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International Dimension of the Polish Hydrogen Strategy

Conditions and Potential for Future Development

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Part of a series edited by Yana Zabanova and Rainer Quitzow

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Summary

Poland is the third largest producer of hydrogen in the EU, with around 1.3 million tonnes produced every year. This grey hydrogen is generated almost exclusively from steam methane reforming and utilised mainly by the chemical, petrochemical, steel and food sectors. The emergence of low-carbon hydrogen technologies has captured a significant interest by various Polish stakeholders, including both oil and gas sector incumbents, renewable energy promoters and local governments.

In 2021, the *Polish Hydrogen Strategy until 2030 with an outlook until 2040* was published as the first official government strategy affecting low-carbon hydrogen development. The document presents an optimistic and ambitious approach to hydrogen potential, with a focus on domestic production and use in multiple sectors. This is despite the fact that production of low-carbon hydrogen in Poland could face significant challenges, such as a relatively low availability of clean electricity, reliance on natural gas imports and limited experience with CCS.

Issues regarding the global hydrogen market and international trade are largely omitted. This paper analyses the possible background of this fact, as well as the factors affecting the future Polish approach to the European and global hydrogen market. Although Poland would not be a frontrunner in these developments, we believe that it could become a pragmatic participant. In fact, we note that Polish companies, including state-owned enterprises, have already launched some relevant cooperative initiatives at European level.

Acknowledgements

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Contents

1. Introduction

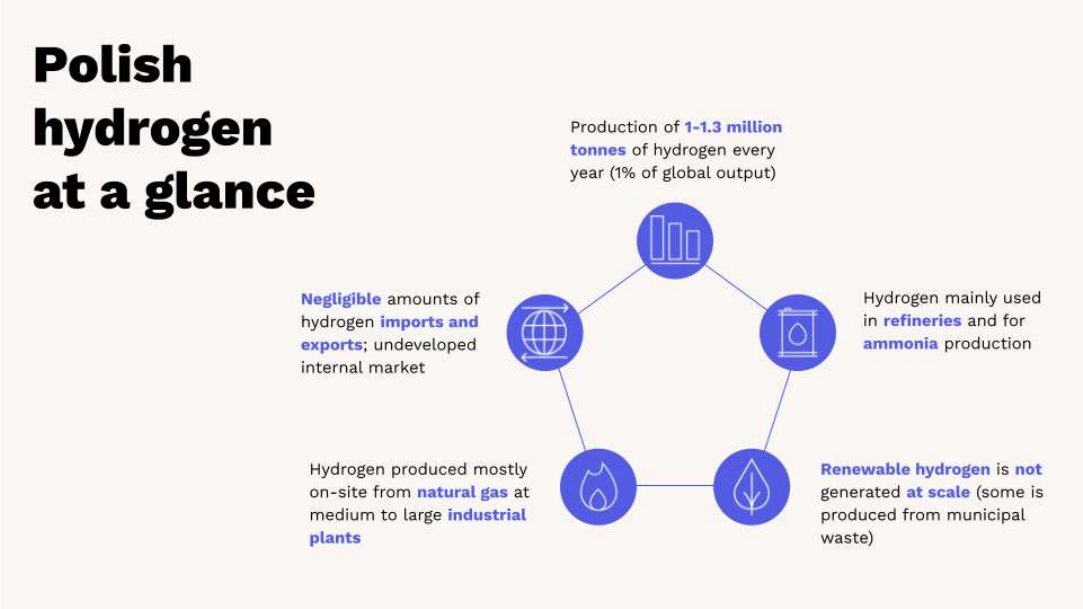
The future of Polish hydrogen has recently sparked significant public interest. In late 2021 the government approved the *Polish Hydrogen Strategy until 2030 with an outlook until 2040*, the first national document of this kind (Polish Ministry of Climate and Environment, 2021a). At present, eight hydrogen valleys are being established to support hydrogen cooperation between regional and local governments, large state-owned enterprises, academia and private businesses (Industrial Development Agency JSC, 2023). All Polish coal regions that are currently undergoing a process of transition have mentioned hydrogen in their respective Territorial Just Transition Plans. Hydrogen solutions are pursued by stakeholders from sectors as diverse as oil and gas, mining, shipping or automotive, as a possible driver for further development in the disruptive era of decarbonisation. Domestic subsidies and industry marketing have already encouraged local administrations to make initial investments (Municipal Office in Konin, 2022) in hydrogen buses to reduce greenhouse gas (GHG) emissions and air pollution from public transport.

Hydrogen is not yet a mainstream topic in Poland, although the introduction of the *Polish Hydrogen Strategy* prompted some discussion among a broad range of stakeholders. There are several diverse visions for the future national hydrogen economy with regard to optimal applications and production modes (zero-carbon versus low-carbon), the shape of the market (centralised versus decentralised) and how best to implement necessary measures (top-down versus bottom-up). For example, some sceptical voices are emerging, raising questions about the environmental sustainability and economic viability of the promoted hydrogen uses or available supply of low-carbon hydrogen in the coming decades.

The international hydrogen market is seen by expert bodies (IRENA, 2022) and some national hydrogen strategies (German Federal Ministry for Economic Affairs and Energy, 2020) as an important source of low-carbon hydrogen that is needed to decarbonise advanced industrial countries. This international dimension of the hydrogen economy is notably less prominent in Polish discussions. The Polish Hydrogen Strategy is, similarly to analogous documents prepared in other countries in 2020 and 2021, noticeably influenced by the economic consequences of the COVID-19 pandemic. Public investment in hydrogen technologies was seen as a way to mobilise domestic industry and the energy sector and to avoid a lasting economic slowdown. While energy security and independence have become key talking points in Polish energy policy discussions after the 2022 Russian invasion of Ukraine, they were initially dominated by the most immediate questions regarding the fossil fuel supply for the 2022/2023 winter and appropriate interventions to shield households and the economy. While there were some early signs of broader reorientation in energy policies such as the March 2022 announcement of assumptions for the energy policy update (Polish Ministry of Climate and Environment, 2022a), the actual strategic and legislative changes were, as of June 2023, carried out only partially, with little focus on hydrogen economy.

Against this backdrop, the aim of this paper is to analyse the external dimensions of the *Polish Hydrogen Strategy*. Firstly, we provide an overview of the Polish hydrogen economy and identify key factors affecting its future potential. Subsequently, we review the *Polish Hydrogen Strategy* and its in-depth analytical annex (Kupecki et al., 2021). On this basis, the third part focuses on the role of international engagement – or the relative lack thereof – within the strategy and its possible explanations. Finally, we place the issue in the broader context of Polish international energy policy, including both preliminary assumptions for the *Energy Policy of Poland until 2040* update and ongoing policy decisions (both domestic and international), arriving at conclusions for European stakeholders.

2. Polish Hydrogen Economy – State of Play, Potential and Challenges



Poland is in a peculiar starting position in the global push towards a new hydrogen economy. It is the third largest producer of hydrogen in the EU, with around 1.3 million tonnes produced every year (Polish Ministry of Climate and Environment, 2021a, p. 7). This hydrogen is so-called grey hydrogen, generated exclusively from steam methane reforming and utilised mainly by the chemical, petrochemical, steel and food sectors. Existing Polish hydrogen production facilities are for the most part a by-product of relatively developed medium-tech industries, in which hydrogen is predominantly made on-site at large industrial plants. Internal trade is limited in scale and hydrogen exports are negligible (Polish Ministry of Climate and Environment, 2021a, p. 7).

