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HYDROGEN DIPLOMACY: BILATERAL INTERESTS OF THE EU AND UKRAINE

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Following the Russian aggression in Ukraine, the EU prioritised the need for energy supply diversification and reducing overall energy dependency on Russian fossil fuels by 2030. Renewable hydrogen is seen as one of the possible sources. Based on previous calculations, Ukraine has the potential to become one of the major hydrogen exporters in the EU energy market. However, currently, Ukraine lacks the strategic documents or policies to implement such a vision. The paper will outline the bilateral interest of the EU and Ukraine, and identify the necessary steps Ukraine should take to meet the EU interests related to the energy transition to zero emissions by 2050.

Introduction

The world is experiencing a second wave of hydrogen energy development. Hydrogen has a high potential in energy, industry, transport, and construction. It enhances the trend towards decarbonising the global economy. Technologies for carbon-free hydrogen production, using water electrolysis from renewable energy sources, already exist. Hydrogen's physical properties allow it to integrate energy systems, increase energy efficiency, improve the balancing of energy systems, and reduce greenhouse gas emissions.

In 2021, 17 governments released details of their hydrogen strategies; more than 20 governments had publicly announced that they were working on developing strategies, and numerous companies were looking to take advantage of the business opportunities[1] offered by hydrogen.

Russia's full-scale invasion of Ukraine, and the political consequences of the war for regional security, provided answers to several questions that have long been debated publicly and behind the scenes by European politicians. These issues included the diversification of the EU energy market, and the shift of member states towards renewable energy. In addition to ensuring energy security, these changes should also contribute to the sustainable development of economies.

For Ukraine, the issue of energy security is one of the priorities of post-war development. From the date of Ukraine's independence

1 International Energy Agency. *Global Hydrogen Review 2021*. Paris: IEA, 2021, p. 5 [https://iea.blob.core.windows.net/assets/5bd46d7b-906a-4429-abda-e9c507a62341/GlobalHydrogenReview2021.pdf access: 31 July 2022]

until 2019, Ukraine was among the top five countries with the highest energy intensity per unit of GDP. According to the Global Energy Statistical Yearbook 2022, only in 2019-2021 did this indicator drop sharply to the level of developed European countries such as Germany, France, the Netherlands, Belgium and Poland.[2] Nevertheless, energy efficiency will be a priority for the post-war redevelopment of energy and industry. Another component is a critical response to the need to restore energy connections and rebuild complexes that have been destroyed, alongside the development of alternative renewable sources. Ukraine's potential for renewable energy sources (RES) will probably provide an opportunity to satisfy both Ukrainian and European strategic interests and needs.

EU Strategic Plans for the Development of Hydrogen Energy

The strategic importance of renewable hydrogen for the EU lies mainly in its potential to reduce greenhouse gas emissions and, more recently, in the need to diversify energy sources, which increased due to the Russian-Ukrainian war. On April 18th, 2022, the European Commission issued the "REPowerEU" Plan, which aims to expand the use of rapidly renewable energy, diversify energy supply and reduce overall energy demand, following Russia's prolonged aggression in Ukraine[3].

Earlier, on December 11th, 2019, the European Commission adopted the "European Green Deal," an action programme centred on a plan of transition to a climate-neutral Europe by 2050. That is the most ambitious European climate and environmental protection programme to date, which envisages a 55% reduction in greenhouse gas emissions compared to those of 1990[4]. It emerged as a renewed strategic vision and a tool for ensuring the EU's contribution to achieving the goals of the Paris Climate Agreement.

Andre Wolff and Nils Zander, from the Hamburg Institute of International Economics, point out that obtaining hydrogen as an energy carrier or raw material, using water electrolysis as a technological option, has been considered for a long time[5]. However, the debate surrounding the low efficiency of converting electricity from RES to hydrogen, and the dubious climate balance became an obstacle to the large-scale application of hydrogen in energy and other areas. Technological improvements in electrolysers, and the widespread use of renewable energy sources in the EU during 2017-2020, influenced the decision of the European Commission to define hydrogen in the European Green Deal as a "priority technology for the transition of the industry to a clean and circular economy". In the Hydrogen Strategy, hydrogen is called "the key to achieving new climate ambitions,

2 World Energy & Climate Statistics – Yearbook 2022. *Energy intensity*. Enerdata. [https://yearbook.enerdata.net/total-energy/world-energy-intensity-gdp-data.html]

3 European Commission. *Communication from the Commission to the European Parliament, the European Council, the Council, the European economic and social commitee and the commitee of the regions REPowerEU Plan*, COM(2022) 230 final, Brussels, 18 April 2022. [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483 accessed: 31 July 2022]

4 European Commission. *Communication from the Commission The European Green Deal*, COM (2019) 640 final, Brussels, 11 December 2019. [https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN accessed: 31 July 2022]

5 A. Wolf, N. Zander, *Green hydrogen in Europe: Do strategies meet expectations?*, "Intereconomics", vol 56, N6, 2021, pp. 316-323 [https://www.intereconomics.eu/contents/year/2021/number/6/article/green-hydrogen-in-europe-do-strategies-meet-expectations.html accessed: 31 July 2022]

reducing greenhouse gas emissions by at least 50-55% by 2030, in a cost-effective way"[6].

