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LATVIAN JOURNAL OF PHYSICS
AND TECHNICAL SCIENCES
2023, N 1

DOI: 10.2478/lpts-2023-0003

GREEN AND SUSTAINABLE HYDROGEN IN EMERGING EUROPEAN SMART ENERGY FRAMEWORK

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Green and sustainable hydrogen has a major role in moving towards decarbonization of energy, providing viable solutions in all most challenging sectors of the national economies. It would penetrate practically all sectors of economic activity, such as long-haul transport, steel and chemical industries, power generation and energy storage. Green and sustainable hydrogen cost competitiveness is also closely linked to developments of large-scale renewable energy sources (in case of green hydrogen; *hereinafter* – RES) and further commercialization of carbon dioxide (in case of sustainable hydrogen produced from natural gas; *hereinafter* – CO_2) capture and storage (*hereinafter* – CCS) technologies.

In the European Union (*hereinafter* – EU), sustainable and especially green hydrogen is gaining strong political and business momentum, emerging as one of major components in governments' net zero plans within the European Green Deal and beyond. Being extremely versatile both in production and consumption sides, it is light, storable, has high energy content per unit mass and can be readily produced at an industrial scale. The key challenge comes from the fact that hydrogen is the lightest known chemical element and so has a low energy density per unit of volume, making some forms of long-distance transportation and storage complex and costly.

In this paper, green and sustainable hydrogen is reviewed as a vital part of emerging European smart energy framework, which could contribute significantly to economy decarbonization agenda of the EU and Latvia in both in short- and mid-term perspective.

Keywords: *Decarbonization, green hydrogen, smart energy systems, sustainable hydrogen.*

1. INTRODUCTION

Use of hydrogen in the energy sector has a long history, which begun with the first internal combustion engines over two centuries ago. Currently, it forms an integral part of the modern chemical and refining industry. Hydrogen is light, storable, energy-dense, and produces no direct emissions of greenhouse gases (*hereinafter* – GHG). For hydrogen to make a significant impact on the EU energy transitions, which is tended to illuminate around 90 % of all EU's GHG emissions by 2050 [1], it needs to be adopted in sectors where it is almost completely absent at the moment. Such sectors include, but are not limited to transport, buildings, power generation and direct gaseous fuel supplies, while introducing renewable gases (*hereinafter* – RGs) to conventional natural gas transmission and distribution networks [2].

Despite characteristics that make hydrogen unique for energy applications, in its pure form hydrogen has highly reactive properties with high combustibility and very low energy density. It means that this gas requires careful handling, transport and distribution as well as typically high-pressure systems for use in final applications. The main characteristics of hydrogen in comparison with the other form of gaseous fuel – methane (the main ingredient of natural gas or biomethane) are shown in Table 1.

Table 1. The Main Characteristics of Hydrogen and Methane

Properties	Hydrogen	Methane (natural gas)
Self-ignition temperature (°C)	585	540
Flame temperature (°C)	2045	1875
Ignition limits in air (vol. %)	4-75	5.3-15
Minimal ignition energy (mWs)	0.02	0.29
Flame propagation in air (m s-1)	2.65	0.4
Diffusion coefficient in air (cm2 s-1)	0.61	0.16
Toxicity	-	-

The International Energy Agency (*hereinafter* – IEA) estimates that the demand for hydrogen in its pure form currently is around 70 million tonnes per annum (*hereinafter* – Mtpa) with the majority or over 90 % of it originated in oil refining industry and ammonia production for the fertilizers manufacturing industry [1]. If demand for hydrogen in pure and non-pure forms is combined, the total demand, according to The International Renewable Energy Agency, can exceed 100 Mtpa, with the actual demand in 2021 standing at 94 Mtpa [3]. All of it was produced almost exclusively from fossil fuels, such as natural gas and coal, releasing around 900 Mt of CO_2 into the atmosphere. The average global percentage of hydrogen produced from natural gas stands for more than 70 % [4]. Today, 6 % of global natural gas and 2 %

of global coal resources go into hydrogen production [3].

