Interreg Baltic Sea Region

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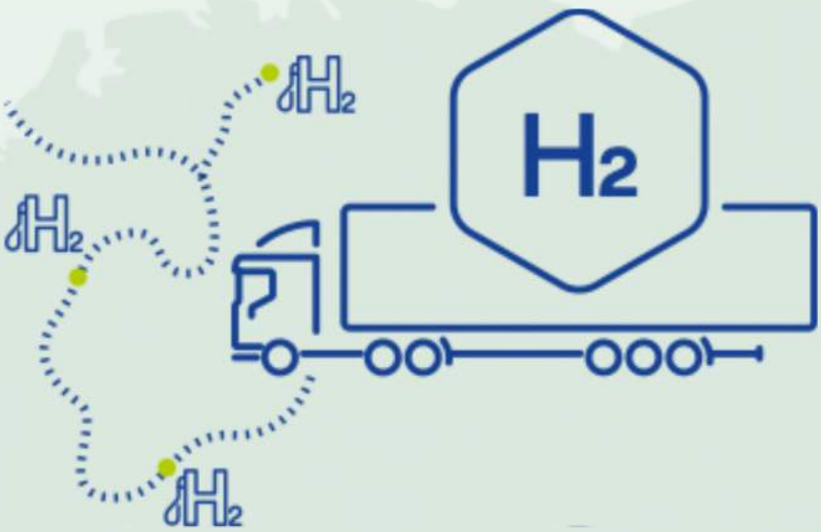
SMART GREEN MOBILITY HyTruck

Report

HRS Spatial Development Concept

Kaunas and Panevėžys regions



MINISTRY OF TRANSPORT AND COMMUNICATIONS OF THE REPUBLIC OF LITHUANIA

CLIMATE-NEUTRAL SOCIETIES

Imprint

HRS Spatial Development Concept. Kaunas and Panevėžys regions.
Published by: Ministry of Transport and Communications of the Republic of Lithuania
Edited by: SICEIT GmbH
Published in December 2024

This publication is a result of the Interreg Baltic Sea Region project HyTruck, financially supported by the European Union through the European Regional Development Fund within the Interreg Baltic Sea Region Programme.

Content

1. Introduction

This study aims to develop a spatial planning concept for creating a network of hydrogen refueling stations for trucks along the Trans-European Transport Network (TEN-T) in the Kaunas and Panevėžys regions. The study is part of the broader Interreg Baltic Sea Region project "Developing an International Network of Hydrogen Refueling Stations for Trucks (HyTruck)," which involves partners from Germany, Poland, Lithuania, Latvia, Estonia, Finland, and Sweden.

The Kaunas region, comprising Kaunas city and Kaunas district, is characterized by high economic development, with a per capita gross domestic product (GDP) of €20,400. The Kaunas District spans 1,496 km² and has over 92,000 inhabitants, while the City of Kaunas has 320,000 inhabitants across 157 km². Two of Lithuania's busiest roads, the E85 and E67, cross through the Kaunas region, with average annual daily traffic volumes of 30,000 and 35,000 vehicles respectively[1]. This makes the region an important economic and transport hub, enhanced by its strategic location in central Lithuania.

The Panevėžys region, comprising the city and district of Panevėžys, has slightly lower but still significant economic potential, with a GDP per capita of €14,100. The city of Panevėžys covers 50 km² and has over 93,000 inhabitants, while the Panevėžys district encompasses 2,179 km² with 35,000 inhabitants. As an important industrial and logistics center in Northern Lithuania, the region is traversed by the E67 road, which carries an average annual daily traffic volume of 11,000 vehicles[2] .

The study aims to assess the prerequisites for the development of hydrogen refueling stations in Kaunas and Panevėžys regions in accordance with Regulation (EU) 2023/1804[3]. The assessment focuses particularly on the E67 Via Baltica, A17, A5, and A1 motorways, considering interactions with primary users. The study comprises five main chapters:

1. Readiness analysis for hydrogen refueling infrastructure development in the pilot region
2. Analysis of social partners in pilot regions
3. Analysis of the hydrogen refueling station network in surrounding regions
4. Concept for hydrogen refueling infrastructure development in the pilot region
5. Evaluation of tools and instruments developed in the HyTruck project's first work package for hydrogen refueling infrastructure development

[1] https://vialietuva.lt/eismo-intensyvumas?cn-reloaded=1#lg=1&slide=0
[2] https://vialietuva.lt/eismo-intensyvumas?cn-reloaded=1#lg=1&slide=0
[3] https://eur-lex.europa.eu/legal-content/LT/TXT/HTML/?uri=CELEX:32023R1804

2. Readiness analysis for the development of hydrogen refueling infrastructure in the pilot region

This chapter presents an analysis of hydrogen refueling infrastructure development readiness in the pilot region, covering five key areas. First, it examines the legal and policy framework that shapes the environment for hydrogen infrastructure development. Second, it provides a state-of-the-art analysis of Lithuania's current hydrogen refueling station network. Third, it analyzes green hydrogen production and supply, examining both the current situation and future scenarios while considering technological developments, market trends, and potential supply chain challenges. Fourth, it focuses on identifying suitable locations for hydrogen refueling infrastructure in the pilot regions, assessing potential sites based on technical, economic, and geographical factors to optimize the future network layout. Finally, it concludes with a consumer analysis that explores potential users of hydrogen refueling stations and their hydrogen consumption patterns.

2.1. Analysis of the legal and policy framework for the development of hydrogen refueling infrastructure

This chapter examines the legal and policy framework governing hydrogen refueling infrastructure development, focusing on two main aspects: national legislation and policy incentives. The first sub-section analyzes national legislation's impact on hydrogen refueling infrastructure deployment, examining laws, regulations, and standards that affect hydrogen technology development. It evaluates how existing legislation either promotes or restricts infrastructure deployment, identifies legal barriers, and proposes potential solutions. The second sub-section addresses policy incentives affecting hydrogen refueling infrastructure development.

2.1.1. National legislation and its impact on the deployment of hydrogen refueling infrastructure

This chapter reviews and assesses the legislation of the Republic of Lithuania pertaining to the construction and operation of hydrogen refueling infrastructure. The analysis focuses on existing regulations for refueling stations and alternative fuels, highlighting potential gaps in hydrogen refueling infrastructure regulations.

The analysis examined 25 pieces of legislation, including related procedures and rules. Their impact on hydrogen refueling is assessed in Table 1. A positive impact indicates clear regulation of relevant aspects of hydrogen refueling infrastructure, where concepts of hydrogen or refueling stations are already included. A negative impact indicates either a lack of clarity or the absence of hydrogen-related concepts in the legislation, creating regulatory uncertainty for hydrogen infrastructure deployment.

No.	Act of law	Impact assessment
1.	Order of the Minister of Energy of the Republic of Lithuania No 1-37 of 16 April 2009 "On the Approval of the Rules for the Operation of Fuel Stations"[4]	Negative
2.	Law on Construction of the Republic of Lithuania[5]	Negative
3.	Order of the Minister of Environment of the Republic of Lithuania No D1-878 of 12 December 2016 "On the Regulation of the Construction Technical Regulation STR 1.05.01:2017 "Construction Permitting Documents. Construction Completion. "Construction Completion Finalization Rules". Removal of the consequences of unauthorized construction. Approval of the "Elimination of the consequences of construction under an illegally issued construction permit""[6]	Positive
4.	Law on Energy of the Republic of Lithuania[7]	Negative
5.	Law of the Republic of Lithuania on Maintenance of Potentially Hazardous Installations[8]	Positive
6.	Resolution of the Government of the Republic of Lithuania No 645 of 9 May 2002 "On Approval of the Provisions of the State Register of Potentially Hazardous Installations"[9]	Positive
7.	Resolution of the Government of the Republic of Lithuania No 817 of 29 June 2001 "On the Implementation of the Law on the Supervision of Potentially Hazardous Installations of the Republic of Lithuania[10]	Positive
8.	Law on Safety and Health at Work of the Republic of Lithuania[11]	Positive
9.	Order No 403 of the Minister of Economy of the Republic of Lithuania of 15 November 2002 "On the Approval of the Pressure Vessel Use Rule DT 12-02"[12]	Positive
10.	Order No 4-791 of the Minister of Economy of the Republic of Lithuania of 11 December 2015 "On the Approval of the Rules for the Protection of the Hardware and Software of Fuel Columns against Tampering with Readings"[13]	Negative
11.	Order of the Head of the Lithuanian Metrology Inspectorate No 11V-24 of 31 March 2016 "On the Approval of the Description	Negative

[4] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/0ded6160859a11eaa51db668f0092944
[5] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.26250/bjUkBIqQYV
[6] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/1bc09e60c04a11e6a3e9de0fc8d85cd8/OfPOIiYxIY?jfwid=-15ekm4aylt
[7] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.167899/UukOQjqsfm?jfwid=y86yx7mrt
[8] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.27535/ZYxTmouQIG?jfwid=-15ekm4ayrz
[9] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.165942/KQOSNXfpdj?jfwid=-15ekm4ayos
[10] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.140405/cFLCiKATHw?jfwid=32wf948v
[11] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.215253/UGpKqNUKuM?jfwid=-15ekm4ayhf
[12] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.196494/EFQdqFulzQ?jfwid=
[13] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/b8c10830a2a511e591078486468c1c39?jfwid=9tq147ng4

	of the Procedure for the Preparation, Modification and Registration of the Sealing Schemes of the Fuel Refueling Columns".[14]	
12.	Law on Metrology of the Republic of Lithuania[15]	Positive
13.	Order of the Minister of Economy of the Republic of Lithuania No 4-523 of 1 August 2014 "On the Approval of the List of Groups of Measuring Instruments Assigned to Legal Metrology and the Time Intervals between Periodic Inspections"[16]	Positive
14.	Resolution of the Government of the Republic of Lithuania No 966 of 17 August 2004 "On the Approval of the Regulations for the Prevention, Elimination and Investigation of Industrial Accidents and of the List of Hazardous Substances and Mixtures, Determination of their Qualifying Quantities and Criteria for Classification of Chemical Substances and Mixtures as Hazardous Substances"[17]	Positive[18]
15.	Order of the Minister of Health of the Republic of Lithuania No V-362 of 10 May 2007 "On the Approval of the Lithuanian Hygienic Standard HN 35:2007 "Maximum Permitted Concentration of Chemical Substances (Pollutants) in the Indoor Air of Buildings for Residential and Public Purposes""[19]	Positive
16.	Order of the Minister of the Environment of the Republic of Lithuania No D1-546 of 16 September 2009 "On the Approval of the Regulations on Environmental Monitoring of Economic Entities"[20]	Positive
17.	Order of the Minister of Health of the Republic of Lithuania No V-604 of 13 June 2011 "On the Approval of the Lithuanian Hygienic Standard HN 33:2011 "Noise Limits in Residential and Public Purpose Buildings and their Environment""[21]	Positive
18.	Order of the Minister of the Environment of the Republic of Lithuania No D1-528 of 15 July 2013 "On the Approval of the Rules for the Issuance, Amendment and Revocation of Pollution Integrated Prevention and Control Permits"[22]	Negative
19.	Order No 1-338 of 7 December 2010 of the Director of the Fire Protection and Rescue Department under the Ministry of the	Negative

[14] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/379ee420f84511e5bf4ee4a6d3cdb874?jfwid=q8i88ls5l
[15] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.29970/nhrAtjZVbD?jfwid=-15ekm4ayd3
[16] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/07d931c019bf11e4988dd8c7447f8ac5/fvXwMJoGLP?jfwid=pd6eq9q2k
[17] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/07d931c019bf11e4988dd8c7447f8ac5/fvXwMJoGLP?jfwid=pd6eq9q2k
[18] Hydrogen is listed as a hazardous substance, with lower level requirements for up to 5t of stored hydrogen, and hydrogen filling stations and service stations typically store less than 5t of hydrogen.
[19] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.297779/fQSCUzMyCb?jfwid=-15ekm4ay63
[20] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.353115/fyhPkWXess?jfwid=-15ekm4ay3k
[21] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.402074/RyjlQsiUhe?jfwid=-15ekm4axz7
[22] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.453692/GVivYajyHQ?jfwid=y86yx7opt

	Interior "On approval of the basic requirements for fire safety"[23]	
20.	Law on Environmental Impact Assessment of Planned Economic Activities of the Republic of Lithuania[24]	Negative
21.	Order No 64 of 18 February 2005 of the Director of the Fire and Rescue Department under the Ministry of the Interior and the Rescue Department under the Ministry of the Interior "On the Approval of the General Fire Safety Rules"[25]	Positive
22.	Law on Special Conditions of Land Use of the Republic of Lithuania[26]	Negative
23.	Law of the Republic of Lithuania on Alternative Fuels[27]	Positive
24.	Resolution of the Minister of Energy of the Republic of Lithuania No 1-81 of 26 April 2024 "On Approval of Guidelines for Hydrogen Development in Lithuania 2024-2050"[28]	Positive
25.	Resolution of the Minister of Transport and Communications of the Republic of Lithuania No 3-105 of 10 March 2023 "On the Approval of the Guidelines for the Development of the Hydrogen Refueling Infrastructure and the Promotion of the Use of Hydrogen-Powered Road Vehicles in Lithuania"[29]	Positive

Table 1. National legislation and assessment of its impact on the deployment of hydrogen refueling infrastructure

Based on this analysis, the following sections discuss all examined legislation and technical regulations in detail.

- No. 1 Order No. 1-37 of the Minister of Energy of the Republic of Lithuania (dated April 16, 2009) "On Approval of the Rules for the Operation of Service Stations" has the following gaps regarding hydrogen:
    - Chapter 3, Paragraph 12 specifies vertical and horizontal distances from liquid fuel dispensers and tanks to buildings and premises but does not address distances for gaseous or liquid hydrogen storage facilities.
    - Chapter 4, Point 45 prohibits refueling road vehicles with fuel, LPG, CNG, and/or LNG in the absence of mandatory vehicle inspections but does not include provisions for hydrogen.
    - Chapter 6, Paragraph 74 mandates regular inspections for service stations and LPG, CNG, and LNG installations but omits requirements for hydrogen installations.

[23] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.388658/lXGOQvzbcr?jfwid=y86yx7qwe
[24] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.30545/VmZtlqmdEb?jfwid=y86yx7qx8
[25] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/d4c6b610549b11edba0ded10be2fa21c
[26] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/46c841f290cf11e98a8298567570d639/zYHNiDwXeZ?jfwid=y86yx7qxx
[27] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/0409c522915c11eb998483d0ae31615c/DjMSedQjxz?jfwid=-15ekm4axwg
[28] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/10783411040711ef8e4be9fad87afa59?jfwid=jrf97qh9r
[29] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/4a206a20bf8411ed924fd817f8fa798e?positionInSearchResults=0&searchModelUUID=9abf73b9-4923-4441-9f0f-165a3f431dfe

- Chapters 7-9 cover the operation of liquid fuels, LPG, and CNG equipment but lack a dedicated chapter on hydrogen equipment operation, including: maintenance of hydrogen equipment, maintenance of refueling station hydrogen pipelines and related equipment, maintenance of compressors, maintenance of hydrogen dehydration equipment, operation of electrochemical corrosion protection equipment, refueling procedures for hydrogen cylinders and their compounds for road transport
- Chapter 11, Paragraph 211.5 addresses repair procedures for liquid fuel, LPG, CNG, LNG, and natural gas pipelines, including their equipment, shut-off devices, and safety devices, but excludes hydrogen-related infrastructure.
- Chapters 14 and 15, which cover fire operations, hazardous operations, and firefighting equipment for LPG, CNG, and LNG, lack provisions for hydrogen-specific hazards and appropriate extinguishing agents.

- No. 2 Law on Construction of the Republic of Lithuania:

  Currently, there are no normative construction technical documents in force that regulate the construction and operation of engineering structures such as hydrogen refueling stations. This includes facilities where planned activities involve installing green hydrogen production through water electrolysis, water and hydrogen storage facilities, compressor stations, pipelines, and hydrogen dispensing equipment. Therefore, project implementers must follow Article 9 of the Law on Construction of the Republic of Lithuania, titled "Application of normative construction technical documents of international, European organizations and foreign countries."

- No. 3 Order of the Minister of Environment of the Republic of Lithuania No. D1-878 (December 12, 2016) titled "Building Technical Regulation STR 1.05.01:2017: Building Permits, Construction Completion, Construction Suspension, Removal of Unauthorized Construction Consequences, and Elimination of Construction Consequences Under Illegally Issued Permits" does not differentiate between fuel types for refueling stations. Therefore, specific regulations for hydrogen refueling stations are not required.

- No. 4 Law on Energy of the Republic of Lithuania:

  Article 21: If an energy undertaking (as defined in Article 7(6)) that holds a permit for retail sale of bulk petroleum products transfers ownership of a service station to another person, terminates the service station usage contract, or ceases operations at the service station, these regulations apply to all products except hydrogen.

  Article 24: While this article of the law governs authorizations for trade in bulk petroleum products, it does not regulate authorizations for trade in hydrogen.

- No. 5 Law of the Republic of Lithuania on Maintenance of Potentially Hazardous Installations: According to this law, hydrogen station equipment is classified as hazardous substances in categories 2, 3, 4.

- No. 6 Resolution of the Government of the Republic of Lithuania No. 645 of 9 May 2002 "On Approval of the Provisions of the State Register of Potentially Hazardous Installations": The Regulations do not distinguish between different types of fuels for refueling stations, so there is no need to include specific regulation for hydrogen refueling stations.

- No. 7 Resolution of the Government of the Republic of Lithuania No. 817 of 29 June 2001 "On the Implementation of the Law on the Supervision of Potentially Hazardous Installations of the Republic of Lithuania": The Regulations do not distinguish between different types of fuels for refueling stations, so there is no need to include specific regulation for hydrogen refueling stations.

- No. 8 Law on Occupational Safety and Health of the Republic of Lithuania: This law does not distinguish between different types of refueling stations or fuels, so there is no need to include specific regulation for hydrogen refueling stations.

