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INTRODUCTION

The use of hydrogen in Lithuania's industrial landscape is presently concentrated in a few key sectors, primarily those with large-scale energy or chemical processes where hydrogen serves as a feedstock or process gas. Based on national and sectoral analysis, the primary hydrogen-consuming sectors are the fertiliser and chemical industries, oil refining, and, to a minimal extent, the energy and transportation sectors. Together, these industries form the foundation of Lithuania's current hydrogen demand, while also representing the most promising avenues for future low-carbon hydrogen integration (Figure 1).

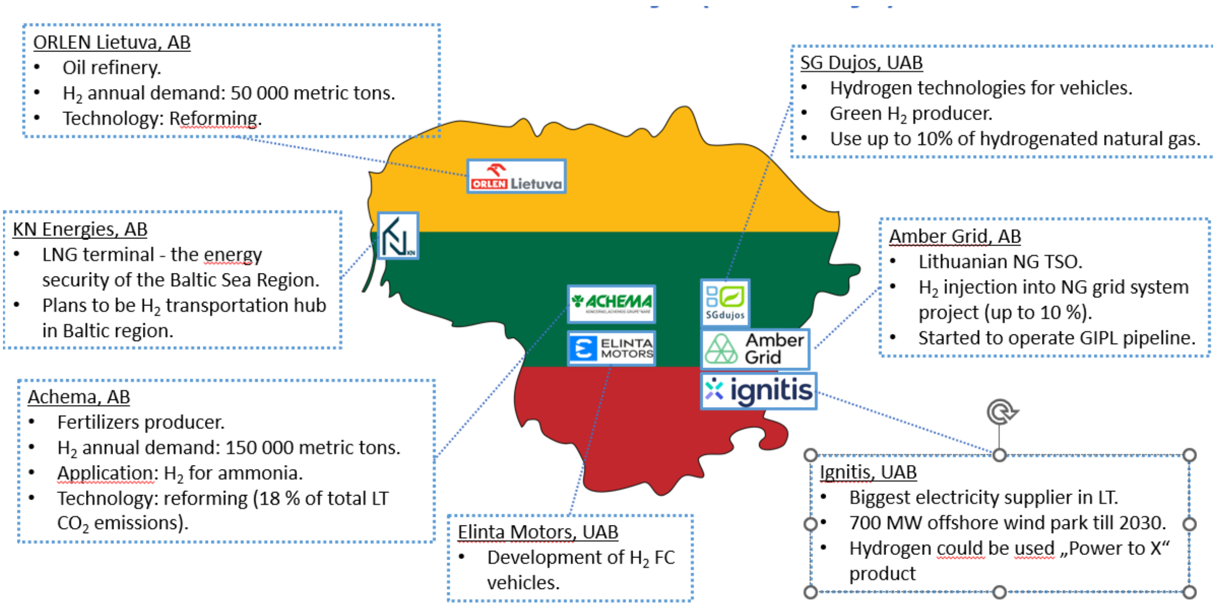

Figure 1. The leading producers and users of hydrogen in Lithuania

Fertiliser and Chemical Industry

The largest single user of hydrogen in Lithuania is AB Achema (https://www.achema.lt/en/), a nitrogen-fertiliser and chemical producer located in Jonava. The company accounts for a significant portion of the country's hydrogen consumption, utilising hydrogen as an intermediate in ammonia synthesis and downstream chemical processes, including the production of urea and methanol. Achema emitted approximately 1.36 million tons of CO_2 in 2023, with the majority of emissions originating from steam methane reforming (SMR), the conventional process for generating hydrogen from natural gas. This hydrogen is then used internally in the Haber–Bosch process for the production of ammonia.

The fertiliser sector remains central to any hydrogen-transition scenario in Lithuania, given its structural dependence on hydrogen as a feedstock rather than as an energy carrier. Substituting fossil-derived hydrogen with green hydrogen produced via electrolysis could substantially reduce industrial emissions in this sector. However, the *Lithuanian Hydrogen Sector Development Roadmap and the Action Plan*[1] highlight several barriers, including high production costs (currently between €5 and € 10 per kg H_2) and limited renewable electricity capacity for electrolysis. Future pilot projects, which integrate renewable energy sources with on-site electrolysers, are considered essential to decarbonise this industry.