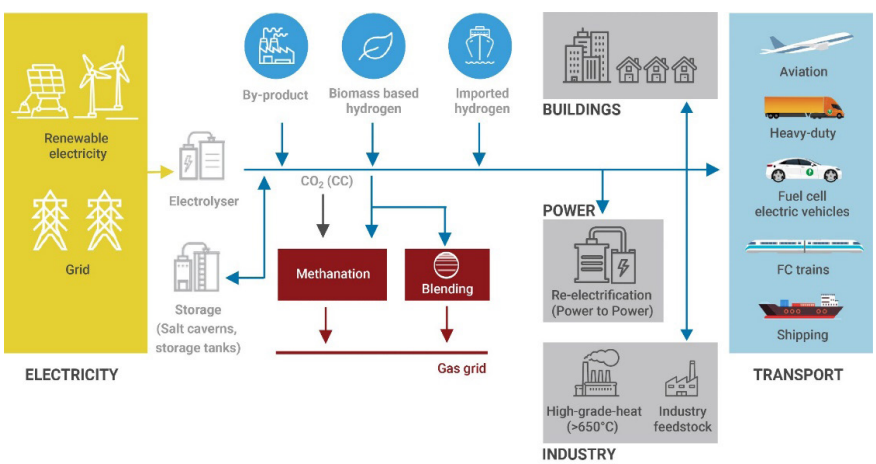
At the same time, by mid-2021, a global capacity of electrolysers, which are needed to produce green hydrogen, reached about 300 megawatts (*hereinafter* – MW). At the end of 2022, according to some estimates [5], it could already reach 1.4 giga-watts (*hereinafter* – GW), but by 2026 – even 8.5 GW [6]. From 2020 to 2021, the hydrogen production market was valued at 130 billion US dollars. It is estimated to grow up to 9.2 % per year through 2030 [7].



Source: GlobalData Thematic Research

Fig. 1. Global electrolyser capacity (GW), 2022.

Around 522 projects, 43 of which at GW scale, are currently under development, and could bring global electrolyser capacity up to 54 GW by the end of this decade. Another 40 projects accounting for more than 35 GW of electrolyser capacity are at the early stages of development. The majority of hydrogen activity, with 261 projects [8], is located in Europe. Many European countries have been investing to find non-carbon intensive alternatives for industrial and transportation usage in line with the EU Green Deal and an effort to strengthen the local fuel value chain.



Source: IRENA

Fig. 2. An example of green hydrogen production, supply and consumption chain.

As for today, the main green hydrogen source technologies are alkaline water electrolysis, proton-exchange membrane electrolysis, and solid oxide electrolysis, with the latter being in the research and first-trial phase [9]. If all planned projects are completed, global green hydrogen supply could reach more than 8 Mt by 2030, but this is still well below the 80 Mt required in the way to net zero CO_2 emissions by 2050, or 70Mt short of the most conservative EU energy decarbonisation target for the same date [3].

The installed capacity growth, coupled with growth in demand, would require rather massive energy input. For instance, 22 000 terawatt-hours (*hereinafter* – TWh) of RES electricity to produce 500 million tons of green hydrogen per year are needed, and the parallels of the hydrogen value chain to that of the fossil fuels (with upstream, midstream, and downstream elements) can be drawn. To date, only a few green hydrogen projects have been successfully brought to market. According to *PricewaterhouseCoopers*, most green hydrogen projects under construction and in operation are at the pre-commercial phase with electrolyser capacity less than 50 MW [10]. While some proposed plants are of 100 MW capacity or more, they remain small compared to fossil fuel counterparts. In addition, green hydrogen projects pose some risks that challenge traditional project financing: relative immaturity of the technology, segmentation and fragmentation of energy input, challenges of production and transformation, challenges of storage and long-distance transportation and limited consumer accessibility [4], [11], [12].

In the EU, the European Commission's (hereinafter – EC) long-term energy and economy decarbonization path includes stimulus for wider adoption of low carbon technologies, including hydrogen. In 2020, the EU hydrogen strategy for a climate-neutral Europe was adopted [13], with many EU countries presenting their own national hydrogen strategies soon after. Even those countries that are currently lacking such strategies as separate policy planning document are integrating the green hydrogen component into their national energy and climate plans (hereinafter – NECPs) [14]. Globally, by 2021, nine governments have already adopted a hydrogen strategy. Thus, the total number of governments that have committed to adopt hydrogen as a clean energy vector in their energy agendas has increased to 26 [15].

