 DOI: 10.22616/RRD.31.2025.090

ESSENTIAL RESOURCES FOR GREEN HYDROGEN INDUSTRY DEVELOPMENT IN THE LATVIAN REGIONS

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Abstract
Hydrogen is one of the renewable fuels that might replace fossil fuels in a wide range of various applications, driving environmentally sustainable economic growth in the EU. According to the International Energy Agency, the use of hydrogen between 1975 and 2023 globally increased from 18 Mt to 97 Mt per year, but in 2023, EU member states produced 10.3 Mt hydrogen, or 10.6% of global output; green hydrogen accounted for less than 1%. The study's aim is to assess the Latvia region's green hydrogen production capacity in terms of the availability of the necessary renewable energy resources (RES) – solar power, wind and hydro energy – to assess available infrastructure suited for the green hydrogen industry. Secondary data on renewable energy (RE) in Latvian regions were collected and analysed according to the research framework; to conduct a detailed comparison, statistical data on RES and infrastructure were collected and assessed by assigning a value to each criterion examined. The research highlighted that Latvia's regions have an unequal distribution of RES, especially in terms of wind power and hydro energy; hydroelectric stations (HES) generate 60% of Latvia's total electricity. At present the Zemgale region is home to the largest HES, which defines its leading position in the RE sector, while the Kurzeme region is rising as a potential wind and solar energy hub of Latvia. Nevertheless, green hydrogen production has not been developed for commercial use in any region of Latvia.
Keywords: green hydrogen, renewables, hydrogen production.

Introduction

The European Union's Green Deal agenda highlights the need for environmentally friendly energy sources to drive further economic progress. Hydrogen, as one of several renewable fuels, has the potential to replace fossil fuels in various applications. The production of green hydrogen derived from RES across Europe plays a pivotal role in achieving this objective. Additionally, the shared EU hydrogen strategy (European Commission, 2020), along with national policy roadmaps from 18 member states, underscores the significance of hydrogen as a key fuel for supporting continued economic growth.

Green hydrogen is important in the energy sector from various perspectives. Hydrogen can play a crucial role in energy storage and maintaining grid stability. Additionally, as an energy carrier, it can be used for heat and power generation, act as a raw material in the production of synthetic fuels and various chemicals, and serve as fuel for transportation.

The International Energy Agency reports that global hydrogen demand increased from 18 Mt to 97 Mt per year between 1975 and 2023. However, in 2023, low-carbon and green hydrogen represented less than 1% of total hydrogen production (International Energy Agency, 2024). Meanwhile, the World Bank predicts that by 2050, hydrogen demand will increase to about 600 Mt annually (World Bank, 2022). In 2023, EU member states produced 10.3 Mt of hydrogen (EU Agency for the Cooperation of Energy Regulators, 2024), constituting 10.6% of global production.

Electricity generated from wind, solar, and hydropower is a key source for green hydrogen production in the EU. Between 2014 and 2023, the combined use of these three RES grew by 64% in the EU (Eurostat, 2024). The availability of these three RES is a fundamental factor in the development of the green hydrogen industry in a specific region.

The object of this study is the hydrogen production potential across Latvia's regions. The subject of this research is to assess the hydrogen production capacity of these regions based on the availability of essential RES and the existing infrastructure.

The aim of this study is to evaluate the capacity of Latvia's regions in terms of wind, solar, and hydropower resources and to assess available infrastructure suited for the green hydrogen industry. The defined aim is accompanied by the following tasks: reviewing the major necessary resources for green hydrogen industry development; identifying and analysing statistical data regarding RES, electricity production, and appropriate infrastructure for green hydrogen production in Latvia regions.

This study aims to provide a valuable resource for industry professionals, researchers, and policymakers in shaping and updating initiatives within the hydrogen industry and related fields of the economy. Its importance lies in being the first study to assess the potential for green hydrogen production across Latvia's regions. Moreover, it provides a basis for future studies aimed at advancing the green hydrogen industry and establishing new production facilities locally.

