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The hydrogen policy of the Visegrad Countries: A comparative study

Polityka wodorowa w państwach Grupy Wyszehradzkiej. Analiza porównawcza

Abstract: The present paper aims to analyse and compare the preconditions for implementing hydrogen strategies in the Visegrad countries. This study attempts to verify that hydrogen policies are going to be implemented at different rates, thereby delaying their introduction. It is extremely important to assert this claim in the context of the energy crisis, the war in Ukraine, and the European Union's aspirations to achieve low-carbon economy goals and energy self-sufficiency policies at both the national and EU levels. Furthermore, the study attempts to provide answers to the following research questions: firstly, does the hydrogen policy have a realistic chance of being implemented in the Visegrad region? Secondly, will it be implemented in the indicated form and extent of cooperation?
Keywords: Hydrogen policy, RES (Renewable Energy Sources), minilateralism
Streszczenie: Celem opracowania jest analiza porównawcza warunków wstępnych w zakresie wdrażania polityki wodorowej w państwach Grupy Wyszehradzkiej (V4). W opracowaniu podjęto próbę weryfikacji hipotezy, że realizacja polityki wodorowej będzie polityką różnych prędkości, co przełoży się na opóźnienia w jej realizacji. Weryfikacja wskazanej hipotezy jest niezwykle istotna w kontekście kryzysu energetycznego, wojny w Ukrainie oraz dążeń Unii Europejskiej do osiągania ambitnych celów w zakresie gospodarki niskoemisyjnej oraz podejmowania zarówno na poziomie państwa, jak i Unii Europejskiej działań na rzecz dążenia do samowystarczalności energetycznej. Dodatkowo w opracowaniu podjęto próbę odpowiedzi na pytania badawcze. Po pierwsze, czy polityka wodorowa ma realne szanse zaistnienia w przestrzeni państw Grupy Wyszehradzkiej? Po drugie, czy będzie realizowana we wskazanym formacie współpracy i w jakim zakresie?
Słowa kluczowe: polityka wodorowa, oze, minilateralizm

Introduction

The global energy crisis following Russia's invasion of Ukraine has led to a shift in energy security perspectives. EU governments, which had

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previously taken a systematic, gradual, and conservative approach to increasing the share of renewables in the energy mix, have had to reassess their thinking in this area and adopt a more dynamic approach. Rising fossil fuel prices have made wind and solar energy more competitive. Member States' energy policies now focus on diversifying energy sources and supply routes while reducing greenhouse gases in the atmosphere. The rules adopted at the EU level provide a starting point for bilateral and multilateral action by countries. They provide a new platform for cooperation on specific sub-regional projects. A practical example of energy cooperation can be found in the activities of the Visegrad Group (V4). With a view to realising national energy interests, such cooperation is practical and focused on the implementation of specific projects. *A Hydrogen Strategy for a Climate Neutral Europe* (hereafter: *The EU Hydrogen Strategy*)[1], announced on 8 July 2020, provided the impetus to intensify cooperation. It sets out a catalogue of activities in the hydrogen sector. The development of hydrogen policy is part of the trend towards energy neutrality and at the same time an instrument for its implementation. It is a key component of EU and national efforts to move towards a low and eventually carbon-free economy. World demand for hydrogen in 2020 was about 95 million tonnes (Mt), with more than 70 Mt used as pure hydrogen and about 20 Mt as feedstock in gas mixtures for methanol and steel production, according to the International Energy Agency (IEA). Refinery and industrial processes accounted for almost all of the hydrogen demand in 2020[2]. Meanwhile, interest in the use of hydrogen in other sectors of the economy has been growing rapidly[3]. This applies to both the normative and practical levels. By adopting the EU Hydrogen Strategy, the European Commission has stimulated activities in the field of hydrogen technology development in EU Member States. The adoption of an EU hydrogen policy framework stems from

1 International Energy Agency, *Hydrogen*, 2022, https://www.iea.org/reports/hydrogen [5.04.2023]; International Energy Agency, *Hydrogen – more efforts needed*, 2023, https://www.iea.org/reports/hydrogen [5.04.2023].