Proponents of the Polish hydrogen economy, including industry stakeholders and policymakers, list several domestic advantages (Kupecki et al., 2021, p. 455-456), such as the scale of the pre-existing hydrogen economy, steady demand from numerous industries, or developed automotive and rolling stock industries which can participate in the hydrogen value chains. Moreover, salt caverns[1] could be used for hydrogen storage, and offshore wind power – with a potential that has been assessed at up to 33 GW by the wind industry association (Polish Wind Energy Association, 2022) – for renewable

[1] For example, Orlen, a state-controlled Polish oil and gas conglomerate, has approximately 20 such caverns presently utilised for gas storage, which in the more distant future could potentially be repurposed for hydrogen. In general, the total potential of hydrogen storage in Polish onshore salt caverns is estimated at roughly 10 000 TWh, the second biggest in the EU (Institute of Power Engineering et al., 2023, p. 53).

hydrogen production.

Nevertheless, various barriers also exist, which can be divided into two loosely defined categories – energy-related and more general barriers. With regard to energy-related issues, Poland lags behind most EU countries in the deployment of renewable energy – the current energy strategy envisions only 32 per cent of renewable energy in electricity production by 2030 (Polish Ministry of Climate and Environment, 2021b, p. 10), though in 2023 that figure may be updated. Onshore wind has stalled after regulations introduced in 2016[2] made it impossible to initiate new projects (or repower old installations) on 99.7 per cent of the Polish land area (Czyżak et al., 2021), whereas offshore wind development is behind schedule (Polish Supreme Audit Office, 2022). Solar power has experienced significant growth since 2019 (Instrat, 2023), but it is mostly in the form of small-scale, rooftop PV with relatively low capacity factors due to climate conditions. Renewable electricity will be crucially needed to replace the ageing fleet of coal-fired power plants. Hydrogen produced from biomass, biofuels or waste, promoted by oil and gas incumbents to local administrations as fuel for hydrogen-powered buses, has limited scale-up potential, especially as the same resources will constitute attractive fuels for district heating. Moreover, Poland is unlikely to become a competitive producer of so-called blue hydrogen, i.e. hydrogen generated from natural gas with additional carbon capture and storage (CCS) to reduce CO_2 emissions, because it is a gas importer (Statistics Poland, 2022, p. 21) and has very few concrete achievements in the field of CCS technologies (Global CCS Institute, 2022).[3] Ultimately, Polish nuclear power will not be available until the mid-2030s at the earliest.

There are other types of challenges to be overcome as well. For example, in comparison with the EU averages, Poland's R&D and innovation performance is relatively weak overall – and hydrogen-related R&D in the country has been limited (Maj & Szpor, 2020). Furthermore, Poland does not currently produce electrolysers or mine minerals used in their manufacturing. Another obstacle in the first stage of development is a spatial dispersion of industrial facilities – key industrial centres such as Silesia are located far from the Baltic Sea with its offshore wind power potential and possible import terminals. Finally, some actors also consider the length of administrative procedures and the lack of necessary regulations as considerable obstacles.

Despite these constraints, the hydrogen economy has the potential to become an essential part of Poland's decarbonisation pathway, especially in uses with no viable clean alternatives, such as steelmaking or the chemical industry. However, the abovementioned limitations affect the competitiveness of Polish hydrogen production against, on the one hand, other clean energy solutions, and on the other, that of international hydrogen players.

Despite the barriers discussed, Polish entities, especially state-owned companies, have already adopted quite an ambitious approach, in the hope of leading the national hydrogen revolution. Orlen, a state-controlled Polish oil and gas conglomerate, has published its own hydrogen strategy (which acknowledges the goals of the *Polish Hydrogen Strategy*), stating the objective of 540 MW of low- and zero-carbon hydrogen capacity (both domestic and international in the Czech Republic and Slovakia) for 2030 (PKN Orlen, 2022). Orlen's strategy focuses on different aspects, such as decarbonising its assets with blue hydrogen, supplying hydrogen fuel to the transport sector or utilising it to generate renewable

[2] These regulations were amended in March 2023. The biggest uncertainty had been their final shape - the initial proposal to modify the minimum required distance between the turbine and its surroundings (mainly houses and environmental protection areas) from the so-called "10H" rule (i.e. ten times the height of the turbine to the tip of its blade; this in practice often corresponds to ca. 2 km) to 500 metres had lost ground in favour of a proposal of 700 metres. This will limit the area available for onshore wind turbines by half and heavily impact the portfolio of projects already prepared for the 500-meter limit, thus delaying the significant addition of new capacities perhaps even beyond 2030 (Kopeć, 2023).

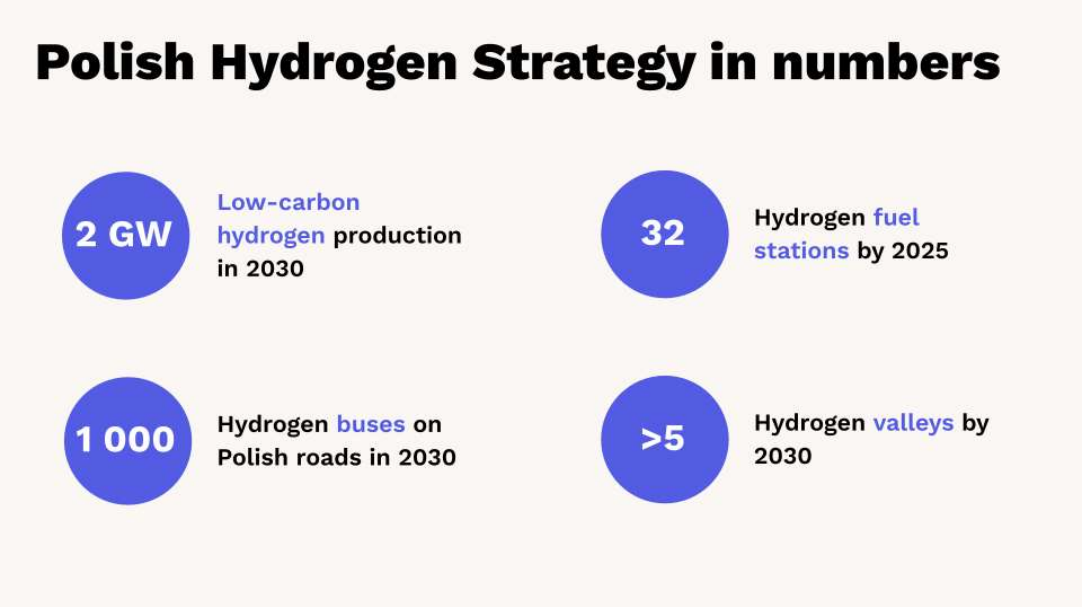
[3] This may change, however, since Poland has recently had talks with Norway over the possibility of realising joint initiatives in the field of CCUS technologies (Polish Ministry of Climate and Environment, 2022f).

electricity and heat, in line with the national strategy. The company envisages the development of hydrogen production facilities and 100 hydrogen fuelling stations across Poland, the Czech Republic, and Slovakia, and explicitly mentions participation "as a supplier and customer" in the European Hydrogen Backbone. Orlen's recent merger with the Polish state-controlled oil and gas enterprises Lotos and PGNiG is likely to further add to its hydrogen projects and plans. For example, PGNiG, a natural gas and crude oil producer also intends to develop blue hydrogen production and storage capacities (PGNiG, 2020 & 2022). Gaz-System, the Polish natural gas transmission system operator, has signed an agreement (Gaz System, 2022a) with gas TSOs from Slovakia (Eustream), Hungary (FGSZ) and Romania (Transgaz), which includes plans to explore the possibility of international hydrogen transmission. Gaz-System has also recently submitted applications for financing two international hydrogen transmission network projects – BEMIP Hydrogen and HI East – in order for them to acquire a status of a PCI (Project of Common Interest) project under the EU's TEN-E Regulation (WNP, 2023). On the other hand, the domestic hydrogen transmission infrastructure is expected to be developed by Gaz-System as a result of actions taken within the European Hydrogen Backbone, e.g., building a north-south hydrogen corridor, connecting hydrogen valleys or creating underground storage facilities (Gaz System, 2022b).