- No. 9 Order of the Minister of Economy of the Republic of Lithuania No 403 of 15 November 2002 "On the Approval of the Rule for the Use of Pressure Vessels DT 12-02": The concept of hydrogen is already included in the specified rules for pressure vessels.

- No. 10 Order of the Minister of Economy of the Republic of Lithuania No 4-791 of 11 December 2015 "On the Approval of the Rules for the Protection of the Hardware and Software of Fuel Columns against Tampering with Readings": Chapter 3 describes equipment protection measures but does not include hydrogen refueling equipment.

- No. 11 Order No 11V-24 of 31 March 2016 of the Head of the Lithuanian Metrology Inspectorate "On the Approval of the Description of the Procedure for the Preparation, Modification and Registration of the Sealing Schemes of the Fuel Refueling Columns": The concept of hydrogen and hydrogen refueling equipment is not included.

- No. 12 Law on Metrology of the Republic of Lithuania: there is no distinction between different types of refueling stations or fuels in the regulatory framework. Therefore, no specific regulations are required for hydrogen refueling stations, as they fall under the existing general provisions.

- No. 13 Order of the Minister of Economy of the Republic of Lithuania No.4-523 of 1 August 2014 "On Approval of the List of Groups of Measuring Instruments Assigned to Legal Metrology and the Time Intervals between Periodic Inspections":

  The Order specifies pressure and other instrument groups without distinguishing specific gas or fuel groups, so there is no need to include specific regulation for hydrogen refueling stations.

- No. 14 Resolution No 966 of the Government of the Republic of Lithuania of 17 August 2004 "On the approval of the Regulations for the prevention, elimination and investigation of industrial accidents and the list of hazardous substances and mixtures, the determination of their qualifying quantities and the description of criteria for classifying chemicals and mixtures as hazardous substances":

  According to this decree, hydrogen is included in the list of hazardous substances, with lower-level requirements applying up to hydrogen storage up to 5 t. Hydrogen refueling stations usually store less than 5t of hydrogen, so the rules should rarely apply to hydrogen refueling stations in practice.

- No. 15 Order of the Minister of Health of the Republic of Lithuania No V-362 of 10 May 2007 "On the approval of the Lithuanian Hygienic Standard HN 35:2007 "Maximum permissible concentrations of chemicals (pollutants) in the indoor air of residential buildings and buildings for public use"":

  Hydrogen gas is not mentioned in the hygiene standard, but hydrogen gas is not poisonous per se, so no changes are foreseen for hydrogen refueling stations.

- No. 16 Order of the Minister of the Environment of the Republic of Lithuania of 16 September 2009 No D1-546 "On the Approval of the Provisions on Environmental Monitoring of Economic Entities":

  The Regulations do not distinguish between different types of fuels for refueling stations, so there is no need to include specific regulation for hydrogen refueling stations.

- No. 17 Order of the Minister of Health of the Republic of Lithuania No V-604 of 13 June 2011 "On the approval of the Lithuanian Hygienic Standard HN 33:2011 "Noise Limits in Residential and Public Buildings and their Surroundings"":

  The noise levels in the hygiene standard define the requirements for equipment related to the hydrogen refueling station, such as compressors or coolers, so no changes are foreseen for hydrogen and its equipment.

- No. 18 Order of the Minister of the Environment of the Republic of Lithuania No D1-528 of 15 July 2013 "On the Approval of the Rules for the Issuance, Amendment and Revocation of Pollution Integrated Prevention and Control Permits":

  Annex 1 of the Rules on the issue, amendment and revocation of integrated pollution prevention and control permits does not include the concept of hydrogen.

- No. 19 Order No. 1-338 of 7 December 2010 of the Director of the Fire Protection and Rescue Department under the Ministry of the Interior "On the approval of the basic requirements for fire safety":

  Lack of technical regulation on hydrogen fire safety.

- No. 20 Law of the Republic of Lithuania on Environmental Impact Assessment of Planned Economic Activities:

  Point 6.2 mentions hydrogen production in the chemical industry, thus requiring an environmental impact assessment regardless of the size of the plant or station, even for individual stations with local production (typically up to 3MW), thus requiring the same depth of analysis as for a 200 MW industrial project.

- No. 21 Order No 64 of 18 February 2005 of the Director of the Fire and Rescue Department under the Ministry of the Interior and the Rescue Department under the Ministry of the Interior "On the Approval of the General Fire Safety Rules":

The Regulations regulate the storage of hydrogen gas in accordance with Annex 8 by classifying it as a flammable and explosive gas.

- No. 22 Law on Special Conditions of Land Use of the Republic of Lithuania:

  The protection zones are only for hydrocarbon storage, so there is no clear regulation for hydrogen storage. A sanitary zone is also required for the design of hydrogen refueling infrastructure, but there is no air pollution during hydrogen refueling. No sanitary buffer zone is provided for other noise-only activities.

- No. 23 Law of the Republic of Lithuania on alternative fuels:

  The concepts of hydrogen and hydrogen refueling points are already included in the Act.

- No. 24 Resolution No 1-81 of the Minister of Energy of the Republic of Lithuania of 26 April 2024 "On the Approval of the Guidelines for the Development of Hydrogen in Lithuania 2024-2050":

  The concepts of hydrogen and hydrogen refueling points are already included in the guidelines.

- No. 25 Resolution No 3-105 of the Minister of Transport and Communications of the Republic of Lithuania of 10 March 2023 "On the Approval of the Guidelines for the Development of the Hydrogen Refueling Infrastructure and the Promotion of the Use of Hydrogen-Powered Road Vehicles in Lithuania":

  The concepts of hydrogen and hydrogen refueling points are already included in the guidelines.

2.1.2. Policy incentives affecting the development of hydrogen refueling infrastructure

When assessing specific policy incentive measures, the Order of the Minister of Transport and Communications of the Republic of Lithuania of 7 April 2023 No 3-181 "On the amendment of the Order of the Minister of Transport and Communications of the Republic of Lithuania of 30 May 2022 No 3-277 "On the Approval of the Description of the Progress Measure of the Transport and Communications Development Program of the Lithuanian Ministry of Transport and Communications of the Republic of Lithuania for the period 2022-2030, the Manager of the Transport and Communications Development Program, Progress Measure No 10-001-06-01-01 "To promote use of alternative fuels in the transport sector". According to this measure, 4 hydrogen refueling stations are planned to be installed by 2026 at the latest. Two hydrogen refueling stations in Klaipėda port have already been financed in 2023 and one refueling station in Vilnius has been financed in 2024. [30]

[30] https://www.e-tar.lt/portal/lt/legalAct/e6ff6ed68f9a11efa605b9842742bf37

2.2. Analysis of the current state of the hydrogen refueling station network

This chapter analyzes Lithuania's hydrogen refueling station infrastructure, with a focus on planned developments in Klaipėda and Vilnius. Currently, Lithuania has no operational hydrogen refueling stations. The analysis examines two planned installation projects that will comply with Regulation (EU) 2023/1804[31], (see Figure 1). The assessment considers equipment capacity, supply pressure, and proposed locations for these hydrogen stations. Additionally, the chapter explores future scenarios for hydrogen demand in the transport sector.

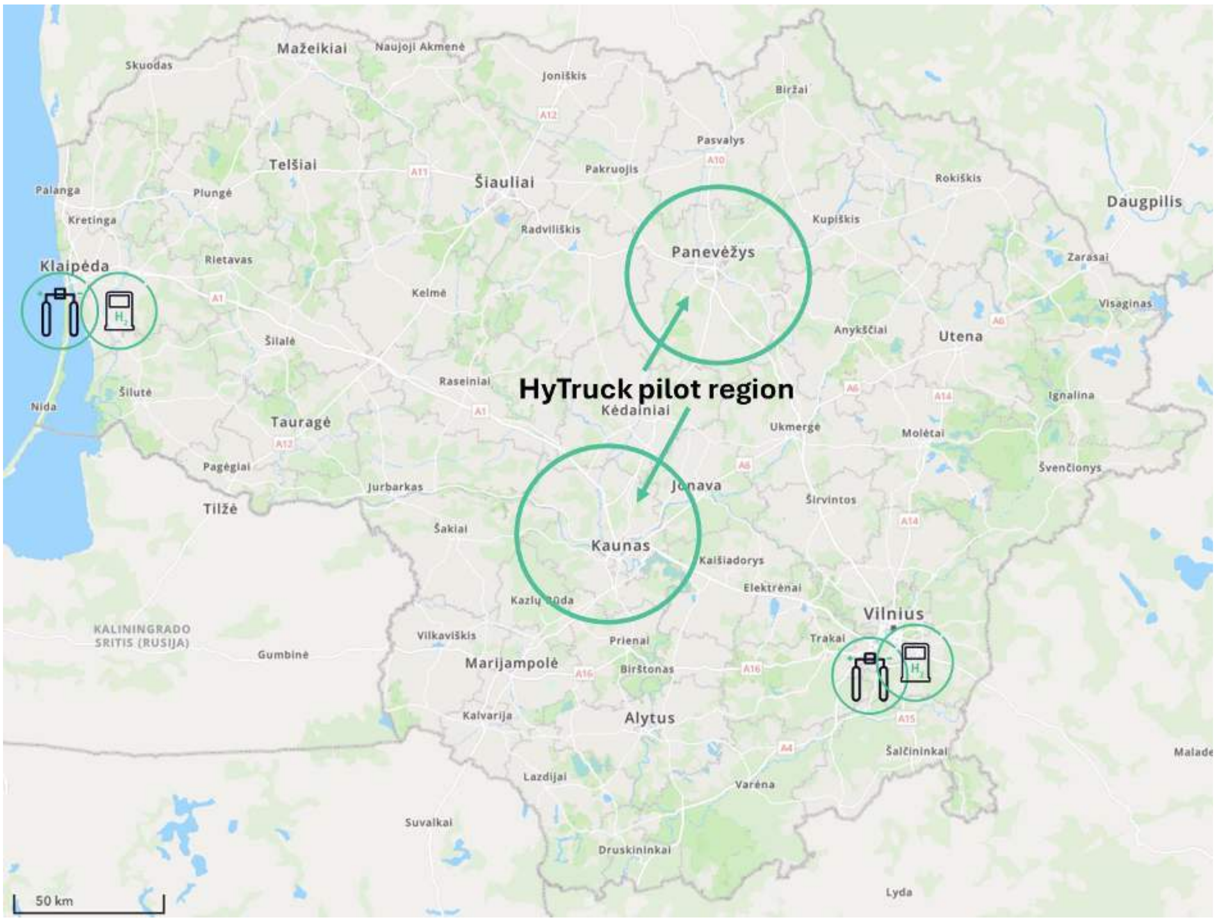


Figure 1. Hydrogen projects in Lithuania and the HyTruck pilot region

2.2.1. Klaipėda

In Klaipėda's port area, two hydrogen refueling stations are planned: a fixed station with a minimum capacity of 1,000 kg/day and a mobile station with a minimum capacity of 500 kg/day. The fixed station will be located adjacent to the hydrogen plant at 40 Nemuno Street,

[31] According to the regulation, stations must meet specific criteria: location within urban transport hubs, proximity within 10 km of the TEN-T main road network, 1000 kg/d capacity, 700 bar pressure capability, and suitability for both heavy and light transport. For more information, see: https://eur-lex.europa.eu/legal-content/LT/TXT/HTML/?uri=CELEX:32023R1804

Klaipėda (see Figure 2 and Figure 3). Both stations are scheduled to begin operations in 2026.[32] Publicly accessible hydrogen stations will supply 350 bar hydrogen to heavy vehicles, buses and boats, and 700 bar hydrogen to cars.

Figure 2. Planned location of the hydrogen plant at Nemuno str. 40, Klaipėda[33]

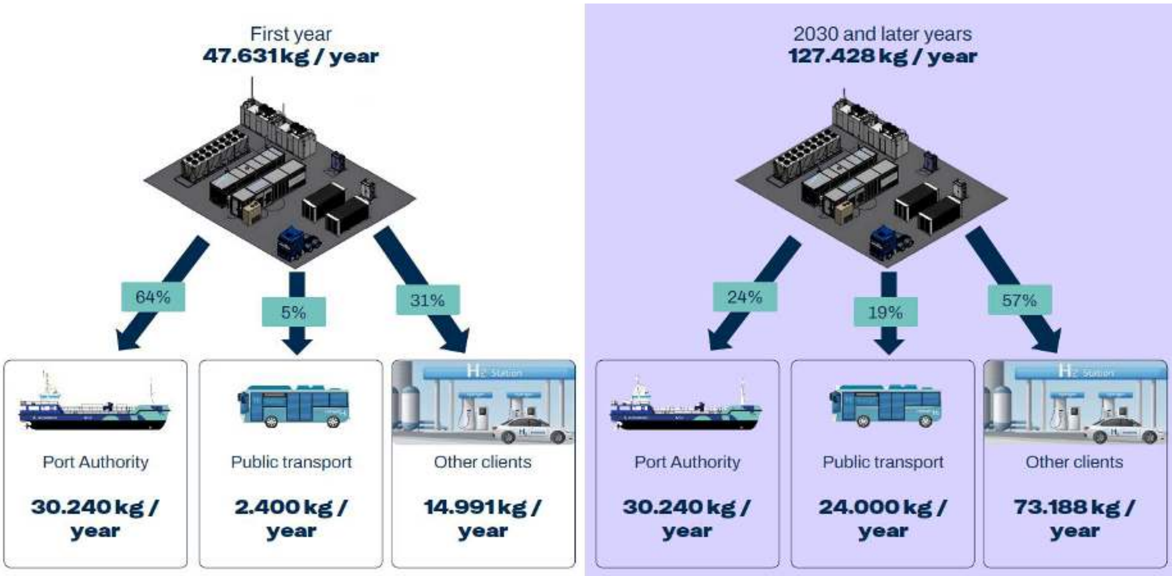


Figure 3. Planned use of hydrogen stations in Klaipėda[34]

2.2.2. Vilnius

In Vilnius it is planned to install up to two public hydrogen refueling stations (see Figure 4 and Figure 5). The first station will be in one of two possible sites: either in the industrial area near

[32] Hydrogen production and benefits, Džiugas Šaulys, Klaipeda Seaport Authority, 2024.06.05
[33] https://tyrens.lt/wp-content/uploads/2024/03/PAV_atasakaita.pdf
[34] Hydrogen production and benefits, Džiugas Šaulys, Klaipeda Seaport Authority, 2024.06.05

the hydrogen plant and high-speed highway, or at a bus depot in a residential district. Each public station will have a daily capacity of 800-1,000 kg of hydrogen. The stations will offer dual pressure capabilities: 350 bar for heavy vehicles and buses, and 700 bar for passenger cars. Operations are scheduled to begin in 2026.[35]

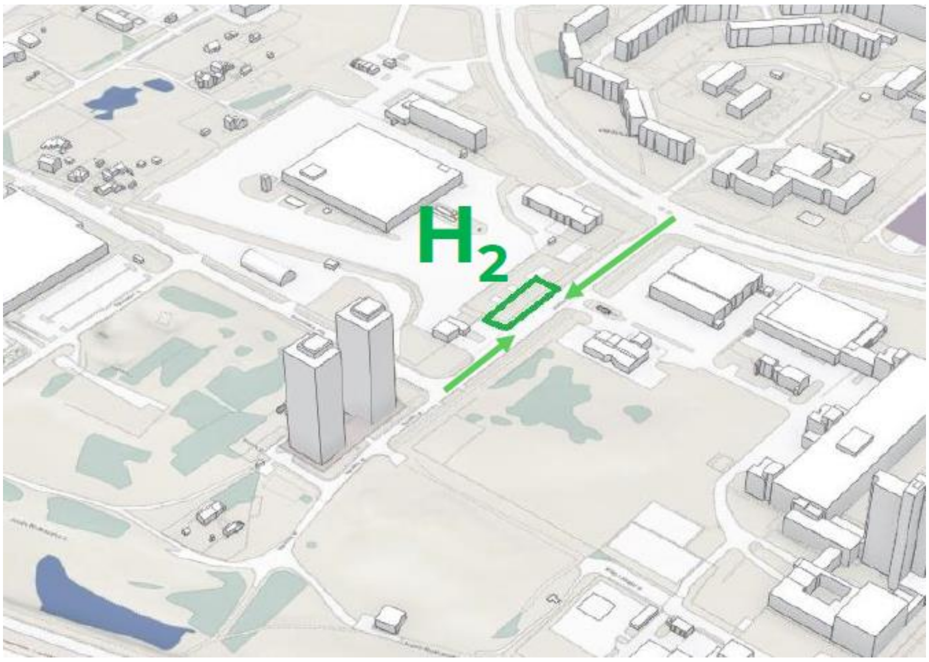


Figure 4. Planned hydrogen refueling station at Justiniškių str. 14, Vilnius[36]

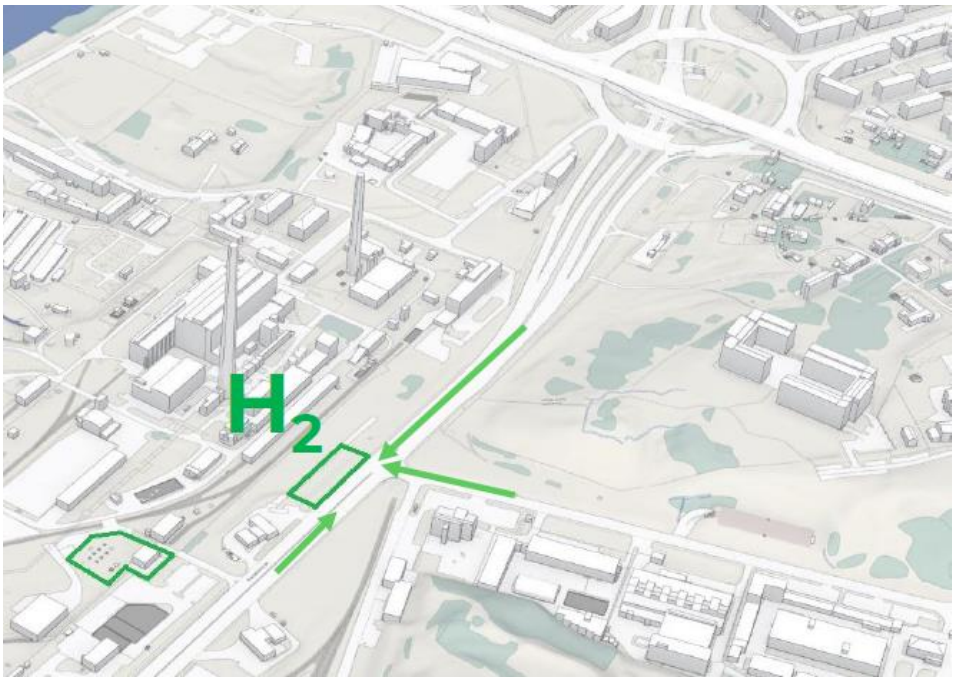


Figure 5. Planned hydrogen refueling station in Savanorių av., Vilnius[37]

[35] Green hydrogen production for public transport in Vilnius, Andrius Agintas, Vilniaus šilumos tinklai, 2024.06.05

[36] Green hydrogen production for public transport in Vilnius, Andrius Agintas, Vilnius district heat company šilumos tinklai, 2024.06.05

[37] Green hydrogen production for public transport in Vilnius, Andrius Agintas, Vilnius district heat company , 2024.06.05

2.2.3. Future scenarios

According to Article 6 of the Alternative Fuels Infrastructure Regulation (AFIR) 2023/1804, one hydrogen refueling station will have to be built every 200 km on the TEN-T core network by the end of 2030, including at each urban transport hub. By 2027, Member States have to develop a plan for the deployment of hydrogen refueling points to meet the needs of hydrogen-powered road transport.[38] According to AFIR requirements, hydrogen refueling stations must provide a capacity of 1 tH2/d for all road vehicles, though this can be reduced to 0.5 tH2/d in areas with low traffic volume. Based on HyTruck partners' analysis[39], Lithuania will need approximately six hydrogen stations to meet these requirements. The long-term hydrogen demand scenarios for Lithuania's transport sector through 2050 present three distinct development pathways (see Figure 6):

- Guidelines for hydrogen development
- AFIR minimum scenario (six stations at 0.5 tH2/d capacity)
- AFIR maximum scenario (six stations at 1 tH2/d capacity)

These scenarios represent different approaches to integrating hydrogen technology into Lithuania's transport infrastructure.