Oil Refining and Petrochemicals

The oil-refining sector, centred around ORLEN Lietuva (https://www.orlenlietuva.lt/EN/Pages/default.aspx) in Mažeikiai (Telšiai County), is the second-largest

[1] https://enmin.lrv.lt/uploads/enmin/documents/files/AmberGrid_Lithuania_Hydrogen_Strategy_v2_0_110522.pdf

consumer of hydrogen in Lithuania. The refinery primarily utilises hydrogen for its hydrocracking and desulfurization processes, which are essential for producing cleaner fuels. ORLEN Lietuva's annual CO_2 emissions reached approximately 1.65 million tons in 2023, mainly resulting from the on-site hydrogen production via steam reforming of natural gas.

ORLEN Lietuva is currently exploring the transition to integrating green hydrogen, aligning with the European Union's climate-neutrality targets. The *Orlen project document*[2] confirms the company's ongoing development of a green-hydrogen production facility in Mažeikiai, intended to partially substitute fossil hydrogen with renewable-based hydrogen in refining operations. This initiative is aligned with the broader corporate strategy of the ORLEN Group to establish hydrogen hubs across Central Europe, including Poland, the Czech Republic, and Lithuania. The Lithuanian component aims to link local hydrogen production with emerging hydrogen-transport corridors through the Baltic Sea and Klaipėda Port, potentially serving maritime and mobility applications in the future.

Methods of hydrogen production (today and planned; based on Lithuanian Hydrogen Sector Development *Roadmap* and the Action Plan for its Implementation[3])

Today ("grey"): On-site steam-methane reforming (SMR) integrated in ammonia and refinery complexes.

Near-term "green": Electrolysis powered by domestic renewables is the core planning assumption for Lithuanian supply through 2030; the Roadmap's infrastructure and cost modelling explicitly assumes domestic electrolytic production in all cases.

Optional "blue": The Roadmap suggests Lithuania could benchmark green-hydrogen costs against blue hydrogen using imported LNG with CO_2 shipped to North Sea storage, and proposes assessing this pathway alongside green hydrogen within longer-term system planning.

By 2030, the Roadmap sets concrete goals of 300–350 MW of electrolysers and ~30,000 tonnes per annum (kt p.a.) of low-carbon hydrogen, alongside enabling 15% of domestic ammonia production to be produced with low-carbon hydrogen.

Methods of storage (plans for short- and long-duration, based on Lithuanian Hydrogen Sector Development *Roadmap* and the Action Plan for its Implementation)

Hydrogen is stored for industrial use at Achema and Orlen Lietuva for internal purposes. The discussed storage options and costs with a view to Lithuanian suitability for short and long duration:

Pressurised tanks/containers: Mature, rapid response, **best for small-scale, short-duration** buffers; typical single-vessel capacity ~1.1 t H_2. Expected to be the leading short-term solution for early projects.
Ammonia storage: Mature infrastructure and deep local know-how (ammonia-centric industry). The analysis expects ammonia to be the dominant vector for long-term/seasonal storage and for import/export, often without reconversion to hydrogen at the point of final use (where ammonia itself is the product or fuel).
Geological storage: Salt caverns are the lowest-cost at large scale where geology allows, while depleted fields are less mature for H_2 and face microbiological/chemical challenges; the Roadmap calls for dedicated geological assessments in Lithuania/neighbours before committing.

[2] https://projects.3seas.eu/projects/posejdon-%28orlen-neptun%29-%2B-hyfly2-%28pkn-orlen%29-hydrogen-connection-from-the-offshore-wind-farms-in-lithuania-latvia-and-estonia-to-the-orlens-refinery-in-mazeikiai-%28proposed-by-orlen-neptun-and-pkn-orlen-orlen-group-poland%29
[3] https://enmin.lrv.lt/uploads/enmin/documents/files/AmberGrid_Lithuania_Hydrogen_Strategy_v2_0_110522.pdf

Liquefied hydrogen storage is technically possible, but it is generally more costly due to the need for cryogenic conditions.

Overall, the strategy assumes a mix of one day of short-term storage and seasonal storage growing from ~7 days (2030) to ~20–25 days by 2040–2050, with ammonia leveraged to provide system flexibility given its central role in Lithuania's hydrogen economy.

On-going projects

The Port of Klaipėda is currently developing Lithuania's first green hydrogen production and refuelling station[4567], a pioneering initiative that also marks the first such facility in the entire Baltic region. The project, implemented by the Klaipėda State Seaport Authority (https://portofklaipeda.lt/en/port/), aims to establish a small-scale but strategically important hydrogen production plant within the port area, designed to support the decarbonization of maritime and land-based transport. The facility will produce approximately 127 tons of green hydrogen per year using a proton exchange membrane (PEM) electrolyser with a power requirement of around 2.25 to 3 MW. The entire system will be housed in a containerised unit occupying roughly 0.06 to 0.08 hectares, reflecting an efficient and modular design suited to port environments.