Other large industrial players have launched their own initiatives as well. ZEPAK, the largest private energy group in Poland, has been actively engaged in developing the hydrogen economy – it already has three mobile hydrogen storage units and a fleet of around 100 fuel cell vehicles, and plans exist to open a stationary hydrogen fuel station in Warsaw in 2023 and build a hydrogen bus factory in Świdnik, which is to begin construction later that year. Grupa Azoty, one of the leading players in the European fertiliser and chemical markets, as part of its Green Azoty strategy (Grupa Azoty, 2021), intends to set up an alternative fuels laboratory to analyse hydrogen fuel quality (and potentially take part in its certification), produce green hydrogen and ammonia in its biggest facility in Puławy, and use the Port of Police as a hydrogen and ammonia hub. They are also considering importing green ammonia from other countries and utilising small modular reactors (SMR) to power their operations (including hydrogen production) (Grupa Azoty, 2021). The JSW Group, the largest producer of high-quality hard coking coal in the EU, has started sourcing hydrogen from coke-oven gas (JSW, 2022a), and has plans to establish a fuel cell factory, along with a production line for hydrogen buses, at the site of the former Krupiński mine (JSW, 2022b). Finally, the Port of Gdynia will become a hydrogen hub on its path towards decarbonisation (Port of Gdynia, 2022).

Not all business stakeholders come from fossil fuel backgrounds. On the other side of the spectrum, there is a notable company HYnfra, which promotes hydrogen as a part of local, integrated, semi-independent energy systems based on renewables, through partnerships with the industry and local administrations (though the investments are still at an early stage) (HYnfra, 2022). One example of a multitude of projects being developed by this company is a Green Industrial Zone in Bucha in Ukraine. As soon as conditions allow, HYnfra, along with its partners from Japan and Ukraine, plans to develop such an energy system based on green hydrogen and ammonia (HYnfra, 2023). Mainstream domestic RES industry associations are also interested in hydrogen (Polish Wind Energy Association & The Lower Silesian Institute for Energy Studies, 2021), although major progress has so far not been achieved.

3. Polish Hydrogen Strategy – Key Information

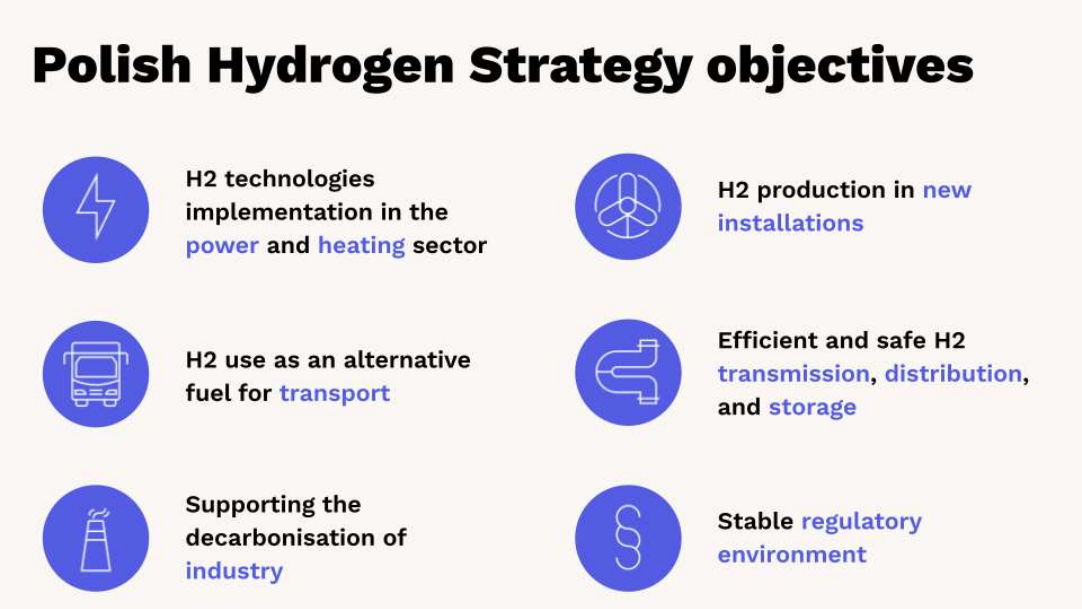


The *Polish Hydrogen Strategy until 2030 with an outlook until 2040* (hereinafter also referred to as: the Strategy) was approved in late 2021. The 37-page document presents a vision for the Polish hydrogen economy, proposes six key goals and lists legislative and non-legislative actions (Polish Ministry of Climate and Environment, 2021a). Its annex, written by the Institute of Power Engineering, the Faculty of Management at the University of Warsaw and the Institute for Ecology of Industrial Areas, is the 516-page *Analysis of the potential of hydrogen technologies in Poland until 2030 with an outlook until 2040* (hereinafter also referred to as: the Analysis), covering the potential for developing these technologies in Poland and providing additional insights into some of the underlying assumptions (Kupecki et al., 2021). This potential has been assessed across the whole value chain through two separate expert surveys, whose end products are sets of recommendations for facilitating the growth of the national hydrogen economy (Kupecki et al., 2021, p. 452-454 and 463-466).

The Strategy is formulated within the context of climate and decarbonisation policy. Hydrogen is described as both a clean energy storage medium and a viable solution for industrial uses where direct electrification is not possible. There is also a significant focus on prospective economic gains related to emerging hydrogen value chains. Issues of national energy security are present but less pronounced (though it must be noted that the Strategy was written before the onset of the European energy crisis).

The Strategy presents an optimistic, undiscriminating and maximalist approach to the hydrogen economy. It states the support for all low-emission methods of production, including niche or controversial technologies such as generation from coal (with CCS/CCU), although, at the same time, scaled-up production capacity envisioned for 2030 is said to consist "in particular" of electrolysers (Polish

Ministry of Climate and Environment, 2021a, p. 20). Even though blue hydrogen is supported, there is surprisingly little focus on adding CCS to existing grey hydrogen production (and to decarbonising this process in general – the Strategy gives the impression that a brand-new green hydrogen economy is supposed to emerge alongside, and not directly replace, the old grey one). The same all-of-the-above approach can be seen with favoured hydrogen uses that encompass somewhat contentious positions, such as building and district heating, cars and blending into the natural gas network, in addition to various more conventional options, such as industrial processes (e.g., steelmaking), fuel cell-powered buses, lorries and locomotives, as well as power grid flexibility enhancement.



The implementation of the Strategy is the responsibility of several different actors – primarily central and regional administrative bodies, government agencies and scientific institutes. The realisation roadmap consists of legislative (e.g., introduction of a hydrogen act) and non-legislative actions (e.g., a sector deal,[4] a hydrogen technologies centre), embedded in a general timeline extending until 2030. While the Strategy will be monitored along key strategic indicators, those will mostly cover production capacity (2 GW) and application in transport (1 000 hydrogen buses), as well as some legislative and policy goals (Polish Ministry of Climate and Environment, 2021a, p. 35). On the other hand, there is no measurable objective for hydrogen use in the industry.

Planned actions and support programmes are to be financed by the National Fund for Environmental Protection and Water Management (for infrastructure, such as fuelling stations and fuel cell buses) and the National Centre for Research and Development (for R&D and innovations). The cost of achieving key indicators is estimated at roughly 2.3 billion EUR[5] (Polish Ministry of Climate and Environment, 2021a, p. 31), while the first round of support programmes listed in the Strategy have a value of at least 450 million EUR[6] (Polish Ministry of Climate and Environment, 2021a, p. 31). However, access

[4] This sector deal is a first-of-a-kind initiative launched in the EU. Over 200 entities are its signatories, aiming to take actions in line with five strategic goals (local content, R&D, investments, people and cooperation). The deal is an executive instrument of the Strategy, set to underpin the growth of the domestic hydrogen economy. The realisation of the goals is to be facilitated by cooperation within the Coordinating Council of Hydrogen Economy, set up for this very reason (Polish Ministry of Climate and Environment, 2022g).