2 K. Błach-Morysińska, G. Tchorek, *Mapa rozwoju rynku i technologii dla obszaru technologii wodorowych*, PARP, Warsaw 2022, p. 31.

3 European Commission, 2020. Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions, *A hydrogen strategy for a climate-neutral Europe*, Brussels, 8 July 2020, 301 final, p. 1.

the fact that efficient hydrogen technology development and building competitiveness in this sector require international cooperation. The share of hydrogen in the European energy mix is expected to grow dynamically, from less than 2% today to 13-14% in 2050[4]. The EU Hydrogen Strategy is, therefore, an important element in building energy neutrality across the whole community. This document proposes policy actions in five areas. First, to support investment in the hydrogen sector. Second, to support hydrogen production and demand. Third, to create a hydrogen market and infrastructure. Fourth, to encourage cooperation and research. Fifth, to cooperate internationally in the field of hydrogen[5]. Hydrogen has a broad range of uses, from power generation to long-term storage. Including hydrogen in the country's raw material and energy balance will, therefore, make energy systems more flexible by balancing supply and demand, ultimately leading to increased energy efficiency. The implementation of a hydrogen policy is an instrument to achieve carbon-neutral targets. In the context of hydrogen production, we must focus on the production of hydrogen from renewable sources, given their zero emissions. The current production of hydrogen is around 70 Mt, of which 76% is from natural gas and almost all the rest (23%) from coal[6]. Therefore, the challenge for designing, implementing, and developing hydrogen technologies in the Visegrad countries is to adopt solutions that focus on hydrogen production from renewable sources.

The present paper aims to analyse and compare the preconditions for implementing hydrogen strategies in the Visegrad countries. This study attempts to verify that hydrogen policies are going to be implemented at different rates, thereby delaying their introduction. It is extremely important to assert this claim in the context of the energy crisis, the war in Ukraine, and the European Union's aspirations to achieve low-carbon economy goals and energy self-sufficiency policies at both the national and EU levels. Furthermore, the study attempts to provide answers to the following research questions: Firstly, does the hydrogen policy have a realistic chance of being implemented in

4 Ibid.
5 Ibid.
6 International Energy Agency, *The future of hydrogen*, 2019, https://www.iea.org/reports/the-future-of-hydrogen [5.04.2023].

the Visegrad region? And secondly, will it be implemented in the indicated form of cooperation and to what extent?

1. Overview of existing resource conditions for the development of hydrogen policy in the Visegrad Group countries

The fuel and energy balances of Visegrad countries are comparable (Figure 1). However, from the point of view of the implementation of both energy and hydrogen policies, it is the differences that are significant. The V4 countries have a comparable level of total energy supply by source, however, there are slight differences in the oil, biofuels, and waste sectors (Figure 1). In contrast, the share of coal varies considerably, with a dominant share in Poland (41.9 %) and Czechia (29.15 %), compared to 15.38 % in Slovakia and 5.18 % in Hungary. Countries with a predominant share of coal in the energy mix will start implementing hydrogen technologies based on conventional energy sources, which is actually the least desirable from the point of view of reducing emissions. Renewable energy resources in the countries analysed, together with the use of water technologies, average 13%, which is a common point for development and investment in the renewable energy sector. This is important for planning joint infrastructure projects.

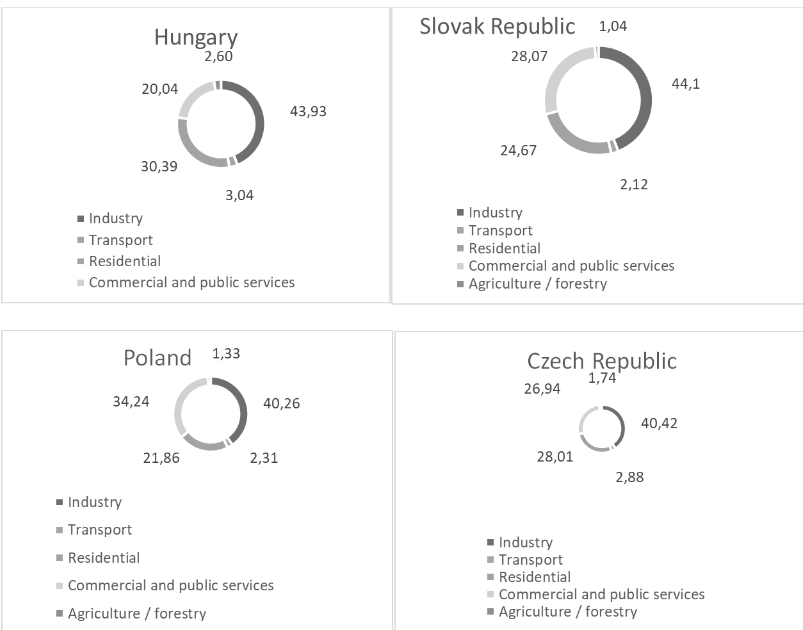
Figure 1. Total Energy Supply (TES) by source in 2021 (%)