Materials and Methods

According to the aim of this research to evaluate the capacity of Latvia's regions in terms of wind, solar, and hydropower resources and to assess potential locations for green hydrogen production, secondary statistical data on the RES, electricity-producing capacity, energy balances, available for green hydrogen production, and transportation infrastructure in Latvia regions – Vidzeme, Latgale, Kurzeme, Zemgale and Riga are provided. The statistical data in this research describe the period from 2019 until 2024. The majority of statistical data was sourced from the databases and publications of the Central Statistical Bureau of the Republic of Latvia.

To facilitate a detailed comparison, the collected data on RE, infrastructure, and industries has been organised by assigning a value to each evaluated criterion (Table 1). A higher value (A) indicates the greater significance of a specific criterion in the development of the green hydrogen industry, taking into account both potential and existing capacities, with a focus on prioritising existing facilities. Moreover, the differences between the data of the five Latvia regions are categorised (Lejnieks & Pelse, 2023) into eleven ranks, with decimal values from 0 to 1, where 1 indicates the smallest difference and 0 highlights a huge gap between statistical data of the regions. The most advanced region receives a score founded on the criteria value multiplied by the difference coefficient or relative percentage difference between the most and least advanced regions (B). The second-place criteria value is determined according to the relative percentage difference between the first two higher-rated regions; for the third-ranked region, the criteria value is determined regarding the relative percentage difference between the first and third-placed regions and so on. Regions with the poorest results in certain criteria obtained only the base value of the analysed criteria. If there is no distinction between two or more regions data, or if its value is equal to or less than 5%, they receive identical scores. For indicators indicating specific counted objects or projects, the outcome is calculated by counting each object as 0.1 of point and multiplying it by its importance value. In this case, the difference coefficient does not apply.

According to the research framework about green hydrogen industry evaluation, 22 indicators were divided into the four categories of analysis: existing and potential RES, possible and current hydrogen-suitable infrastructure (Table 2).

In the beginning, the research provides some important assumptions determining suitable RES for green hydrogen generation and the overall growth of the hydrogen industry within the particular region.

Table 1

Criteria and difference coefficient values for green hydrogen industry potential assessment in a certain territory

Criteria for the green hydrogen industry	*Value for existing capacity (A)*	*Value for potential capacity (A_1)*	*Difference between regions in statistical data*		*Value (B)*
Adjacent fields	10	*	No	≤ 5%	1
Connected fields	20	*	Micro	≤ 10%	0.9
Integrated fields	30	10	Minor	≤ 20%	0.8
			Below Average	≤ 30%	0.7
			Average	≤ 40%	0.6
			Above Average	≤ 50%	0.5
			Solid	≤ 60%	0.4
			Significant	≤ 70%	0.3
			Major	≤ 80%	0.2
			Substantial	≤ 90%	0.1
			Huge	≤ 100%	0

Table 2

Four categories and 22 indicators for analysis for the green hydrogen industry in Latvian regions

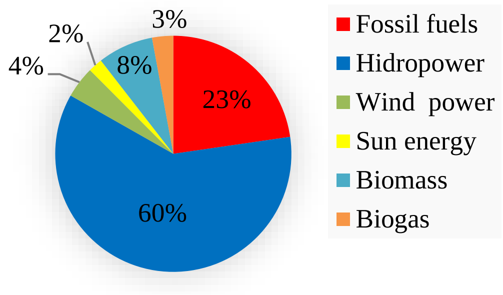
Available renewable energy sources	
Existing capacity	***Potential capacity***
1. Wind power density 2. Photovoltaic power output 3. Hydropower potential 4. Renewables in electricity 5. Wind, solar, hydro energy in electricity 6. Wind power in electricity 7. Solar energy in electricity 8. Hydropower in electricity 9. Solar farms capacity 10. Wind farms capacity 11. Hydro plants capacity	12. Planned wind farms 13. Solar farms projects 14. Hybrid renewable energy parks
Hydrogen-suitable infrastructure	
Existing infrastructure	***Planned infrastructure***
1. Hydrogen fuel stations 2. Sea ports 3. Natural gas (NG) network density 4. Major cities in gas network 5. NG storage capacity	6. Planned hydrogen production sites 7. Potential hydrogen fuel stations 8. Liquid NG terminals