[5] 1 EUR = 4.7 PLN

[6] 1 EUR = 4.7 PLN

to a key source of hydrogen funding – the EU's Recovery and Resilience Facility (RRF) – remains blocked as of June 2023 due to the government's refusal to adhere to related EU requirements, which might threaten the growth of future hydrogen projects.[7]

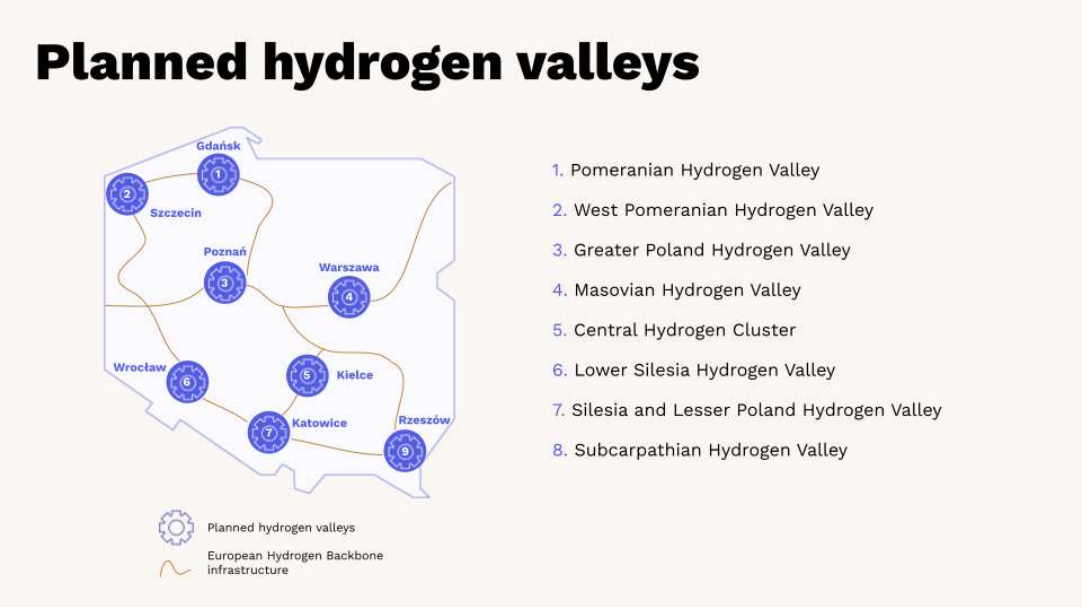
Based on the factors above, it may seem that the Strategy often loses sight of clear sustainability goals and focuses instead on promoting the development of the broad domestic hydrogen economy for its own sake – or on appeasing all stakeholders interested in possessing a share of the emerging market. Many insights from the Analysis, for example regarding the viability of different methods of production or applications, are not reflected in the strategic document itself. The most glaring problem is the contradiction between existing renewable energy targets in the *Energy Policy of Poland until 2040* (PEP2040) and the scale of planned renewable hydrogen production. The Analysis calculates that 2 GW of (primarily) renewable hydrogen production capacity envisioned for 2030 by the Strategy would require 40 per cent of the renewable energy capacity predicted for that year by the PEP2040 (Kupecki et al., 2021, p. 428-429). While the exact number can be disputed, the fact remains that the projected demand for renewable electricity by electrolysers is not aligned with official supply forecasts (or policies), and that the issue is not directly addressed in the Strategy itself – this is related to the reasons discussed in the next chapter.

Ongoing government efforts with regard to the Strategy are now concentrated on creating a so-called hydrogen constitution, which was originally expected to be completed in 2022. The document will establish a regulatory framework for the operation of the national hydrogen economy. Apart from the constitution, this will include a hydrogen act (and possibly some form of contracts for difference [CfD]) to regulate rules for conducting hydrogen-related business activities, likely to be introduced in 2023 (Polish Government Legislative Centre, 2022), as well as an update of the Analysis. This update will revise the initial version's conclusions and include some additional content, such as an examination of the possibility of creating local hydrogen ecosystems (e.g., valleys, hubs, clusters) or the viability of particular business models in the national hydrogen economy. In addition, in late February 2023, the Polish Ministry of Climate and Environment published a draft regulation on state aid for the development of hydrogen technologies (Polish Government Legislative Centre, 2023). It is aimed at simplifying the rules for granting subsidies for investments required under the RRF, including for hydrogen production, transmission or storage projects. The regulation is also seen as an enabler of accomplishing hydrogen goals from the Strategy.

As for the hydrogen act mentioned above, over 40 entities, including some industry players and the Energy Regulatory Office, have submitted their remarks in the consultation process. The act is likely to undergo significant changes in its final form, since many reservations have been expressed about it, e.g., that this document overregulates and hampers the growth of the emerging hydrogen market by opening it only partially and discouraging investors to build the necessary infrastructure. The hydrogen act is a milestone of the Recovery and Resilience Facility, and for this reason is expected to be introduced in Q4 2023 at the latest (Business Insider, 2023).

[7] Since 2016, the Polish government has been criticised at EU level for multiple actions that are said to threaten the rule of law and the independence of judges, among various other controversies. Moreover, Poland has not introduced some of the agreed milestones necessary to access Recovery and Resilience Facility funds, although partial liberalisation of the so-called "10h rule" which in practice blocked the development or repowering of onshore wind power plants in Poland was finally introduced in 2023. Currently, there are public disagreements within the ruling coalition about de-escalating the conflict to access funds and strengthen EU unity against the background of the Russian threat.

4. International Dimensions of the Polish Hydrogen Strategy



The main focus of the *Polish Hydrogen Strategy* is on the domestic hydrogen value chain. The Strategy's stated goals are to create a Polish hydrogen industry, contribute to reaching climate neutrality, and help the Polish economy preserve its competitiveness on the path to net zero (Polish Ministry of Climate and Environment, 2021c, p. 2). The development of international hydrogen trade is generally omitted, whereas that of hydrogen value chains – from hydrogen production to use in multiple sectors – is implicitly described as a domestic affair (initially, at the level of regional hydrogen valleys). While long-distance hydrogen transportation by pipeline is considered an option in principle (despite the significant technical challenges associated with repurposing), partly due to the availability of new renewable energy capacity offshore, which is located away from industrial and population centres, this does not involve the notion of cross-border trade.

This does not mean that the Strategy explicitly adopts a negative approach to international trade. Instead, the topic is generally avoided, though not entirely. The Polish document acknowledges that the EU Hydrogen Strategy aims to integrate European energy systems and incorporates an international perspective on the hydrogen market, which the Polish strategy claims to support. The Strategy also mentions the European Hydrogen Backbone,[8] although only as a way to facilitate the development of

[8] Within this project, several new pipelines, both new and repurposed, are expected to be built in Poland, thus constituting a link to the infrastructure of neighbouring countries, notably Germany and Lithuania (European

domestic hydrogen gas networks (Polish Ministry of Climate and Environment, 2021a, p. 22). There is also some mention of participation in knowledge sharing and joint R&D initiatives at EU level. The Strategy, however, makes no explicit reference to hydrogen import or export. This is linked, to a certain extent, to the limitations described in the previous chapter; since the scale of domestic production potential is not critically examined, neither the hydrogen supply gap nor the resulting domestic hydrogen cost are apparent.