Source: Own study based on data from IEA, www.iea.org.

Electricity consumption is most prominent in industry, where its average share is around 41% (Figure 2). Except for Hungary, this consumption is covered by coal. By contrast, transport accounts for an average of 2.5 % (Figure 2). These figures have implications for the intensity of carbon dioxide emissions in industry (Figure 3) and transport (Figure 4). It should be noted that investment in industry, which is the main source of greenhouse gas emissions, is crucial for reducing emissions. The relatively high share of high-emission fuels in the structure of the raw material and fuel balance in the Visegrad countries translates into high costs of energy transformation in the region. However, considering the process of energy transformation and the related trend, including the shift from the use of high-emission to lower-emission fuels, this share is going to be sustained.

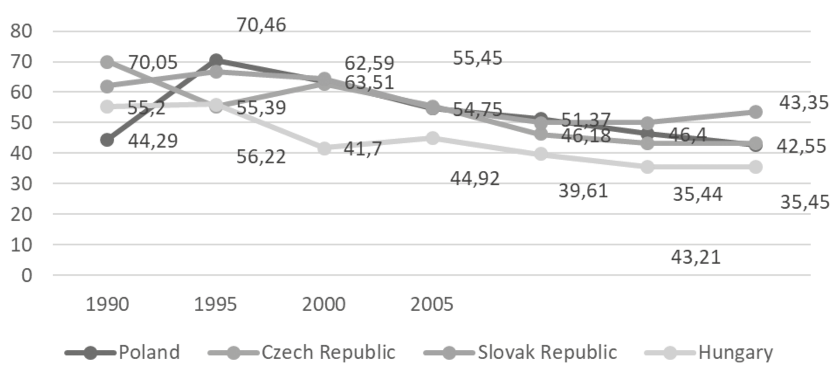
It is, therefore, reasonable to assume that hydrogen technologies will be used primarily in industry. Another reason for this assumption is that hydrogen use in transport is effective and cost-efficient, but most viable for long-distance transport (shipping, aviation).

Figure 2. Electricity consumption by sector 2020 (%)



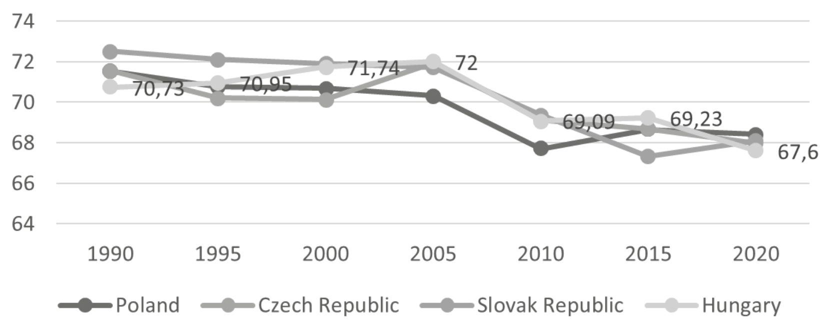
Source: Own study based on data from IEA, www.iea.org.

Figure 3. Carbon intensity of industry energy consumption (gCO2/MJ)



Source: Own study based on data from IEA, www.iea.org.

Figure 4. Carbon intensity of road transport energy consumption (gCO2/MJ)



Source: Own study based on data from IEA, www.iea.org.