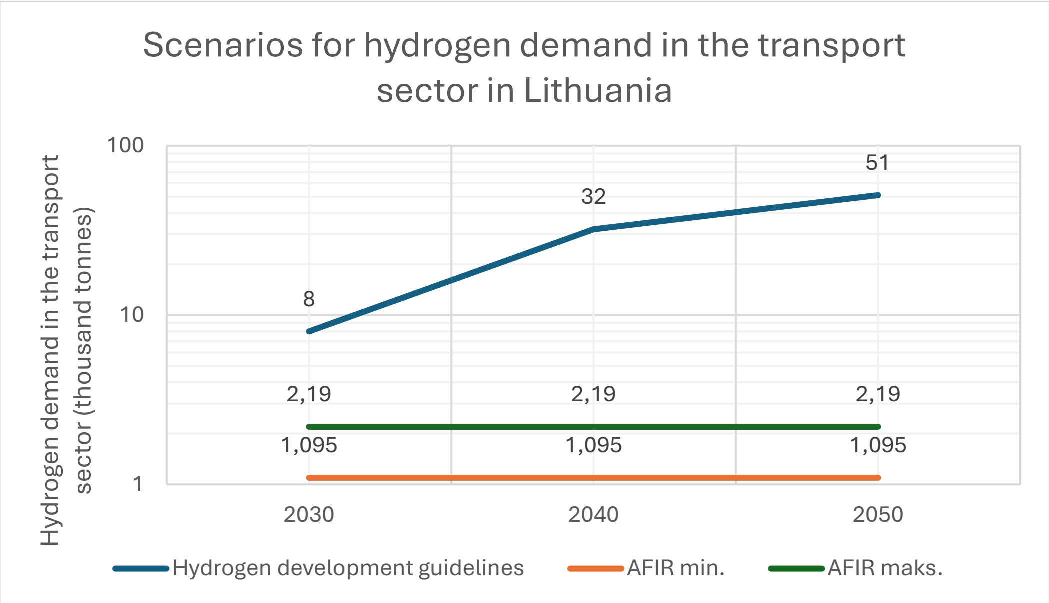


Figure 6. Scenarios for hydrogen demand in the transport sector in Lithuania[40][41]

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[38] https://eur-lex.europa.eu/legal-content/LT/TXT/HTML/?uri=CELEX:32023R1804
[39] The analysis considers two location scenarios for Lithuania: 1. Base scenario: 5 stations in urban transport hubs, 2. Extended scenario: 5 urban hub stations plus 3 additional stations along TEN-T main roads (approximately 600 km total distance). Both scenarios converge on an average need for 6 hydrogen filling stations. Stations must meet AFIR requirements: location within 10 km of TEN-T network and minimum capacity of 1000 kg/day. For detailed analysis, see: https://reiner-lemoine-institut.de/en/study-of-the-regional-strategy-for-the-development-of-hydrogen-filling-stations-for-fuel-cell-trucks-in-the-baltic-sea-region-hytruck/
[40] Guidelines for hydrogen development in Lithuania 2023-2050 https://enmin.lrv.lt/media/viesa/saugykla/2024/4/ZNrRbiZ96Hs.pdf
[41] AFIR Directive https://www.consilium.europa.eu/en/press/press-releases/2023/07/25/alternative-fuels-infrastructure-council-adopts-new-law-for-more-recharging-and-refueling-stations-across-europe/

The scenario in guidelines for hydrogen development presents an ambitious vision for hydrogen adoption. Under this scenario, hydrogen demand increases substantially: from 8,000 tonnes in 2030 to 32,000 tonnes in 2040, ultimately reaching 51,000 tonnes in 2050. The most dramatic growth occurs between 2030 and 2040, when demand increases fourfold. While the growth rate moderates somewhat between 2040 and 2050, it remains substantial. The feasibility of this scenario depends on strong political support, substantial infrastructure investment, and accelerated technological advancement.

The AFIR scenarios offer a more conservative outlook. The AFIR minimum scenario projects consistent but minimal hydrogen demand at 1,095 tonnes annually throughout the projection period. Similarly, the AFIR maximum scenario anticipates steady demand at a marginally higher level of 2,190 tonnes per year. These projections appear to reflect basic EU infrastructure requirements rather than market potential. The actual trajectory of hydrogen demand will likely fall between these extremes, influenced by several critical factors: technological innovation pace, policy support, infrastructure investment levels, market dynamics, and public acceptance.

2.3. Analysis of green hydrogen production and supply

According to the adopted hydrogen development guidelines, 1.3 GW of electrolysis plants with an annual capacity of 129,000 tonnes of hydrogen are planned to be installed in Lithuania by 2030, which should reach 8.5 GW and 732,000 tonnes of hydrogen produced per year by 2050.[42] Of the targeted 129,000 tonnes of annual hydrogen production by 2030, the transportation sector is allocated 9,000 tonnes: 8,000 tonnes for road transport and 1,000 tonnes for other transport modes. The following sections will examine two specific hydrogen supply development projects in Lithuania in detail (see Figure 1).

2.3.1. Klaipėda

By 2026, in Klaipėda it is planned to install a 2 MW electrolysis plant with hydrogen storage capacity of 1,500 kg[43], expected to produce approximately 127 tonnes of hydrogen annually (see Figure 7 and Figure 8). The facility will source its green electricity through a combination of grid power and renewable energy from local onshore and offshore wind farms in the Klaipėda region.

[42] Guidelines for hydrogen development in Lithuania 2024-2050
[43] Hydrogen production and benefits, Džiugas Šaulys, Klaipeda Seaport Authority, 2024.06.05

Figure 7. Planned location of the hydrogen plant at Nemuno str. 40, Klaipėda[44]

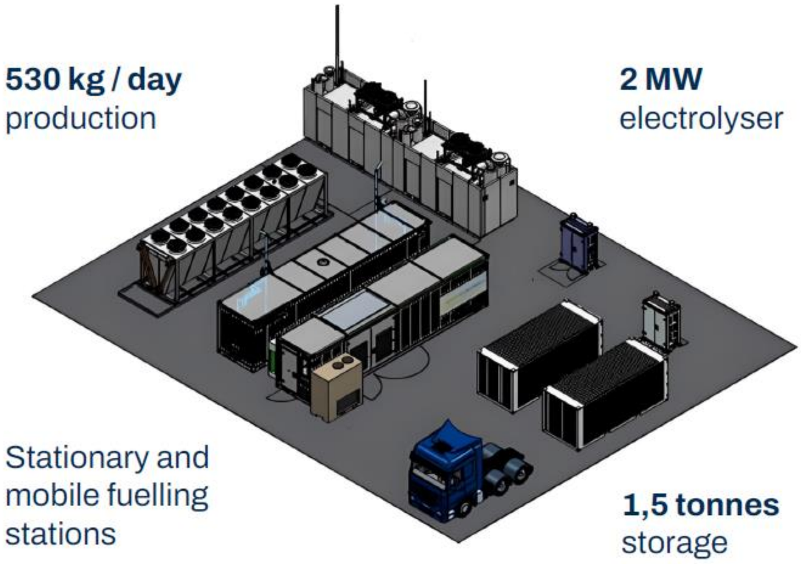

Figure 8. Schematic of the hydrogen plant planned for Klaipėda[45]

2.3.2. Vilnius

In Vilnius it is planned to install a 3 MW electrolysis plant capable of producing up to 128 tonnes of hydrogen annually. The facility will feature hydrogen storage tanks with 1,700 kg capacity to facilitate transport to refueling stations. Power for hydrogen production will come from a combination of locally generated green electricity and grid-sourced green power.

The plant's strategic location near the heat network creates two key operational efficiencies. First, it enables the utilization of waste heat, reducing energy losses and enhancing the equipment's economic value. Second, the facility will repurpose water from thermal power plant processes for hydrogen production, maximizing resource efficiency (see Figure 9).

[44] https://tyrens.lt/wp-content/uploads/2024/03/PAV_atasakaita.pdf
[45] Hydrogen production and benefits, Džiugas Šaulys, Klaipeda Seaport Authority, 2024.06.05

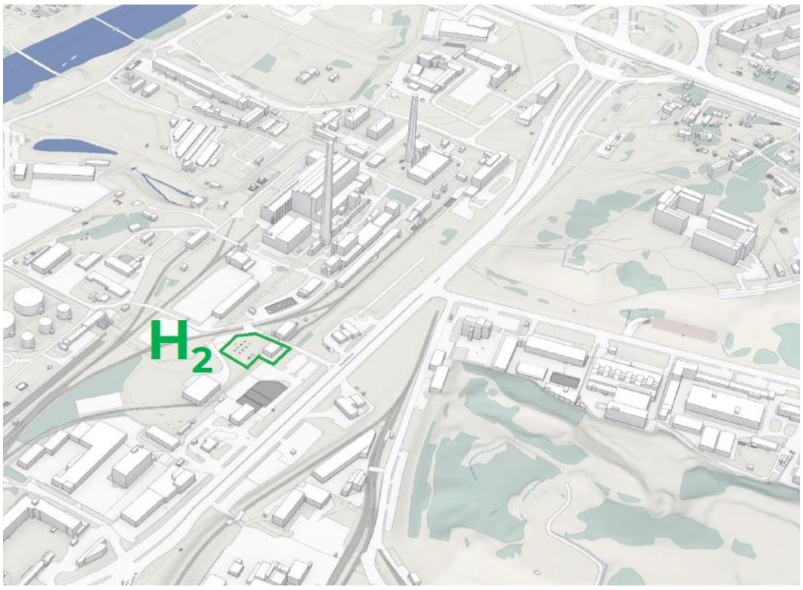

Figure 9. Planned hydrogen production site in Savanorių av., Vilnius[46]

2.3.3. Future scenarios

The scenario in guidelines for hydrogen development for Lithuania through 2050 present an ambitious vision for expanding green hydrogen infrastructure. The core of this expansion centers on a dramatic increase in electrolysis capacity, projected to grow from 1.3 GW in 2030 to 8.5 GW by 2050 (see Figure 10). This more than sixfold increase within two decades demonstrates Lithuania's strong commitment to hydrogen technology development. This substantial growth trajectory requires comprehensive infrastructure development beyond the electrolysis plants themselves. Success will depend on parallel investments in supporting infrastructure and renewable energy generation capacity to ensure sufficient green power supply for hydrogen production. The scale of this planned expansion reflects both the strategic importance of hydrogen in Lithuania's energy future and the significant financial commitment required to achieve these ambitious targets.

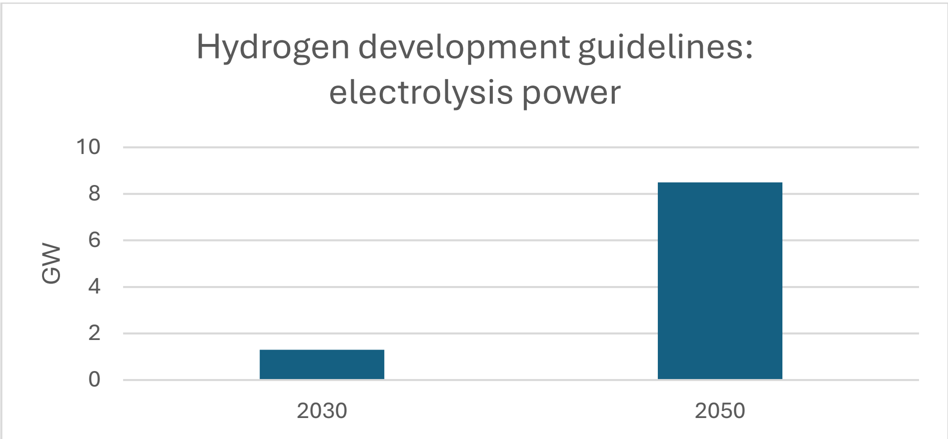

Figure 10. Planned electrolysis capacity in Lithuania

[46] Green hydrogen production for public transport in Vilnius, Andrius Agintas, Vilnius district heat company , 2024.06.05

The projected growth in green hydrogen production parallels the expansion of electrolysis capacity (see Figure 11). Annual production volumes are expected to increase more than fivefold, from 129,000 tonnes in 2030 to 688,000 tonnes by 2050. This substantial production growth reflects both anticipated technological advancements and increasing hydrogen demand across key economic sectors, particularly in transport and industry.

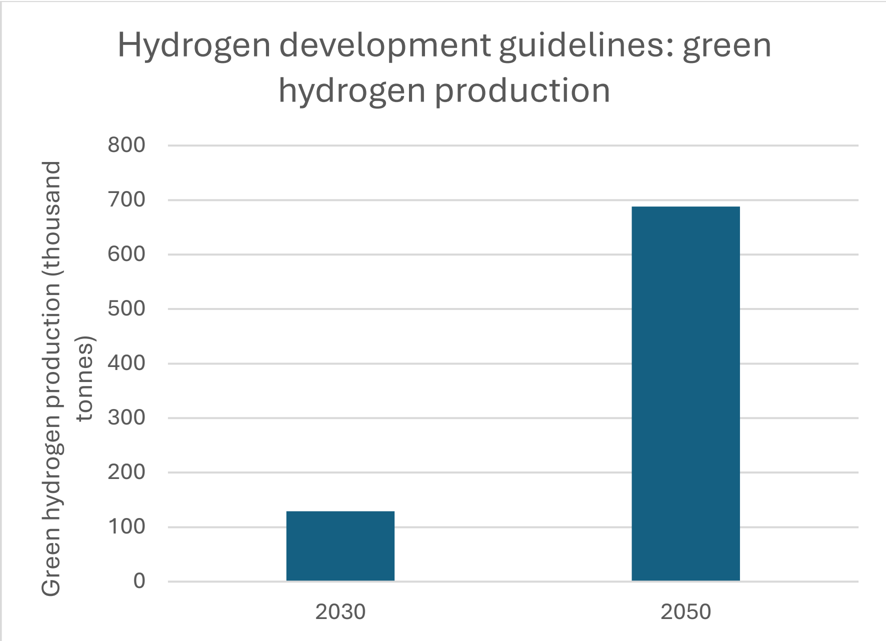

Figure 11. Planned hydrogen production in Lithuania

2.3.4. Supply chain analysis

Currently, hydrogen production for industrial use relies predominantly on natural gas. However, the increasing decarbonization of electricity generation has enabled an alternative method: extracting hydrogen from water through electrolysis (EL). The two main electrolysis technologies are alkaline (AEL) and polymer electrolyte membrane (PEMEL). Among these, AEL is the most mature technology, with industrial-scale implementations reaching several tens of megawatts in capacity. AEL currently accounts for 2-4% of total hydrogen production.[47] AEL technology faces significant operational constraints due to its limited ability to function at low current densities. The system requires a minimum load of approximately 20% and exhibits relatively slow transitions between operating points, taking over 30 seconds to adjust. These limitations affect its flexibility and responsiveness to varying power inputs[48]. On the other hand, PEMEL has a wider operating range from 0% to 150% and a dynamic time between operating points of <2 s, which allows PEMEL to be directly connected to highly intermittent energy sources such as solar and wind power plants[49]. This enhanced flexibility makes PEMEL

[47] https://www.portofrotterdam.com/en/news-and-press-releases/air-liquide-and-port-of-rotterdam-authority-hydrogen-road-transport.
[48] Schmidt, O., A. Gambhir, I. Staffell, A. Hawkes, J. Nelson, and S. Few, Future cost and performance of water electrolysis: An expert elicitation study. International Journal of Hydrogen Energy, 2017. 42(52): p. 30470-30492.
[49] Kopp, M., D. Coleman, C. Stiller, K. Scheffer, J. Aichinger, and B. Scheppat, Energiepark Mainz: Technical and economic analysis of the worldwide largest Power-to-Gas plant with PEM electrolysis. International Journal of Hydrogen Energy, 2017. 42(19): p. 13311-13320

particularly well-suited for integration with intermittent renewable energy sources, such as solar and wind power installations.