This contrasts with the findings of the Analysis, which provides a basis for the abovementioned considerations and addresses a host of relevant issues in this regard: factors affecting the national capacity and competitiveness of renewable hydrogen production, the role of different countries in international hydrogen trade and possible hydrogen transport modes. These questions are examined with a significant degree of detail, albeit mostly in the form of a review of numerous national strategies and international reports. There is even an original scenario analysis of the Polish hydrogen export potential, although this would only exist if production outpaces domestic consumption, which is not likely considering the substantial current industrial demand.[9] The potential need for Polish hydrogen imports, however, is not addressed at all, which appears to be a deliberate decision. By contrast, the potential to replace fossil fuel imports with domestic hydrogen production has been assessed in detail. Nevertheless, from a 2030 perspective, the impact of hydrogen imports would be very limited, amounting to no more than replacing just under 3 per cent of liquid fuels, energy raw materials and energy imports (Kupecki et al., 2021, p. 334).

Why then does the *Polish Hydrogen Strategy* omit the issue of international hydrogen trade? And why does the scientific review in the annex avoid the topic of imports when applied to Poland, despite acknowledging its global significance and prominent role in other national strategies? Various answers have been provided by experts and stakeholders, including the following:

- **Rapid obsolescence of the document:** As the Strategy was implemented in the context of support for the post-COVID recovery of the Polish industry, the focus on international energy policy is for the most part missing.

- **A wait-and-see approach:** A large-scale global hydrogen market does not yet exist. With many uncertainties about technologies, costs and environmental impacts, less advanced countries may be tempted to avoid the issue for the time being, and instead choose to follow in the footsteps of frontrunners at a later point in time and implement already proven solutions. Poland is likely to be such a country, taking the approach of waiting for the global hydrogen economy to materialise and only then defining its specific role in it.

- **Avoiding hard truths:** The *Polish Hydrogen Strategy* aims to promote the potential of hydrogen technologies and build the goodwill necessary for legislative changes and pilot-stage implementations. Despite concessions to fossil fuel-based industries (see below), it generally advocates for the development of renewables and introduces a vision of the decarbonised industry, transport and heating. Renewable energy is promoted in Poland as a way to achieve energy independence and limit fossil fuel imports. Hydrogen imports complicate this narrative, raising (not unfounded) concerns about new dependencies – which can reduce not only public support for hydrogen but also partly undermine support for decarbonisation as such. On the other hand, explicitly ruling out hydrogen imports would also be problematic and hard to justify given the circumstances. Hence, it is convenient for Poland to avoid the issue for now.

Hydrogen Backbone, 2022). Nevertheless, the Strategy does not explore how these pipelines may be utilised for transnational trade.

[9] This is surprisingly not fully acknowledged: both the Strategy and the Analysis, in part, treat the low-carbon hydrogen industry as somehow separate from existing grey hydrogen value chains.

- **Appeasing stakeholders:** The interests of different hydrogen stakeholders (including the oil and gas industry, renewable energy industry associations, climate pressure groups, local administrations in coal regions and others) are not perfectly aligned. As a result, at this early stage of building a domestic hydrogen narrative, it might be better to steer clear of these contradictions. Thus, the Strategy reflects the interests and opinions of different pressure groups, e.g. through an optimistic outlook on the potential for domestic renewable and blue hydrogen production. In the absence of any voices supporting hydrogen imports, this perspective is simply omitted.

Despite this, the Strategy may still be an effective tool for shaping some further actions and policy decisions. The *Polish Hydrogen Strategy* can be seen as a way to promote the concept of a hydrogen economy, initiate first hydrogen partnerships along the domestic value chain, kick-start legislative action and prepare the country for taking part in European funding programmes. It does not, however, provide any kind of framework for Polish participation in the global hydrogen trade.

Another important area for international cooperation is R&D and pilot implementations, although the participation of Polish stakeholders has so far been rather limited. In the European Clean Hydrogen Partnership, there are no projects from Poland; the only sign of Polish participation is the presence of the Polish Alternative Fuels Association (Clean Hydrogen Partnership, 2022) in the Stakeholders Group, which is an official advisory body. Under the EU's Horizon 2020 research funding programme (2014-2020), Polish entities were engaged in several hydrogen projects, e.g., on photoelectrochemical splitting of water (CORDIS, 2022) or hydrogen production from second-generation biomass (CORDIS, 2016). It is likely that some Polish entities will also participate in research projects under the current funding programme for 2021-2027 called Horizon Europe.

Within the two ongoing hydrogen-related "Important Projects of Common European Interest" (IPCEI) - Hy2Tech (European Commission, 2022a) and Hy2Use (European Commission, 2022b) - the European Commission has approved financial support for one Polish project in each. In Hy2Tech, Synthos, a private-owned chemical manufacturer, runs a project (USNC, 2020) with the final objective of generating hydrogen, principally for its facilities, using high-temperature electrolysis powered by so-called Micro Modular Reactors supplied by its US-based partner Ultra Safe Nuclear Corporation. In Hy2Use, the company Orlen, as part of its Hydrogen Eagle project (PKN Orlen, 2021), aims to create over 100 hydrogen fuel stations and install a total of roughly 250 MW of electrolyser capacity in Poland, Slovakia, and the Czech Republic to supply hydrogen to industrial and transportation customers.

Poland is also represented in the European Clean Hydrogen Alliance, which incorporates over 750 undertakings, over 50 of which are located in or include Poland (European Commission, 2022c). They are related to, for example, hydrogen storage in underground salt caverns or laser-induced hydrogen generation. Within the EU's Innovation Fund, ZEPAK has been awarded a grant for its 5 MW green hydrogen production facility (with PEM electrolysers), with a view to generating hydrogen for the domestic public bus transport sector. As for international undertakings, Mission Innovation (Mission Innovation, 2022) and Breakthrough Energy Catalyst Europe (Breakthrough Energy, 2022) do not feature Poland or Polish businesses whatsoever.

There are also some other examples of R&D cooperation. The privately owned energy company Polenergia, for example, is involved in an international consortium for implementing pure hydrogen combustion in gas turbines and is also seeking to utilise green hydrogen to produce sustainable aviation fuel (Polenergia, 2022). ZEPAK, apart from the projects mentioned in the previous paragraph, has developed a 0.5 MW alkaline electrolyser, the first Polish-made electrolyser, through its company Exion Hydrogen, which has a manufacturing plant in Poland and an R&D facility in Belgium; its production and commercial availability is expected to begin in 2023. In the next step, Exion intends

to launch the production of another electrolyser, the 2.5 MW capacity PEM, at the beginning of 2024. In addition to this, ZEPAK, in a collaboration with the Italian design studio Torino Design, has developed a hydrogen bus that has already been tested on the streets of Warsaw (NesoBus, 2022).

Regarding hydrogen sustainability and standards issues, Poland has not been particularly active in shaping them through certification norms either at the EU or international level. There are no Polish entities in the EU's voluntary CertifHy programme (CertifHy, 2022), and Poland does not participate directly in processes within the International Partnership for Hydrogen and Fuel Cells in the Economy, IPHE (IPHE, 2022) or influence the EU's delegated acts on hydrogen. A lack of action may be explained by the fact that solving these issues is still in its infancy globally (IEA, 2022). As a result, Poland is, at least for now, not deeply engaged, instead assuming a rather secondary role in the green hydrogen economy development, which explains the omissions in the Strategy. Furthermore, significantly more attention is being given to establishing a regulatory framework for the domestic hydrogen economy, as such a framework is currently non-existent. Nevertheless, there are some regulations in place, for example linked to sustainability and standards concerning the quality of hydrogen fuel for automotive uses (Polish Journal of Laws, 2022b), which were effectively introduced in 2023, as well as technical requirements for hydrogen fuel stations (Polish Journal of Laws, 2022a). There are also some amendments to the Energy Act, including the definition of hydrogen and electrolytic conversion or the rules of operating hydrogen storage sites and hydrogen grids (Institute of Power Engineering, 2023, p. 25, 49, 69). In addition to that, more new legislation is currently being developed.