Hydrogen is considered one of the priority energy sources for the EU for several reasons. First of all, it will help to reduce greenhouse gas emissions. Existing hydrogen production in the EU impacts the climate. Demand for hydrogen in European EU countries reached 8.3 million tons in 2018, while the carbon intensity of steam reforming, the most common hydrogen production process, is 10 kg CO2 per 1 kg of hydrogen produced.[7]

> ***the debate surrounding the low efficiency of converting electricity from RES to hydrogen, and the dubious climate balance became an obstacle to the large-scale application of hydrogen in energy and other areas***

It turns out that hydrogen production in European countries generated at least 83 million tons of CO2, not including emissions from coal mining. Hence, in 2018, hydrogen production probably accounted for 2% of the total CO2 equivalent emissions in the EU[8]. That is, by only replacing "grey" hydrogen with the renewable alternative, the EU would potentially achieve a reduction in CO2 emissions of 2% every year.

Another goal is energy balance. Hydrogen provides the ability to store electricity generated from RES during low demand, and feed it back into the grid during peak loads[9].

In addition, hydrogen has the potential to replace natural gas and coking coal in various industrial processes, thereby making EU countries independent from Russian fossil fuels. "REPowerEU" sets new targets for renewable hydrogen that go far beyond the already ambitious goals in the original EU 2020 Hydrogen Strategy. Instead of the planned 5 million tons by 2030, the European Commission proposes 20 million tons of renewable hydrogen. Among the proposed measures are revitalising hydrogen infrastructure development and expanding funding streams, including storage and port infrastructure, streamlining state aid processes, adjusting the regulatory framework, and creating a Global European Hydrogen Facility[10]. Therefore, Russian aggression against Ukraine and the EU's desire for energy independence from the Russian Federation brings the topic of the hydrogen market, economy, and energy in general, up to a more ambitious level.

6 Ibid, p. 316.

7 Gmucova, N. *Future of Renewable and Low-Carbon Hydrogen in Europe*, Stratas Advisors 2020. [https://stratasadvisors.com/Insights/2020/111620-Future-of-Renewable-and-Low-Carbon-Hydrogen-in-Europe]

8 Gmucova, N. *Future of Renewable and Low-Carbon Hydrogen in Europe*, "Stratas Advisors", 16 November 2020. [https://stratasadvisors.com/Insights/2020/111620-Future-of-Renewable-and-Low-Carbon-Hydrogen-in-Europe accessed: 31 July 2022]

9 European Commission. *Proposal for a directive of European Parliament and of the Council on common rules for the internal markets in renewable and natural gases and in hydrogen*, COM (2021) 803 final, Brussels, 15 December 2021(a). [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0803&qid=1640002501099 accessed: 31 July 2022]

10 European Commission. *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Commitee and the Commitee of the Regions REPowerEU Plan*, COM(2022) 230 final, Brussels, 18 April 2022. [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483 accessed: 31 July 2022]

Finally, there is support for decarbonisation. Hydrogen can also be an environmentally friendly solution for challenging industries to harness for electrification. Significant sources of pollution come from aviation, shipping, iron, steel production, chemical production, fertilisers, high-temperature industrial heat, long-distance vehicles, and building heating[11]. Some industries still require incredibly high temperatures and cannot do without combustion. Previously, fossil fuel was considered the only option for such industries. However, renewable hydrogen and hydrogen technologies make it possible to use it in metallurgy, glass production, and fertilisers, without greenhouse gas emissions.

In its 2020 Hydrogen Strategy, the European Commission announced a plan to reach 6 GW renewable hydrogen electrolyser capacity by 2024 and 40 GW by 2030[12]. The Strategy also included renewable hydrogen production targets of 1 million tons by 2024 and 10 million tons by 2030. The specified amount of hydrogen and production capacity until 2024, noted in the Strategy, are necessary for decarbonising existing hydrogen production, for example, in the chemical sector, and for using hydrogen in new areas of end-use (e.g. industrial processes and, possibly, freight transport). At this stage, there are studies on the siting of local RES near oil refineries, metallurgical and chemical plants, which are currently the main centres of demand for hydrogen.

