demonstration facilities.
3. **Establish** a strong group of energy stakeholders devoted to, through the use of hydrogen, "sustainabilise" the energy matrix of the NWE region.

Two years after the project end, throughout 2023–2025, more research is planned to evaluate the potential role integrated energy parks might play in the Irish energy system, as well as any potential drawbacks or obstacles. Additionally, as part of the plan, an early hydrogen innovation fund will be established to co-finance demonstration initiatives along the hydrogen value chain.

GAS NETWORKS IRELAND PARTNER AND RESEARCH PROJECTS

Green hydrogen is produced by using renewable electricity to split water into hydrogen and oxygen using electrolysis, meaning its production does not involve the release of carbon dioxide. It is therefore a clean and renewable gas. Gas Networks Ireland sees itself as a focal point in solidifying Ireland's clean energy future by working on projects with various stakeholders to conduct thorough research. The goal of this kind of research is to guarantee that green hydrogen can be used to safely operate gas appliances and networks in order to satisfy consumer demands. Increasing the usage of green hydrogen will require connecting end consumers, storage, and generation of hydrogen within hydrogen clusters.

Gas Networks Ireland maintains strong connections to the government and key players in the energy industry both in Ireland and throughout Europe, as evidenced by its close engagement with the University College Dublin's Energy Institute (UCDEI) and other related institutions. To fulfill the requirements and recommendations of the National Hydrogen Strategy and the Irish Government's Climate Action Plan, stakeholders across Ireland must work together in order to decarbonise its gas network and achieve net-zero emissions by 2050.

Gas Networks Ireland

The National Hydrogen Startegy and Climate Action Plan of the Irish Government clearly follow the 17 Sustainable Development Goals; a commitment of all UN countries.

Gas Networks Ireland established the Network Innovation Centre in Dublin with this goal in mind. The centre's experts and innovation team have been working on projects with external research partners from Europe to fully grasp hydrogen's potential and make sure the Irish gas network can safely transport and store hydrogen to homes and public entities.

The Network Innovation Centre aims to provide stakeholders with the necessary data to understand how green hydrogen will impact the gas network and help ensure a smooth transition; considering any costs and potential disruption to Ireland's energy system and the general population. As one of the first projects, the centre worked with UCDEI on the 'Testing of Blends of Hydrogen and Natural Gas' (HyTest). The research found that householders using natural gas blended with up to 20% hydrogen will not need to make any change to their existing domestic appliances or notice any difference. There was also a substantial emissions reduction obtained by blending hydrogen with natural gas. These outcomes are important from a network safety and end user perspective, in terms of gas pressure and leakage identification, and also to support plans to fully convert the network to renewable gas over time.

Summary of outcomes:

- The domestic gas appliances tested operated safely and effectively with various hydrogen blends tested ranging from 2% to 20% hydrogen by volume.
- There was a substantial emissions reduction obtained by blending hydrogen with natural gas.
- The average emission reduction found was a 12% reduction in CO_2 , a 37% reduction in CO, a 43% reduction in the CO:CO_2 ratio, and a 40% reduction in NOx emissions.
- There were no changes observed in the minimum operating pressure of appliances while burning the hydrogen gas blends.
- No leakage was detected during pre-testing or during operations for all pipework, connections, fittings, and valves at operating pressure.
- The domestic gas flow meter was consistently accurate when used for measuring gas volume flows containing up to 20% hydrogen compared to natural gas.
- The flame motion and colour of the hydrogen gas mixtures stayed similar to natural gas.

GAS NETWORKS IRELAND TECHNICAL AND SAFETY FEASIBILITY STUDY

Gas Networks Ireland builds, develops, and operates Ireland’s natural gas infrastructure, maintaining over 14,664 km of gas pipelines and two sub-sea interconnectors. The Gas Networks Ireland transmission network includes onshore pipelines, any interconnectors, as well as offshore and onshore Scotland pipelines and assets; highlighting the importance of collaboration between countries to maintain energy safety and security. Gas Networks Ireland began with an initial 31km of transmission pipeline in 1978. Today, it continues to grow to a network covering 2,476 km high-pressure steel transmission pipelines and 12,188 km lower pressure polyethylene distribution pipelines. Furthermore, Gas Networks Ireland holds ownership to various Above Ground Installations (AGIs), District Regulating Installations (DRIs) and compressor stations.