For instance, the EC has set up a "Hydrogen Energy Network", an informal group of experts composed of representatives from the ministries in charge of energy policy in the EU Member States, aiming to support national authorities to develop hydrogen technology opportunities. The countries have signed the declaration on the "Hydrogen Initiative", which promotes cooperation on sustainable hydrogen technologies. "Hydrogen Europe" is a leading European association promoting the development of hydrogen as the enabler of net zero society. Currently, it has over 160 industrial members across Europe [16]. Initiatives include the Fuel Cells and Hydrogen Joint Undertaking (*hereinafter* – FCH JU), a public-private partnership with the EC that drives a funding stream of 1.33 billion euro (*hereinafter* – EUR) under the EU Horizon 2020 Program, with the aim of accelerating the market adoption of hydrogen technologies in energy, industry and transport [17].

However, strong green hydrogen backing strategies can only work as part of a smart energy framework or all-inclusive, innovative energy supply agenda. It means that not only the current EU energy distribution grids, but also transmission systems need to transform into unified, fully flex-

ible and remotely manageable frameworks with new technologies such as smart solar, energy storage, smart metering and smart gas management. These components would help form self-sufficient and synergetic energy ecosystem, where green and sustainable hydrogen would also play an important role not only in industrial applications, but also in transport and, to some extent, in household energy supply. Low-volume energy consumers in this framework would become prosumers and actively participate in the energy market, and their behaviour would have a major impact on the entire energy ecosystem. A unified smart energy framework will enable consumers to transform into individual energy "uploaders and downloaders", while keeping the overall, differentiated energy system safe, reliable, and affordable and ensuring the system develops toward increasing sustainability [18].

Such a framework building approach is also applicable to RGs like biomethane, sustainable and green hydrogen, which in future would be present in almost all segments of the EU energy sector, and need to be adequately integrated into the new energy ecosystems.

2. A HYDROGEN PATHWAY TO SMART GAS DISTRIBUTION

In order to increase not only production of sustainable and green hydrogen, but also boost its use across the energy sector, the smart energy systems – new, digitalized and sectorally synergized energy architecture solutions and frameworks – are needed to be implemented. The smart energy system concept in most cases addresses cost-effective, highly digitalized RES-only based systems [19], with an inclusion of energy efficiency and infrastructure enhancement efforts. However, not all interpretations of the concept are exclusively dealing with RES, as smart energy systems often are identified with maximally diversified, sustainable energy systems, where some forms of fossil fuel and, especially, energy storage, can or must be present [20].

As green and sustainable hydrogen is RG, smart energy systems should include gas supply chain elements both at the level of transportation and distribution, and storage. In some infrastructure-oriented cases of smart energy system concept interpretation, as shown in Fig. 3, neither fossil nor RES take a central stage – on the contrary, smart grids and storage capacities take the lead [21].

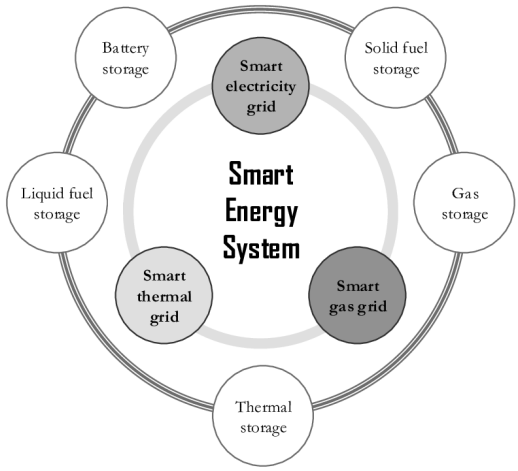


Fig. 3. Principial scheme of grid and storage centered (infrastructure-oriented) smart energy system [21].

As opposed to the smart grid concept, which first and foremost took a sole focus on the electricity sector [22], the smart energy systems approach includes the entire energy generation and consumption spectrum in its identification of suitable energy

infrastructure designs and operation strategies. Focusing only on the smart electricity grid often leads to the definition of transmission lines, flexible electricity demands, and electricity storage as the primary means of dealing with the integration of fluctuating RES. However, these measures alone are neither very effective nor cost-efficient considering the nature of large, variable energy sources. The most effective and least-costly solutions are to be found when the electricity sector is combined with the heating and cooling sectors, gas supply and transport sector. Moreover, the combination of electricity and gas infrastructures may play an important role in the design of future RES systems, and the electrification of heating and transport can play a pivotal role in providing flexibility and ensuring RES integration in all sectors [23].