The distribution of hydrogen via land transportation encompasses three primary methods: gaseous hydrogen trailers transported by trucks, pipeline networks, and liquid hydrogen trailers. The optimal delivery method selection depends on several key factors: the chosen storage approach, the energy losses associated with state changes, the required transportation distance, and the volume of hydrogen flow needed. In the market's initial phase, characterized by low and dispersed demand, gaseous hydrogen trailers present a cost-effective distribution solution. However, their economic efficiency diminishes as market demand increases. Even as the market matures and hydrogen pipeline infrastructure develops, gaseous trailers remain economically viable for last-mile distribution from pipeline terminals to refueling stations. The transportation of liquefied hydrogen (LH2) presents challenges comparable to those encountered in liquefied natural gas (LNG) distribution. Both require sophisticated thermal insulation systems to minimize evaporative losses. While ships and trucks can operate effectively with some hydrogen evaporation losses, similar to LNG transport, the primary challenge lies in the hydrogen liquefaction infrastructure. This equipment proves cost-effective only on a large scale. Consequently, liquefied hydrogen supply chains demonstrate optimal cost-efficiency under specific conditions: when utilizing existing liquefaction facilities, when hydrogen requires liquefaction for maritime export, or when supplying hydrogen from large-scale centralized production facilities to multiple distant distribution points.[50]

Hydrogen pipeline networks represent a compelling solution for large-scale hydrogen distribution, offering superior cost-effectiveness and environmental benefits compared to alternative transport methods, particularly for medium to long-distance delivery. This infrastructure approach significantly reduces the impact on road congestion, making it especially advantageous for transmission networks and industrial site connectivity. The viability of hydrogen pipelines is demonstrated by existing infrastructure in both the European Union and United States, where established networks currently serve industrial facilities. These networks, constructed in accordance with international hydrogen pipeline standards, span a combined length of 3,000 kilometers. The expansion of hydrogen pipeline infrastructure continues to advance through international collaboration. A notable example is the Nordic-Baltic Hydrogen Corridor project, which involves Amber Grid, Lithuania's natural gas transmission system operator. This strategic initiative aims to establish pipeline connectivity between Northern Europe's green energy production regions and major consumption centers in Central Europe.[51] The deployment of hydrogen pipelines faces two significant initial challenges: the substantial upfront infrastructure investment required and the risk of low utilization during the market's early phases. However, several strategic approaches can help mitigate these financial and operational risks. One promising strategy involves retrofitting existing natural gas infrastructure for hydrogen transport. This option becomes increasingly viable as the heating sector transitions toward electrification and biofuels, making current natural gas pipeline capacity available for repurposing. This approach significantly reduces initial capital requirements while leveraging established infrastructure. An alternative strategy involves blending hydrogen with natural gas in existing networks. Several countries currently implement hydrogen blending at concentrations up to 10% by volume. The potential exists to increase these concentrations, though this would require modifications to existing heating

[50] Introduction Strategies for Hydrogen Infrastructure, RWTH Aachen, Simonas Černiauskas, 2022

[51] https://ambergrid.lt/zaliosios-dujos/vandenilis/siaures-ir-baltijos-saliu-vandenilio-koridorius/959

installations, natural gas turbines, and compressed natural gas vehicles, which are currently limited to 2% hydrogen concentration by volume. While hydrogen blending offers advantages through the utilization of existing natural gas infrastructure and minimizes new construction requirements, it presents a significant limitation: the mixed gas stream primarily serves heating applications. Any alternative hydrogen applications would necessitate additional purification processes, potentially reducing the overall efficiency and economic viability of this approach. Table 2 gives an overview of the main characteristics of the above supply chains for hydrogen refueling stations.

Hydrogen supply method for hydrogen refueling station	Benefits	Disadvantages
On-site production by electrolysis	- Unnecessary transport of hydrogen - Exploiting local electricity production - Self-sufficient hydrogen supply	- Stations need access to sufficient water and electricity networks - High investments - High storage needs
Pipelines	- Low storage requirements - More compact hydrogen stations	- Initial investment for new pipelines - Time required for construction or pipeline modifications - Large hydrogen flows are required to support pipelines, e.g. for industry - Refueling locations only near pipelines
Trucks	- Small investments - Lower cost of a hydrogen station - Flexibility in the choice of stop location	- Hydrogen transport costs are higher than on-site production for high consumption or long-distance transport

Table 2 Overview of the hydrogen supply chain

Recent analysis from the European Hydrogen Observatory indicates that hydrogen production via electrolysis costs between €7 and €9 per kilogram[52] (see Figure 12). When using grid electricity, production costs are primarily driven by electricity prices and associated grid charges. Alternatively, while producing hydrogen directly from renewable energy sources (RES) reduces ongoing electricity costs, it requires significantly higher initial capital investment, particularly for storage infrastructure.

[52] https://observatory.clean-hydrogen.europa.eu/hydrogen-landscape/production-trade-and-cost/cost-hydrogen-production

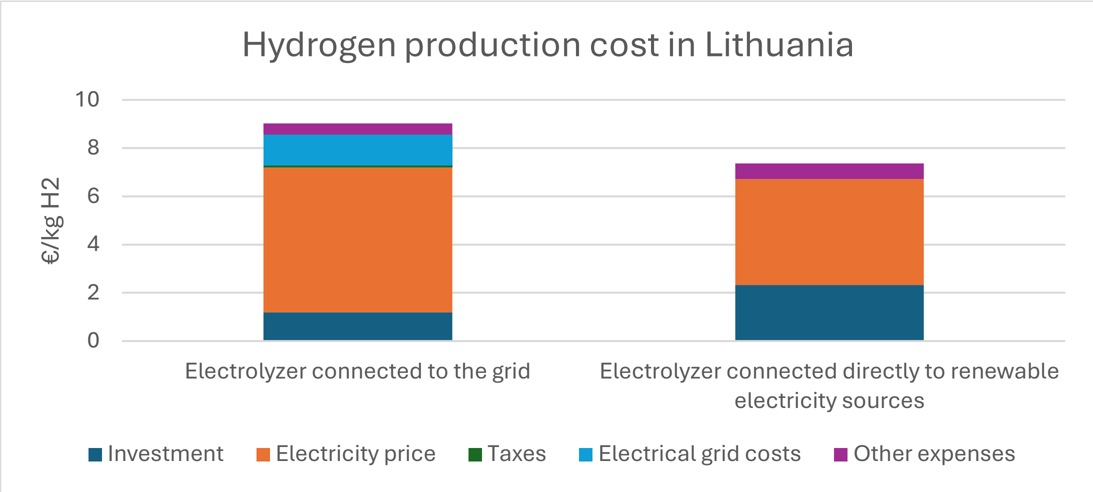

Figure 12. Hydrogen production cost in Lithuania according to the European Hydrogen Observatory

Transportation and distribution costs contribute significantly to the final consumer price of hydrogen in European markets. Based on regional analyses, truck transportation of hydrogen for distances between 100-300 kilometers adds approximately €1-1.5 per kilogram to the final cost.[53] [54] The infrastructure costs for hydrogen refueling stations, with daily capacity ranging from 700 to 1,000 kilograms, contribute an additional €1 per kilogram to the total final cost at the pump.[55] Correspondingly Figure 13 shows that these production and distribution costs result in pre-tax consumer prices at hydrogen refueling stations ranging from €8.3 to €11.5 per kilogram. This pricing aligns with market data from existing hydrogen valleys, where nearly half (45%) of operations sell vehicular hydrogen at prices exceeding €8 per kilogram.[56]

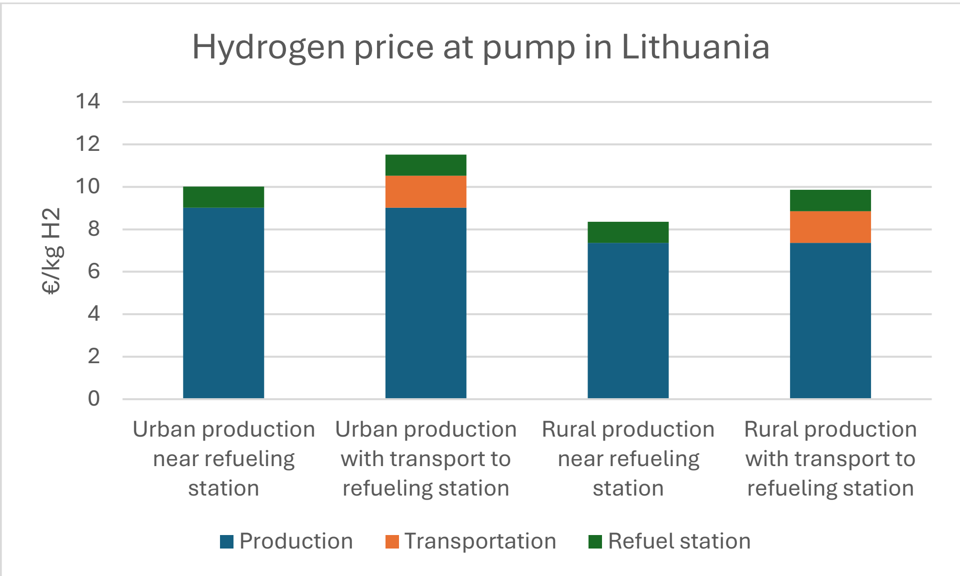

Figure 13. Hydrogen price at bottling points in Lithuania before taxes (urban production requires connection to the electricity grid, extra-urban production uses direct connection to RES)

[53] https://onlinelibrary.wiley.com/doi/10.1002/ente.202300785
[54] https://juser.fz-juelich.de/record/894233/files/energies-14-03166-v2.pdf
[55] Introduction Strategies for Hydrogen Infrastructure, RWTH Aachen, Simonas Černiauskas, 2022
[56] https://h2v.eu/analysis/statistics/financing/hydrogen-cost-and-sales-prices

2.4. Analysis to identify suitable locations for the development of hydrogen refueling infrastructure in the pilot region

The HyTruck project has developed a comprehensive analytical tool for identifying optimal hydrogen refueling station locations in the pilot region. This tool employs a multi-faceted approach that evaluates several key factors critical to infrastructure planning. The assessment begins with an analysis of existing infrastructure, particularly focusing on current refueling station networks. This evaluation helps identify established traffic patterns and potential strategic locations for new hydrogen stations. The tool incorporates coastal proximity analysis, recognizing its significance for both logistics operations and hydrogen production capabilities. Renewable energy potential forms a crucial component of the assessment criteria. The tool evaluates both solar and wind energy resources to ensure alignment with green hydrogen production objectives. This analysis is particularly vital for planning integrated energy systems that can support sustainable hydrogen production processes. Population density and urban development patterns are carefully considered to anticipate demand patterns. The tool analyzes both urban centers and peripheral areas to identify zones of potentially high hydrogen demand. Additionally, it maps water resource availability, addressing both production requirements and environmental considerations. The assessment also incorporates existing gas infrastructure networks, particularly pipeline systems, viewing these as potential foundations for future hydrogen transportation networks. This approach allows for the strategic leveraging of established infrastructure while planning for future hydrogen distribution needs. This systematic evaluation method ensures a comprehensive understanding of the region's potential for hydrogen refueling infrastructure development, taking into account both current capabilities and future expansion opportunities. The analytical tool extends beyond basic infrastructure assessment to incorporate several additional strategic factors crucial for hydrogen station planning. Integration with existing and planned hydrogen pipeline networks is a key consideration, ensuring new stations align with the broader hydrogen infrastructure development. The tool prioritizes major transportation corridors, particularly Trans-European Transport Network (TEN-T) routes and significant transport hubs, recognizing these as prime locations for hydrogen stations due to their high traffic volumes. Power infrastructure assessment forms another critical component, examining electricity grid capabilities to ensure reliable energy supply for both station operations and hydrogen production facilities. The tool also evaluates proximity to residential areas to gauge potential local demand patterns. Site-specific factors receive careful consideration in the analysis. The tool examines recreational areas and established rest stops along major routes as potential station locations. Terrain analysis, including topographical features and slope gradients, helps determine the technical feasibility of potential sites. This comprehensive evaluation framework incorporates geographic, infrastructural, economic, and environmental considerations through a structured hierarchical analytical process. Each criterion receives a specific weight in the final scoring system, enabling objective, data-driven decisions for hydrogen station placement. This methodical approach supports the strategic development of hydrogen refueling infrastructure while promoting sustainable economic growth in the sector. The resulting analysis provides stakeholders with robust, quantitative insights for informed decision-making about hydrogen station locations, supporting the systematic expansion of hydrogen refueling infrastructure.

Based on these initial results, the analysis of sites for the installation of hydrogen refueling points in Kaunas region has identified several locations that score well according to the above mentioned criteria (see green areas visible in Figure 14). Meanwhile, for the Panevėžys region, the criteria used also show several optimal locations for hydrogen refueling stations (see Figure 15).

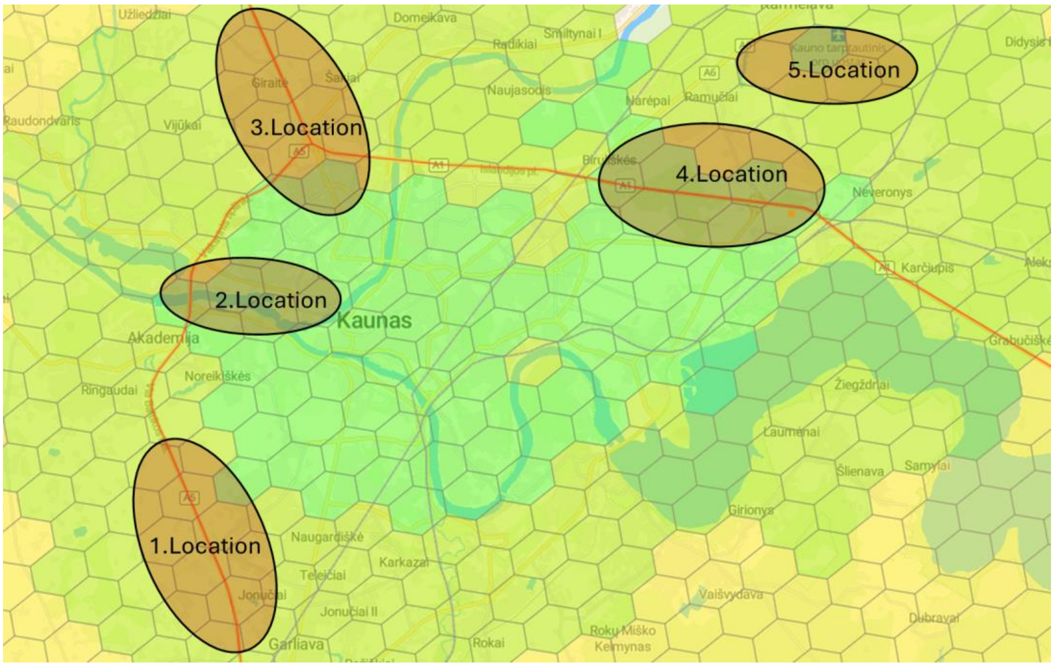

Figure 14. Identified regions for hydrogen refueling stations in Kaunas region. Scale from worst location for a hydrogen station (purple and red) to best location (green).

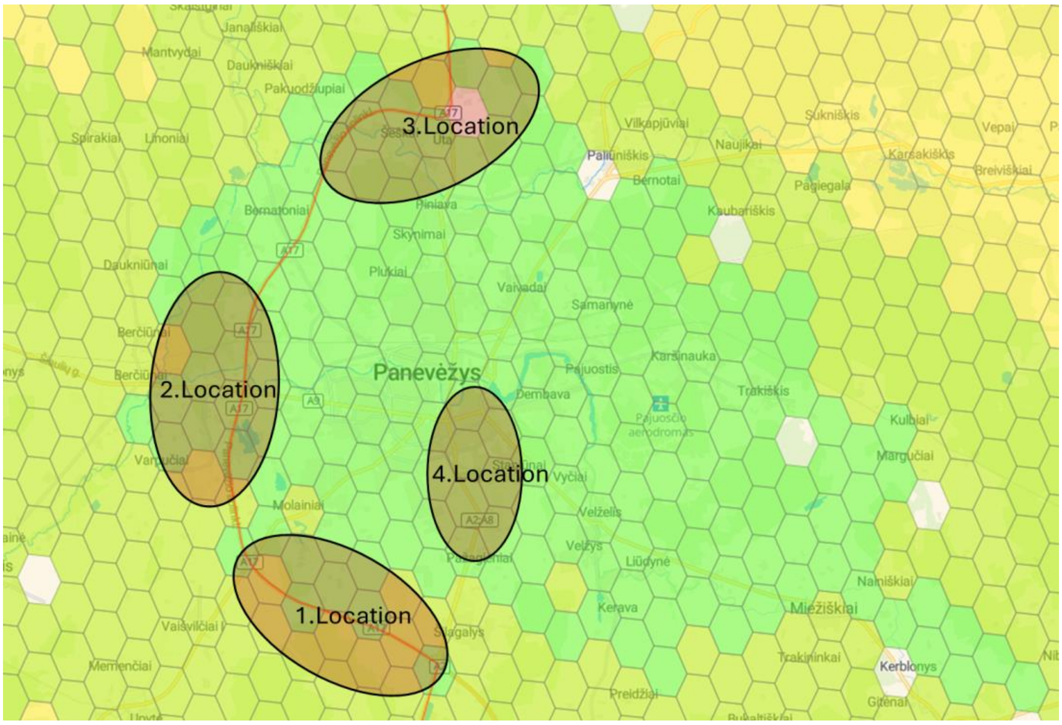

Figure 15. Hydrogen refueling station location planning map for the Panevėžys region. Scale of assessment from worst location for a hydrogen refueling station (purple and red) to best location (green).