To maintain safety and a high-standard of work and tech use, Gas Networks Ireland assembled an internal cross-functional technical and safety working group assisted by global energy consultancy DNV. In the year 2022, the DNV conducted many technical evaluations of Gas Networks Ireland’s assets, policies, practices, and installations, in addition to a survey of global research and experiments, creating a report presenting thefindings and suggestions that resulted from the above research. The report is based on the ‘Technical and Safety Feasibility Study’: a high-level assessment of the readiness of Gas Networks Ireland technology and assets for transporting hydrogen/natural gas blends.

This work included the following objectives:

1. To evaluate the potential impacts of hydrogen and natural gas blends on Ireland’s distribution and transmission network (in Ireland, subsea interconnectors and Gas Networks Ireland's assets in Northern Ireland, Scotland and the Isle of Man).
2. To assess the impacts of hydrogen blends on current network operations and the integrity of the gas networks.
3. To determine the impacts of hydrogen blends on downstream end-user appliances.

The findings were very positive and indicate that it will be both safe and feasible to utilise the existing gas network to transport blended hydrogen. However, the report states that further detailed research will be required before commencing with the commercialisation of hydrogen in the network, for example in relation to the high pressure transmission network and large industrial, commercial and power generation users. The report, provides next steps including an assessment of the impact on end-users. **It was recommended that developing the safety assessment strategy for hydrogen/ natural gas blends should commence immediately before the start of any hydrogen blending demonstration pilot studies/schemes.**

The findings of the Gas Networks Ireland technical and safety feasibility study on 'Injecting green hydrogen blends into Ireland's gas network', were very positive, showing that Ireland's gas distribution network is compatible with hydrogen blends of up to 20% and even 100% hydrogen with only some modifications required.

As part of next steps in the utilisation of hydrogen in the network, Gas Networks Ireland will undertake a programme of materials testing for around 50% of transmission pipelines to maintain the current operating pressures when operating with hydrogen blends above 10%.

Gas Networks Ireland will also undertake targeted research on certain equipment contained within transmission gas installations and compressor stations to support the adaptation of large industrial, commercial power generation. The Technical and Safety feasibility study outlines a proposed Safety and Technical Roadmap for Gas Networks Ireland and its stakeholders to follow in future hydrogen-related pilot projects.

The risk assessment and safety demonstration summary states that hydrogen injection requires careful consideration of flows, pressures, hydrogen quality, control of the mixing process and accurate measurement and monitoring of the blend and its energy content.

The research concluded with the recommendation that the start of a pilot hydrogen blending project on the Irish gas network will aid in demonstrating the network's safe functioning as well as the safety of any appliances used by end users, for example in homes or power plants. The pilot studies and further implementation of hydrogen blending into the network will require cooperation from every stakeholder associated with Gas Networks Ireland and support from the appropriate regulatory bodies.

HYDROGEN MOBILITY IRELAND: DEVELOPING THE USE OF HYDROGEN FOR TRANSPORT

The 'Hydrogen Mobility Ireland' (HMI) is a cross-sector partnership bringing together leading companies, research institutions and government agencies that are working together to develop infrastructure related to hydrogen mobility technologies and promote hydrogen technologies in the country. These include organisations such as ESB (Irish electricity supplier), Gas Networks Ireland (gas network operator), motor/car distributors such as Toyota Ireland, Hyundai Ireland, and Honda Ireland, as well as University College Dublin. These entities and more are working together to develop and promote hydrocarbon technologies in Ireland.

The main goals of the partnership are:

1. **Introduction and development of infrastructure for the production, distribution and supply of hydrogen:** creating a network of hydrogen refueling stations that will enable users of hydrogen cars to have easy access to fuel.

2. **Encouraging the increased use of hydrogen vehicles:** promoting the benefits of hydrogen vehicles, such as zero emissions and lower operating costs.

3. **Supporting research and technological development in the field of hydrogen:** working with universities and research institutes to promote innovation and technological development related to hydrogen.

4. **Building international partnerships and collaborating with other entities operating in the hydrogen sector:** establishing collaborations with similar initiatives and organizations around the world to exchange knowledge and experiences and promote the global development of hydrogen technologies.