In order to stimulate automation of data processing and overall digitalization in energy, the EC has proclaimed a support to the development of all kind of the smart energy systems, where simultaneous use of the natural gas and RG will play one of the major sustainability ensuring roles. First, it will help achieve designated energy efficiency goals and, second, it will allow for cost-saving synergetic solutions at the early stages of the energy supply chain decarbonisation [24], [25].

Synergy of natural gas and RG, in particular, sustainable and green hydrogen, emphasises the need for a modern, smart and sustainable energy infrastructure to allow developing more flexible back-up and balancing power capacity, storage solutions and innovative demand-response mechanisms. In a nutshell, usage of green or sustainable hydrogen in smart energy systems would emerge as a concept of smart hydrogen, which combines the following options: a solution to the electrical grid network challenges faced by the mature RES electricity technologies, opportunities in hydrogen supply pathway, prospects for new hydrogen applications, creation of different and new trends in energy markets with power to X (hereinafter – P2X) technologies. The aim of smart hydrogen would be to create a hydrogen value chain that is optimal in technical performance and financial revenues. With this in mind, the concept of P2X refers to energy conversion technologies that allow for the decoupling of power production plants from the electrical market to use their product in a number of other sectors, such as transport, heating and chemical industry.

There is a belief that green and sustainable hydrogen network development should start at the energy transmission level, where the EU Hydrogen Backbone will be created by 2050 the latest [26], [27], and only then come down to reach distribution systems. This is a reason why transmission level projects and initiatives are more widespread and accounted for at the moment. Still at the distribution level, there are a few activities to address. For instance, in December 2021, DNV announced that it would lead a study aimed at the production of a roadmap for the European gas distribution networks to show how they could help unlock the growth potential of hydrogen distribution for wider and more feasible further use. The aim of the project is to combine the hydrogen expertise and experiences from across eighty European gas distribution companies and organisations [28]. It is planned that analysis of the European gas distributors will be performed in order to determine how they can contribute to the hydrogen development before drawing up a roadmap to show how gas distribution companies can support the transformation of Europe's primary hydrogen distribution infrastructure and enhance emerging smart energy systems in gas distribution. The European

gas distribution network consists of about 2 million kilometres of pipeline across the continent. It would be a significant benefit if large parts of the gas distribution network could be repurposed and extended, since they will drive the transition from natural gas to hydrogen at a lower cost compared to developing a new network [29].

For decades European local gas networks have shown the ability to deliver reliable, cost-effective and safe distribution to millions of customers, and it is strongly believed that local gas networks will also add value to address the challenges to achieve the huge growth and CO_2 reduction potential of hydrogen in Europe, as infrastructure provides the means to cope with rapidly growing shares of variable wind and solar power by transporting hydrogen from decentralized productions points to consumers throughout the EU market. The gas infrastructure has the capacity to handle demand seasonality providing reliable supply of hydrogen even during all periods of the year. Moreover, in this context large-scale hydrogen underground storage facilities linked to gas networks are considered to be the only fast-acting, long-lasting storage capacity at enormous scale to cope with variable power production and demand [12].

Also, local gas networks provide a flexible decarbonisation pathway for customers as they are well-positioned to distribute and manage varying local blends of molecules and, to a large extent, are ready to convert relatively quickly to pure hydrogen. Local gas network would facilitate a competitive and expanding hydrogen market, meaning more hydrogen for users at a lower price. At the same time, local gas networks provide a cost-efficient pathway, including significant volumes of hydrogen and biomethane, investment in the combined power and gas infrastructure [30]. Such initiatives are tended to contribute to significant financial savings, which are estimated to reach over 40 billion EUR a year.

To ensure a hydrogen pathway to smart gas distribution and, thus, a smart energy framework, hydrogen ready smart meters with capacity to extraordinary precision and versatility must be developed and tested in the prospect of wide hydrogen blending into the gas distribution networks in the EU. One option is to replace mechanical diaphragm meters with ultrasonic devices, which rely on accurate measurement of the speed of sound to determine the gas flow rate. Because the speed of sound in hydrogen is around three times faster than that in natural gas, significantly better timing precision is needed [31].