The emergence of hydrogen value chains serving multiple industrial sectors and other end-uses could mean creating up to 1 million jobs, directly or indirectly. The Strategy cites forecasts from analysts at BloombergNEF that pure hydrogen could satisfy 24% of global energy demand by 2050, with annual sales of around EUR 630 billion[13].

> ***even with the implementation of the planned goals in the EU Hydrogen Strategy by 2030, the volumes of renewable hydrogen will not be able to reach even those production indicators that, according to the latest data, satisfy the demand for hydrogen in the EU countries***

The investment agenda in this area should be provided by the post-pandemic financial mechanism of the EU "InvestEU" and coordinated by the stakeholder platform European Clean Hydrogen Alliance. The EU expects to mobilise 372 billion euros of private and public investments during 2021-2027 to the "InvestEU" fund. This programme is envisaged as channelling the accumulated investments into projects related to the following four policy areas: permanent infrastructure, innovation research and digitalisation, small and medium-sized businesses, and social investments and skills. Investments in hydrogen projects are a priority task of the fund, and they will be given preference in the list of sustainable infrastructure projects.

In December 2021, the European Commission proposed a legislative initiative to revise and amend the Gas Directive 2009/73/EC and the Gas Regulation (EC)

11 International Energy Agency. *Global Hydrogen Review 2021*. Paris: IEA, 2021, p. 5 [https://iea.blob.core.windows.net/assets/5bd46d7b-906a-4429-abda-e9c507a62341/GlobalHydrogenReview2021.pdf accessed: 31 July 2022]

12 European Commission, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Commitee and the Commitee of the Regions A hydrogen strategy for a climate-neutral Europe*, COM(2020) 301 final, Brussels, 8 July 2020 (b). [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0301 accessed: 31 July 2022]

13 Ibid

No 715/2009, called the Hydrogen and Gas Market Decarbonisation Package. It consists of a "Proposal for a Directive of the European Parliament and the European Council on general rules for the internal markets of renewable and natural gases and hydrogen"[14] and "Proposals for the Regulation on the internal markets of renewable and natural gases and hydrogen"[15]. With these changes, The European Commission proposes bringing hydrogen to the same "regulatory" level as natural gas.

It is still difficult to predict the demand for renewable hydrogen in the coming decades. However, even with the implementation of the planned goals in the EU Hydrogen Strategy by 2030, the volumes of renewable hydrogen will not be able to reach even those production indicators that, according to the latest data, satisfy the demand for hydrogen in the EU countries. According to the Strategy, the 40 GW of planned capacity will produce only 5 to 10 million tons of renewable hydrogen annually[16]. Currently, according to Alejandro Núñez-Jimenez from the John F. Kennedy School of Government at Harvard, hydrogen production capacity in EU countries has reached 11.3 million tons per year. Only 0.4% of all production capacity is for low-carbon (blue) and 0.1% for renewable (green) hydrogen[17]. According to this report, the expected annual demand for hydrogen in EU countries in 2050 will approach 76 million tons of hydrogen[18].

Potential importers of renewable hydrogen with high infrastructural potential are Austria, Belgium, Germany, Italy, the Czech Republic, the Netherlands, and Slovenia. Croatia, Denmark, Estonia, Finland, France, Greece, Ireland, Lithuania, Latvia, Poland, Portugal, Spain, and Sweden possess the necessary resources for producing renewable hydrogen, as well as having highly developed infrastructure. Among non-EU countries, potential exporters are Albania, Turkey, Iceland, Morocco, and Norway. According to this paper, Ukraine belongs to the fifth group of countries, those with high production capacity but low infrastructure potential[19]. Such a positioning of Ukraine is probably caused by the great destruction due to the war with the Russian Federation. This group also includes Bulgaria and Romania, which are members of the EU.

Hydrogen Potential of Ukraine

In August, 2021, the Ministry of Energy set up a working group to design a strategy for developing hydrogen energy by 2030. However, there is currently only a Draft of the Hydrogen Strategy, which has never been

14 European Commission, *Proposal for a directive of European Parliament and of the Council on common rules for the internal markets in renewable and natural gases and in hydrogen*, COM (2021) 803 final, Brussels, 15 December 2021(a). [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0803&qid=1640002501099 accessed: 31 July 2022]

15 European Commission, *Proposal for a regulation of European Parliament and of the Council on common rules for the internal markets in renewable and natural gases and in hydrogen*, COM(2021) 804 final. Brussels: 15 December 2021(b). [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A804%3AFIN&qid=1640001545187 accessed: 31 July 2022]

16 European Commission, *Communication from the Commission to the European Parliament, the European Council, the Council, the European economic and social commitee and the commitee of the regions. A hydrogen strategy for a climate-neutral Europe*, COM(2020) 301 final, Brussels, 8 July 2020 (b). [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0301 accessed: 31 July 2022]