By working towards these objectives, Hydrogen Mobility Ireland hopes to expedite the shift in Ireland towards a more environmentally friendly and sustainable transportation system and encourage the advancement of hydro-related technologies in various domains, such as the construction of infrastructure for hydrogen production, distribution, and supply, and the creation of a network of hydrogen refuelling stations to facilitate the easy access of fuel for drivers of hydrogen-powered vehicles, such as buses.

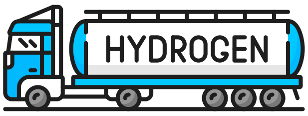
In addition, the partnership actively promotes technical advancement and research by facilitating the sharing of expertise and knowledge among partners and participating organisations. The planning of conferences, seminars, and workshops where professionals in the field of hydrogen are able to share their expertise and experience facilitates the sharing of best practices, helps identify problems in the hydrogen industry, and establishes a centre for creative solutions.

A report from Hydrogen Mobility Ireland, published in May 2023, explains the role of hydrogen derived e-fuels in aviation and maritime, as well as the opportunities for Ireland, to make recommendations on how the development of a domestic hydrogen ecosystem can facilitate the production of sustainable e-fuels for use in aviation and shipping transport. The research examined e-fuels, which are created when CO2 and electrolytic hydrogen combine to form hydrocarbon liquids or oxygenated (methanol or ethanol) by chemical or biological synthesis. It was found that the amount of hydrogen that will be required to cover the projected demand when considering proposed EU policies ranges from 0.25-0.35 kt in 2025, up to 7-11 kt in 2030, finally reaching 230-330 kt in 2050.

E-fuels, produced from hydrogen and captured CO2, can produce drop-in fuels chemically identical to fossil fuels. At the date of writing, the production of e-methanol is at commercial scale, while e-kerosene production is at pilot scale.

The report further states that through developing the Irish hydrogen economy further, expanding into e-fuels, could result in:

- **Gross Value Added of €11m/year in 2030**
- **Gross Value Added of up to €300m/year in 2050**
- **10,500 associated jobs by 2050**



A wide range of fuel types and technologies will be needed to decarbonise the transportation industry in Ireland and Europe as a whole. The industry will continue to rely heavily on liquid carbon fuels due to unique operational needs and variations in journey length (for example, national compared to international shipping). Furthermore, the cost of producing e-fuels is currently higher than that of fossil fuels, which makes it difficult for producers to commercialise these technologies. The scaling up of these technologies hence requires immediate financial backing as well as clear and precise national and EU policy.

SUMMARY

Poland is one of the leaders in hydrogen production in Europe and the world (3rd in Europe and 5th in the world). Unfortunately, this is gray hydrogen production, realized mainly for the companies' own needs. With the acceleration of the green economy in the EU, Poland also faced the need to develop a hydrogen economy in the coming years. Hydrogen technologies for the entire value chain of the hydrogen economy are undoubtedly now one of the main priorities, enshrined in EU and national strategic documents. They are also the subject of research and analysis by representatives of academia, business and governments of many countries.

However, it is still an area with a still relatively low level of development, which faces many barriers. This is particularly evident in Poland. Among the most important barriers and challenges to the development of the hydrogen economy in Poland diagnosed in a survey conducted in 2023 among a group of 34 entities belonging to various sectors related to its value chain, experts, representatives of hydrogen valleys mentioned (Tchorek et al., 2023):

- Poland lacks systemic support dedicated to renewable hydrogen and derivatives (covering the financing gap, long-term off-take),
- impediments related to the lack of an adequately developed and regulated electricity system in Poland (including a lack of regulations for direct lines, a poor PPA market, a highly carbon-intensive energy mix, grid and RES connection problems),
- Lack of transmission, distribution, storage and terminal infrastructure, making it difficult to create a liquid wholesale market and connect the demand and supply sides,
- Lack of adequate regulations in Poland dedicated to renewable hydrogen and derivatives (difficulty in implementing investments, especially at the administrative and environmental level),
- Lack of a clearly defined strategic vision for the development of the hydrogen economy (update of the PSW, PEP2040, KPEiK in terms of hydrogen).