Also, the introduction of sustainable and green hydrogen as a replacement for natural gas, which is firmly on agenda, is set to require large-scale modification and probable eventual replacement of the gas distribution infrastructure and gas-powered appliances and other equipment. While there are supporters for pure hydrogen consumption, in practice in most cases its introduction is most likely to be blended with natural gas in proportions up to about 20 %, as the production and supply of green hydrogen is ramped up and the full hydrogen infrastructure is put in place [32].

Hydrogen energy content is about only one-third of natural gas. Thus, not only more hydrogen-blended natural gas is needed to deliver the same amount of energy to users compared to pure natural gas but also a higher volumetric flow rate is required. Options for the latter include increasing the operating pressure in the distribution system or replacing the existing pipelines with ones of larger diameter.

In case of its use in appliances, for example, the main concerns are potentially higher combustion temperatures with

hydrogen-natural gas blends, which could lead to local overheating of components, and the increase in the burning velocity, which poses a risk of potential flashbacks. Coupled with the changes on both the utility and consumer sides, there also will be a need for the changes in the primary interface, the meter, with eventual full gas smart meter replacement with hydrogen-ready or hydrogen only meters. At the moment, ultrasonic hydrogen meters are being developed, demonstrated and tested by several manufacturers, such as Pietro Fiorentini [33] and MeterTech [34]. It is expected that in close future these meters will be available on the market and ready for installation not only for large consumers, but also for households.

3. HYDROGEN AS AN ENABLER OF SECTORAL INTEGRATION

The versatility of hydrogen allows for wide potential energy sector integration as part of smart energy framework and, thus, contributes to the Europe's energy transition.

Power generation offers many opportunities for hydrogen and hydrogen-based fuels. In the near-term ammonia could be co-fired in coal-fired power plants to reduce CO_2 emissions. Hydrogen and ammonia can be flexible generation options when used in gas turbines or fuel cells. At the low-capacity factors typical of flexible power plants, hydrogen costing under USD 2.5/kg has good potential to compete. Key low-carbon competitors for such services include natural gas with CCS and biomethane. In the longer term, hydrogen can play a role in large-scale and long-term storage to balance seasonal variations.

It is believed that green and sustainable hydrogen, first and foremost, is meant to be used in decarbonisation of industry and energy generation processes, with smaller segments of energy sector not being the first priority. District and local heating are one of these sectors, where there is a great dispute on the necessity to include hydrogen in energy mix in Europe in a short- and mid-term perspective. According to the IEA, globally, district heating supplies a relatively small share of heat used in buildings, at only 8.5 % of the sector's heat consumption – a share that has remained impressively constant since 2000, considering that floor area has increased by 65 % at the same time. Although the global average share is low, district heating does cover a high portion of heat delivered to buildings in some European countries, such as Denmark and Sweden (both above 45 %) [35].

As usage of natural gas in district heating is still rather widespread in the EU and the United Kingdom, the injecting of up to 10 % hydrogen by volume into the natural gas transportation and distribution networks would not require any major alterations to equipment and would significantly reduce CO_2 [36] for households and small business consumers. At the same time, injection of up to 10 % hydrogen into the natural gas networks would contribute not only to district heating companies and their clients, but also to local and individual heating system users. They would also use hydrogen – natural gas – biomethane blend in their natural gas boilers and other equipment, not replacing them by new ones, and, at the same time, contributing to national and the EU emission reduction targets [37].

In the electricity sector, burning of liquid and gaseous hydrocarbons currently represents the largest share of electricity generation around the world. Countries with

limited RES and hydrocarbon resources rely significantly on expensive imported and polluting fuels. Importing electricity through transmission lines might sometimes be problematic due to high costs, system losses, and geographical barriers [37]. However, green hydrogen offers a viable alternative. Countries importing large amounts of hydrocarbons today, in the near future could switch to import of low-cost green hydrogen and convert it into electricity through large-scale fuel cells in domestic power plants [38]. Hydrogen concentrations of up to 10 % and 20 % are still permissible for the operation of turbines and compression stations, respectively, while pipelines can stand mixtures of up to 50 % (given some technical adjustments); anything above those values is currently still being researched [39]. For instance, Mitsubishi Hitachi Power Systems, Ltd. has recently disclosed the successful test of a large-scale highly efficient turbine fed with a 30 % hydrogen blend, attaining a stable combustion with a 10 % reduction in CO_2 emissions [40].