Image: Klaipeda Port hydrogen project.

The total investment in the project amounts to approximately €12 million, of which around €5.7 to €6 million comes from the European Union's Recovery and Resilience Facility under the NextGenerationEU programme. Construction permits were issued in 2025, and factory testing of the electrolyser equipment was successfully completed later that year, marking a significant milestone. Full

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[4] https://fuelcellsworks.com/2025/05/30/energy-innovation/klaipeda-port-to-launch-baltic-region-s-first-green-hydrogen-facility

[5] https://hydrogeneurope.eu/klaipeda-port-to-launch-baltic-regions-first-green-hydrogen-facility/

[6] https://processautomation.imiplc.com/news-and-insights/company-news/imi-to-equip-port-of-klaipeda-with-regions-first-green-hydrogen-electrolyser

[7] https://www.mtgroup.lt/mt-group-to-build-the-first-hydrogen-station-in-the-baltic-states-within-the-klaipeda-port/

commissioning and the start of hydrogen production are planned for 2026. The EPC contractor for the project is MT Group, a Lithuanian engineering company with experience in energy infrastructure. The electrolyser technology is provided by the Italian firm IMI Critical Engineering.

Once operational, the Klaipėda hydrogen station will serve multiple purposes. It will supply clean hydrogen fuel for port service vessels, including a hydrogen-powered vessel under development, as well as for various types of port and city transportation, such as trucks, buses, and other heavy-duty vehicles. The facility is also expected to support future bunkering activities for ships and contribute to the development of a broader hydrogen logistics and distribution chain in Lithuania. In the long term, the project could connect with rail and maritime transport systems, enhancing regional connectivity and promoting sustainable logistics solutions.

Strategically, the project aligns closely with Lithuania's national energy and climate goals. The Lithuanian Hydrogen Strategy[8] foresees the deployment of about 1.3 gigawatts of electrolysis capacity by 2030 and the establishment of at least five hydrogen refuelling stations, including one in a maritime setting. The Klaipėda initiative, therefore, represents a key early milestone in building the national hydrogen ecosystem and gaining practical experience in the production, handling, and use of green hydrogen. The project is also consistent with the European Commission's objectives for renewable fuels of non-biological origin (RFNBOs) and contributes to strengthening energy independence in the region.

Despite its relatively modest scale, the Klaipėda hydrogen project is of high strategic importance. It demonstrates the feasibility of green hydrogen production in Lithuania, helps establish technical and regulatory standards, and serves as a pilot case for larger future investments. The project also faces certain challenges typical for early-stage hydrogen infrastructure, such as high production costs, safety and regulatory complexity, and uncertainties regarding market demand from transport and industrial users. Nevertheless, as the first functional hydrogen production and refuelling station in the Baltic States, it will provide a vital foundation for future expansion of hydrogen technologies, encourage private investment, and support Lithuania's transition toward a low-carbon economy.

AB Miesto Gijos is implementing one of Lithuania's first urban green hydrogen production projects, located in Vilnius[9][10][11][12]. The initiative, titled "Green Hydrogen Plant in Vilnius", aims to integrate renewable hydrogen production into the city's energy and transport systems, supporting national decarbonisation and EU climate goals. The project foresees the installation of a 3 MW electrolyser on the territory of Miesto Gijos (https://miestogijos.lt/en/), which operates within the Vilnius district heating system. The hydrogen produced will be generated from renewable electricity, primarily sourced from local and regional renewable energy installations.

[8] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/10783411040711ef8e4be9fad87afa59?jfwid=jrf97qh9r
[9] https://miestogijos.lt/en/zaliasis-vandenilis/
[10] https://miestogijos.lt/en/2025/05/vilniuje-iskils-zaliojo-vandenilio-gamykla-pasirasyta-statybu-sutartis/
[11] https://miestogijos.lt/en/finansuoti-projektai/
[12] https://www.mtgroup.lt/3mw-green-hydrogen-plant-to-rise-in-vilnius/

Picture: Lithuania's first urban green hydrogen production projects, located in Vilnius.