Hydrogen is currently used in the chemical and refining industries. Low-carbon hydrogen accounts for less than 1% of global hydrogen production in 2021. At present, hydrogen production in the Visegrad countries varies widely. The level of hydrogen production in Poland is about 1.3 million tonnes, which ranks Poland 3rd among European hydrogen producers (14% of European hydrogen is produced in Poland), mainly in industrial processes[7]. Grupa Azoty S.A. is the largest producer of hydrogen in Poland, producing approximately one tonne of hydrogen. PKN Orlen produces approximately 145,000 tonnes of conventional hydrogen. Pure hydrogen will be produced in the pro-

7 K. Błach-Morysińska, G. Tchorek, op. cit., p. 70.

pane dehydrogenation process at the new Grupa Azoty plant. Hydrogen is produced as a co-product of this reaction and is of very high quality, reaching a purity of 99.99%. Poland has significant potential for developing renewable hydrogen, especially for using energy from offshore wind farms[8]. Unipetrol, which produces over 85,000 tonnes of hydrogen annually, is the largest producer in Czechia[9]. The conditions for the development of hydrogen technologies for industry are unfavourable in Czechia. The country has neither significant RES resources nor infrastructure for commercial production of renewable hydrogen[10]. In Slovakia, the largest producer of hydrogen is the Duslo chemical plant, which produces 100,000 tonnes of hydrogen per year. In Hungary, MOL Group produces and consumes nearly 150,000 tons of hydrogen annually[11].

A number of observations can be made from the above analysis of the conditions for the development of hydrogen technologies. First of all, an analysis of the structure of power generation in the V4 countries reveals a relatively diverse picture. The gradual increase of RES is in line with the EU climate and energy policy. The level of energy dependence leaves room to search for alternative solutions to improve the level of energy security in the V4 countries, taking into account both the level of diversification of sources and the direction of supply. At the same time, it should be emphasised that diversifying sources has so far not translated into diversifying sources of conventional energy. It is also important to note that the current share of renewable energy sources in the analysed countries is inadequate, both from the point of view of the targets and the EU regulations as well as from the point of view of renewable hydrogen production. The second observation is that the share of nuclear technologies, which are considered to be relatively safe and an alternative solution for improving energy security, seems to contradict the above statement in a detailed analysis of the energy mix of the Visegrad countries. This is mainly due to

8 P. Niewiński, *Critical infrastructure at sea and the energy security of the Republic of Poland*, "Energy Policy Studies" 2022, vol. 2, no. 10, pp. 3-14.
9 L. Janiček, L. Reichmann, *Hydrogen law, regulations & strategy in the Czech Republic*, https://cms.law/en/pol/ [5.04.2023].
10 Ibid.
11 Ibid.

the technological and raw material dependence on Russian technologies of Czechia, Slovakia and, to a large extent, Hungary. Together with the dependence on natural gas and oil supplies, this often blocks rational energy solutions and, more broadly, the political choices of the analysed countries. At present, they do not have the flexibility and freedom to create their own energy portfolio, which is a consequence of technological and infrastructural dependence, among other things. As a result, the V4 countries face a national security dilemma. They are heavily dependent on one supplier for all their raw materials, and this dependence is determined by infrastructure links. This is best illustrated by the example of Hungary, where severing energy cooperation with Russia is against Hungarian national interests. This has implications for the low energy self-sufficiency indicator, energy security, and ultimately state security. Thirdly, mainly because of its high emissivity but also because of the depletion of mines, especially in Czechia, the legitimacy of coal use is widely questioned. Depleting reserves is forcing a shift in energy mixes. Fourthly, the Visegrad countries have the potential to implement major infrastructure projects. The completed natural gas transmission project, the N-S corridor, has increased gas supply flexibility and is also an interesting alternative for its use in hydrogen transport. Fifthly, for the design of hydrogen policy, the location of the Visegrad countries is important. Investments in hydrogen technologies and infrastructure will directly contribute to strengthening the energy security of the countries in the region, while specialisation in this sector has the potential to create competitive advantages in the subregion. As Marlena Gołębiowska, Michał Paszkowski, and Damian Szacawa rightly point out: "The countries of Central Europe are only at the beginning of the process of building new energy systems in which renewable energies will play a dominant role. (…) The process of energy transformation will require significant financial outlays. However, technological development and a decrease in the cost of electricity generation from low-emission energy sources will facilitate this process"[12]. At the same time, we have to agree with

12 M. Gołębiowska, M. Paszkowski, D. Szacawa, *Neutralni dla klimatu: zielona transformacja państw Europy Środkowej w dobie pandemii COVID-19*, "Prace IES" 2021, no. 15, p. 43.