2.5. Analysis of hydrogen refueling station users

An analysis of consumer potential for hydrogen vehicles focuses on specific commercial transport categories in the Kaunas and Panevėžys regions. The assessment examines two primary vehicle classifications: buses with categories M2 and M3 and heavy-duty trucks with categories N2 and N3, covering vehicles above 3.5 tonnes (see. Table 3 and Table 4). The Kaunas region shows significant potential in the heavy-duty segment, with more than 2,100 N2 category trucks and 15,000 N3 category vehicles currently in operation. The bus fleet in this region comprises 1,400 vehicles across categories M2 and M3. The Panevėžys region, while smaller in scale, maintains a substantial commercial vehicle presence with 600 N2 and 3,000 N3 category trucks, alongside 290 buses.

	M2	M3	N2	N3	TOTAL
Kaunas district	44	24	741	5081	5846
City of Kaunas	369	970	1374	10335	13048
Total	413	994	2115	15416	18938

Table 3 Registered M3, N2 and N3 vehicles in Kaunas pilot region (2024.05)

	M2	M3	N2	N3	TOTAL
Panevėžys district	44	31	247	1010	1288
City of Panevėžys	69	151	352	1976	2548
Total	113	182	599	2986	3836

Table 4 Registered M3, N2 and N3 vehicles in Panevėžys district (2024.05)

Based on this data, the potential for technical hydrogen consumption in each region can be calculated using scenarios modelled in the scientific literature for the development of hydrogen vehicles in different markets[57]. Based on the scenarios for the market share of different hydrogen-powered vehicles for different road transport segments such as trucks and buses, it can be concluded that by 2050, hydrogen-powered buses could reach on average 36% and trucks 25% of the total number of vehicles in this segment (see Figure 16).

[57] Introduction Strategies for Hydrogen Infrastructure, RWTH Aachen, Simonas Černiauskas, 2022

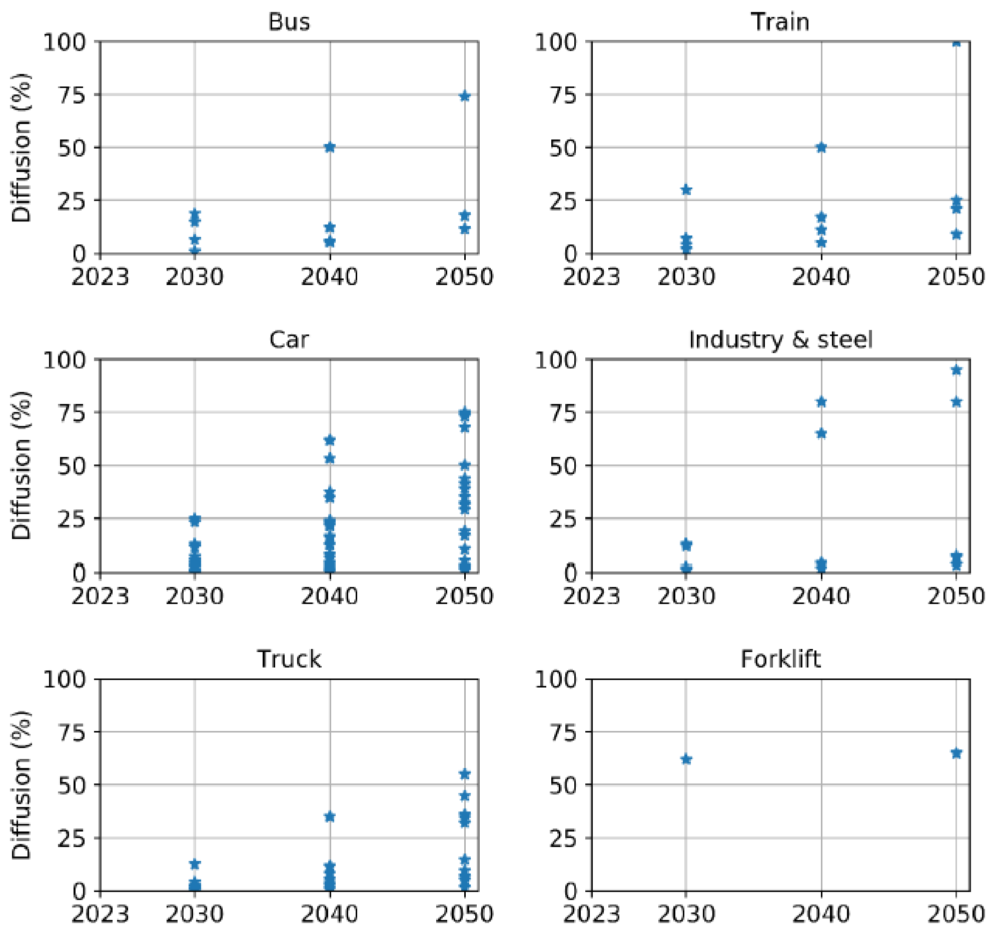

Figure 16. Hydrogen penetration scenarios 2023-2050[58]

Analysis of current hydrogen truck models reveals consistent patterns in vehicle specifications and fuel consumption rates. All available models fall into the N3 category, with gross weights exceeding 12 tonnes. (see Table 5). These vehicles demonstrate relatively consistent hydrogen consumption rates, averaging 7.5 kilograms per 100 kilometers based on manufacturer specifications for tank capacity and range. While real-world operating conditions may result in higher consumption rates, anticipated technological advances in fuel cell efficiency through 2050 are expected to offset these variations. Therefore, the current average consumption rate provides a reasonable baseline for long-term planning and analysis. For N2 category vehicles, consumption projections have been extrapolated using data from N3 vehicles, which have an average weight of 30 tonnes. Adjusting for the lighter weight of N2 vehicles, the projected hydrogen consumption rate is estimated at 3 kilograms per 100 kilometers.

Vehicle model	Total weight [t]	Tank pressure [bar]	Tank capacity [kg]	Chemical phase	Full tank range [km]	Hydrogen consumption [kg/100 km]
Esoro	35	350	31	gas	400	7,8
Hyundai Xcient Fuel Cell	18	350	31	gas	400	7,8

[58] Introduction Strategies for Hydrogen Infrastructure, RWTH Aachen, Simonas Černiauskas, 2022

Paul Nutzfahrzeuge Ph2P	24	350	30	gas	450	6,7
Hyzon Motors HyMaxSeries	24	350	30	gas	400	7,5
Enginius (Faun group) CITYPOWER	16	700	32	gas	500	6,4
Quantron QHM FCEV 44-1000	40	700	54	gas	700	7,7
Zepp.solutions	40	350	50	gas	700	7,1
Nicola /Iveco	40	700	70	gas	805	8,7

Table 5 Current models of fuel cell trucks

Figure 17 shows a comparison of the maximum range after a full tank or battery charge for hydrogen and electric bus and truck models. The truck data confirm Table 5 the trend that hydrogen trucks typically cover 400 km after a full tank. In the case of buses, the maximum range is similar and varies between 300 and 450 km.

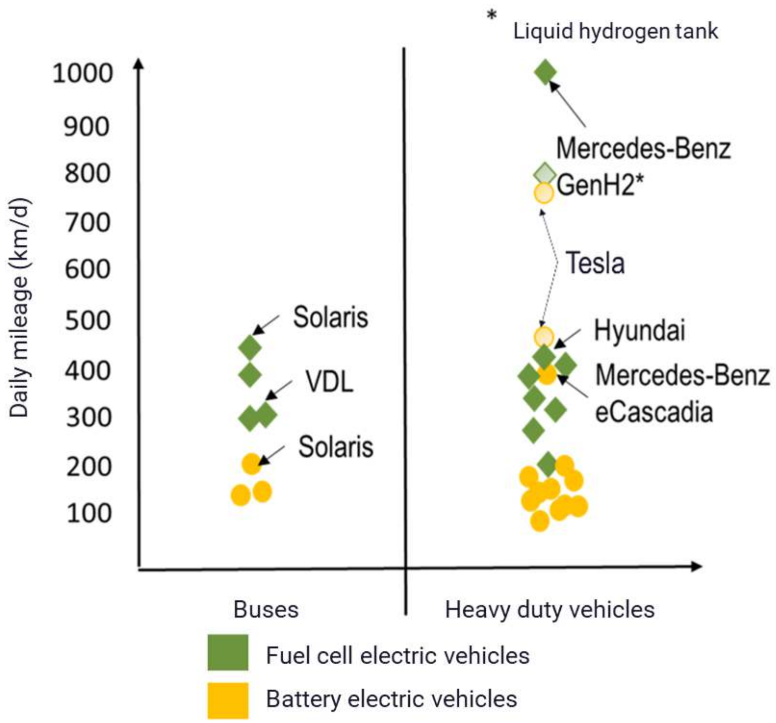

Figure 17. Model ranges for hydrogen and electric buses and trucks

Figure 18 reveals consistent specifications across the M3 vehicle category. These vehicles range in mass from 10 to 29 tonnes and feature an average hydrogen storage capacity of 40 kilograms. Under standard operating conditions, these M3 category buses demonstrate an average hydrogen consumption rate of 7.8 kilograms per 100 kilometers. For the lighter M2 category buses, consumption projections have been calculated based on vehicle mass ratios. Using this analytical approach, M2 buses are estimated to consume approximately 2 kilograms of hydrogen per 100 kilometers, reflecting their smaller size and lower power requirements.

Manufacturer	APTS	Mercedes -Benz	New Flyer	Van Hool	Wrightbus	Solaris
Length (m)	18,5	12	12,5	13,2	11,9	18
Passengers	96	76	60	101	49	138
Weight (t)	20,59	13,2	15,42	15,7	10,35	29
Engine power (kW)	240	240	170	170	134	240
Fuel cell power (kW)	150	120	150	150	75	100
Hydrogen tank (kg)	40	35	56	40	31	55
Battery capacity (kWh)	26	27	47	24	20	60

Figure 18. Current models of fuel cell buses in the M3 vehicle category

Table 6 shows the assumptions for fuel consumption and annual mileage of hydrogen vehicles. Based on these data and the scenarios given in Figure 16 and the vehicle registration data shown in Table 3 and Table 4 the hydrogen consumption potential in Kaunas and Panevėžys districts is calculated and presented in Table 7.

	M2	M3	N2	N3
Annual mileage [km/pa]	35000	56000	22000	89000
Hydrogen consumption [kg/100 km]	2	7,8	3	7,5

Table 6 Assumptions for vehicle categories M2, M3, N2 and N3[59]

	Hydrogen technical potential in Kaunas region t H2	Hydrogen technical potential in the Panevėžys region t H2
M2	290	80
M3	4340	800
N2	1400	400
N3	102900	19930
Total	108930	21210

Table 7 Technical potential of hydrogen consumption in Kaunas and Panevėžys regions

Based on these data, it is possible to calculate the potential for hydrogen consumption in heavy transport (buses and trucks) in Kaunas and Panevėžys regions (see. Table 8). Additionally, Table 9 and Table 10 present the main customers and their hydrogen consumption potentials.

[59] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Road_freight_transport_by_vehicle_characteristics#Road_freight_transport_by_maximum_permissible_laden_weight_of_vehicle

	Hydrogen consumption potential in Kaunas region t H2	Hydrogen consumption potential in Panevėžys region t H2
Buses all	4630	880
Trucks all	104300	20330
Total	108930	21210

Table 8 Hydrogen consumption potential for heavy transport in Kaunas and Panevėžys regions by 2050

Company name	**M2**	**M3**	**N2**	**N3**	**Hydrogen demand potential (tonnes/year)**
UAB "HOPTRANSA"	0	0	0	829	5533,575
UAB "HEGELMANN TRANSPORTE"	0	0	6	756	5050,26
KAJ MADSEN KAUNAS	0	2	0	583	3902,165
UAB "PETVA"	0	0	0	557	3717,975
UAB "HOPTRANS1"	0	0	0	503	3357,525
AB "ROAD MAINTENANCE"	11	0	115	429	2947,175
UAB "BALTIC TRANSLINE TRANSPORT"	0	0	3	440	2938,98
UAB "VYTAUTO PASLAUGOS"	0	0	0	367	2449,725
UAB "KAUNO AUTOBUSAI"	50	421	4	3	2297,385
UAB "KAMIDA"	0	0	0	344	2296,2
KAUTRA UAB	112	377	0	1	2090,715
UAB "TRANSDEPAS"	0	0	0	249	1662,075
UAB "ROSTEKA"	0	0	0	229	1528,575
UAB RAM EU	0	0	0	204	1361,7
UAB "VIČIŪNAI"	0	0	0	187	1248,225
UAB "SOLOTRANSA"	0	0	0	176	1174,8
UAB "VOSAS"	0	0	0	174	1161,45
HEGELMANN SPECIAL TRANSPORTE UAB	0	0	0	164	1094,7
UAB "KAUNO DAISOTRA"	0	0	0	157	1047,975
UAB "VYKOM"	0	0	0	156	1041,3
UAB "KAUTRA CARGO"	0	0	0	142	947,85
UAB "RAMRENTA"	0	0	0	140	934,5
UAB "KAUNO ŠVARA"	1	0	14	135	911,065
UAB "BELJANA"	0	0	0	135	901,125

UAB "MERULA"	10	45	0	0	246,4

Table 9. Twenty-five heavy vehicle fleets with the highest hydrogen potential in Kaunas region

Company name	**M2**	**M3**	**N2**	**N3**	**Hydrogen demand potential (tonnes/year)**
"GG TRANSPORT" UAB	0	0	0	158	1054,65
UAB "TRANSFERA"	0	0	0	128	854,4
UAB "SIRAMIS"	0	0	0	111	740,925
AB "HISK"	3	0	13	101	684,855
UAB "PANEVĖŽIO AUTOBUSŲ PARKAS"	4	88	1	1	478,295
UAB "KETRONA"	0	0	0	65	433,875
"ANETUS". UAB	0	0	0	43	287,025
UAB "NORVEKA"	0	0	0	39	260,325
XX GALLERY MB	0	0	1	38	254,31
FREIRAS UAB	0	0	1	38	254,31
UAB "KELIAS"	0	0	0	38	253,65
UAB "VARPAS TRANSPORT"	0	0	0	36	240,3
UAB "LAGERA"	0	0	0	33	220,275
"AUTECHA". UAB	0	0	11	31	214,185
UAB "DAJUREMA"	0	0	0	32	213,6
UAB "SKANDEKA"	0	0	2	30	201,57
AB "PANEVĖŽIO SPECIALUS AUTOTRANSPORTAS"	0	0	1	30	200,91
UAB "AUTIKA"	0	0	0	29	193,575
"TRANSPROFUS UAB	0	0	0	26	173,55
MB "IVITO"	0	0	0	26	173,55
"KRAUTA" UAB	0	0	4	24	162,84
"EISTURAS". UAB	2	11	0	0	59,92
UAB "AUTREGA"	13	9	0	0	56,98
UAB "BUSAUTA"	1	8	0	0	43,26
V. MILINAVIČIUS IIS	3	6	0	0	34,02

Table 10. Twenty-five heavy vehicle fleets with the highest hydrogen potential in the Panevėžys region

3. Analysis of social partners in pilot regions

A comprehensive analysis of stakeholder partnerships in the HyTruck pilot projects across the Kaunas and Panevėžys regions reveals a robust ecosystem of organizations essential for implementing hydrogen technology in Lithuania (see Figure 19). This network encompasses public sector leadership, private enterprise innovation, and academic expertise. Public sector engagement demonstrates significant governmental support, with key participants including the Lithuanian Energy Agency and the Ministries of Environment and Energy. Their involvement ensures alignment with national energy and environmental strategies. The participation of Kaunas and Panevėžys municipal authorities facilitates targeted implementation addressing specific local requirements and conditions. The private sector component features strategic participants across the hydrogen value chain. Energy sector leaders including KN Energies, Linde Gas, and Ignitis provide crucial infrastructure and supply capabilities. Transportation industry engagement through companies like Girteka and Kautra indicates strong commercial interest in hydrogen technology adoption, particularly in logistics applications. Non-governmental organizations serve as vital connectors across stakeholder groups. The Hydrogen Energy Association and Lithuanian Logistics Association facilitate communication between public institutions, private enterprises, and research organizations. These organizations play a crucial role in public engagement, information dissemination, and stakeholder advocacy. Academic participation through Vilnius Gediminas Technical University and the Lithuanian Energy Institute ensures access to current research and innovation capabilities. Their expertise provides critical support for addressing technical challenges and optimizing hydrogen technology implementation within the Lithuanian context. This wide-ranging cooperation between representatives of different sectors provides the perfect conditions for a holistic approach to project implementation. It is hoped that all relevant aspects, from technological and infrastructural to legal and social, will be considered.

The consultation process with social partners consisted of two meetings held in June and October 2024. The initial meeting brought together a diverse group of stakeholders, including representatives from municipalities, associations, universities, and businesses. For the second meeting, participation was expanded to include representatives from areas identified in the study as promising locations for hydrogen infrastructure development.

The overall feedback from social partners was neutral, with participants raising several key concerns. Primary issues included the limited number of potential hydrogen refueling station users, insufficient green hydrogen production capacity in Lithuania to enable competitive pricing and concerning global trends such as declining demand for hydrogen vehicles and closures of hydrogen refueling stations in other markets. Among the proposed solutions, Vilnius Gediminas Technical University suggested retrofitting existing vehicles for hydrogen use, though they emphasized the high equipment costs involved. These consultations revealed important considerations regarding hydrogen infrastructure development in Lithuania. The neutral stance from stakeholders suggests both opportunities and challenges that warrant careful attention in future planning phases.