According to the company's official information, the facility will produce approximately 1.14 million cubic metres of green hydrogen per year, corresponding to an annual output of roughly 100 tonnes of hydrogen. This clean fuel will be used initially to power up to 16 hydrogen buses planned for Vilnius' public transport fleet, with the possibility of expanding its application to other heavy-duty transport or industrial users in later phases. The project is also expected to contribute to the decarbonisation of Vilnius' municipal energy infrastructure by supporting cleaner mobility solutions and offering a demonstration model for hydrogen integration in urban contexts.

The total investment in the Vilnius hydrogen plant amounts to approximately €8.06 million, with around €5.64 million (or 70%) provided through European Union funding under the Recovery and Resilience Facility. The construction contract for the plant was signed in May 2025, and the facility is expected to become operational in 2026. The engineering, procurement, and construction (EPC) contractor for the project is MT Group, a Lithuanian company specialising in energy and infrastructure projects. The electrolyser technology, based on proton exchange membrane (PEM) technology, will enable flexible hydrogen production in line with fluctuating renewable energy supply.

Beyond its technical parameters, the project carries significant strategic importance. It represents Lithuania's move toward establishing a domestic hydrogen value chain, starting with small-scale but scalable projects closely linked to real consumption points. The Vilnius hydrogen plant supports national targets defined in the Lithuanian Hydrogen Strategy, which envisions the development of over 1 GW of electrolysis capacity by 2030 and a gradual rollout of hydrogen refuelling and production facilities across the country. In this context, the Miesto Gijos initiative complements similar efforts, such as the Klaipėda Port hydrogen station, by expanding hydrogen infrastructure inland and linking it to the decarbonisation of urban and public transport.

Overall, the Miesto Gijos Green Hydrogen Plant in Vilnius exemplifies a practical, city-level application of renewable hydrogen, integrating sustainable energy production, transportation transformation, and innovation. It is one of the first concrete steps in implementing Lithuania's hydrogen roadmap. It is expected to serve as a replicable model for other municipalities seeking to integrate green hydrogen into their energy transition pathways.

THE HYDROGEN MARKET IN DETAIL AND NUMBERS

Lithuania's hydrogen market today rests on two industrial pillars: ammonia and fertilisers, as well as oil refining. Green hydrogen is foreseen as the primary growth vector for the period up to 2030 and beyond. Strategy modelling (Figure 2), done by *the Ministry of Energy of the Republic of Lithuania, assumes early electrolyser deployment close to existing off-takers* (Jonava/Kaunas for fertilisers; the refinery in the north), followed by dedicated hydrogen pipelines in the 2030s and connection to a Baltic hydrogen backbone by ~2040.

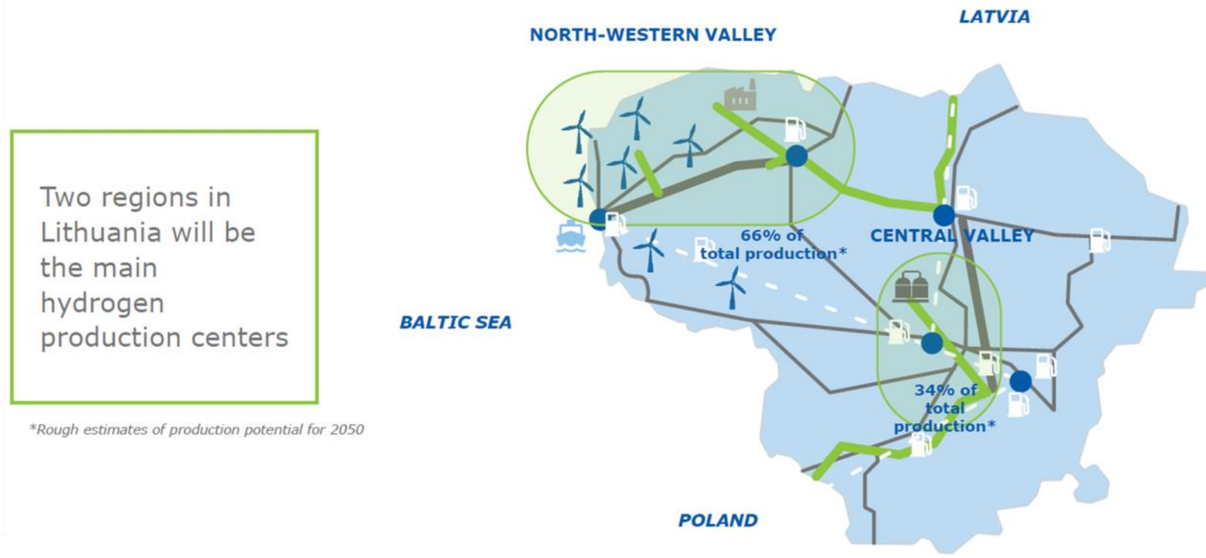

Figure 2. Hydrogen Valleys in Lithuania. *Source: Ministry of Energy of the Republic of Lithuania*