As for general intergovernmental cooperation, in December 2022 Poland announced a hydrogen partnership with Iceland (Polish Ministry of Climate and Environment, 2022e) with a focus on clean hydrogen and hydrogen-derived fuel production by using Iceland's geothermal power. This cooperation is expected to have a positive effect on Polish energy security and independence. Also, in May 2023, Poland signed a memorandum of cooperation on hydrogen with Japan (Polish Ministry of Climate and Environment, 2023a). Its objectives include the deepening of Polish-Japanese collaboration in the area of low-carbon hydrogen production and the development of sustainable and cost-effective hydrogen value chains in the power, transport, heating and industry sectors.

5. Hydrogen in the Context of a Broader Polish Approach to International Energy Security

Given the Strategy's failure to address the question of hydrogen imports, Polish interests related to an emerging international hydrogen economy may be better understood by considering the broader national energy strategy, as well as policies and initiatives undertaken by public and private stakeholders.

The *Energy Policy of Poland until 2040* is a key strategic document for the future development of the Polish energy system. Its 2021 version focused on three pillars: "Just transition", "Zero-emission energy system" and "Good air quality" (Polish Ministry of Climate and Environment, 2021b, p. 13). Energy security and independence, however, were already important parts of the rationale behind various objectives, including the use of domestically mined coal, the diversification of fuel imports, the development of transnational energy connections and the expansion of alternative generation technologies such as nuclear and renewables (mainly offshore wind). In March 2022, the government announced that a fourth pillar would be added in the upcoming PEP2040 update, with an explicit focus on energy security and independence (Polish Ministry of Climate and Environment, 2022a). However, the related objectives are mainly a restatement of those previously covered, without any substantial shift in the strategic outlook or policies.

In early 2023, the Ministry of Climate and Environment announced that PEP2040 will be soon updated with a new scenario for the power sector (Polish Ministry of Climate and Environment, 2023b). According to both official communication and a leaked draft, the new scenario envisions a much quicker development of renewable energy (expected to cover up to 47 per cent of the total electricity demand already in 2030, up from 32 per cent envisioned in the 2021 version), dynamic additions of nuclear power in the 2030s, and a lower reliance on imported natural gas. The new scenario is more coherent with the Polish Hydrogen Strategy in that it is expected to take into account the additional electricity demand stemming from domestic hydrogen production. Hydrogen is mentioned among the possible solutions to the issue of generation curtailment, which is expected to significantly affect the RES in the late 2030s due to renewable energy saturation and the competition with the always-on nuclear power. The announcement was generally welcomed by the stakeholders as a step in the right direction, though there were discussions about both the level of ambition as well as about the possibility to achieve even the described targets with the current policies and investment levels (Kubiczek & Smoleń, 2023).

However, despite the Ministry communication about the prompt amendment, the change has not been in fact officially accepted by the Council of Ministers as of early June 2023. The reason for that is the brewing contest inside the ruling right-wing coalition ahead of the autumn 2023 elections. A minor coalition partner, Sovereign Poland (called Solidarity Poland until 2023), is currently trying to raise its profile by positioning itself in direct opposition to the EU's climate policies, publicly criticising the Prime Minister for his allegedly too lenient approach. The party calls for a further development of

domestic coal mining and leaving the EU ETS system – in fact, abandoning the decarbonisation goal altogether. It is now possible that the PEP2040 update will not be introduced before the election, which would also negatively affect the Polish National Energy and Climate Plan update. Though strategic documents do not necessarily have an immediate impact on the decarbonisation process (which is currently ongoing at a much faster rate than that envisioned by the current strategies due to the proliferation of solar power), the uncertainty affects especially the early-state solutions that are reliant on public subsidies and declarations of support, such as green hydrogen.

When it comes to the issue of energy independence, since at least 2015, the government has interpreted it primarily as reducing the country's reliance on Russian imports. Even before the war in Ukraine, the last contract for Russian natural gas was meant to expire at the end of 2022, which was made possible by investments in the LNG terminals in Świnoujście and Klaipeda, as well as the new pipelines connecting Poland with Denmark (i.e., the Baltic Pipe) and Lithuania (Polish Ministry of Climate and Environment, 2022c). Poland also planned to continue importing Russian-sourced gas from Germany, although that is of course no longer feasible. Divestment from Russian oil and coal has been more gradual,[10] as these ties were thought to be less strategically risky due to the existence of possible alternative sources (this, however, was shown to be not entirely true in 2022, as the import of the types of coal suited for household consumption proved to be a significant challenge).

At the risk of oversimplification, it is possible to identify the following key characteristics of the Polish government's approach to international energy policy, which may also clarify the current and future potential role of hydrogen within it:

1. Poland wants to fully phase out its dependence on Russian fossil fuel imports, which are considered both a national security risk and a source of income for a hostile power (Kupecki et al., 2021, p. 318-322).

2. Poland is open to importing energy carriers that it cannot produce domestically from countries other than Russia, especially from Europe and the U.S., but also from elsewhere, given an appropriate level of diversification (Polish Ministry of Climate and Environment, 2021b, p. 36 & 41). Before the war in Ukraine, Poland planned to increase natural gas imports and continue oil imports for the foreseeable future (Polish Ministry of Climate and Environment, 2021d, p. 16-17). Its view on these issues is pragmatic and driven by economic and security interests, with little focus on the more distant issues of international relations or environmental and social sustainability.

3. Poland, in principle, supports technologies that can replace fossil fuels. In practice, however, the government opposes any measures taken exclusively for climate protection unless they are accompanied by economic benefits (Polish Ministry of Climate and Environment, 2022b). Furthermore, it is wary of measures that could harm established stakeholders, such as state-owned enterprises from the energy and industrial sectors (for example the coal, fertiliser and automotive sectors). On the other hand, it sees the emergence of new value chains as an opportunity for industrial development.

4. Poland would like to expand transnational energy connections to increase the resilience of its energy system against external shocks (Polish Ministry of State Assets, 2019, p. 40-48). For example, although additional grid connections are to a certain extent seen (or even opposed) as unwelcome competition to

[10] Russian coal imports grew between 2015 and 2018 due to a combination of low prices, high quality and the decreasing output of Polish mines.

domestic producers, their role in emergencies is highly valued. Gas connectors with neighbouring friendly countries are perceived as factors that improve energy security in the region, while at the same time strengthening the international position of Poland as an aspiring CEE (Central Eastern Europe) leader.

5. The current Polish government vocally opposes the leading role of Germany in the EU. While this position is to a degree a narrative tool that serves domestic purposes, among key decision-makers there is a genuine distrust of German motives and a sense of judgement. When applied to international energy policy, this negative outlook is now (after years of dealing with the issue of the Nord Stream gas pipeline, but also the nuclear phase-out) shared by opposition parties as well, which affects how German initiatives regarding international trade in energy carriers will be received.

Under the PEP2040 and, to some extent, the *Polish Hydrogen Strategy*, the international potential of hydrogen is viewed mostly in the context of points 1 and 3 – i.e. as a domestically produced resource which can potentially be utilised to reduce imports of Russian fossil fuels, in addition to the secondary goals of protecting the business models of "national champions" (state-owned enterprises in the oil and gas and chemical sectors). External decarbonisation pressures and possible opportunities for manufacturing industries (automotive, machinery) operating in Poland do not figure prominently here. Moreover, views on German support for hydrogen imports are likely to be affected by the issues described in point 5.

Polish documents do not cover the potential role of hydrogen in the context of points 2 (diversified import of energy carriers) and 4 (CEE energy cooperation). The import and export of hydrogen have not been thoroughly explored, although they are not excluded either. Poland is not dogmatically opposed to importing energy carriers, provided that some diversification of supply is ensured, especially if they serve as a basis for a further generation of added value. What is more, Poland welcomes initiatives that increase the resilience of the CEE energy system.