Results and Discussion

An essential element of green hydrogen production is the availability of RE in a particular territory. The share of energy from RES varies significantly among EU member states. According to available data in 2023, RE accounted for 24.5% of total EU energy consumption. In the last 10 years, the amount of RE used has increased by 29% (Eurostat, 2025). Meanwhile, Latvia has 43% of RE in the energy balance, which is an increase of 13% since 2015. In 2023, RES provided 77% of total power generation (Central Statistical Bureau, 2025). The most important renewables in 2023 in Latvia in electricity production were hydropower, highlighting this RES as a cornerstone of electricity production (Figure 1).

Figure 1

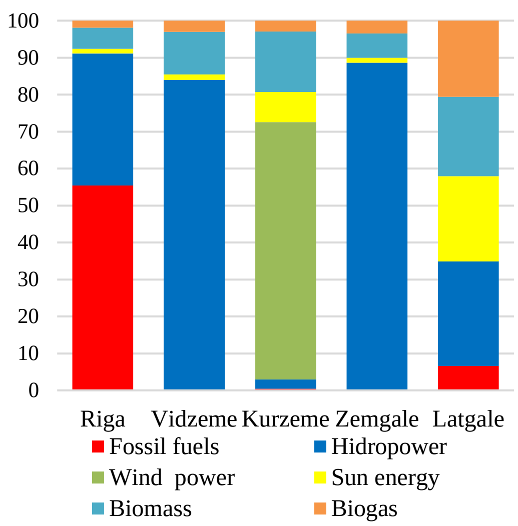
Proportion of produced electricity by source in Latvia in 2023, %



Within Latvian regions composition of RES used for electricity generation differs radically (Figure 2).

Figure 2

Proportion of produced electricity by source in Latvia regions in 2023, %



Two of five Latvia regions rely heavily on hydropower for electricity production (Zemgale – 89%, Vidzeme – 84%). While only the Kurzeme region is highly focused on wind power utilisation for electricity generation with 70% of produced electricity. Only the Latgale region has obtained a balanced mix of all RES. Apart from hydro energy, which accounts for 60% of the country's electricity production, biomass and biogas continue to play key roles in the country's RE sector. In recent years, a significant reduction in the bioenergy proportions within electricity production can be identified; between 2019 and 2023, biomass amount dropped by 17%, while biogas utilisation plummeted by almost 49% (Central Statistical Bureau, 2025). During the same period, the decline in EU countries was less significant; biogas decreased by 6%, and the total biomass use in electricity generation dropped by 3% (Eurostat, 2025). In the EU regulatory documents, RES such as solar and wind energy have priority over biogas (Millers et al., 2023). According to existing tendencies in the RE sector, large-scale production of green hydrogen in Latvian regions is more probable from wind, solar, and hydro energy sources than from biomass.

From 2019 till 2023, wind and solar energy utilisation for electricity production has risen significantly in EU member states. Electricity produced from wind power increased by 25%, while solar power generated 52% more electricity. In the same time period, Latvia generated 57% more electricity from wind power and almost 99% more from solar energy (Eurostat, 2025). The importance of these RES is increasing significantly.

Geographical location and climate characteristics define the necessity for the utilisation of different RES applications for balanced green hydrogen production throughout the year. Using integrated wind and solar power installations for electricity generation in hydrogen production is an important aspect in attaining consistent production patterns (Algburi et al., 2024; Stolte, 2024; Martinez & Iglesias, 2024).