Science and research	Public sector	Non- governmental organizations	Businesses
Lithuanian energy institute	Ministry of environment of the Republic of Lithuania	Lithuanian hydrogen association	Ambergrid
Research council of Lithuania	Ministry of energy of the Republic of Lithuania	Lithuanian logistics association	Orlen
Vilnius Gediminas Technical University	Kaunas city municipal administration	Lithuanian national road carriers' association LINAVA	Achema
	Kaunas district municipal administration	Lithuanian national association of forwarders and logistics	Linde Gas
	Panevėžys city municipal administration		Green Genius
	Panevėžys district municipal administration		Ignitis
	Lithuanian energy agency		KN Energies
			SG Dujos
			Dogaras
			Telepartner
			Vilnius district heat company
			Lucidus Techno

Figure 19. Social partners in the pilot regions of the HyTruck Project in Lithuania

4. Analysis of the network of hydrogen refueling stations in the surrounding regions

This chapter examines the hydrogen refueling infrastructure network in regions adjacent to the pilot area, with a specific focus on Latvia and Poland. The analysis encompasses both existing and planned hydrogen refueling facilities in these neighboring countries, providing essential context for understanding how the pilot region's infrastructure fits into the broader international network. This regional perspective helps identify potential opportunities for cross-border collaboration and infrastructure integration. A key component of the analysis is evaluating whether the existing and planned infrastructure can adequately serve heavy-duty hydrogen vehicles. This assessment is crucial for developing efficient cross-border transportation routes and ensuring that commercial vehicles can effectively utilize hydrogen technology across national boundaries. Understanding these infrastructure capabilities directly impacts the viability of international hydrogen-powered freight transport in the region.

4.1. Hydrogen infrastructure in Latvia

Latvia's hydrogen infrastructure plans reveal an ambitious but unevenly developed vision for the future of the country's hydrogen economy. Central to these plans is the impressive CIS Liepāja Ltd project, which envisages the installation of a 1.5 GW electrolysis plant capable of producing up to 150,000 tonnes of hydrogen per year by 2029[60]. Other potential hydrogen suppliers that have announced planned projects include Latvenergo[61] and Purplegreen.[62]

Latvia's plans for hydrogen infrastructure development, particularly for heavy transport, appear modest compared to larger-scale production initiatives in the region. The country's current hydrogen refueling capacity centers on a single station in Riga (see Figure 20), operating at both 350 bar and 700 bar pressure levels with a capacity of 600 kg/day. This facility primarily serves a trolleybus operation at present. The infrastructure expansion plans include an additional station in the Vidzeme region, along with developments through the H2Value project, which will establish new facilities in Tartu, Estonia, and Valmiera, Latvia. While these initial facilities will enable basic transit operations, the planned infrastructure presents significant limitations for heavy transport operations, particularly in Eastern Latvia and notably in Western Latvia. This limitation is especially noteworthy given the planned 1.5 GW electrolysis plant in Liepaja. The proposed network of three hydrogen refueling points falls short of creating the comprehensive infrastructure required for nationwide coverage and efficient international transit operations with neighboring countries.

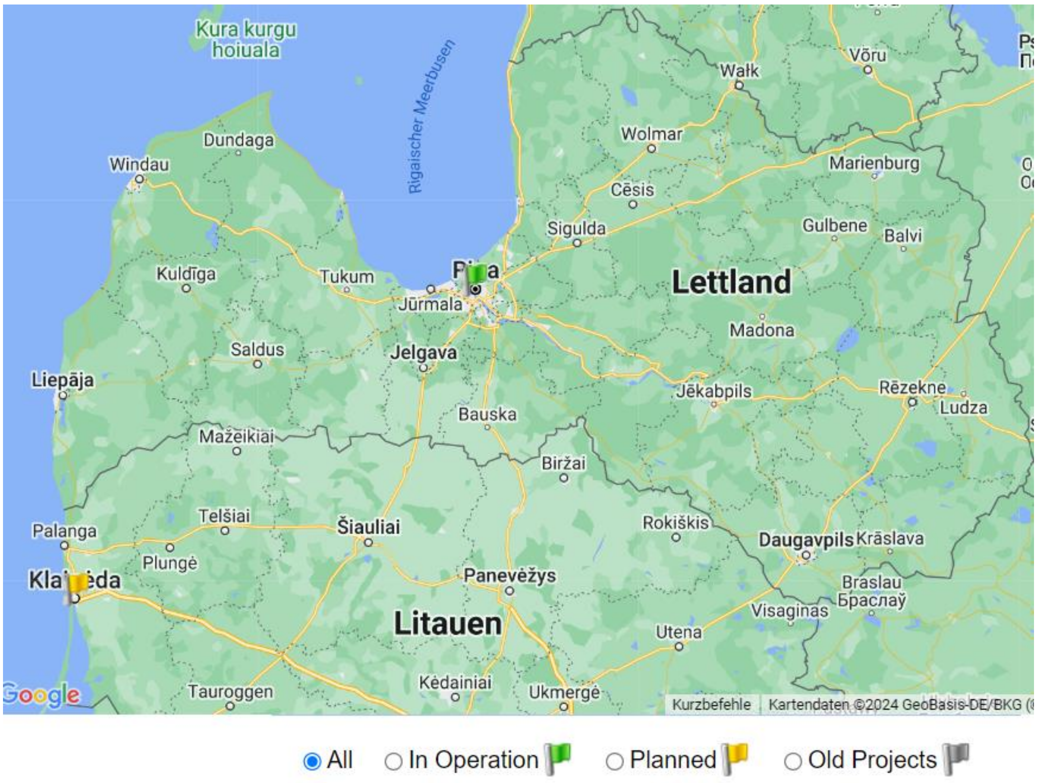

Figure 20. Hydrogen refueling stations (350 bar and 700 bar) in the Republic of Latvia

The AFIR for 2030 foresees a conservative hydrogen supply requirement of between 1,825 and 3,65 thousand tonnes per year distributed among ten refueling stations. These figures are in stark contrast to the currently announced plans for a total of two hydrogen refueling stations.

60 https://eng.lsm.lv/article/economy/business/10.04.2024-liepaja-plans-first-hydrogen-production-plant-in-latvia.a549823/#:~:text=Hydrogen%20could%20be%20industrially%20produced,Kurzeme%20TV%20reported%20April%209.
61 https://latvenergo.lv/lv/jaunumi/preses-relizes/relize/sacies-zviedrijas-un-baltijas-valstu-atjaunigas-energetikas-sadarbibas-izpetes-projekts
62 https://purplegreen.eu/projects/

There is also an imbalance between planned hydrogen production and expected consumption in the transport sector, opening a large potential for hydrogen to be used in other sectors or exported to other countries.

4.2. Hydrogen infrastructure in Poland

Poland's hydrogen infrastructure plans aim to install 2 GW of electrolysis and low GHG-intensity hydrogen production capacity by 2030[63] , which shows Poland's strong commitment to hydrogen technology (see already planned projects in Figure 21). This production potential could produce around 200,000 tonnes of hydrogen and should be sufficient to meet the supply needs projected in the AFIR, which range from 7.3 to 14.6 thousand tonnes of hydrogen per year. There are currently four hydrogen refueling stations in Poland - in Warsaw, Poznań, Konin and Rybnik - and 11 refueling stations are in the planning or installation phase (see Figure 22). The plan is to increase the number of such refueling stations to at least 32 by 2030[64] , which is a significant jump but still falls short of the 40 refueling stations required by AFIR. The location of existing refueling stations in major cities shows a clear orientation towards urban transport but raises questions about the capacity to handle heavy goods transport.

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[63] Poland's hydrogen strategy https://energy.ec.europa.eu/document/download/e63cb8ff-2a56-4f0b-98f6-59b4e15cf3f7_en?filename=8_-_polish_hydrogen_strategy_draft_presentation.pdf&prefLang=lv#:~:text=Strategy%20sets%20the%20long%2Dterm,key%20for%20its%20successful%20implementation.&text=50%20MW%20and%202%20GW,by%202030%20and%202040%20accordingly.

[64] Poland's hydrogen strategy https://energy.ec.europa.eu/document/download/e63cb8ff-2a56-4f0b-98f6-59b4e15cf3f7_en?filename=8_-_polish_hydrogen_strategy_draft_presentation.pdf&prefLang=lv#:~:text=Strategy%20sets%20the%20long%2Dterm,key%20for%20its%20successful%20implementation.&text=50%20MW%20and%202%20GW,by%202030%20and%202040%20accordingly.

[64] https://www.h2inframap.eu/

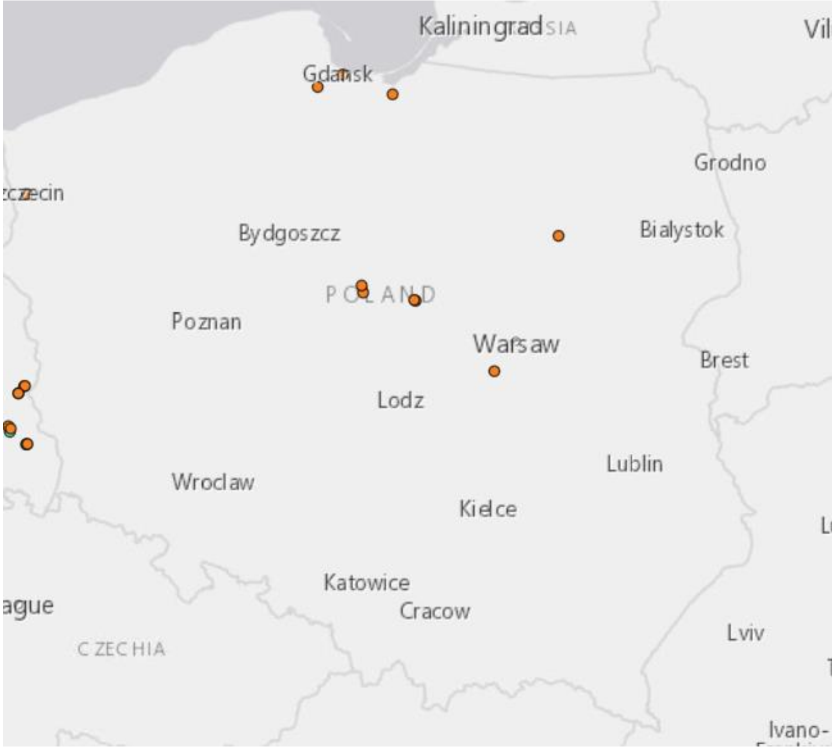

Figure 21. Hydrogen production projects in Poland[65]

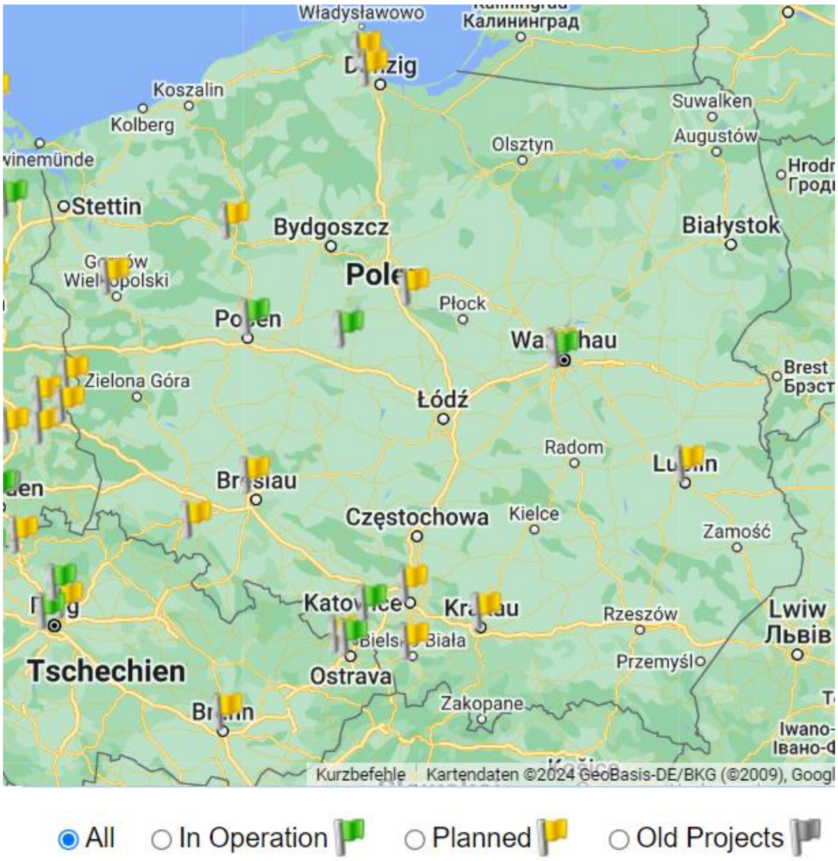

Figure 22. Hydrogen station (350 bar) projects in Poland[66]

[65] https://www.h2inframap.eu/
[66] https://www.h2stations.org/stations-map/?lat=49.763948&lng=12.582221&zoom=4

Poland is focusing on public transport, with plans to purchase 1,000 hydrogen-powered buses, in line with its current plans for hydrogen refueling stations[67]. This fleet of buses is expected to consume around 6.6 thousand tonnes of hydrogen per year, which corresponds to most of the minimum demand set by the AFIR and can ensure the use of the hydrogen refueling infrastructure related to the AFIR. At the same time, Poland's hydrogen strategy lacks a clear strategy for heavy freight transport, which is an important gap given Poland's role as a transit country in Europe.

The current geographic distribution of hydrogen infrastructure in Poland presents strategic challenges, particularly for heavy transport operations. While the concentration of hydrogen refueling stations in major metropolitan areas effectively supports public transportation needs, the network requires significant expansion to facilitate efficient commercial transport and ensure seamless transit operations. This expansion is especially critical given Poland's substantial geographic size and its strategic position as a transportation hub in Central Europe. The limitations of the current infrastructure are particularly evident in the context of the HyTruck project, where the absence of hydrogen facilities in Poland's northeastern regions creates a significant operational gap. The 400-kilometer distance between the HyTruck pilot region in Kaunas and the nearest hydrogen refueling station in Warsaw exceeds practical operational parameters. To align with AFIR requirements and ensure viable transit operations, at least one additional hydrogen station must be established along this corridor.

5. Concept for the development of hydrogen refueling infrastructure in the pilot region

This chapter presents a comprehensive framework for developing hydrogen refueling infrastructure in the pilot region, addressing both strategic location planning and implementation requirements. The first section focuses on identifying optimal locations for hydrogen refueling facilities through rigorous analysis of technical parameters. This strategic assessment establishes a prioritized roadmap for infrastructure placement to maximize operational efficiency and market impact. The second section provides detailed implementation guidance, outlining a systematic approach to infrastructure development. This includes establishing clear project phases, conducting thorough risk assessment and mitigation planning, and developing strategies for user engagement and adoption. The analysis encompasses technical installation requirements, regulatory compliance measures, and potential financing mechanisms to support successful deployment.

5.1. The most suitable locations for hydrogen refueling infrastructure in the pilot region

The selection of optimal locations for hydrogen facilities requires careful evaluation of several critical factors, with particular emphasis on energy infrastructure capacity, existing site

[67] Poland's hydrogen strategy https://energy.ec.europa.eu/document/download/e63cb8ff-2a56-4f0b-98f6-59b4e15cf3f7_en?filename=8_-_polish_hydrogen_strategy_draft_presentation.pdf&prefLang=lv#:~:text=Strategy%20sets%20the%20long%2Dterm,key%20for%20its%20successful%20implementation.&text=50%20MW%20and%202%20GW,by%202030%20and%202040%20accordingly.

facilities, and proximity to potential users. A primary consideration is the available electrical capacity at nearby substations, measured in megawatts (MW). This factor carries significant weight because hydrogen production through electrolysis, combined with compression systems at refueling stations, demands substantial power resources. Sites with greater electrical capacity offer two distinct advantages: they reduce initial infrastructure investment requirements and provide opportunities for future expansion. Furthermore, locations with excess capacity enable the integration of renewable energy sources, such as solar arrays or wind turbines, which can contribute to reducing long-term operational costs through lower hydrogen production expenses (see Figure 13). The assessment of transport infrastructure represents another crucial dimension in site selection, with particular attention to existing fueling facilities in the target area. The presence of established fueling stations offers multiple strategic advantages: it facilitates the integration of hydrogen infrastructure into current operations, indicates proven traffic patterns, and provides opportunities to leverage existing customer relationships. A key metric in the evaluation process is the hydrogen consumption potential from primary customers, specifically heavy transport operators located within a 10-kilometer radius of the proposed site. This analysis should extend to examining opportunities for customer diversification across different vehicle categories. Sites that can serve a diverse range of hydrogen-powered vehicles present a more robust business case by minimizing equipment utilization risk and enhancing the economic viability of the facility through multiple revenue streams.

Analysis of the five candidate sites for hydrogen infrastructure development in the Kaunas region reveals significant variations in their strategic potential (see Figure 23 and Table 11). The first location, despite having established fueling facilities, emerges as the least viable option due to two critical limitations: insufficient electrical infrastructure capacity and minimal projected consumption from heavy transport operators.