17 Nuñez-Jimenez, A., De Blasio, N., *The Future of Renewable Hydrogen in the European Union Market and Geopolitical Implications*. Cambridge, MA, USA: Environment and Natural Resources Program, Belfer Center for Science and International Affairs, Harvard Kennedy School, 2022, p. 11 [https://www.belfercenter.org/sites/default/files/files/publication/Report_EU%20Hydrogen_FINAL.pdf accessed: 31 July 2022]

18 Ibid, p.17

19 Ibid, pp.19, 28

approved. The potential of RES, political signals from Germany and the EU, and the European energy crisis have prompted Ukraine to determine the most promising approaches to integrating hydrogen into its energy system.

According to the assessment of the Institute of Renewable Energy of the National Academy of Sciences of Ukraine, the country has the potential to create 537-771 GW of RES-based capacity, with an average annual electricity production of 1,516-2,273 billion kWh[20]. That is 10-15 times higher than the current annual electricity consumption in Ukraine, and is enough for production of 337-505 billion/nm3 of hydrogen by electrolysis[21]. It is important to note that a large part of the territories with high RES energy potential are currently under occupation by the Russian Federation, and that significantly reduces Ukraine's overall potential for producing renewable hydrogen. Odesa, Kherson, Zaporizhzhia, Dnipro, and Luhansk regions have the highest potential for producing "green" hydrogen. The Autonomous Republic of Crimea, Kherson, Donetsk, and Luhansk regions account for 15.3% of Ukraine's total production potential of "green" hydrogen.

According to the Hydrogen Council and McKinsey & Company Report, gas pipelines can achieve a minimal cost of transporting hydrogen compared to alternative modes of transportation, such as land and sea transportation[22]. This is especially relevant to the Ukrainian situation, where modernisation of the existing infrastructure is an easier option compared to building a new one. For example, the modernisation of pipelines can save 60-90% of the costs of constructing a new pipeline[23]. Therefore, the advantages of Ukraine as an exporter lie in its existing and potential gas infrastructure. Also, Ukraine ranks second after Russia in terms of storage capacities in Europe, with 37.8 billion cubic meters, which can be partially converted into CCS (Carbon capture and storage from hydrogen production) carbon storage facilities.

> ***Ukraine's weakest point regarding its hydrogen potential is the stagnation of the country's fuel and energy complex, in terms of innovation and new technologies***

Ukraine is already negotiating with the European Commission regarding the development of this potential. An example of the movement in the direction of adapting the gas infrastructure to hydrogen is the "Regional Gas Company" (RGC). RGC started Ukraine's first hydrogen research project back in 2020. There are five particular test sites in the Volyn, Dnipropetrovsk, Zhytomyr, Ivano-Frankivsk, and Kharkiv regions. Currently, field research and laboratory experiments are being conducted, with the involvement of seven scientific partners (research institutes and universities). This first stage brings about scientifically confirmed conclusions on hydrogen-resistant equipment and materials. Starting from 2023, the project's

20 United Nations Economic Commission for Europe , *Draft Roadmap for production and use of hydrogen in Ukraine*, Geneva, 25 February 2021, p. 34 [https://unece.org/sites/default/files/2021-02/Draft_Report_H2_Roadmap_25.02.2021_e.pdf accessed: 31 July 2022]

21 Ibid

22 Hydrogen Council, McKinsey & Company, *Hydrogen Insights: A perspective on hydrogen investment, market development and cost competitiveness*, Hydrogen Council, 2021. [https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021.pdf accessed: 31 July 2022]

23 Ibid, p.20

second stage should begin, using a gas-hydrogen mixture in practical application in several household clusters[24]. This project is part of the Project Portfolio of the European Clean Hydrogen Alliance, of which RGC and several other Ukrainian gas companies and public organisations are members. The company had certain successes in connecting biomethane plants to the gas network in 2022. However, the latest results of the hydrogen project were published at the end of 2021, and it is difficult to predict its timing in the future, due to the problems that have arisen as a result of the war.

Ukraine's weakest point regarding its hydrogen potential is the stagnation of the country's fuel and energy complex, in terms of innovation and new technologies. In particular, the share of R&D expenditure in the GDP from 2014 to 2020 dropped from 0.6% to 0.41%. A shortage of qualified personnel is a characteristic of the Ukrainian fuel and energy complex, and this trend has worsened with the migration of labour resources.

Currently, no legislative framework would regulate the production, storage, and transportation of renewable hydrogen in Ukraine. That creates additional uncertainty for potential investors and restrains market growth. The Dixi Group notes that there are no references to hydrogen in Ukraine's current energy and transport strategies[25]. The report also states that in the National Economic Strategy 2030, hydrogen is mentioned only as one of the possible options for energy export to the EU.