Apart from the importance of the availability of RES, appropriate infrastructure must be established for the hydrogen sector to evolve. The NG pipeline network is the best solution for hydrogen transportation and long-term energy sector growth (Jansons et al., 2023). When assessing hydrogen production, it is critical to evaluate the distance between local production facilities and the gas grid. If the hydrogen production facility is located far from the gas grid, the hydrogen must be delivered to the injection point (Kleperis et al., 2021). The NG network facilitates stable hydrogen flow from production to consumer; a sophisticated and diverse grid, especially via the largest cities, increases opportunities for parties involved in the hydrogen industry.

Moreover, hydrogen can play a key role in energy storage, especially in combination with RES. Intermittency of RES can be addressed by storing excess energy via electrolysis process, splitting water into hydrogen and oxygen. Then the hydrogen is stored for later use, generating electricity when RES production is low. Unlike batteries, hydrogen storage systems are expandable to store large amounts of energy long-term, and have a higher energy density (Zemite et al., 2023).

The crucial importance for the green hydrogen industry is the possibility to export and import hydrogen via seaports (Shu-Ling Chen et al., 2023). Moreover, seaports are not just gateways of trade but can also be used as green hydrogen production sites due to large industrial areas, rail, pipeline networks, and near-existing offshore wind harvesting potential. At the same time, green hydrogen may be used to reduce carbon emissions created by operating port infrastructure and machinery (Pivetta et al., 2024; Mio et al., 2023). Finally, refuelling of sea transport can be provided within the port area.

A widespread and well-established network of hydrogen refuelling stations is crucial for the growth of hydrogen demand. However, technical challenges and high costs are significant barriers to the development of these networks (Karayel & Dincer, 2024). For last year's hydrogen-driven commercial and heavy-duty transport and its refuelling options are in focus (Rose & Neumann, 2020; De Padova et al., 2024). The location of major hydrogen refuelling stations must be considered by proximity to three major infrastructure elements—ports, railways, and highways (Vidzeme planning region, 2024). The proximity to highways connecting regions and countries facilitates green hydrogen demand for long-range transport requiring large amounts of hydrogen.

The growth of hydrogen infrastructure is closely tied to the development of the hydrogen economy. The infrastructure scale depends on hydrogen's role in the future energy mix, while the growth of the supply chain could be limited by the absence of connection facilities. Prioritising the creation of green hydrogen hubs, aligned with demand from synthetic fuels, industry, and power, is crucial in the near term (Dergunova & Lyden, 2024).

To assess how the previously outlined general guidelines for green hydrogen industry development and facts about Latvia are applied to the country's five regions, we conducted a detailed comparison using statistical data on existing and potential RES, along with infrastructure for future hydrogen utilization. (Table 3). Each criterion is assigned a specific value, which is then summarised for further analysis (Table 4).

Table 3

Statistical data on RE and connected infrastructure for potential hydrogen utilisation in Latvia's regions