Market size vs. other European countries

Lithuania's 2030 supply target is 300–350 MW of electrolysers and ~30 kt/yr of low-carbon hydrogen, described as ~1% of the EU's 2030 electrolyser capacity and ~0.3% of EU hydrogen production – an "ambitious but appropriate" scale for serving proven domestic demand. Peer benchmarking in the Roadmap highlights that Lithuania's ambition per capita is credible, albeit smaller in absolute terms than those of large EU economies[13].

Production methods and CO_2 implications

- **"Grey" hydrogen (SMR)** is the current mode embedded in fertiliser and refinery complexes; it is carbon-intensive without capture. The Roadmap expects grey to persist into the 2040s while plants transition in steps to a low-carbon supply.
- **"Green" hydrogen (electrolysis)** is the core long-run supply in all Lithuanian modelling cases; it avoids process CO_2 and reduces commodity-price exposure, provided renewable power is available.
- **"Blue" hydrogen (SMR/ATR+CCS)** is treated as optional benchmarking – technically viable, but dependent on gas prices and CO_2 transport/storage; the Roadmap proposes

[13] https://enmin.lrv.lt/uploads/enmin/documents/files/AmberGrid_Lithuania_Hydrogen_Strategy_v2_0_110522.pdf

assessing imported LNG + CO_2 shipping to the North Sea as a cost benchmark rather than planning domestic CO_2 storage.

Price volatility of (grey) hydrogen

The Roadmap explicitly links the choice to prioritise domestic green hydrogen to reduce exposure to commodity price volatility and geopolitical risk – i.e., grey hydrogen costs swing with natural gas and CO_2 prices. Illustrative frames in the strategy compare green versus blue costs under volatile TTF (TTF stands for Title Transfer Facility, which is the main natural gas trading hub in the Netherlands and, by extension, the benchmark price for natural gas in Europe) gas (e.g., spot at approximately $33/MMBtu vs. forward at $11/MMBtu), highlighting why electrolysis can become competitive in high-gas-price regimes.

Application sectors in detail

The Roadmap sequences use cases by economics and policy pressure:

- **Fertilisers (Achema, Jonava)** as the anchor demand, moving in steps (e.g., ~15% low-carbon substitution by 2030) and using ammonia storage to provide system flexibility.
- **Oil refining** retains significant hydrogen needs for desulphurization/upgrading; switching trajectories depend on EU ETS/carbon prices and site-level upgrades.
- **Heavy-duty road transport (HGVs, buses)** scale as parity with diesel approaches; breakeven analyses show HGVs/buses among earlier transport adopters with rising carbon prices.
- **Flexible power** is considered later, mainly as part of Net Zero power system balancing; aviation and marine shift materially in the 2030s–2040s via e-kerosene and ammonia. Building heat and low-temperature process heat show limited roles compared to other EU states due to Lithuania’s biomass options.

Quantitatively, the Base-Case trajectory foresees ~26–30 kt/yr of low-carbon hydrogen around 2030, dominated by fertilisers, oil refining and early transport, rising thereafter with shipping/aviation.

Contribution of low-emission hydrogen in total production

Today’s market is predominantly grey (on-site reforming in fertilisers/refining). By 2030, the strategy sets a goal of ~30 kt/yr of low-carbon hydrogen and aims to enable around 15% of domestic ammonia output through low-carbon hydrogen, representing a minority share by 2030, which is expected to rise over time as plants retool. The Roadmap explicitly notes that grey production continues through staged replacements into the 2040s.