Co-funded by the European Union

SUMMARY

Although the respondents did not point to a competence gap as a barrier to the development of the hydrogen economy in Poland, it should be noted that currently Polish society and potential cadres for this economy are not yet prepared to participate in such a huge green transformation. As PARP experts point out, "It is necessary to include the needs of the Polish economy in the area of hydrogen technologies in the guidelines of the Polish Qualification Framework. Building a hydrogen economy requires strongly specialized and interdisciplinary knowledge.

The problem of the Polish hydrogen technology market is the lack of an education system at all levels of the Polish Qualification Framework. This significantly weakens the country's potential to implement groundbreaking R&D projects, as specialists largelyhave to learn 'on a living organism', i.e., during the implementation of project work itself." (PARP, 2022, p. 194).

BIBLIOGRAPHY

- Antas Ł., Bocian M., Bajek M., Giers M., Bijoś K. (2021). Wodór w Europie Środkowo-Wschodniej. Perspektywy rozwoju w krajach Grupy Wyszehradzkiej i na Ukrainie, Esperis, Warszawa.
- ARP. S.A. (2024). Doliny wodorowe, https://arp.pl/pl/jak-dzialamy/transformacja-energetyczna-/doliny-wodorowe/
- Brodacki D., Gajowiecki J., Hajduk R., Kocejko P., Kowalski S., Mataczyńska E., Miętkiewicz R., Nowakowski R., Plaskiewicz N., Ruszel M., Sienkiweicz M., Skwierz S., Turowski P., Witkowska A. (2021). Zielony wodór z OZE w Polsce. Wykorzystanie energetyki wiatrowej i PV do produkcji zielonego wodoru jako szansa na realizację założeń Polityki Klimatyczno-Energetycznej UE w Polsce, Dolnośląski Instytut Studiów Energetycznych, Polskie Stowarzyszenie Energetyki Wiatrowej, Wrocław 2021.
- de Jongh P.E., Adelhelm Ph. (2010). Nanosizing and Nanoconfinement: New Strategies
- EC. (2018). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0773
- EC. (2019). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. The European Green Deal, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640.
- EC. (2020). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. A hydrogen strategy for a climate-neutral Europe, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0301.
- EC. (2021). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS EMPTY. 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality, Brussels, https://eur-lex.europa.eu/legal-content/EN-PL/TXT/?from=EN&uri=CELEX%3A52021DC0550.
- EC. (2022). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. REPowerEU: Joint European Action for more affordable, secure and sustainable energy, COM(2022) 108 final, Brussels, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0108
- Elżbieciak T. (2023). Jakie elektrolizery wyprodukują zielony wodór w Polsce?, Wysokie Napięcie.pl, https://wysokienapiecie.pl/82287-elektrolizery-wyprodukuja-wodor-w-polsce/
- EY. (2023). Zielony wodór- rewolucja czy przejściowa moda? Szanse i wyzwania dla polskiej gospodarki, Warszawa.
- Folentarska A., Kulawik D., Ciesielski W., Pavlyuk V. (2016). Nowoczesne materiały do przechowywania wodoru jako paliwa przyszłości, Chemistry. Environment. Biotechnology, nr 19, s. 125–130.