Germany will likely become the largest importer of renewable hydrogen in the EU. Over the past two years, Germany has been sending many political, business, and diplomatic signals indicating their early interest in importing Ukrainian green hydrogen. From 2021 to 2022, a few memoranda were signed between Ukrainian and German gas companies regarding the development of hydrogen energy. In addition, the Ukrainian company EcoOptima also plays a crucial role in the European partnership "H2EU-Store". This project involves the production of green hydrogen in Ukraine, and its transportation through the Slovak EUSTREAM pipeline network to Austria and Germany.

Ukraine's renewable hydrogen energy market is at an earlier stage of formation than that in the EU. Ukraine's potential is sufficient for producing and using renewable hydrogen not only within the country but also abroad. However, the Ministry of Energy of Ukraine is still only working on a single and basic document that would set the direction of the development of the hydrogen market in Ukraine, but it does not fully consider hydrogen export in relation to the EU.

EU Interests in the Import of Renewable Hydrogen

According to the report of the Hydrogen Europe Association, 7.5 GW of capacity for hydrogen production in the domestic market and 32.5 GW exported from the region of North Africa and Ukraine will

24 РГК, До 2023 року РГК *закінчить перший етап підготовки газових мереж до транспортування водню*, Регіональна газова компанія (RGK, *By 2023, RGK will complete the first stage of preparing gas networks for hydrogen transportation*, Regional Gas Company), 14 July 2021 [https://rgc.ua/ua/news/voden/id/do-2023-roku-rgk-zakinchit-pershij-etap-pidgotovki-42324 accessed: 31 July 2022]

25 А. Корогод, Ю. Огаренко, Р. Ніцович, *Правова база для розвитку водневої енергетики: міжнародний досвід та ситуація в Україні,* "ГО «Діксі Груп»" (Korogot, A., Oharenko, Y., Nitsovysh, R., *Legal framework for the development of hydrogen energy: international experience and the situation in Ukraine,* "NGO Dixi Group"), 2021 [https://dixigroup.org/wp-content/uploads/2021/09/dixi_group_hydrogen_legal_policy-brief_final.pdf accessed: 31 July 2022]

allow for achieving a reduction in CO2 emissions by 82 million tons in the EU every year[26].

Although there is still no clarity on the future demand for renewable hydrogen in the EU, according to various forecasts, in 2050, it could range from 12 to 123 million tons per year, with an average demand of 76 million tons. According to Alejandro Núñez-Jimenez's paper, almost half of the EU member states will not be able to meet their demand independently[27]. Therefore, the EU has two options for further action. The first option is to import from non-EU countries at a lower price, due to more significant production potential. An alternative option of expansion of its own production causes a higher price per kilogram of renewable hydrogen, but ensures more reliable energy security due to independence from external producers. EU member states have the potential to produce up to 106 million tons of renewable hydrogen. However, in EU member states, production costs per kilogram of hydrogen range from US$2.7 to US$4.4[28]. Therefore, some EU countries will have to increase their production costs to satisfy their ever-growing demand, which will lead to an increase in prices and a decrease in competitiveness.

As a result, the EU is considering third countries that can offer higher production potential and lower prices, and has already started preliminary arrangements with them. In particular, Morocco can produce up to 68 million tons of renewable hydrogen at less than US$3 per kilogram[29]. Ukraine has considerable potential for hydrogen production, but the expected production costs have not been calculated yet.

The annual potential of electricity generation from SPPs in Ukraine is about 45 million tons. Therefore, compared to the "export champion" Morocco, Ukraine has a lower average annual renewable hydrogen production potential. However, due to the lack of overall analysis of Ukraine's price competitiveness, the lack of data on projected investments in production facilities, and redesigning/modernisation of the gas transportation system, it is difficult to determine the competitive price of Ukrainian renewable hydrogen.

The advantage of Ukraine over other potential exporters of "green" hydrogen is its developed gas transportation system, and proximity to the largest centres of demand, such as Germany. Morocco also has a Maghreb-Europe gas pipeline, but it was decommissioned in 2021, and ended with connections to the Spanish and Portuguese gas networks, which are by no means the largest centres of projected demand. A longer pipe length, accordingly, requires more investments. Therefore, according to its strategy, Morocco will prefer a slightly more expensive type of hydrogen transportation – with the help of ships, given its well-developed maritime export infrastructure.