Infrastructure: electrolysers, HRSs, pipelines

- **Electrolysers**: current status “not present”**;** 300–350 MW by 2030 in the Base Case (up to ~1.2 GW in the High Case), requiring ~0.45–1.75 GW of accompanying renewables for 2030 and 2.9–8.3 GW by 2050. Early siting is near demand (Kaunas–Jonava), with later relocation toward renewable supply as dedicated H_2 pipelines emerge.
- **Hydrogen refuelling stations (HRS)**: current status “not present”; to meet EU TEN-T spacing (≤150 km), ~5 stations are needed nationally by 2030 (indicative siting along Vilnius–Kaunas–Klaipėda corridor and borders).
- **Pipelines**: current status “not present”; Amber Grid indicates parts of the existing gas network can be retrofitted; new segments will still be needed to connect fertiliser/refinery demand. In

the 2030s, dedicated H_2 lines become more economical at higher volumes, with Baltic/EU backbone integration around 2040 (Figure 3).

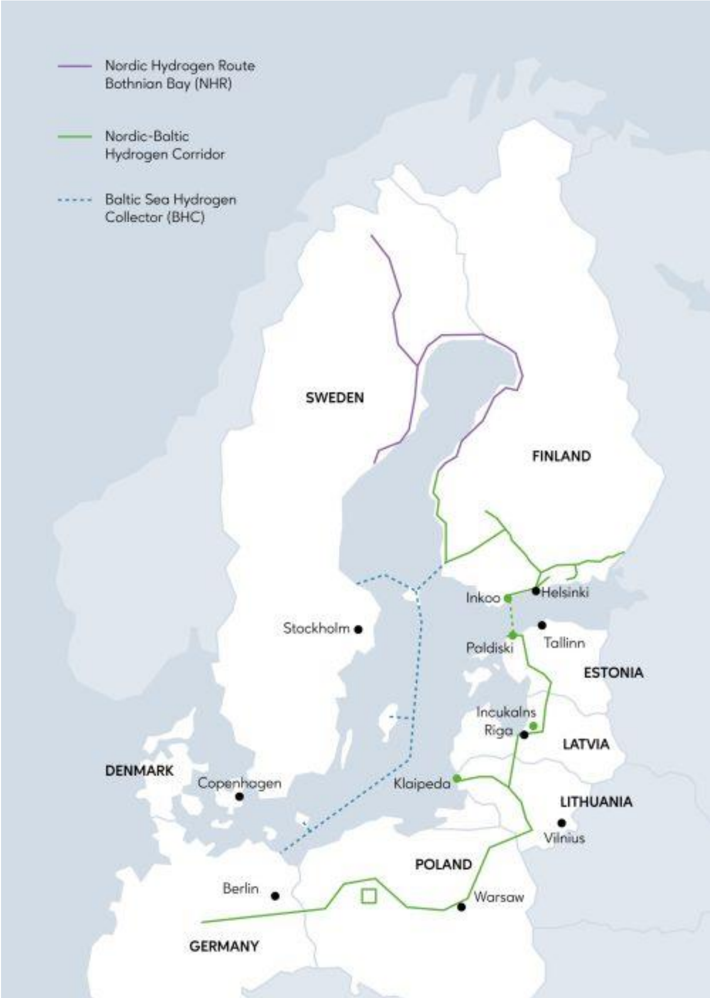

Figure 3. Hydrogen pipelines. *Source: Ministry of Energy of the Republic of Lithuania*

In summary, Hydrogen Market Snapshot – Lithuania (2025–2030 Outlook):

Metric	Lithuania	EU Context
Low-carbon H_2 target (2030)	~30 kt/year	~0.3% of EU production
Electrolyser capacity goal (2030)	300–350 MW	~1% of EU capacity
Main users today	Fertilisers (Achema), Refining (Orlen Lietuva)	Similar to other Baltic states
Main hubs	Jonava–Kaunas (fertiliser), Mažeikiai (refinery), Klaipėda (port)	2 anchor "hydrogen valleys"

DETERMINANTS OF THE DEVELOPMENT OF THE HYDROGEN ECONOMY

Lithuania's hydrogen economy is being shaped by a clear policy spine and a pragmatic sequencing of projects around existing industrial anchors. At the national level, the Lithuanian Hydrogen Sector Development Roadmap and Action Plan for its Implementation[14] sets the strategic logic: prioritise domestic, renewable-based hydrogen, scale around proven off takers (fertilisers, refining), and phase infrastructure from local pilots to dedicated hydrogen pipelines that connect into a Baltic hydrogen backbone by ~2040. This approach is explicitly tied to energy security (replacing natural gas and oil dependence), price-volatility shielding, and value-chain capture through R&D and skills development. In parallel, the National Energy Independence Strategy (NENS, 2024)[15] codifies ambition in numbers, targeting 1.3 GW of electrolysis and ~129 kt/year of green hydrogen by 2030, expanding to 8.5 GW and ~732 kt/year by 2050, with hydrogen and its derivatives positioned as an export base and a source of usable residual heat for district heating.