At the same time, hydrogen blending into the existing natural gas network has multiple advantages and can be a cost-effective transitional option in the short term in regions without parallel or duplicated networks. The retrofitting and repurposing of existing natural gas networks can be combined and complemented with the construction of new dedicated hydrogen infrastructure. It needs to be reminded that a purely hydrogen pipeline infrastructure is not a novelty. Such networks, although strictly compact and localized, are already used to supply single consumers, for example, petrochemical and fertilizer plant. At present, a 900 km long hydrogen pipeline network is built along the Gulf coast of the United States, which is regarded as the longest high-pressure hydrogen transportation network in the world [41]. In Europe, currently the largest and longest industrial hydrogen pipeline network is located in the area of ports of Rotterdam and Antwerp, with total length around 1500 km, where the longest part consists of small diameter distribution infrastructure [42]. In line with this, there are various initiatives, EHB and the Re-Stream studies carried out [43], in order to assess the potential of the existing European oil and gas infrastructure to carry hydrogen and/or carbon monoxide.

In addition, in the EU, a well-developed and regulated network of natural gas is already in place, with the transmission grid being approximately 2 million kilometres long.

A distribution grid, which is double the size of the current transmission grid, implies that the natural gas infrastructure is the key enabler for the deployment of a hydrogen economy. The UNECE Group of Experts on Gas recognised the key role of the natural gas transmission and distribution operators (*hereinafter* – TSO, DSO), natural gas industry and the natural gas infrastructure in the transition to a hydrogen economy through the energy system integration [44]. Even though pipelines and the natural gas storage facilities today are being considered the most cost-competitive solution for hydrogen distribution, numerous challenges remain. One of them is an increasing difficulty of building new pipelines, as many landowners are not ready to have such objects close to their properties. Thus, it is in the best interest of actors in the hydrogen value chain to find ways to extensively reuse existing natural gas infrastructure instead of constructing an entirely new hydrogen infrastructure. It is necessary to start immediate retrofitting and repurposing of current natural gas infrastructure. Given TSO and DSO know-how in operating natural gas transmission and distribution infrastructure, the gas TSOs should be among those certified as owners and operators of future hydrogen networks [45].

Authorizing the natural gas TSOs to carry out activities related to the development, integration and operation of hydrogen infrastructure would facilitate an efficient way forward due to their experience in planning, financing, constructing, operating and maintaining gas infrastructure, since existing gas grids will be retrofitted and repurposed for hydrogen [42].

One of the solutions to transform the gas network pipes suitable for hydrogen transportation is to use an inner coating. The inner coating would chemically protect the steel layer and reduce the hydrogen diffusion into the metal. This aspect might allow increasing the overall pressure in the tubes. Initial hydrogen conversion projects in Germany and the Netherlands have shown that existing pipelines in those regions do not require internal coating; studies in France show that re-coating can be a viable part of the optimisation solution by enabling pipes to be operated at pressures closer to the pressure of natural gas [46].

4. THE SITUATION OF LATVIA

In case of Latvia, hydrogen production targets are not included in the NECP, so the development of the sector is therefore not politically or legally governed by provisions of this document. Latvia also lacks a hydrogen strategy, which could be a substitute for it. In regard to hydrogen energy future plans, different estimates are made, studies performed and technical projects proposed. For instance, the study by "Fuel Cells and Hydrogen 2 Joint Undertaking" outlines the amount of green hydrogen used in the industry, transport and energy production, as planned for 2030. The study offers two scenarios for hydrogen demand: low and high. In a low hydrogen demand scenario, green hydrogen would account for 0.1 % of total final energy demand (0.05 terawatt-hours (*hereinafter* – TWh)), but in the high one – 0.5 % of the total final energy demand (0.2 TWh) [47].

Several hydrogen production and usage proposals can be mentioned among those, which can be implemented in foreseeable future. The plan for a hydrogen filling station near Ainazi wind park envisages that a green hydrogen production point and a filling station with 100 kilo-watt (*hereinafter* – kW) electrolyser would be built near Ainazu wind park [48].