Reliability also includes a safety factor. Ukraine's entire energy infrastructure is under threat of destruction. Since the beginning of the war, the EU has been

26 van Wijk, A., Chatzimarkakis, J. *Green hydrogen for the European Green Course: 2x40 GW initiatives*, Dii, 2020 [https://dii-desertenergy.org/wp-content/uploads/2020/04/2020-04-01_Dii_Hydrogen_Studie2020_v13_SP.pdf access: 31 July 2022]

27 Nuñez-Jimenez, A., De Blasio, N., *The Future of Renewable Hydrogen in the European Union Market and Geopolitical Implications*. Cambridge, MA, USA: Environment and Natural Resources Program, Belfer Center for Science and International Affairs, Harvard Kennedy School, 2022 [https://www.belfercenter.org/sites/default/files/files/publication/Report_EU%20Hydrogen_FINAL.pdf accessed: 31 July 2022]

28 Ibid, p.31

29 Ibid, p.35

sending specialised energy equipment from member states to Ukraine through the EU Civil Protection Mechanism. This mechanism signals the EU's interest in long-term energy cooperation with Ukraine.

Morocco is also not a stable region due to the disputed territory of Western Sahara, and the severing of diplomatic relations with the neighbouring hydrocarbon giant – Algeria – which has spare underwater gas pipelines to the EU, bypassing Morocco. Due to Germany's political position on the sovereignty of Western Sahara, Morocco temporarily terminated the agreement on energy cooperation, which in particular provided for the development of renewable hydrogen[30]. However, as early as in March, 2022, Morocco and Germany's cooperation on "green" hydrogen resumed, after a year of strained relations. The EU also stresses that it is ready to continue cooperation with Ukraine on hydrogen, as soon as favourable circumstances arise. The Commission will also support the development of three main hydrogen import corridors through the Mediterranean (Morocco), the North Sea region (Norway), and, as soon as conditions will allow, Ukraine. The EU is already working on a document with Ukraine on a renewable gas partnership, which they plan to sign in 2022.

The price factor plays an essential role in transportation. As we noted earlier, according to the Hydrogen Council and McKinsey & Company Report, gas pipelines are significantly more competitive than alternative modes of transportation such as land and sea transportation[31]. Therefore, a developed network of Ukraine's gas transmission system (GTS) is essential in satisfying the EU's interest in cheap and convenient transportation.

Finally, the energy trade between Morocco and the EU is limited to bilateral trade with Spain. Also, both countries have experience in gas transit to the EU: Ukraine – from Russia, Morocco – from Algeria. While Morocco no longer transits gas to the EU, Ukraine, according to the Contract for the transit of Russian gas to the EU, will transit it until 2024.

> ***Similar to the LNG trade, the development of the international hydrogen market requires international agreements and other forms of international cooperation, to establish a common infrastructure, rules, and distribution of markets***

Therefore, Ukraine, as a potential exporter of renewable hydrogen, satisfies the EU's interest in sufficiently integrating the exporter into the EU energy markets. Compared to Morocco, Ukraine is better integrated into EU energy markets and has more experience exporting electricity.

Ukraine's Need to Adopt a Hydrogen Strategy and Conduct Active Hydrogen Diplomacy

Similar to the LNG trade, the development of the international hydrogen market requires international agreements and other forms of international cooperation, to establish a common infrastructure, rules, and distribution of markets. The creation of international organisations and stakeholder organisations is also necessary. Therefore,

30 J. Ortiz, *Increase in Morocco's electricity exports*. Atalayar, 1 March 2022 [https://atalayar.com/en/content/increase-moroccos-electricity-exports accessed: 31 July 2022]

31 Hydrogen Council, McKinsey & Company, *Hydrogen Insights: A perspective on hydrogen investment, market development and cost competitiveness*, Hydrogen Council, 2021, p. 20. [https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021.pdf accessed: 31 July 2022]

"hydrogen diplomacy" should become an instrument of the revitalisation and creation of renewable hydrogen markets.

Germany is a successful example of using the tool of "hydrogen diplomacy". Germany has planned to install electrolysers, the production capacity of which should be equal to 5 GW, which roughly corresponds to 14 TWh, and thus covers only about a seventh of Germany's projected hydrogen demand until 2030 (90-110 TWh)[32]. Germany plans to compensate for the limited production of hydrogen by importing it. As early as 2022, the German Foreign Ministry announced plans to establish hydrogen diplomacy offices in Luanda (Angola), Abuja (Nigeria), Moscow (Russia), Riyadh (Saudi Arabia), and Kyiv (Ukraine). The Future Package primarily provides financing for the first phases of the strategy implementation: 7 billion euros to accelerate the market entry of hydrogen technology into Germany, and another 2 billion euros to promote international partnerships[33]. In addition, countries such as Canada, Chile, Italy, Japan, and Spain have explicitly mentioned potential bilateral hydrogen trade relations in their national strategies.