Regionally, Lithuania aligns its decarbonization pathway with the Baltic-wide infrastructure and EU fuels policy. The Roadmap envisions dedicated hydrogen transmission emerging in the 2030s and a physical connection to the EU/Baltic backbone by 2040, enabling cross-border balancing and trade. Complementing this, the ORLEN & S&P Global (2024)[16] Analysis frames Baltic RFNBO trajectories, highlighting tight supply-demand balances for Lithuania by 2030–35 under RED III requirements, underscoring the importance of domestic electrolytic build-out and import routes via the Baltic Sea for ensuring supply security. The latest plans of offshore wind energy projects are presented in Figure 4.

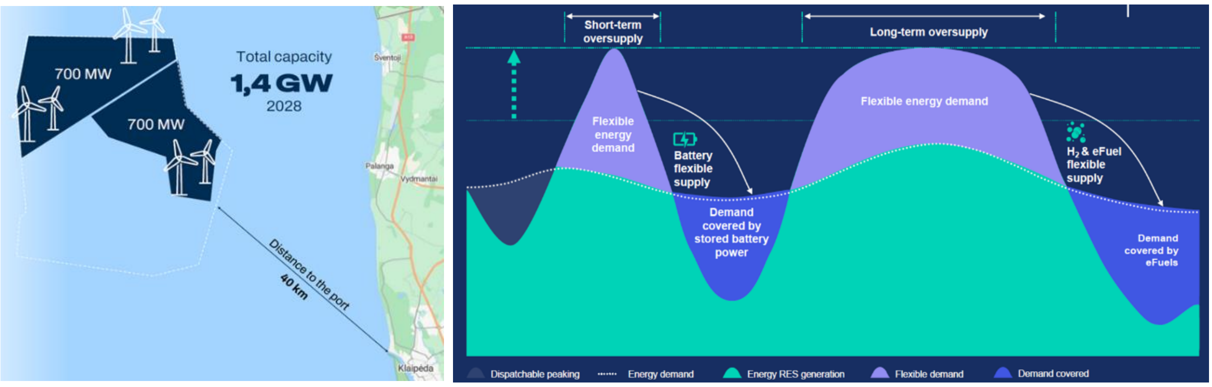

Figure 4. Short-term plans on offshore wind and possibilities to use oversupply for hydrogen production. *Source: Ignitis.*

Regarding the potential of renewables versus hydrogen output, the Roadmap concludes that current renewable energy expansion plans (approximately 7 GW combined onshore/offshore wind and solar) are sufficient to meet hydrogen demand through 2030, assuming competitive power prices for electrolysers (approximately €35–40/MWh). Thereafter, additional RES, network upgrades, cross-border cooperation, or off-grid/co-located schemes are needed as ambitions rise. The same analysis shows that by 2050, the Base Case requires ~2.9 GW of wind equivalent for hydrogen (with higher needs in the High Case), reinforcing the message that hydrogen scale-up is a power-system question as much as a fuel question.

[14] https://enmin.lrv.lt/uploads/enmin/documents/files/AmberGrid_Lithuania_Hydrogen_Strategy_v2_0_110522.pdf

[15] https://enmin.lrv.lt/public/canonical/1740735085/5963/NENS%202024-2.12_EN.pdf

[16] https://www.orlen.pl/content/dam/internet/orlen/pl/en/sustainable-development/transition-projects/hydrogen/Hydrogen-market-in-Poland-and-the-Baltics-until-2040.pdf

Production pathways are treated with realism. Grey hydrogen (SMR) remains embedded in fertilizer and refinery sites in the near term; green hydrogen (electrolysis) is the core national pathway in modelling and infrastructure costing; and blue hydrogen (SMR/ATR+CCS) is retained as a benchmark option feasible via LNG imports and CO_2 shipping to North Sea storage against which the economics of green hydrogen can be compared for major investment decisions. This combination of pathways allows Lithuania to progress projects now while preserving flexibility as costs and EU rules evolve.