Nr	*Indicators for available RES*	*Riga*	*Vidzeme*	*Kurzeme*	*Zemgale*	*Latgale*
1	Wind energy, W/m^2	422	421	509	418	405
2	Photovoltaic. power, kWh/day max	2.95	2.94	3.03	2.94	2.88
3	Hydro power pot. rivers ≥ 0.01 TWh/y	1.75	2.15	0.3	2.25	1.85
4	Major RE, GWh, 2023	1,140.509	887.217	384.576	2,382.765	51.545
5	Wind, solar, hydro, GWh, 2023	946.655	757.946	310.190	2,144.419	28.326
6	Hydro power, GWh, 2023	912.257	745.072	9.852	2,111.405	15.622
7	Wind energy, GWh, 2003	1.324	0.098	268.707	0.628	0.001
8	Solar power, GWh, 2023	33.074	12.776	31.631	32.386	12.703
9	Solar farms cap. ≥2MW, 2024	55.44	93	47.4	55.4	43.7
10	Wind farms cap. turbines ≥0.6MW, 2024	0	1.2	100.7	0	0
11	HES cap. plants ≥5 MW, 2024	402	248	0	908	0
12	Potential wind parks cap. ≥10MW	245	1,870	8,444	2,821	2,413
13	Potential solar plants cap. ≥2MW	117	138	1,215	268.4	490
14	Planned hybrid parks wind/solar ≥2MW, pcs	0	2	1	2	1
Nr	*Hydrogen-suitable infrastructure*	*Riga*	*Vidzeme*	*Kurzeme*	*Zemgale*	*Latgale*
1	H_2 fuel stations, pcs, 2024	1	0	0	0	0
2	Sea ports and terminals, pcs, 2024	1	2	6	0	0
3	NG network, % of adm. territory, 2024	80	11	13	42	12
4	NG network in cities ≥ 5.000 inh., %, 2024	100	50	33	100	57
5	NG storage ≥ 1m m^3, pcs, 2024	0	1	0	0	0
6	Planned H_2 production sites, pcs	0	0	3	0	1
7	Potential H_2 refuelling stations, pcs	1	0	0	0	0
8	Potential liquid NG terminal, pcs	0	1	0	0	0

Table 4
Assessment of criteria for green hydrogen industry potential in Latvia's regions

Nr	*Indicators*	*Value (A)*	*Riga*	*Vidzeme*	*Kurzeme*	*Zemgale*	*Latgale*
1	Wind energy, W/m^2	30	24	24	30	24	18
2	Photovoltaic. power, kWh/day max	30	30	30	30	30	30
3	Hydro power pot. rivers ≥ 0.01 TWh/y	30	21	30	3	30	24
4	Major RE, GWh, 2023	20	8	6	2	20	0
5	Wind, solar, hydro, GWh, 2023	30	12	9	3	30	0
6	Hydro power, GWh, 2023	30	12	9	0	30	0
7	Wind energy, GWh, 2003	30	0	0	30	0	0
8	Solar power, GWh, 2023	30	30	9	30	30	9
9	Solar farms cap. ≥2MW, 2024	30	18	30	15	18	12
10	Wind farms cap. turbines ≥0.6MW, 2024	30	0	3	30	0	0
11	HES cap. plants ≥5 MW, 2024	30	12	6	0	30	0
	Total	320	167	156	173	242	93
12	Potential wind parks cap. ≥10MW	10	0	2	10	3	2
13	Potential solar plants cap. ≥2MW	10	1	1	10	2	3
14	Planned hybrid parks wind/solar ≥2MW, pcs	10	0	2	1	2	1
	Total	30	1	5	21	7	6
1	H_2 fuel stations, pcs, 2024	30	3	0	0	0	0
2	Sea ports and terminals, pcs, 2024	10	1	2	6	0	0
3	NG network, % of adm. territory, 2024	20	20	2	2	10	2
4	NG network in cities ≥ 5.000 inh., %, 2024	20	20	10	6	20	10
5	NG storage ≥ 1m m^3, pcs, 2024	20	2	0	0	0	0
	Total	100	46	14	14	30	12
6	Planned H_2 production sites, pcs	10	0	0	3	0	1
7	Potential H_2 refuelling stations, pcs	10	1	0	0	0	0
8	Potential liquid NG terminal, pcs	10	0	1	0	0	0
	Total	30	1	1	3	0	1
	Overall score	*480*	***215***	***176***	***211***	***279***	***112***

The evaluation of 22 criteria revealed significant differences regarding RES among Latvia regions. For instance, a significant disparity can be observed regarding the availability of hydroelectric capacity, positioning Kurzeme and Latgale at the lowest ranks. Moreover, Latgale suffers from lesser natural wind power. At the same time, solar power is more evenly spread across Latvian territory and can be harnessed more easily than wind or hydro resources. It must be highlighted that regarding importance in the energy mix, hydropower capacities heavily influence the overall score of regions in the RES assessment, and in this case, Zemgale has a much higher score than other regions.