Ewelina Kochanek that atmospheric and geological conditions limit the expansion of the RES market in the region[13].

2. Normative requirements for the development of hydrogen policy in the Visegrad Group countries

Hydrogen policy is another area of opportunity for energy partnerships in the region. This creates the possibility of strengthening cooperation in the regional initiatives that are functioning even in a less structured formula (the Lublin Triangle, the Visegrad Group). At present, the countries find themselves in a kind of energy paradox, which consists in trying to balance energy policy by taking account of at least four variables: their own raw material potential (i.e., their own recoverable energy resources), EU requirements setting targets in the field of carbon neutrality, external conditions related to the aftermath of the conflict in Ukraine (which will determine the geopolitics of raw materials in the world now and in the future), and measures aimed at stabilizing the supply chain of energy resources. All these elements play a decisive role in ensuring the energy security of countries and the wider area.

The proposed hydrogen policy is a relatively new element in the complex matter of ensuring energy security in the EU. *The EU Hydrogen Policy* outlines the most important development paths for Member States to follow when diversifying their energy mix with a view to 2035 and 2050. The adoption of similar documents at the Member State level was a prerequisite for the EU Hydrogen Strategy.

13 E. Kochanek, *The role of hydrogen in the Visegrad Group approach to energy transition*, "Energies" 2022, vol. 15, no. 19, p. 9.

Table 1. List of hydrogen strategies in EU and Visegrad countries

EU	Slovakia	Poland	Czechia	Hungary
Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee, and the Committee of the Regions, A hydrogen strategy for a climate-neutral Europe, Brussels, 8 July 2020, COM (2020) 301 final. (July 2020)	National Hydrogen Strategy: Ready for the Future (June 2021)	Polish Hydrogen Strategy Until 2030 with an Outlook Until 2040 (November 2021)	Czechia's Hydrogen Strategy (July 2021)	Hungary's National Hydrogen Strategy. Strategy for the Introduction of Clean Hydrogen and Hydrogen Technologies to the Domestic Market and for Establishing Background Infrastructure for the Hydrogen Industry (May 2021)

Source: Own study.

The analysis of hydrogen policies in the V4 countries reveals the importance of hydrogen in improving energy security parameters and the need to reduce GHGs. Up to 2021, no comprehensive solutions for the use of hydrogen technologies in the regulatory area existed at the level of the investigated states. Despite their similar structure, the strategies differ in detail, both in terms of objectives and the issue of setting implementation deadlines. The Polish strategy includes a reference to the concept of the hydrogen economy, defined as technologies for the production, storage, distribution, and use of hydrogen and its derivatives, including centralised and decentralised systems for the production, storage, and transport of hydrogen using the transmission and distribution network and other forms of transport, and its subsequent use in various sectors of the economy[14]. It is important to note that the national strategies have clarified the terms used for hydrogen technologies. However, a number of inconsistencies exist in the way hydrogen technologies have been categorised in the documentation reviewed. The regulations adopted at the EU level refer to two concepts: renewable hydrogen, which is produced from energy from renewable sources other than biomass and provides a 70% reduction in greenhouse gas emissions compared to hydrogen produced from fossil fuels, and low-emission hydrogen, which is produced from energy from non-renewable sources and meets the threshold of a 70% reduction