The analysis of the Polish approach to international energy policy shows that the country could be supportive of international hydrogen trade if it is proven in practice and presented in the right framework. This includes conceptualising renewable hydrogen as a basic commodity that could be feasibly and cheaply imported and used domestically in further stages of value creation, including generating jobs, added value and taxable incomes. An analogous role is currently played by imports of oil and gas, which are used in multiple Polish industries. Successful development of international hydrogen trade by early adopters, if it materialises, could persuade Poland that it is economically feasible. Polish energy security concerns could be addressed by measures such as the diversification of hydrogen sources and the development of flexible international markets, and the creation of a hydrogen infrastructure that is resilient against acts of sabotage, at a level similar to or better than LNG. Furthermore, if developed as a new sphere for cooperation between the Czech Republic, Slovakia, the Baltic states, Romania, Hungary and possibly Ukraine,[11] hydrogen trade could become much more attractive than the current image of the international hydrogen market as a "German" plan that is mainly tailored to Germany's needs and strategic objectives. This regional cooperation is already emerging – in May 2023, hydrogen clusters and associations from the Visegrad Group, the Baltic states, Ukraine and Slovenia initiated the 3 Seas Hydrogen Council initiative to support business cooperation, strengthen joint policy impact and share experience (CIRE, 2023). This new partnership has received support from the

[11] The issue of prospective hydrogen import from Ukraine to the EU in the post-war future has not been brought up in the Strategy, and Poland has not formulated a clear position on it. As of mid-2023, the main challenge that will need to be addressed in Ukraine, which requires considerable external support, will be the rebuilding or replacement of lost power generation for domestic consumption alone.

Polish government.

Another tool that can be leveraged to improve strategic hydrogen planning in the EU countries is European funding for R&D or infrastructure. At this point, one of the reasons why Poland and other EU Member States such as France (French Ministry of Ecological Transition and Solidarity, 2018) or Hungary (Hungarian Ministry of State for Energy and Climate Policy, 2021) are either avoiding or opposing international hydrogen trade is the lack of a fair assessment of their domestic hydrogen production capacity. If such a quantitative assessment were an obligatory part of national hydrogen strategies, possibly as a prerequisite for receiving hydrogen-related EU funding, it might encourage the countries in question to either pursue a more ambitious development of renewable energy capacities to meet this demand and/or to look more openly at the possible necessity of hydrogen imports. Such an approach would also support a better prioritisation of hydrogen applications, especially the decarbonisation of industrial processes that are heavily reliant on grey hydrogen.

6. Conclusion

The question of a Polish position in the European and global hydrogen value chain is a complex one. In light of Poland's modest hydrogen production capacity deployment plans in comparison with the European frontrunners like Germany or France, it will be difficult for Poland to maintain its current position in the hydrogen economy. In the long run, smaller ambitions could potentially jeopardise one of the pillars of the Strategy, namely energy security, as they would make domestic hydrogen production less competitive, thus increasing the attractiveness of imports. Despite the government's hesitancy, the country is under pressure from both European policymakers and international investors to pursue decarbonisation. This requires mitigating substantial GHG emissions in the existing grey hydrogen production and, in the longer term, using hydrogen to cut emissions in industry, some segments of the transport sector, and possibly energy storage and power generation. At the same time, domestic production of low-carbon hydrogen will be limited by the available renewable energy capacity and natural gas supply.

The issue of importing hydrogen, which so far has been largely avoided in Polish official documents and has notably even been absent from the discussion following the release of the European Commission's REPowerEU plan, will thus have to be addressed sooner or later. When (or if) the viability of global hydrogen trade is demonstrated, Poland is likely to follow these trends, as it will not want to fully miss out on the resulting economic opportunities. At that point, the country could potentially become a supporter of the European hydrogen cooperation, while at the same time improving bilateral relations with non-EU prospective green hydrogen exporters and implementing its ambition to become an energy and resource hub for Central Eastern Europe.

7. Literature

Breakthrough Energy (2022), available at: https://breakthroughenergy.org/our-work/europe/ (Accessed: 30.11.2022)

Business Insider (2023), available at: https://businessinsider.com.pl/prawo/firma/ustawa-wodorowa-nawet-sluzby-mialy-uwagi-resort-klimatu-wprowadza-zmiany/qptpwpw (In Polish) (Accessed: 24.01.2023)

CertifHy (2022), available at: https://www.certifhy.eu/wp-content/uploads/2022/07/CertifHy-Stakeholder-Platform-Members-Mid_2022.pdf (Accessed: 02.12.2022)

CIRE (2023), available at: https://www.cire.pl/artykuly/serwis-informacyjny-cire-24/z-inicjatywy-polski-powstala-rada-wodorowa-europejskich-panstw- (In Polish) (Accessed: 02.06.2023)

Clean Hydrogen Partnership (2022), available at: https://www.clean-hydrogen.europa.eu/about-us/organisation/stakeholders-group_en (Accessed: 30.11.2022)

CORDIS (2016), available at: https://cordis.europa.eu/project/id/278855 (Accessed: 30.11.2022)

CORDIS (2022), available at: https://cordis.europa.eu/project/id/310333 (Accessed: 30.11.2022)

Czyżak, P., Sikorski, M., Wrona, A. (2021). Wiatr w żagle. Zasada 10H a potencjał lądowej energetyki wiatrowej w Polsce, Instrat Foundation (In Polish).

European Commission (2022a), available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_4544 (Accessed: 30.11.2022)

European Commission (2022b), available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_5676 (Accessed: 30.11.2022)

European Commission (2022c), available at: https://single-market-economy.ec.europa.eu/industry/strategy/industrial-alliances/european-clean-hydrogen-alliance/project-pipeline_en (Accessed: 30.11.2022)

European Hydrogen Backbone (2022), available at: https://ehb.eu/page/european-hydrogen-backbone-maps (Accessed: 05.12.2022)

Exion Hydrogen (2023), available at: https://exionhydrogen.com/what-we-do/ (Accessed: 17.05.2023)

French Ministry of Ecological Transition and Solidarity (2018). National strategy for the development of decarbonised and renewable hydrogen in France.

Gaz System (2022a), available at: https://www.gaz-system.pl/en/for-media/press-releases/2022/april/07-04-2022-transmission-system-operators-from-poland-romania-slovakia-and-hungary-cooperate-on-the-development-of-a-regional-hydrogen-grid.html (Accessed: 30.11.2022)

Gaz System (2022b), available at: https://www.gaz-system.pl/dam/jcr:2b8a40ac-ea03-4f0d-af90-ace06dc97688/13_Wyzwania%20w%20nadchodzącym%20roku%20gazowym%202022%202023.pdf (In Polish) (Accessed: 02.12.2022)

German Federal Ministry for Economic Affairs and Energy (2020). The National Hydrogen Strategy.

Global CCS Institute (2022), available at: https://co2re.co/FacilityData (Accessed: 30.11.2022)

Grupa Azoty (2021), available at: https://grupaazoty.com/upload/1/files/2021/strategia2021-2030/29.10.2021/Grupa_azoty_strategia_2030_prezentacja_28_10_2021_EN.pdf (Accessed: 30.11.2022)

Hungarian Ministry of State for Energy and Climate Policy (2021). Hungary's National Hydrogen Strategy.

Hydrogen Valley Platform (2022), available at: https://h2v.eu/hydrogen-valleys/black-horse (Accessed: 05.12.2022)

HYNFRA (2022), available at: https://www.hynfra.pl/?lang=en (Accessed: 05.12.2022)

HYNFRA (2023), available at: https://www.hynfra.pl/post/hynfra-to-build-the-green-industrial-zone-in-bucha?lang=en (Accessed: 02.06.2023)

IEA (2022), available at: https://www.iea.org/reports/hydrogen-supply (Accessed: 30.11.2022)

Industrial Development Agency JSC (2023), available at: https://arp.pl/pl/jak-dzialamy/doliny-wodorowe/ (Accessed: 03.03.2023)

Institute of Power Engineering, Faculty of Management at the University of Warsaw, Energy Club (2023). Łańcuch wartości gospodarki wodorowej w Polsce (In Polish).