BIBLIOGRAPHY

- Global Hydrogen Council (2017). Hydrogen Scaling Up: A Sustainable Pathway for the Global Energy Transition, https://www.h2knowledgecentre.com/content/policypaper1201
- IEA. (2023). Energy Technology Perspectives, https://www.iea.org/reports/energy-technology-perspectives-2023
- Komorowska A., Mokrzycki E., Gawlik L. (2023). Hydrogen production in Poland – the current state and directions of development, Polityka Energetyczna – Energy Policy Journal, 26(4), pp. 81-98, https://doi.org/10.33223/epj/170913
- Kozikowski S., Szymlek K. (2022). Wodór – zielone złoto. Bezpieczne magazynowanie, Elektroinstalator, nr 9, s. 14-21.
- Kryczka D. (red.). (2021). Rozwój gospodarki wodorowej w UE i państwach członkowskich – środowisko regulacyjne i finansowe, ESPERIS, UN Global Compact, Warszawa.
- Łącka I. (2023). The Role of Green Energy in the Economic Growth of the World, in: Bąk I., Cheba K., Green Energy. Meta-analysis of the Research Results, Springer, Cham, pp. 41-57.
- Łącka I., Wojdyła P. (2022). Transformacja energetyczna w cieniu wojny. Finansowanie ze środków unijnych szansą na rozwój technologii wodorowych w Polsce, Chemia Przemysłowa, Zeszyt 2, s. 80-88.
- Łańcuch wartości gospodarki wodorowej w Polsce. (2023). CIRE.pl, https://www.cire.pl/artykuly/serwis-informacyjny-cire-24/lancuch-wartosci-gospodarki-wodorowej-w-polsce.
- Mierwiński R. (2022). Zielone strony biznesu. Wodór na ratunek energetyki, https://mycompanypolska.pl/artykul/zielone-strony-biznesu-wodor-na-ratunek-energetyki/8304 (dostęp: 12.03.2024).
- Mohan M., Sharma V.K., Kumar E.A., Gayathri V. (2018). Hydrogen storage in carbon materials—A review, Energy Storage, 1:e35, DOI: 10.1002/est2.35.
- Monitor Polski z dnia 7 grudnia 2021 r., poz. 1138. (2021). Polska strategia wodorowa do roku 20230 z perspektywą do 2040 r. Załącznik do uchwały Rady Ministrów z dnia 2 listopada 2021 (poz. 1138).
- PARP. (2022). Mapa rozwoju rynku i technologii dla obszaru technologii wodorowych, Warszawa.
- Pilszyk, M., Juszczak, A., Gonera, Ł. (2023), Wyścig po wodór. Państwa i ich strategie wodorowe, Policy Paper, nr 5, Polski Instytut Ekonomiczny, Warszawa.
- Siekierski M., Majewska K., Mroczkowska-Szerszeń M. (2023). Metody efektywnego i bezpiecznego magazynowania wodoru jako warunek powszechnego jego wykorzystania w transporcie i energetyce, Nafta-Gaz, nr 2, s. 114-130.
- Smoleń M., Żelisko W. (2023). International Dimension of the Polish Hydrogen Strategy: Conditions and Potential for Future Development, RIFS Discussion Paper, June 2023, https://doi.org/10.48481/rifs.2023.019
- Sobolewski M. (2022). Gospodarka wodorowa. Infos, nr 6(298).
- Tchorek G. (2022). Rewolucja wodorowa - jak skorzystać?, Webinarium PARP, Warszawa 18.10.2022 r., https://www.parp.gov.pl/attachments/article/83293/webinarium_18102022_wodor.pdf

BIBLIOGRAPHY

- Tchorek G., Targowski F., Mikusek P., Grzybowski M., Kupecki J., Hercog J., Skrzypkiewicz M., Niemczyk A., Błesznowski M., Wierzbicki M. (2023a). Łańcuch wartości gospodarki wodorowej w Polsce. Raport, Uniwersytet Warszawski, Instytut Energetyki, Warszawa.
- Tchorek G., Targowski F., Mikusek P., Grzybowski M., Kupecki J., Hercog J., Skrzypkiewicz M., Niemczyk A., Błesznowski M., Wierzbicki M. (2023b). Łańcuch wartości gospodarki wodorowej w Polsce. Skrót raportu, Uniwersytet Warszawski, Instytut Energetyki, Warszawa.
- THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION. (2023). REGULATION (EU) 2023/1804 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1804
- Towards Meeting Hydrogen Storage Goals, ChemSusChem, No. 3, pp. 1332–1348.
- UN. 2015. Transforming our World: The 2030 Agenda for Sustainable Development, Geneva, https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981
- VIII posiedzenie Rady Koordynacyjnej ds. Gospodarki Wodorowej. (2024), https://www.gov.pl/web/klimat/viii-posiedzenie-rady-koordynacyjnej-ds-gospodarki-wodorowej.
- Wyszkowski K., Piwowarek Z., Nowakowska M., Pałejko Z., Kryczka D. (2022). Prawo wodorowe – środowisko regulacyjne wspierające rozwój gospodarki wodorowej, UN Global Compact, Warszawa.
- https://www.gov.ie/en/publication/624ab-national-hydrogen-strategy/
- https://hydrogenireland.org/wp-content/uploads/2019/10/HMI_report_final_Oct3rd2019-2.pdf
- https://h2mi.ie/wp-content/uploads/2022/08/HMI-White-Paper-Policy-to-Enable-Green-Hydrogen.pdf
- https://windenergyireland.com/images/files/final-hydrogen-and-wind-energy-report.pdf
- https://www.researchgate.net/publication/371700718_Hydrogen_in_the_Irish_Energy_Transition_Opportunities_and_Challenges
- https://www.gasnetworks.ie/docs/renewable/Hydrogen-and-Irelands-National-Gas-Network.pdf
- https://www.sciencedirect.com/science/article/pii/S2590123023001573
- https://hydrogenireland.org/wp-content/uploads/2024/02/H2IRL-CEO-Job-description-.pdf
- https://www.dcu.ie/sites/default/files/inline-files/rf1575-research-fellow-in-hydrogen-storage-and-gas-grid-analytics-job-description.pdf
- https://www.climatexchange.org.uk/wp-content/uploads/2023/09/cxc-mapping-the-current-and-forecasted-hydrogen-skills-landscape-jun-2023.pdf
- https://www.lexology.com/library/detail.aspx?g=893b6c94-2b70-4ef1-883e-45fde9e89971
- https://www.skillnetireland.ie/newsroom/green-hydrogen-talent-development-for-the-jobs-of-tomorrow
- https://op.europa.eu/en/publication-detail/-/publication/0817d60d-332f-11e9-8d04-01aa75ed71a1/language-en
- https://hyskills.org/wp-content/uploads/2022/10/HySkills-IO1T1-3-Report.pdf
- https://www.skillnetireland.ie/wp-content/uploads/2022/01/WindEnergy-Hydrogen-Offshore-Report-Green-Tech-Skillnet.pdf