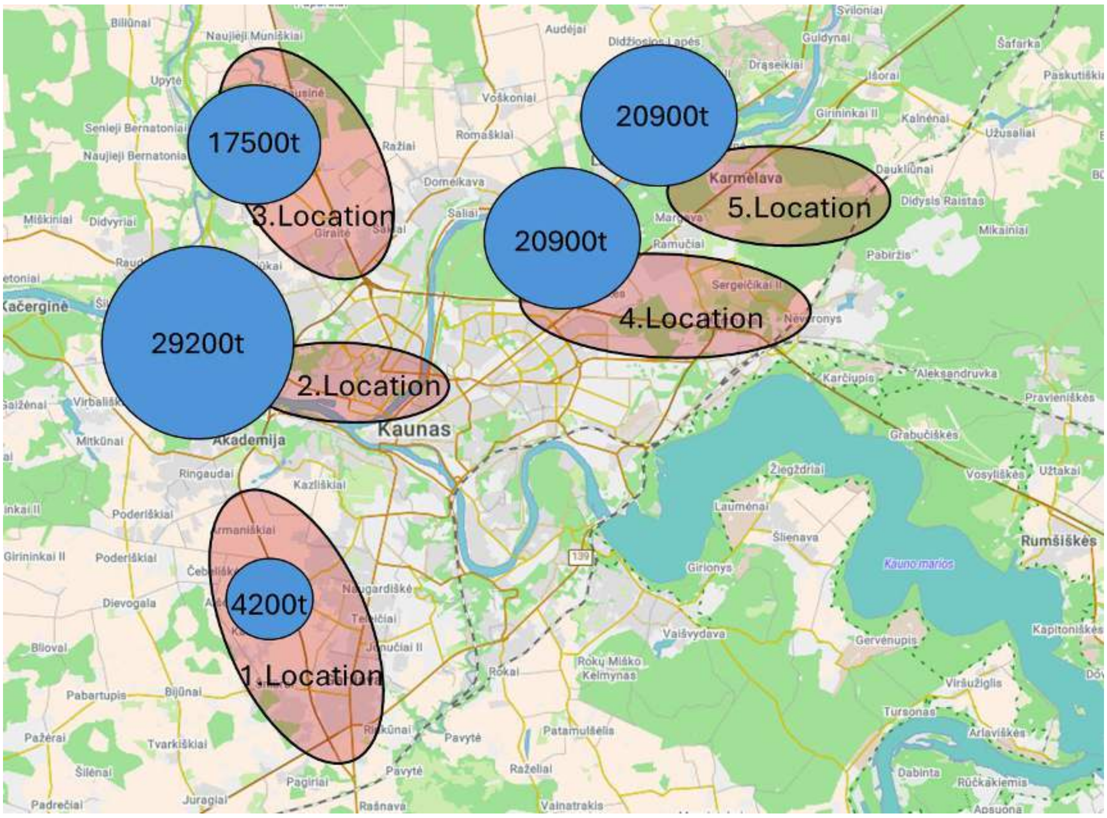

Figure 23. Hydrogen consumption potential of primary customers within a 10 km radius of the identified sites in Kaunas region.

The second location emerges as a prime candidate, featuring significant advantages including 25 MW of available electrical capacity and the highest potential primary customer demand at 29,200 tonnes annually. This strong demand projection stems from its central location and accessibility to logistics companies, complemented by the Kaunas bus fleet's anticipated consumption of 2,300 tonnes of hydrogen per year (see Table 9). The site's existing high-traffic fuel stations and potential to serve both urban and inter-urban transport create opportunities for diverse revenue streams, enhancing the project's financial viability. The third location presents moderate potential with 4 MW of grid capacity and the second-highest projected heavy transport consumption, though limited user diversification affects its overall viability. In contrast, the fourth location offers promising characteristics, including 8 MW of available power capacity—crucial for on-site hydrogen production—and existing fuel stations that could be adapted for hydrogen distribution, reducing initial capital requirements. The site's projected annual heavy transport consumption of 20,900 tonnes, coupled with the presence of a Lidl logistics center, indicates strong potential demand. The fifth location demonstrates notable strengths, combining substantial energy infrastructure capacity with high heavy transport consumption potential. Its airport location enables diverse user segments, including urban transport, intercity airport connections, and airport operations. While the absence of existing fuel stations indicates lower current traffic volumes, the strategic advantages of user diversification and high public visibility offset this limitation. Based on comprehensive analysis of these factors, the second and fifth locations warrant detailed investigation as primary candidates for hydrogen infrastructure development. Further assessment should focus on engaging potential users, particularly carriers operating at these locations, Kaunas Airport, and associated urban and intercity transport providers.

	1.Location	2. Location	3. Location	4. Location	5. Location
Available grid power[68]	0 MW	25 MW	4 MW	8 MW	8 MW
Transport infrastructure	Petrol stations	Petrol stations	Petrol stations	Petrol stations	No petrol stations
Heavy transport consumption potential of primary customers (tonnes of hydrogen per year)	4200	29200	17500	20900	20900
Possible diversification of customers	Heavy transport, intercity buses, passenger cars	City buses, intercity buses, heavy transport, cars	Heavy transport, intercity buses, passenger cars	Heavy transport, intercity buses, cars, trains*	Buses, heavy transport, intercity buses, airport transport, passenger cars
* Palemonas train terminal nearby					

Table 11 Technical assessment of sites for hydrogen stations in Kaunas region

[68] Free power in substations based on https://www.eso.lt/lt/verslui/elektra_99/paslaugos-ir-elektros-prietaisu-remontas/elektros-liniju-zemelapiai_2630/transformatoriu-pastociu-laisvu-galiu-zemelapis_2452.html

Analysis of the four candidate sites for hydrogen infrastructure development in the Panevėžys pilot region reveals distinct advantages and disadvantages at each location (see Table 12 and Figure 24). The first location offers established fueling infrastructure, providing a valuable foundation for hydrogen facility integration. However, this advantage is significantly offset by insufficient electrical grid capacity, which would necessitate substantial additional investment for on-site hydrogen production capabilities. The site demonstrates moderate potential, with projected annual hydrogen consumption of 2,200 tonnes from primary customers and opportunities to serve diverse market segments, including intercity buses, heavy transport operators, and passenger vehicles.

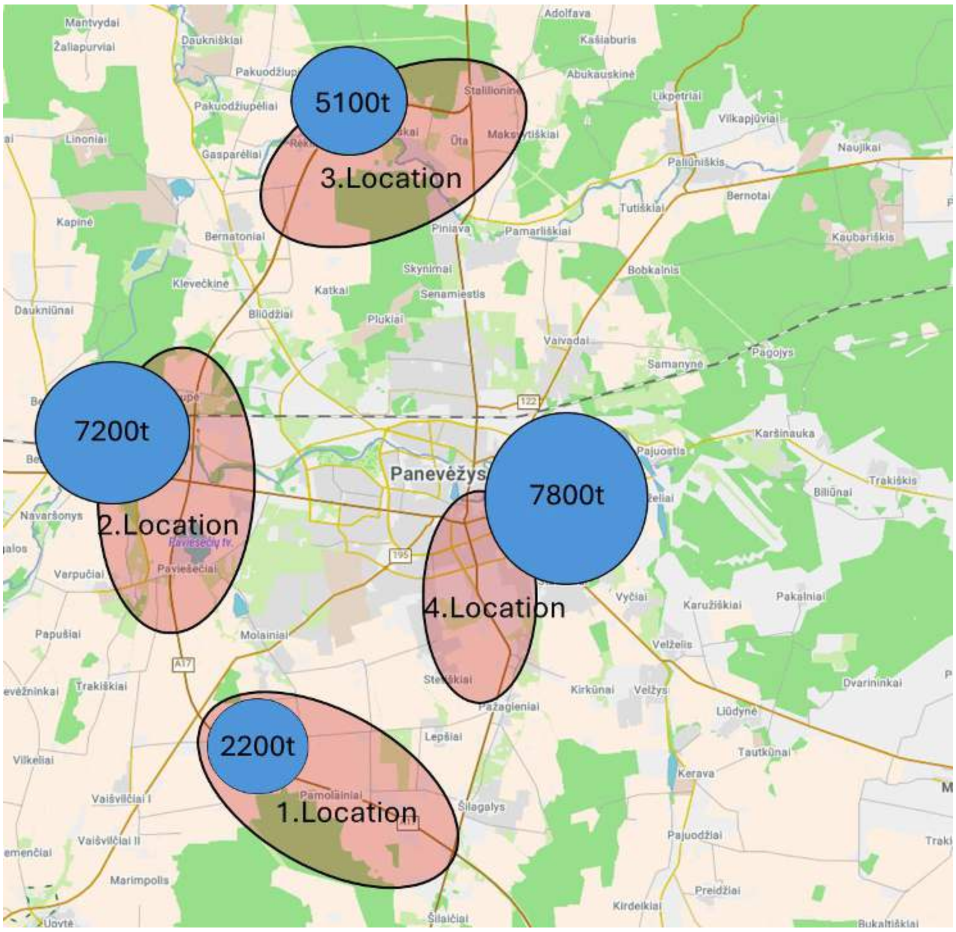

Figure 24. Hydrogen consumption potential of primary customers within a 10 km radius of the identified sites in Panevėžys region.

The second location emerges as a significantly stronger candidate, offering 11 MW of available grid capacity—a critical enabler for on-site hydrogen production. This site combines existing fuel station infrastructure that could be adapted for hydrogen distribution with substantial projected demand of 7,200 tonnes annually from primary customers. The location presents opportunities across multiple market segments, including intercity buses, heavy transport, and passenger vehicles. The third location, despite having established fueling facilities, faces significant infrastructure constraints due to insufficient electrical grid capacity. While the site projects moderate demand potential at 5,100 tonnes of hydrogen annually from primary customers and offers diversification across transportation segments, the grid capacity limitation poses a substantial challenge to development. The fourth location demonstrates the highest consumption potential, driven by its strategic position near logistics companies and the Panevėžys bus fleet. This central location enables the broadest diversification of potential hydrogen consumers in the road transport sector. However, the absence of available grid capacity suggests this site would be most suitable for a hydrogen distribution facility without on-site production capabilities, thereby avoiding substantial electrical infrastructure investment.

Criterion	1.Place	2. Location	3. Location	4. Location
Available grid power[69]	0 MW	11 MW	3 MW	0 MW
Transport infrastructure	Existing service stations	Existing service stations	Existing service stations	Existing service stations
Heavy transport consumption potential of primary customers (tonnes of hydrogen per year)	2200	7200	5100	7800
Possible diversification of customers	Heavy transport, intercity buses, passenger cars	Heavy transport, intercity buses, passenger cars	Heavy transport, intercity buses, passenger cars	Buses, coaches, intercity buses, heavy transport, passenger cars

Table 12 Technical assessment of hydrogen station sites in the Panevėžys region

Based on comprehensive analysis of all factors, two locations emerge as primary candidates for hydrogen infrastructure development in the region, each optimal for different strategic approaches. Site 2 presents the strongest case for a facility incorporating on-site hydrogen production, given its substantial grid capacity and established fueling infrastructure. In contrast, Site 4 offers compelling advantages as a distribution-only facility, particularly due to its superior consumption potential and diverse customer base across multiple transport segments. Further detailed assessment of these locations is warranted, focusing on engagement with transport operators based at these sites and analysis of urban and intercity passenger transport patterns. This evaluation will provide essential insights for final site selection and facility configuration decisions.

5.2. Recommendations for the development of hydrogen refueling infrastructure in the region

This chapter examines the key aspects of developing hydrogen refueling infrastructure. It outlines the major phases of infrastructure development, including identifying and mitigating potential risks throughout the process. The chapter also addresses methods for identifying prospective users and incorporating their input into infrastructure planning and development. The discussion includes a comprehensive analysis of the technical specifications required for hydrogen refueling facilities, along with an overview of essential regulatory frameworks and compliance measures. The chapter concludes with an assessment of available financial

[69] Available power in substations based on https://www.eso.lt/lt/verslui/elektra_99/paslaugos-ir-elektros-prietaisu-remontas/elektros-liniju-zemelapiai_2630/transformatoriu-pastociu-laisvu-galiu-zemelapis_2452.html

mechanisms and incentives that can accelerate the development of hydrogen refueling infrastructure.

5.2.1. Stages in the development of hydrogen refueling infrastructure

The process of deploying hydrogen infrastructure can be divided into five main phases, which progress from strategic planning to practical implementation and follow-up (see Figure 25). The first phase focuses on identifying the strategic role by analyzing and aligning with the objectives outlined in the guidelines for hydrogen development. This establishes the overarching vision and strategic direction for infrastructure development. Regional planning comprises the second phase, involving comprehensive analysis to forecast the distribution of hydrogen-powered vehicles. This phase identifies major transit corridors and high-traffic areas while evaluating existing infrastructure for potential integration. Stakeholder engagement remains crucial during planning to ensure effective collaboration. The current study directly supports these objectives in Central and Northern Lithuania's pilot regions. The third phase centers on process development, establishing the essential legal and technical framework. This includes collaborating with international partners to develop and harmonize hydrogen system standards that facilitate cross-border transport. During this phase, technical regulations are implemented, regulatory gaps are addressed, and clear permitting processes are established for hydrogen infrastructure. Additionally, incentive programs are developed to attract private sector investment. Equipment deployment constitutes the fourth phase, focusing on building a skilled workforce capable of handling, installing, repairing, and maintaining hydrogen systems. This phase integrates new hydrogen infrastructure with existing planning and marketing systems to ensure operational effectiveness. The fifth and final phase encompasses monitoring and maintenance, including continuous assessment of infrastructure economic viability, tracking hydrogen supply volumes, and measuring greenhouse gas emissions. This phase ensures effective knowledge sharing and best practices among stakeholders, promoting continuous system improvement and operational efficiency.

Figure 25. Hydrogen infrastructure deployment milestones

5.2.2. Potential risks in the development of hydrogen refueling infrastructure and mitigation strategies

The deployment of hydrogen infrastructure involves several significant risks that require careful management to ensure successful technology adoption (see. Table 13). The potential for slow vehicle deployment represents a primary concern. To address this challenge, a comprehensive strategy includes implementing robust purchase incentives, establishing strong manufacturer partnerships to ensure adequate supply, and aligning infrastructure support with vehicle incentive programs. Additionally, maintaining minimum infrastructure utilization rates proves essential for achieving economic viability of investments. Substantial initial infrastructure costs present another significant challenge. This risk can be effectively mitigated through strategic access to EU funding mechanisms and the development of public-private partnerships. These collaborative arrangements help distribute financial exposure while reducing individual investor risk. Demand uncertainty poses an additional critical consideration. Managing this risk requires active engagement with stakeholders across the entire hydrogen value chain and support for integrated projects encompassing production, supply, and consumption. This comprehensive approach helps establish stable market dynamics and sustainable supply-demand relationships. Supply chain disruptions represent a serious operational risk. Mitigation strategies include developing diversified hydrogen sources, expanding local green hydrogen production capacity, and establishing robust transport connections with alternative production facilities. This multi-faceted approach enhances supply security and system resilience.

No.	Risks	Mitigation measures
1.	Slow deployment of hydrogen vehicles	- Implement vehicle purchase incentives - Cooperate with producers to ensure sufficient supply - Linking infrastructure incentives to vehicle support - Ensuring the minimum required load on infrastructure - Consumer diversification
2.	High initial infrastructure costs	- Seek EU funding - Developing public-private partnerships
3.	Uncertain demand for hydrogen	- Involve stakeholders from all hydrogen supply chains - Supporting full-cycle projects covering production, supply and consumption
4.	Hydrogen supply chain disruptions	- Developing different sources of hydrogen - Developing local green hydrogen production capacity - Ensuring hydrogen can be transported from other production sites
5.	Shortage of skilled labor	- Establish partnerships with educational institutions - Develop specialized education programs
6.	Competition from other alternative fuel technologies	- Maintaining a technology-neutral approach in transport policy

		- Highlighting the unique advantages of hydrogen for heavy and long-distance transport - Diversification of consumer groups
7.	Security concerns and public opinion	- Implement EU recognized safety standards - Conduct public education campaigns - Ensure transparent information on safety measures
8.	Insufficient coordination of infrastructure with neighboring countries	- Actively participate in international working groups and projects - Conclude bilateral and multilateral agreements on harmonization of standards

Table 13 Risks and mitigation measures

Workforce development presents another critical challenge, as skilled labor shortages could impede sector growth. Addressing this constraint requires establishing strategic partnerships with educational institutions and developing specialized training programs to build the necessary technical expertise. The emergence of competing alternative fuel technologies necessitates strategic positioning. Maintaining hydrogen's competitive advantage requires advocating for technology-neutral transport policies while emphasizing hydrogen's distinct benefits, particularly for heavy-duty and long-distance transportation applications. Public safety concerns represent a significant adoption barrier. Addressing these concerns requires implementing EU-recognized safety standards, conducting targeted public education campaigns, and maintaining transparent communication about safety protocols. These measures help build public confidence in hydrogen technology adoption. Infrastructure harmonization gaps between neighboring countries can create obstacles for cross-border transport efficiency. Mitigating this challenge requires active participation in international working groups and initiatives, coupled with the establishment of bilateral and multilateral agreements to standardize infrastructure specifications. Successfully managing these diverse risks demands an integrated approach and robust stakeholder collaboration. This comprehensive strategy proves essential for achieving sustainable hydrogen infrastructure deployment that advances the transition toward a cleaner, more efficient transportation sector.

5.2.3. Identification of hydrogen infrastructure users and opportunities for their involvement in infrastructure development

The development of hydrogen infrastructure and consumer adoption requires a strategic approach and collaboration among diverse stakeholders. To ensure the successful growth of the hydrogen economy, the user base must expand beyond heavy transport to include public transit, non-electrified railways, light commercial vehicles, maritime transport, and industrial applications. A comprehensive market analysis, incorporating user surveys, stakeholder interviews, and traffic flow studies, is essential for understanding actual needs and expectations. Close partnerships with manufacturers provide critical insights into upcoming hydrogen-powered vehicle models and their infrastructure requirements, enabling more effective planning and infrastructure deployment.

Organizing regular stakeholder forums that bring together transport operators, municipal authorities, and energy companies creates opportunities to develop shared objectives and identify potential synergies. Strategic incentives, such as financial support for early adopters and innovative partnership models, can accelerate engagement and investment in hydrogen technologies. A centralized information platform serves multiple crucial functions: monitoring infrastructure utilization, gathering demand data, and sharing deployment plans. Collaboration with academic institutions and analysis of international best practices provides scientific validation and enables the application of proven solutions. Regular strategy reviews ensure plans remain relevant amid evolving technology and market conditions. Local ecosystem development requires partnerships with community organizations, municipal departments, business associations, fueling station operators, and equipment suppliers. This collaborative network promotes hydrogen adoption readiness at the local level.

Based on this analysis, three key recommendations emerge:

- First, develop and maintain a comprehensive hydrogen infrastructure strategy that encompasses diverse user groups and adapts to technological and market evolution through regular updates.
- Second, implement a centralized information platform to track infrastructure usage, collect demand data, communicate deployment plans, and enable potential users to register their interest.
- Third, forge robust partnerships across public sector, industry, and academia to facilitate knowledge sharing, optimize resources, and advance a unified vision for hydrogen infrastructure development.

5.2.4. Technical requirements and regulatory measures for the installation of hydrogen refueling infrastructure

This chapter provides an overview of the main international standards and the gaps in national legislation and regulations that need to be considered in the development of hydrogen refueling station infrastructure.