14 The Government of Poland, *Polish Hydrogen Strategy Until 2030 with an Outlook Until 2040*, 2021, p. 3.

in greenhouse gas emissions compared to hydrogen produced from fossil fuels. The Polish document follows the terminology adopted at the EU level. When specifying the types of hydrogen, the emissivity level was emphasised, whereas other countries referred to the criterion of how it was produced. Thus, in the former, conventional and renewable hydrogen are mentioned, and in the latter, the documents refer to green, grey, and blue hydrogen. The primary objective stated in the documents analysed is the same. It is to decarbonise economies, while eventually seeking to use hydrogen produced from renewable energy. The analysis of the Visegrad Group countries' hydrogen strategies shows that all countries envisage using hydrogen technologies for power generation, industrial decarbonisation, and transport. Therefore, the current use of hydrogen needs to be extended beyond the chemical, petrochemical, and refining industries. The production of hydrogen will require the establishment of a plant for the production of hydrogen from sources with low or zero emissions. It must be noted, however, that the Strategies allow for the production of hydrogen from various forms. The development of hydrogen production implies the need to develop the transport and storage infrastructure. Notably, the development of the hydrogen economy should help create a hydrogen industry. The Hydrogen Strategies of the Visegrad countries emphasise the need to develop international cooperation involving both the public and private sectors.

What favours the implementation of hydrogen technologies in the analysed countries is their strong orientation towards developing RES. One of the most important factors for the development and implementation of hydrogen policies has been the changing perception and approach to hydrogen policies, with a close link between energy security (the primary objective of the V4 energy policies) and climate policies. The level of reduction of greenhouse gas emissions is used to evaluate the progress and effectiveness of the hydrogen policy. This should be seen as a change in the way we think about energy security, which is already inextricably linked to the natural environment, not only in the sphere of declarations and postulates, or in the effort to build a Green Deal in the EU, but also in determining its level through specific quantitative indicators in terms of the desired level of greenhouse gas emissions into the atmosphere, and not the percentage share of individual suppliers and carriers in the energy mix of each country. Cooperation in the field of hydrogen technologies has taken the form of hydrogen valleys, which will ultimately be part of the European Hydrogen Ecosystem. Hydrogen valleys are going to be located in specific geographical areas and the decision to create them will be strongly embedded in the context of cooperation at the (sub)regional level. The solutions identified are expected to help create a globally competitive industry and their location has already been identified. In Hungary, the hydrogen ecosystem of the Transdanubian region has been selected as the first site. It is going to involve the development of the ammonia industry and refineries (Pétfürdő, Százhalombatta). The document shows that there are unique opportunities even at the regional level, and in addition to the current large hydrogen users, there are several sectors that have the potential to become new hydrogen users, e.g., iron and steel works (Dunaújváros) and cement production (Beremend, Királyegyháza). The nuclear power plant in Paks can provide a significant amount of emission-free electricity to build the hydrogen value chain. The second northeastern hydrogen valley is a region with a well-developed industry (Miskolc, Tiszaújváros, Kazincbarcika, strong chemical and petrochemical industry, with significant existing hydrogen consumption), with significant hydrogen demand in a concentrated area. The inclusion of the Mátra power plant and its area should also be explored[15]. In the field of transport, Hungary has decided to reduce the carbon footprint of heavy goods vehicles by increasing the use of hydrogen to about 65,000 tonnes by 2040 and 212,000 tonnes by 2050, following the rapid spread of fuel cell vehicles. Eventually, five valleys will be built in Poland: Silesian HV (construction of fuel cells, hydrogen buses), Lower Silesian (networks of economic links with suppliers, subcontractors, and collaborators), Greater Polish (production of zero-emission green hydrogen), Pomeranian (production of buses and trains, hydrogen education), Mazovian (research and development projects), and Subcarpathian (construction of fuel cells, hydrogen buses)[16]. In Czechia, the valleys

15 The Hungarian Government, *Hungary's National Hydrogen Strategy. Strategy for the Introduction of Clean Hydrogen and Hydrogen Technologies to the Domestic Market and for Establishing Background Infrastructure for the Hydrogen Industry*, 2021, p. 6.