BIBLIOGRAPHY

- https://www.4coffshore.com/windfarms/ireland/
- https://windenergyireland.com/about-wind/the-basics/facts-stats
- https://www.clean-hydrogen.europa.eu/media/news/interested-hydrogen-safety-2023-06-07_en
- https://www.clean-hydrogen.europa.eu/system/files/2023-05/2022_Safety_Planning_Implementation_v2_1-Final%20%281%29.pdf
- https://seshydrogen.com/9-kolorow-wodoru-poznaj-ich-znaczenie-zastosowanie-i-potencjal-wykorzystania/
- https://arp.pl/pl/jak-dzialamy/transformacja-energetyczna-/doliny-wodorowe/
- https://przemyslprzyszlosci.gov.pl/polskie-plany-wodorowe/
- https://www.cire.pl/artykuly/materialy-problemowe/179840-jak-napedzimy-gospodarke-wodorem-wszystko,-co-musisz-wiedziec-o-polskiej-strategii-wodorowej
- https://zielonagospodarka.pl/h2idea-tv-sd-polska-i-partnerzy-buduja-kompetencje-i-innowacje-w-gospodarce-wodorowej-12798
- https://www.fgreenlab.org/publikacje/strategie-rozwoju-gospodarki-wodorowej
- https://www.forum-ekonomiczne.pl/doliny-wodorowe-trampolina-do-ogolnoeuropejskiej-gospodarki-wodorowej/
- https://www.gov.pl/web/klimat/polska-strategia-wodorowa-do-roku-2030
- „Polska strategia wodorowa do roku 2030 z perspektywą do roku 2040", załącznik do uchwały nr 149 Rady Ministrów z dnia 2 listopada 2021 r. (poz. 1138), Warszawa, październik 2021 r.
- https://www.eit.edu.au/courses/professional-certificate-of-competency-in-hydrogen-energy-production-delivery-storage-and-use/
- https://www.eit.edu.au/why-eit/
- https://www.dnv.com/news/dnv-grows-energy-testing-capability-in-groningen-with-new-technology-centre-to-accelerate-energy-transition-242452/
- https://www.dnv.com/training/hydrogen-transmission-training-course-244912/#:~:text=The%20three%2Dday%20training%20will,concepts%20covered%20during%20the%20training
- https://www.mondragon.edu/cursos/es/master-interuniversitario-tecnologias-hidrogeno?utm_source=5498_NdP_Ind_TOT_22-23&utm_medium=POST&utm_campaign=22205900_MITH
- https://council.ie/new-hydrogen-buses-for-initial-use-on-commuter-route-105x/

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Co-funded by the European Union