With regard to smart energy systems and frameworks, larger initiatives are crucial. Projects conceived by Ventspils nafta terminals (*hereinafter* – VNT) and JSC Latvenergo should be pointed out. VNT intends to create a green hydrogen valley, which would provide not only hydrogen production and consumption, but locally integrated green hydrogen ecosystem for climate change mitigation and regional economic development. Hydrogen valley would cover a substantial part of the hydrogen value chain: production, storage, transportation, and various consumption options.

The hydrogen production project by JSC Latvenergo states that green hydrogen would be produced using a polymer electrolyte membrane electrolyser, and electricity needed for the process would come from the Daugava hydropower plants, Riga CHP-2 or from the planned new large-scale wind parks. The produced hydrogen would be stored or used immediately for combustion in gas turbines at CHP-2. Beforehand, the produced hydrogen would be blended with natural gas, so percentage of hydrogen in the gas mixture would not exceed 5 % by volume in order not to affect the opera-

tion of the plant equipment. Hydrogen storage is intended for its later use in cooling of the CHP-2 electric generators or for sale to local consumers such as transport companies or the industry [48]. Based on the initial research results, the electrolysis capacity of 6.5 MW was determined [49]. In-depth and detailed studies on the subject are currently underway with the involvement of external experts.

Another potential solution for the utilization of produced hydrogen is to inject it into the natural gas grid. JSC Latvenergo is also evaluating the possibilities to build a new interconnection to the gas transmission system. The potential transmission natural gas pipeline together with the existing distribution gas pipeline can be used to inject a mixture of hydrogen and methane into the gas grid. The hydrogen pilot project is planned to be implemented until 2025, but until 2030–2035 a larger capacity electrolysis plant (over 100 MW) would come online. For the production of green hydrogen, JSC Latvenergo plans to significantly increase the capacity of wind and solar plants as well, which can exceed 2000 MW in total installed capacity. Together with existing hydropower capacities, it can provide electrolysis plants with green electricity at competitive prices. In addition, production of green hydrogen in the small-scale hydropower plants has also been considered in scientific research [50].

5. CONCLUSIONS

Most likely, green and sustainable hydrogen will play an important role in the emerging European smart energy framework, as it opens many possible avenues for energy production, transportation and storage, while new technological and sectoral synergy options are explored further in order to make them the part of all the European energy supply chain, and not only a fraction of it.

Green and sustainable hydrogen provides an opportunity to extend the boundaries of smart energy system concept beyond the electricity sector, as hydrogen helps tackle both problems faced by the gas industry and electricity sector alike. It is not limited to one of these important segments of energy, and technical readiness of the infrastructure – primarily, of gas transmission and distribution, will be a critical link between the two.

The most effective and least-costly solutions in smart energy framework can be found, when the electricity sector is combined with the heating and cooling sectors, gas supply and transport sector. Moreover, the combination of electricity and gas infrastructures may play an important role in the design of future RES systems, and the electrification of heating and transport can play a pivotal role in providing flexibility and ensuring RES integration in all sectors.

Power generation also offers many opportunities for hydrogen and hydrogen-based fuels, as in the near-term ammonia could be co-fired in coal-fired power plants, but the hydrogen itself in gas-fired power plants to reduce CO_2 emissions. At the same time, hydrogen blending into the existing natural gas network has multiple advantages and can be a cost-effective transitional option in the short term in regions without parallel or duplicated networks. The retrofitting and repurposing of existing natural gas networks can be combined and complemented with the construction of new dedicated hydrogen infrastructure.

If even in Latvia hydrogen-based

energy initiatives of different scale are still a novelty, and the lack of definite hydrogen energy development strategic framework is obvious, there are several proposals to develop the hydrogen production and consumption value chain (or elements of it) both in isolated applications, like fuelling stations, and wider applications, like hydrogen valley envisaged by VNT. Industrial applications of hydrogen production and co-firing in gas power plants are also underway, as there is the theoretical possibility to feed the hydrogen into the gas transmission system.

ACKNOWLEDGEMENTS

The research has been supported by the National Research Programme, project "Trends, Challenges and Solutions of Latvian Gas Infrastructure Development" (LAGAS) (No. VPP-EM-INFRA-2018/1-0003).

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