16 *Doliny wodorowe w Polsce*, https://h2poland.eu/pl/kategorie/doliny-wodorowe/odbior-spoleczny/doliny-wodorowe-w-polsce/ [5.04.2023].

are going to be located in the Karlovy Vary region (transport) in the northwest, Moravia and Silesia in the east, and Ústecký in the northwest. The first two of these locations have the potential to become the main hydrogen hubs in Central Europe according to Environment Minister Petr Hladik[17]. Furthermore, the development of hydrogen technologies within the countries studied will involve the production, storage, and use of hydrogen, especially for transport. In the Slovak Republic, advanced work on hydrogen technology is conducted at the Košice Centre[18]. The implementation of hydrogen technologies is not only a unilateral effort of the EU to conquer the market for hydrogen technologies. It is also dictated by the changing political and economic situation in the world, especially in the context of the military operations in Ukraine and the resulting consequences for the EU. In March 2022, the European Commission announced the REPowerEU Communication, a document whose premise is to expedite the reduction of dependence on Russian fossil fuels and the acceleration of the energy transition. The Communication highlighted the need to accelerate the use of hydrogen, in particular from renewable energy sources. It also highlights the importance of hydrogen as a replacement for natural gas, coal, and oil in industries and transport that are difficult to decarbonise. REPowerEU targets 10Mt of domestic renewable hydrogen production and 10Mt of renewable hydrogen imports by 2030[19]. It also stressed that hydrogen infrastructure must be developed more rapidly to produce, import, and ship 20 million tonnes of hydrogen by 2030. Cross-border hydrogen infrastructure is still at an early stage of development, but the basis for planning and development has already been laid with the inclusion of hydrogen infrastructure in the modernised Trans-European Energy Networks. Total investment needs for

17 I. Todorović, *Czech coal regions to introduce hydrogen technologies*, Balkans Green Energy News, https://balkangreenenergynews.com/czech-coal-regions-to-introduce-hydrogen-technologies/ [5.04.2023].

18 J. Trubalska, *Slovakia – case study*, [in:] A. Wiącek, M. Ruszel. J. Stec-Rusiecka (eds.), *Energy security. Selected issues*, Rzeszów 2022, p. 221.

19 Communication from the Commission to the European Parliament, The European Council, The Council, The European Economic and Social Committee and the Committee of the Regions, *REPowerEU Plan* {SWD(2022) 230 final}, p. 8.

the main categories of hydrogen infrastructure are estimated at EUR 28-38 billion for internal EU piping and EUR 6-11 billion for storage[20].

The focus of hydrogen policy development cooperation in the Visegrad countries is currently on the decarbonisation of transport. To this end, a project is being implemented as part of the Black Horse Hydrogen Valley in Slovakia. The project plans to deploy 10,000 HDV vehicles, invest in 40 electrolysers for hydrogen production, and build a hydrogen refuelling infrastructure along the TEN-T corridors with a total of 270 refuelling stations to be completed by 2030. Current status high-level planning at the government level exists[21]. Moreover, the Visegrad countries cooperate on hydrogen technologies within Horizon Europe, Clean Hydrogen Partnership, Important Projects of Common European Interest as well as at a bilateral level.

In summary, it should be noted that the different levels of commitment of the Visegrad countries already at the strategic policy level may determine the success of their cooperation in the field of hydrogen technologies. As mentioned above, the hydrogen strategies are quite different in terms of setting specific dates and quantifiable targets.

Heterogeneous conditions, especially in terms of renewable energy potential, are a constant that will affect the success of hydrogen production from renewables. Although governments have stated their desire and need to develop the whole hydrogen chain, they are concentrating their efforts on developing the transport sector. As indicated above, the bulk of decarbonisation efforts should be focused on industrial solutions. Furthermore, as the V4 countries begin to implement their hydrogen policies on a large scale, they are operating in a similar regulatory environment, lacking uniform and detailed legislation. The regulatory environment for the implementation and development of hydrogen technologies, therefore, requires the development of certain permanent legal instruments that take into account local conditions.

20 Ibid.
21 *Black Horse*, https://h2v.eu/hydrogen-valleys/black-horse [5.04.2023].

Conclusions

Since 2009, the energy sector has gained momentum within the Visegrad Group. Before that, it was not the main platform for cooperation. Changing energy market conditions, political changes, and the implementation of infrastructure projects that undermine the energy security of the countries in the region (e.g., Nord Stream) are currently driving the forms and directions of cooperation in the energy sector. This cooperation lacks an institutionalised framework and is characterised by its network structure. This, in turn, affects the flexibility that is crucial in the context of ensuring energy security, not only at the state level but also at the regional level. In practice, this means that cooperation is focused on specific infrastructure projects that are important for the improvement of the parameters of energy security in the region. The drive to decarbonise industry leads us to believe that implementing a hydrogen policy is rational and justified from an energy security perspective for the V4 countries. Hydrogen in industry is useful in areas where electrification is hard to achieve. Switching to renewable hydrogen will contribute to significant emission reductions in the identified sectors[22].