Instrat (2022), available at: https://energy.instrat.pl/installed_power (Accessed: 02.12.2022)

IPHE (2022), available at: https://www.iphe.net/partners (Accessed: 02.12.2022)

IRENA (2022). Global hydrogen trade to meet the 1.5°C climate goal: Part I - Trade outlook for 2050 and way forward.

JSW (2022a), available at: https://www.jsw.pl/en/responsible-business/we-respect-natural-resources/jsws-environmental-projects/production-of-hydrogen (Accessed: 30.11.2022)

JSW (2022b), available at: https://www.jsw.pl/en/responsible-business/we-respect-natural-resources/jsws-environmental-projects/hydrogen-cells-factory-electric-and-hydrogen-vehicles (Accessed: 30.11.2022)

Kopeć, J. (2023). Poland risks losing half of previously greenlighted onshore wind land potential due to recent parliamentary amendment. Available at: https://instrat.pl/en/500m-vs-700m/.

Kubiczek, P., Smoleń, M. (2023). Poland cannot afford medium ambitions. Savings driven by fast deployment of renewables by 2030. Instrat Policy Paper 03/2023. Available at: https://instrat.pl/wp-content/uploads/2023/04/Instrat_Policy-Paper-03-2023-Poland-Cannot-Afford-Medium-Ambitions.pdf.

Kupecki, J. et al. (2021). Analiza potencjału technologii wodorowych w Polsce do roku 2030 z perspektywą do 2040 roku (In Polish).

Maj, M., Szpor, A. (2020). Gospodarka wodorowa w Polsce. Obserwacje na podstawie ram badawczych technologicznego Systemu Innowacji, Polski Instytut Ekonomiczny (In Polish).

Mission Innovation (2022), available at: http://mission-innovation.net/our-members/ (Accessed: 30.11.2022)

Municipal Office in Konin (2022), available at: https://www.konin.pl/index.php/jeden-news-1432/wodorowy-solaris-wozi-pasazerow-w-koninie.html (In Polish) (Accessed: 30.11.2022)

NesoBus (2022), available at: https://www.nesobus.pl/en/ (Accessed: 02.12.2022)

PGNiG (2020), available at: https://en.pgnig.pl/news/-/news-list/id/pgnig-launches-new-hydrogen-program/newsGroupId/1910852 (Accessed: 30.11.2022)

PGNiG (2022), available at: https://pgnig.pl/aktualnosci/-/news-list/id/gk-pgnig-stawia-na-paliwa-przyszlosci/newsGroupId/10184 (In Polish) (Accessed: 30.11.2022)

PKN Orlen (2021), available at: https://www.orlen.pl/content/dam/internet/orlen/pl/en/about-company/media/press-releases/2021/obrazy/Orlen_prezentacja_Hydrogen_final.pdf.coredownload.pdf (Accessed: 30.11.2022)

PKN Orlen (2022). ORLEN Group Hydrogen Strategy 2030.

Polenergia (2022), available at: https://www.polenergia.pl/en/polenergia-launches-hydrogen-rd-project/ (Accessed: 30.11.2022)

Polish Government Legislative Centre (2022), available at: https://legislacja.rcl.gov.pl/projekt/12365500/katalog/12921264#12921264 (In Polish) (Accessed: 30.11.2022)

Polish Government Legislative Centre (2023), available at: https://legislacja.rcl.gov.pl/projekt/12369601 (In Polish) (Accessed: 21.02.2023)

Polish Journal of Laws (2022a), available at: https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20220002158/O/D20222158.pdf (In Polish) (Accessed: 30.11.2022)

Polish Journal of Laws (2022b), available at: https://dziennikustaw.gov.pl/D2022000279301.pdf (In Polish) (Accessed: 30.11.2022)

Polish Ministry of Climate and Environment (2021a). Polska Strategia Wodorowa do roku 2030 z perspektywą do roku 2040 (In Polish).

Polish Ministry of Climate and Environment (2021b). Polityka Energetyczna Polski do 2040 roku (In Polish).

Polish Ministry of Climate and Environment (2021c). Polish Hydrogen Strategy until 2030 with an outlook until 2040 - Summary.

Polish Ministry of Climate and Environment (2021d). Polityka Energetyczna Polski do 2040 r. Załącznik 2 - wnioski z analiz prognostycznych dla sektora energetycznego (In Polish).

Polish Ministry of Climate and Environment (2022a). Principles for the update of the Energy Policy of Poland until 2040 (EPP2040): strengthening energy security and independence.

Polish Ministry of Climate and Environment (2022b), available at: https://www.gov.pl/web/klimat/polska-nie-popiera-pakietu-fit-for-55-minister-anna-moskwa-stanowczo-o-postulatach-polski-na-posiedzeniu-rady-unii-europejskiej-ds-srodowiska (In Polish) (Accessed: 30.11.2022)

Polish Ministry of Climate and Environment (2022c), available at: https://www.gov.pl/web/klimat/otwarcie-gazociagu-baltic-pipe (In Polish) (Accessed: 02.12.2022)

Polish Ministry of Climate and Environment (2022d), available at: https://www.gov.pl/web/klimat/polska-wspiera-odbudowe-ukrainskiego-systemu-energetycznego (In Polish) (Accessed: 05.12.2022)

Polish Ministry of Climate and Environment (2022e), available at: https://www.gov.pl/web/klimat/polska-i-islandia-wspolnie-o-wspolpracy-wodorowej (In Polish) (Accessed: 05.12.2022)

Polish Ministry of Climate and Environment (2022f), available at: https://www.gov.pl/web/klimat/polsko-norweskie-spotkanie-okraglego-stolu-dla-rozwoju-technologii-wychwytu-wykorzystania-oraz-skladowania-dwutlenku-wegla (In Polish) (Accessed: 06.12.2022)

Polish Ministry of Climate and Environment (2022g), available at: https://www.gov.pl/web/klimat/pierwsze-posiedzenie-rady-koordynacyjnej-ds-gospodarki-wodorowej (In Polish) (Accessed: 06.12.2022)

Polish Ministry of Climate and Environment (2023a), available at: https://www.gov.pl/web/klimat/polska-i-japonia-wzmocnily-wspolprace-w-dziedzinie-wodoru (In Polish) (Accessed: 17.05.2023)

Polish Ministry of Climate and Environment (2023b), available at: https://www.gov.pl/web/premier/zalozenia-do-aktualizacji-polityki-energetycznej-polski-do-2040-r-pep2040--wzmocnienie-bezpieczenstwa-i-niezaleznosci-energetycznej (In Polish) (Accessed: 17.05.2023)

Polish Ministry of State Assets (2019). Krajowy plan na rzecz energii i klimatu na lata 2021-2030 (In Polish).

Polish Supreme Audit Office (2022). Informacja o wynikach kontroli. Rozwój morskiej energetyki wiatrowej (In Polish).

Polish Wind Energy Association (2022). Potential of Offshore Wind in Poland.

Polish Wind Energy Association, The Lower Silesian Institute for Energy Studies (2021). Green hydrogen from RES in Poland. The use of wind and PV power for the production of green hydrogen as an opportunity to implement the assumptions of the EU Climate and Energy Policy in Poland.

Port of Gdynia (2022), available at: https://www.port.gdynia.pl/hub-wodorowy-w-porcie-gdynia/ (In Polish) (Accessed: 30.11.2022)

Statistics Poland (2022). Energy 2022.

USNC (2020), available at: https://www.usnc.com/ultra-safe-nuclear-corporation-partners-with-synthos-green-energy-to-develop-micro-reactor-based-systems-to-decarbonize-company-chemical-facilities/ (Accessed: 30.11.2022)

WNP (2023), available at: https://www.wnp.pl/energetyka/gaz-system-zlozyl-wnioski-o-finansowania-dwoch-projektow-przesylania-wodoru,679560.html (In Polish) (Accessed: 20.02.2023)

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