Even before the full-scale invasion by Russia, and the EU's adoption of strategic decisions on hydrogen energy, the first dialogues regarding cooperation in this area had begun. Persistent rhetoric about "hydrogen cooperation" was at the forefront of German-Ukrainian relations before the full-scale Russian invasion. At the last pre-war meeting of the foreign ministers, Annalena Baerbock and Dmytro Kuleba, on February 7, 2022, special attention was paid to the development of cooperation in the field of hydrogen energy.

With the beginning of the war, the issue of hydrogen diplomacy was put on the backburner. It is obvious that supporting Ukraine and ensuring the conditions for victory are a priority. However, another reason for the lull is that Ukraine does not consider the need for an active hydrogen export lobby in official documents and strategies.

In August 2021, the Ministry of Energy established a working group to create a Strategy for developing hydrogen energy by 2030. The strategy's release was expected at the end of February 2022, but it was never published and approved, due to the war. However, as early as 2021, the Institute of Renewable Energy of the National Academy of Sciences of Ukraine, and the energy association "Ukrainian Hydrogen Council" published the Draft of the Hydrogen Strategy of Ukraine[34].

The general purpose of the Draft Strategy does not envisage the provision of hydrogen energy for the export of renewable gas to EU countries as a tool for deepening integration with the EU energy system. Although it is worth mentioning that the first stage (short-term goals) of the strategy involves launching the export market of "green" hydrogen, which requires reviewing the role of its GTS. The pipeline is the cheapest way to transport hydrogen, so Ukraine needs to prioritise the modernisation of its GTS, and set clear goals for the transportation of hydrogen mixed

32 Federal Government of Germany. *The National Hydrogen Strategy*, Berlin: Federal Ministry for Economic Affairs and Energy, 2020. [https://www.bmwk.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6 accessed: 31 July 2022]

33 Ibid, p.3

34 Інститут відновлюваної енергетики НАН України, *Воднева стратегія України: проєкт* (Institute of Renewable Energy of the National Academy of Sciences of Ukraine, *Hydrogen Strategy of Ukraine: Draft*), Kyiv, 2021 [https://www.ive.org.ua/wp-content/uploads/Vodneva-Strategia-Cover.pdf accessed: 31 July 2022]

with natural gas. It should also define the necessary amount of investment, develop a mechanism for financing such a project, and, possibly, attract foreign stakeholders such as Germany.

The medium-term goals for 2030-2035 include an increase in exports as a factor influencing the growth of the domestic Ukrainian market. Although such a statement does not fully correspond to the general purpose of the draft strategy, it well reveals the essence of the export orientation of the Ukrainian renewable hydrogen market. After all, hydrogen will be needed by those countries that have found solutions for the use of hydrogen in their sectors of the economy, and only later will Ukraine be able to adopt and finance them. That is, the expansion of the domestic market will take place in the medium term, due to the increase in exports.

Another risk that an export-oriented hydrogen strategy will help overcome is the potential halting of Ukrainian transit of Russian gas to the EU, when the current contract expires in 2024

In the third stage, from 2030 to 2050, the intention is to use 50% of Ukraine's available RES potential for hydrogen production by 2050. This is approximately 22,500 thousand tons of green hydrogen annually, allowing Ukraine to go beyond the European market to the global market, which is not mentioned in the project. Unlocking such a significant potential encourages us to strategise more widely about the sale of Ukrainian hydrogen to other centres of demand, apart from the European Union.

An obvious problem with the current Draft Hydrogen Strategy is the lack of quantitative indicators. That is, the strategy does not foresee conditions, does not forecast the amount of investments and expected production, and therefore it is impossible to draw a conclusion from the project about what quantitative indicators Ukraine needs to achieve so as to obtain profits or satisfy its interests.

Among the benefits to Ukraine from the large-scale production of green hydrogen, the following are mentioned in the Project of the Hydrogen Strategy of Ukraine: the creation of new jobs and the reorientation of people employed in the energy sector, the creation of a new economic sector with the attraction of multibillion-dollar foreign investments, which will contribute to the sustainable development of Ukraine, the provision of significant foreign exchange revenues for an extended period, additional growth of GDP due to the development of RES, which may amount to 4-6% in 2030 and 12-15% in 2050, and a decrease in budget expenditures for the health care of citizens, due to the diminishing of air pollution[35].

After the war's end, Ukraine will need not only to carry out post-war reconstruction but also to attract investments in various areas, to strengthen the weakened economy. This will be essential for fully or partially destroyed industrial sectors, such as metallurgy. Renewable hydrogen can open the way to entirely new technologies, aiming not only to rebuild the economy but to saturate it with new sectors, applications, investments, and markets, that will cause rapid growth.