There are few dedicated hydrogen projects being implemented. Most of the key projects for hydrogen production, transport, and storage are in the design phase. Implementing hydrogen investments is contingent upon increasing renewable energy shares in the energy mix. In the countries under review, hydrogen is a by-product of chemical processes and is mainly produced and used for own consumption. This means that no investment has been made so far in developing the transmission network dedicated to hydrogen on a large scale. At all levels of the hydrogen value chain (production, transport, and storage), the European Hydrogen Ecosystem project is forcing profound changes in infrastructure development.

From the point of view of the national interests of the V4 countries, it is important to diversify energy sources. This is especially true in the current dynamically changing environment. Hydrogen offers real benefits in both the economic and, more importantly, the political dimension. The diversity of conditions in the hydrogen sector in

22 K. Błach-Morysińska, G. Tchorek, op. cit., p. 28.

the countries analysed should be seen as an added value. It allows for specialisation in individual countries within the developed hydrogen sector and of the whole group within the EU.

Networking energy cooperation in this region requires a systematic approach to hydrogen technology activities. Such an approach must be reflected in the dynamics of the development of the analysed area, in which the states develop individual partial systems and create a competitive advantage in a fragmented manner, but in the aggregate create a new, specialized quality. This is why it is important that projects carried out at governmental and bi-national levels take account of and capitalise on existing potential.

In view of the above energy mix of the Visegrad countries, it should be noted that hydrogen will be complementary to existing solutions in the field of energy feedstock security. Therefore, hydrogen technologies are not expected to replace existing solutions, and their implementation and development will be complementary and simultaneous with the development of existing technologies.

Each of the countries analysed has aspirations to play a leading role in the hydrogen sector. In the future, it will be necessary for individual countries to specialise in a particular sector so that the relationship is one of cooperation rather than competition. In this way, it will be possible to plan future investments, including infrastructure investments in the hydrogen sector, as well as to plan for the security of energy supply in the medium and long term. Developing and implementing hydrogen policies will allow initiatives to be taken within sub-regions to enhance their competitiveness and energy edge. Considering the geopolitical position of the V4 countries and the potential of hydrogen technologies, their proper management can not only ensure energy security in the region but also help to increase their competitiveness. There are preconditions for the practical implementation of cooperation in the discussed sector, given the possibility of using the existing natural gas transmission network in the region and the geopolitical position of the V4 countries. At the same time, as evidenced by the implementation of joint investments, it is worth noting that energy companies have noticed the economic potential in the hydrogen sector.

The analysis conducted herein confirms that hydrogen policy is being implemented at an uneven pace, thus delaying it. This is mainly due to the heterogeneous resource potential for the development of the hydrogen sector in the countries examined. The highly politicised nature of the energy sector means that the countries analysed have to make decisions on the basis of rational national considerations rather than economic ones. Therefore, these decisions will strongly correspond to actions taken at the political level, which sometimes limits options and hinders decisions to implement specific infrastructural projects. Thus, a logical consequence will be the implementation of a hydrogen policy by individual states, taking into account local conditions strongly embedded in an international context that often goes beyond the scope of the V4 and the EU. Furthermore, there will be far-reaching consequences for other sectors of the economy in the V4 countries if we assume that other EU countries will implement their own hydrogen strategies in a consistent manner and that delays will occur in the analysed group. Hydrogen policy in the Visegrad Group countries can be implemented not only at the national level through the adoption of strategies and the adaptation of legislation but also at the subregional level through the development of energy infrastructure. Based on this analysis, it is possible to conclude that hydrogen policy implementation in V4 countries is multi-vectoral and involves both direct collaboration in hydrogen (production, transmission, and storage) and in renewable energy.

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