ISO 15916:2015[70] provides guidance on the use of gaseous and liquid hydrogen and its storage in these or other forms (hydrides). It identifies the main safety issues, hazards and risks and describes the safety relevant properties of hydrogen. Detailed safety requirements for specific hydrogen applications are addressed in individual international standards.

ISO 19880-1[71] Hydrogen gas. Service stations. Part 1: General requirements - Specifies the minimum requirements for the design, installation, commissioning, operation, testing and maintenance, safety and, where appropriate, performance of public and non-public service stations for the dispensing of gaseous hydrogen into light road vehicles (e.g. fuel-cell powered electric vehicles). While this document is focused on light hydrogen vehicles, it also covers fuel supply requirements and guidelines for medium and heavy-duty road vehicles (e.g. buses, trucks).

[70] https://www.iso.org/standard/56546.html
[71] https://www.iso.org/standard/71940.html

Standard EN 17127[72] "Outdoor hydrogen refueling stations dispensing gaseous hydrogen and using refueling protocols" defines the minimum requirements for the interoperability of hydrogen refueling stations, including refueling protocols for dispensing gaseous hydrogen to on-road vehicles (e.g. fuel cell electric vehicles) complying with the legislation applicable to such vehicles. The safety and performance requirements for a full hydrogen refueling station, as addressed by existing relevant European and national legislation, are not included in this document.

ISO 19885-3[73], which is currently being updated, describes high-flow hydrogen refueling protocols for heavy-duty road vehicles powered by compressed gases at 350 or 700 bar nominal operating pressure with a hydrogen capacity of 10 to 200 kg, and considers the results and conclusions of the European Commission-funded project on protocols for the supply of heavy-duty hydrogen fuels (PRHYDE). ISO 14687, Part 2[74] specifies the minimum quality characteristics for hydrogen fuels for use in vehicles and stationary applications.

ISO 13984[75] "Liquid hydrogen. Refueling interface for land vehicles specifies the characteristics of liquid hydrogen refueling systems for land vehicles to reduce the risk of fire and explosion during refueling and thus provide an adequate level of protection against loss of life and property. It applies to the design and installation of liquid hydrogen refueling systems. It describes the system for the delivery of liquid hydrogen to the vehicle, including the subsystem that handles the cold gaseous hydrogen discharged from the vehicle's tank, i.e. the system located between the ground vehicle and the storage tank.

ISO 13985[76] "Liquid hydrogen. Tanks for fuel tanks for land vehicles specifies the design requirements and test methods for liquid hydrogen tank systems for land vehicles in order to ensure a sufficient level of protection against fire and explosion.

ISO 17268[77] Refueling connectors for land vehicles powered by gaseous hydrogen define the design, safety and performance characteristics of refueling connectors for land vehicles powered by gaseous hydrogen.

ISO 22734:2019[78] and its near-term successor ISO 22734-1[79] specify the design, safety, qualification testing and documentation requirements for modular or factory-fitted hydrogen gas production devices or systems (hereinafter referred to as "hydrogen generators") that produce hydrogen by electrochemical reactions.

The analysis of Lithuanian legislation governing hydrogen refueling infrastructure construction and operation, as detailed in Chapter 2.1.1, reveals the need for significant regulatory enhancement. Current legal acts and technical regulations require updates to establish a clear regulatory framework that will facilitate the development and expansion of hydrogen refueling infrastructure across Lithuania. Based on the analysis findings, we recommend a comprehensive revision of relevant legislation and technical regulations to incorporate specific provisions for hydrogen infrastructure. These updates should include clear definitions of

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[72] https://www.en-standard.eu/bs-en-17127-2024-outdoor-hydrogen-refueling-points-dispensing-gaseous-hydrogen-and-incorporating-filling-protocols/
[73] https://www.iso.org/standard/89206.html
[74] https://www.iso.org/standard/69539.html
[75] https://www.iso.org/standard/23570.html
[76] https://www.iso.org/standard/39892.html
[77] https://www.iso.org/standard/68442.html
[78] https://www.iso.org/standard/69212.html
[79] https://www.iso.org/standard/82766.html

hydrogen-related concepts and establish corresponding regulatory guidelines. This regulatory modernization will create the necessary legal foundation to support Lithuania's expanding hydrogen refueling network.

The Regulations for the Operation of Service Stations[80] require substantial amendments to incorporate hydrogen as an alternative fuel. Key sections of the regulations need updating to address essential aspects of hydrogen infrastructure, including safety distance requirements, vehicle refueling protocols, equipment maintenance procedures, and hydrogen-specific fire safety measures. A significant regulatory gap exists in Lithuania's construction standards, as there are no specific normative technical documents governing the construction of hydrogen refueling stations and associated infrastructure. This absence of dedicated construction regulations creates uncertainty for infrastructure development projects. For this reason, project promoters are obliged to comply with Article 9 of the Law on Construction of the Republic of Lithuania[81], which allows for the application of international, European organizations and foreign normative technical construction documents.

The Law on Energy of the Republic of Lithuania[82] does not contain any provisions regulating hydrogen trading or related infrastructure. The Law only mentions petrol stations and trade in petroleum products, excluding hydrogen from the scope of regulation. The Rules for the Protection of Fuel Column Hardware and Software against Tampering with Readings, approved by the Minister of Economy of the Republic of Lithuania in 2015[83], do not contain any provisions for hydrogen refueling equipment. These rules should be updated to include safeguards for hydrogen refueling devices to ensure correct and safe sale of hydrogen at service stations. The Fuel Refueling Column Sealing Procedures Regulation[84] does not contain any provisions relating to hydrogen or hydrogen refueling equipment. This document needs to be updated to include hydrogen technologies to ensure proper metrological control of hydrogen refueling equipment.

The rules on integrated pollution prevention and control permits approved by the Minister of the Environment of the Republic of Lithuania[85] , and Annex 1 thereto, do not mention the notion of hydrogen. This document should be updated to include hydrogen and related technologies to ensure adequate environmental regulation of hydrogen production and use. The Basic Requirements for Fire Safety approved by the Fire and Rescue Department[86] lack specific provisions related to hydrogen fire safety. This document needs to be updated to include specific requirements for hydrogen infrastructure and use to ensure adequate fire safety in the context of hydrogen technology.

Point 6.2 of the Law on Environmental Impact Assessment of Planned Economic Activities of the Republic of Lithuania[87] requires that an environmental impact assessment be carried out to produce hydrogen, irrespective of the size of the plant or station. This requirement is

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80 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/0ded6160859a11eaa51db668f0092944
81 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.26250/BRDVRhmTFA?jfwid=u2mdik6y
82 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.167899/BxwiqMcIUi?jfwid=u2mdikf5
83 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.342132/LIAZQkAoZk?jfwid=u2mdikls
84 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/379ee420f84511e5bf4ee4a6d3cdb874/AlzTGaUaCL?jfwid=q8i88ls5l
85 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.453692/GVivYajyHQ?jfwid=10novr8we3
86 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/0fd21952597f11ee8e3cc6ee348ebf6d?jfwid=z0x9j62v1
87 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.30545/VmZtlqmdEb?jfwid=10novr8wpk

disproportionate for small-scale projects, such as 3 MW local production stations, as they are subject to the same in-depth analysis as large 200 MW industrial projects.

The Law on Special Land Use Conditions of the Republic of Lithuania[88] does not have clear provisions on hydrogen storage protection zones, and hydrogen refueling infrastructure is inappropriately subject to the requirements of a sanitary zone, notwithstanding the fact that hydrogen refueling does not cause air pollution. This law should be reviewed and updated to consider the specific features of hydrogen technology and its real environmental impact.

5.2.5. Analysis of possible financial instruments for the development of hydrogen refueling infrastructure

This chapter analyses the various financial instruments for the development of hydrogen refueling infrastructure in the EU and Lithuania. It provides an overview of the main EU funding programs and funds, such as the Connecting Europe Facility (CEF-T), the European Regional Development Fund, the Cohesion Fund, the Interreg program, the Just Transition Fund, the InvestEU program, which supports sustainable investment, innovation and job creation in Europe, the Innovation Fund, the Modernization Fund, and the European Instrument for Recovery and Resilience Program (EERP).[89] These financial instruments are designed to support a wide range of projects related to the development of hydrogen technology, the creation of infrastructure and the promotion of sustainable mobility.

The Connecting Europe Facility (CEF-T[90]) finances projects that modernize infrastructure and remove bottlenecks while promoting sustainable and innovative mobility solutions. It supports hydrogen refueling infrastructure for all modes of transport (road, rail, etc., maritime, inland waterways).

The European Regional Development Fund (ERDF) and the Cohesion Fund aim to reduce regional disparities and promote sustainable development in the European Union[91] . A large part of its budget - 30% - is dedicated to climate change objectives. While it does not support nuclear energy or fossil fuel infrastructure development, it can support projects such as smart energy systems, green infrastructure and sustainable urban mobility. In particular, the ERDF can support the improvement of energy efficiency in housing and the development of renewable energy sources in accordance with the sustainability criteria set out in Directive (EU) 2018/2001, thereby indirectly supporting hydrogen and renewable fuels infrastructure projects.

Interreg[92] promotes cross-border, transnational and interregional cooperation within the EU and in neighboring countries. It aims to address common challenges and unlock the potential for growth in border regions, through projects promoting integrated territorial development and resource efficiency. Although there is no specific budget for hydrogen, Interreg can support projects related to the transition to clean energy and sustainable mobility, indirectly by helping to install hydrogen refueling stations in border regions. In addition, Interreg helps to access

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88 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/46c841f290cf11e98a8298567570d639/zYHNiDwXeZ?jfwid=10novr8wvl

89 https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/recovery-and-resilience-facility_en

90 https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/connecting-europe-facility-transport_en

91 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021R1058

92 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021R1059

funding from a variety of sources, such as Interreg can also help to secure funding from other sources, such as the ERDF, which can create attractive funding packages for hydrogen projects.

The Just Transition Fund[93] is one of the EU's cohesion policy funds. It aims to mitigate the socio-economic impacts of the transition to climate neutrality in the most affected regions, given their dependence on fossil fuels or carbon-intensive industries.

The InvestEU[94] program provides a budget guarantee to the European Investment Bank Group and selected implementing partners to facilitate access to finance for riskier projects, including renewable hydrogen production, on-site storage, refueling infrastructure for transport, and critical infrastructure to support hydrogen deployment. The EU Innovation Fund[95] is one of the world's largest funding programs for demonstrating innovative low-carbon technologies included in Annex 1 of the EU Emissions Trading Scheme (ETS) Directive. The Fund finances demonstration projects for the innovative, low-carbon, renewable and hydrogen production and use (production, storage and utilization) of hydrogen at pre-commercial and commercial scales, with a view to bringing it to the market.

The EU's Modernization Fund[96] is a fund that supports the transition to climate neutrality in 10 low-income EU countries (including Lithuania) by modernizing their energy systems and improving energy efficiency. The Fund supports investments in energy storage, renewable energy production and use, and energy networks. From a hydrogen perspective, the Modernization Fund could finance as priority investments, among others, activities such as the generation and use of electricity from renewable sources, the production of green hydrogen from renewable electricity, the use of hydrogen produced from RES, and transport powered by hydrogen from RES (e.g. hydrogen trains, trucks or cars).

The European Hydrogen Bank is a financial instrument to accelerate the development of the hydrogen value chain in Europe[97] . The Bank operates through four main axes. The local strand focuses on the development of the market for hydrogen production in the European Economic Area, where financial support is provided for the hydrogen produced. On the international front, a specific mechanism is being developed to attract imports of renewable hydrogen to the European Union market. In the area of transparency and coordination, the Bank will ensure transparent management of information on market and infrastructure developments and will implement a pilot mechanism to collect and share information on hydrogen demand and supply. In the area of coordination of support instruments, the aim will be to improve the coordination of support instruments between the European Union and its Member States, providing technical assistance and investment support both within and outside the European Union. In addition, the Green Hydrogen Partnership Program will help to promote the import of renewable hydrogen from outside the European Union. The scheme is designed to ensure a level playing field

[93] https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/just-transition-fund_en
[94] https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/investeu_en
[95] https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/innovation-fund_en
[96] https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/modernisation-fund_en
[97] https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/european-hydrogen-bank_en#ref-4-pillars-of-action

between European Union production and imports from third countries, thus creating an efficient and competitive hydrogen market.

The Economic Recovery and Resilience Facility (ERRF)[98] is at the heart of the EU's Economic Recovery Plan. It aims to make the EU economy and society more sustainable by supporting the green and digital transition. Funding for projects depends on what each EU country has included in its plan.

The EU encourages Member States to develop and implement national hydrogen strategies, providing detailed guidance on how to develop the potential of hydrogen technologies. These strategies should cover the entire hydrogen value chain, from production to end-use in a wide range of sectors, including transport and industry. Particular attention shall be paid to innovative projects demonstrating and deploying new technologies. The European Commission encourages Member States to invest in two main projects:

- "The European Flagship PowerUp is an ambitious project dedicated to clean technology and renewable energy. It aims to create 6 GW of electrolysis capacity and produce and transport 1 million tonnes of renewable hydrogen at EU level by 2025. This project is a key step towards a large-scale hydrogen production and supply infrastructure.
- "European Flagship Recharge and Refuel focuses on sustainable transport and charging infrastructure. The project includes the development of a network of hydrogen refueling stations to make Europe's cities and regions cleaner. This will not only contribute to the decarbonization of the transport sector, but also accelerate the overall industrial transition towards sustainable technologies.

[98] https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/recovery-and-resilience-facility_en

1. Annex: Evaluation of the use of the tools and instruments developed in the HyTruck Project's first work package for the development of hydrogen refueling infrastructure

This chapter evaluates the effectiveness of select tools and instruments developed through HyTruck project deliverables D.1.1, D.1.3, and D.1.4 for hydrogen refueling infrastructure development. Due to their incomplete status during the study preparation, tools from deliverable D.1.2 were not included in this assessment.

The digital spatial planning tool from HyTruck D.1.1 was designed to optimize the placement of new hydrogen fueling stations along the existing TEN-T network. Its primary objective is to ensure refueling stations are positioned at maximum intervals of 200 kilometers while meeting operational requirements. The tool employs a regional data grid for suitability analysis, evaluating potential locations based on accessibility, cost-effectiveness, and compatibility with existing infrastructure and landscapes. By integrating current hydrogen and alternative fuel stations into the transport network, the tool uses algorithms and available data to strategically select new locations. This approach aims to minimize the number of new refueling points while maximizing network efficiency and coverage area. The tool strives to ensure comprehensive coverage without creating redundant fueling points. Additional details about this digital spatial planning tool are available in section 2.4.

Several limitations affect the tool's efficiency and accuracy. Users have reported interpretation challenges stemming from inconsistent area boundaries and color coding when adjusting scale. The tool demonstrates low sensitivity in identifying large areas suitable for hydrogen refueling points and fails to automatically exclude unsuitable locations, such as water bodies, from proposed green zones. Furthermore, it lacks integration with AFIR-mandated corridors. To enhance the tool's functionality, four key improvements are recommended: refined scaling capabilities, increased location sensitivity, automated exclusion of unsuitable areas, and integration of AFIR requirements, particularly regarding the 10-kilometer corridors to the TEN-T network.

The Technical Standards Catalogue developed in HyTruck D.1.3 provides comprehensive guidance for hydrogen refueling stations serving heavy transport in the Baltic Sea Region. The catalogue addresses several critical aspects of hydrogen infrastructure development and implementation. The catalogue first documents current technological standards for hydrogen refueling station construction in the Baltic Sea Region, encompassing hydrogen storage technologies, pressure levels, and refueling nozzle specifications across different countries. It then examines the operational range and technological advancement of hydrogen refueling systems for heavy-duty vehicles, offering detailed insights into future technical specifications for both refueling processes and onboard storage systems. A significant portion of the catalogue focuses on hauler requirements regarding hydrogen technology adoption in heavy-duty vehicles, particularly emphasizing essential parameters such as refueling duration and station specifications. The document also provides a thorough analysis of European legal frameworks governing technical standards for refueling stations, including legislative requirements and guidelines specified in the AFIR Regulation. The catalogue concludes with comprehensive guidance on technological considerations for heavy-duty hydrogen refueling across Europe.

The catalogue serves as an effective reference document for technical standards in hydrogen refueling, offering a well-structured overview of current requirements and specifications. While the content is sufficiently comprehensive, two key recommendations would enhance its utility: implementing regular updates to incorporate emerging standards and technological advancements and developing an interactive digital platform that enables efficient navigation and filtering of standards based on specific criteria. Additionally, incorporating a new section on implementation of best practices and practical guidance would further increase the catalogue's value for stakeholders.

The guidelines "Building up Hydrogen Refueling Stations in the Baltic Sea Region"[99], developed by the Reiner Lemone Institut as part of HyTruck project D1.4 for public authorities, cover a wide range of important topics. The document presents a systematic analysis beginning with fundamental hydrogen requirements and refueling station needs, followed by environmental considerations. It then addresses hydrogen demand specifically related to truck transportation and distribution logistics. The guidelines proceed to detail technical specifications for hydrogen refueling stations, including essential equipment requirements. Economic considerations and greenhouse gas emissions analysis form integral components of the framework. Critical operational aspects, including site selection criteria, permitting requirements, and applicable regulations, receive thorough examination. The document emphasizes the strategic importance of stakeholder networking and cooperation. Supporting methodologies for implementing the discussed concepts are provided in the comprehensive appendix. These guidelines establish a robust foundation for standardizing approaches to hydrogen refueling station spatial development. To maintain and enhance their utility, three key improvements are recommended: First, implement regular updates to reflect evolving technological advances and regulatory changes. Second, incorporate additional case studies and practical examples from diverse Baltic Sea Region countries to provide real-world context. Third, develop an interactive digital version to enhance accessibility and enable customization for different implementation scenarios.

[99] https://reiner-lemoine-institut.de/en/study-of-the-regional-strategy-for-the-development-of-hydrogen-filling-stations-for-fuel-cell-trucks-in-the-baltic-sea-region-hytruck/