Another risk that an export-oriented hydrogen strategy will help overcome is the potential halting of Ukrainian transit

35 Інститут відновлюваної енергетики НАН України, *Воднева стратегія України: проєкт* (Institute of Renewable Energy of the National Academy of Sciences of Ukraine, *Hydrogen Strategy of Ukraine: Draft*), Kyiv, 2021, p.60 [https://www.ive.org.ua/wp-content/uploads/Vodneva-Strategia-Cover.pdf accessed: 31 July 2022]

of Russian gas to the EU, when the current contract expires in 2024. Due to the Russian-Ukrainian war, there is a high probability that the next transit contract may not be signed, which will nullify Ukraine's transit capacities. If so, the potential of the Ukrainian GTS will remain unused. On the other hand, the EU's desire to diversify its energy supplies and abandon Russian natural gas has also prompted Ukraine to think differently about the future use of its own GTS. Its transformation into a hydrogen supply network is one of the most financially and organisationally beneficial options.

In total, hydrogen has the potential to account for 12 to 24% of the world's final energy use by 2050, with annual sales of up to 630 bln euros[36]. Given the global and, in particular, the European agenda for decarbonisation and the Ukrainian potential for the production of renewable hydrogen, Ukraine can offer to fill the gap between the expectations and capabilities of the most ambitious players of energy transition to zero emissions, including the EU and the potentially largest consumer of hydrogen – Germany. Therefore, it is time to restore Ukraine's active "hydrogen diplomacy", while the EU forms just the foundations of its potential hydrogen market.

Recommendations for the Development of Hydrogen Diplomacy in Ukraine

To support a future export-oriented hydrogen strategy, Ukraine's current hydrogen diplomacy should address three main issues: to identify sales markets, find a potential exporter of hydrogen technologies, and define potential collaborators. At the present stage, Germany could be considered as the main trading partner. In addition, Ukraine should make agreements with Morocco and other potential hydrogen exporters, to simultaneously conduct its hydrogen diplomacy with the EU, jointly taking a share of the export market.

Taking into account the evaluation and analysis of the Hydrogen Strategy Project of Ukraine, in order to improve it, we suggest focusing on the implementation and development of the following areas:

- to substantiate economically the goals of hydrogen production, taking into account the forecast demand in the EU, Ukrainian potential, and the capabilities of potential competitor countries;
- to model expected investments in the hydrogen infrastructure (production, storage, transportation, and application in the domestic market);
- to prioritise sectors of the economy for the use of renewable hydrogen in Ukraine, taking into account the interest of "green" exports to the EU;
- to include the factor of post-war reconstruction and the possibility of using hydrogen technologies in the restoration of the metallurgical industry, partly destroyed by the Russian invasion

It is also necessary to specify the recommendations regarding the legal framework, taking into account the experience of the EU, and the current problems and opportunities of the Ukrainian energy industry. At this stage, Ukraine still does not have any regulations for "transitional" hydrogen. However, using "pink" atomic hydrogen as a transitional stage, and using the Ukrainian GTS for hydrogen transportation, can become critical competitive advantages for Ukraine. In the EU and Germany, the transitional

36 Д.Г. Бобро, *Проблемні питання та перспективи розвитку водневої енергетики в Україні*, "Національний Інститут Стратегічних Досліджень" (D.G.Bobro, *Issues and prospects for the development of hydrogen energy in Ukraine*, National Institute for Strategic Studies), March 2021 [https://niss.gov.ua/sites/default/files/2021-03/voden.pdf accessed: 31 July 2022]

option is "blue" hydrogen, for increasing low-carbon hydrogen production with the simultaneous replacement of the "grey" hydrogen. "Blue" hydrogen is produced by steam recreating methane from natural gas, but using carbon capture and storage technology. "Pink" hydrogen is produced by an electrolyser powered by electricity from nuclear power plants. The Ukrainian atomic potential allows for this option, but requires the same calculations as in the case of "green" hydrogen. In connection with the introduction of gas and nuclear energy into the EU taxonomy, this transitional option for Ukraine can become an essential strategic leap in the direction of the hydrogen trade.

Currently, a wide range of stakeholders interested in developing hydrogen energy is being formed in Ukraine: gas and development companies, public organisations, universities, and research institutions. In addition, the EU member countries' interest plays a significant role in shaping the future energy market. Separately, we can single out Germany, which is expected to become the leading importer of hydrogen in the EU, and, therefore, at the diplomatic level, is currently trying to involve Ukraine in cooperation in the production and supply of renewable hydrogen. The perspective of Ukraine is in export-oriented strategising, development of the hydrogen market, and the application of hydrogen technologies in reconstructing the Ukrainian domestic economy. To achieve its goals, Ukraine needs to do its homework today: to adopt an updated Hydrogen Strategy, taking into account its export potential, and to start active "hydrogen diplomacy" with the EU, jointly building up the European hydrogen market.

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