In discussions about electricity production from solar power, it is important to highlight that the production volumes in 2023 were significantly lower and more unevenly distributed across Latvia's regions compared to the capacity of newly built solar farms in 2024. This shift has an impact on the current assessment, which is influenced by the rapid growth of solar energy production in Latvia.

Regarding potential RES, the planned solar parks in Kurzeme have a larger total capacity than those in all other regions combined, and a similar trend is observed with wind energy. It must be highlighted that solar parks are more easily built than wind parks, which have more complexities regarding formal procedures and the overall attitude from society about wind turbines harmful influence on neighbourhoods (Aaen et al., 2022; Dallenbachn & Wustenhagen, 2022). Accordingly, solar park development is more dynamic, and more planned solar parks are aiming to be built than wind farms.

As part of the broader push for increased RES utilisation, the development of wind and solar hybrid parks is emerging as a new strategy to ensure sustainable energy production year-round (Hassan et al., 2023; Couto & Estanqueiro, 2023). As solar parks are easier to build, they are often considered the first step in hybrid park development. In other cases, solar panel plantations can be added to existing wind turbine installations.

Existing hydrogen-suitable infrastructure in Latvia is very limited; only one hydrogen refuel station is located in Riga. As ports are considered crucial for hydrogen production facilities; Zemgale and Latgale are landlocked territories, which puts them at a disadvantage against other regions. Furthermore, Ventspils, as a potential hydrogen-producing site, lacks an NG network. Vidzeme, Latgale, and Kurzeme have limited dispersion of NG networks in their territories, which is an obstacle for pure hydrogen or mixed hydrogen transportation for potential consumers. Currently, priority is being given to expanding the NG grid in areas where it is economically justified and offers a higher return on investment, such as the Riga region (Jansons et al., 2023).

In the beginning of 2025, no existing commercial green hydrogen production sites are in Latvia. There are some green hydrogen plant projects in the early planning stages. Few are connected with green ammonia production initiatives (Purple Green, 2023; The Energy and Environment Agency, 2024). The initiatives regarding hydrogen refuelling stations and liquid NG terminals are of a more conceptual or theoretical nature.

Conclusions

1. The research examined 22 criteria related to the RES and hydrogen industry, with the results highlighting the Zemgale region's notable lead in the RES sector. Overall, the Zemgale region received 279 points from 480 available, the Riga region gained 215, Kurzeme – 211, Vidzeme – 176, and Latgale – 112 points.
2. The research focused on measuring both the existing and potential RES capacity, with two-thirds of the total available points allocated to this topic. The Zemgale region gained 242 points from 320 available in this category. Riga, Vidzeme, and Kurzeme regions fall behind significantly with similar scores, and Latgale gained just 38% of Zemgale points in this list of criteria. A key factor that influenced the score was the presence of HES in the regions, as HES generates 60% of Latvia's total electricity. The Zemgale region is home to the largest HES in terms of electricity production and holds significant potential for green hydrogen production near HES, which can be complemented by nearby solar farm capacities.
3. Regarding available and potential infrastructure for hydrogen utilisation, the Riga region has a notable lead with 47 points, while Zemgale has 30 points, and other regions are falling behind significantly. Riga's leading position is attributed to its well-developed NG network and the presence of an existing hydrogen fuel station.
4. Despite the research findings, it must be acknowledged that if the main green production scenario is wind farms or solar/wind hybrid parks, then the Kurzeme region has an advantage in this scenario because of the times higher existing wind farm capacity than other regions and a large list of future wind park projects. Besides, this region has the largest number of ports in Latvia and a significant potential for offshore wind projects.

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