Leaders and market makers coalesce around three groups. First, industrial anchor off-takers include fertiliser (Jonava) and the refinery (north-west), which stabilise early volumes and justify siting choices. The Roadmap explicitly clusters early demand in the Kaunas–Jonava and Klaipėda–Mažeikiai–Šiauliai/Panėvėžys corridors, evolving into "hydrogen valleys" that later interconnect. Second, system operators and state actors**:** Amber Grid and Litgrid are central to the pipeline-versus-wire planning and to the staged transmission build-out (pre-2030 pilots → 2030s dedicated lines → 2040 backbone); the government is tasked to stand up funding envelopes, CfD-like mechanisms, and an H_2 taskforce to accelerate permits and safety rules. Third, R&D and skills ecosystems**:** universities and innovation platforms in Vilnius, Kaunas and Klaipėda (with LNG/cryogenics know-how) are identified as enablers for component manufacturing and operations capability. At the same time, Klaipėda FEZ provides an industrialisation locus. The Roadmap estimates approximately €1 billion in public-private investment by 2030 in the Base Case, sequenced from pilots (buses, HGVs, HRS) to scale, and outlines fiscal levers (ETS-linked measures, fuel taxes, CfDs) to attract private capital.

As for applications, the development plan phases sectors by maturity and abatement value. Fertilizers lead (e.g., a first ~15% substitution of ammonia with low-carbon hydrogen by 2030, then higher shares as plant and grid upgrades land); refining follows policy and site-upgrade economics; municipal buses and HGV corridors are targeted for earlier adoption given total-cost-of-ownership convergence and TEN-T obligations; rail, marine and aviation enter through pilots and scale in the 2030s–40s as e-fuel economics improve. Uses in flexible power are reserved for later system balancing, while building heat and low-temperature process heat are likely niche due to Lithuania's biomass alternatives. The infrastructure logic mirrors this: electrolysers are initially located near demand, then migrate toward resources as dedicated H_2 pipelines become cheaper than reinforcing the power grid beyond ~50–100 kt/year flows; five hydrogen refuelling stations are expected to satisfy the ≤150 km TEN-T spacing by 2030.

A decisive strategic choice concerns long-duration storage. The Roadmap compares options and concludes that salt caverns are the lowest-cost large-volume, long-duration solution where geology permits, but recognises that Lithuania lacks proven cavern capacity today, so geological assessment is a to-do, and ammonia will likely serve as the dominant storage and import/export vector in the interim (often without reconversion). Pressurised tanks cover short-term buffers. The regional study adds that substantial cavern potential exists in Poland and Latvia, which could complement Lithuanian system needs via the Baltic backbone once established. In practice, this means planning for ammonia storage at Klaipėda (leveraging port logistics and chemical know-how) while scoping geological options and safety trade-offs against centralised ammonia inventories.

Taken together, the determinants of Lithuania's hydrogen economy are coherent and actionable: a national strategy that privileges domestic green hydrogen, quantified capacity targets (NENS), early industrial offtake to underwrite investment, renewables-system alignment that is adequate to 2030 but tight thereafter, sequenced networks culminating in a Baltic backbone, and a storage pathway that pragmatically uses ammonia now while assessing salt-cavern potential for the medium term. The result is a policy-anchored, industry-led expansion that can credibly move from pilots to a traded market node in the Baltic Sea region.

BARRIERS TO THE DEVELOPMENT OF THE HYDROGEN ECONOMY

Lithuania's hydrogen vision is coherent, but execution faces a stack of practical obstacles spanning regulation, economics, supply chains, environment, and infrastructure.

Regulatory and decision-making barriers

The Roadmap underscores that Lithuania will lean on the EU's emerging hydrogen market design (network codes, ENNOH, regulated TPA, blending rules) and on gas-sector governance—but many elements still require national transposition and rule-making, from certification/traceability of renewable and low-carbon hydrogen to rules for hydrogen transport on public roads and network injection. Health and safety, in particular, "may need action at the national level." The package also caps cross-border hydrogen blending at 5% from October 2025, which limits early "blending-led" routes to scale and pushes Lithuania toward dedicated offtake/pipeline solutions rather than relying on wide blending into the gas grid.

Beyond hydrogen-specific rules, there is clear regulatory fragmentation and certification multiplicity as a non-technical barrier for market integration and investment. Without mutual recognition, projects risk stranded value between producers, traders and off-takers. It is also worth highlighting the length and complexity of permitting for large industrial decarbonization chains (e.g., hydrogen coupled with CCUS logistics), where multiple EU and national frameworks (EIA, transport, storage, cross-border rules) must align, delaying FIDs and inflating development risk.

Economics: CAPEX, OPEX and price risk

On the supply side, the Roadmap's cost base shows electrolyser stacks account for ~60% of total electrolyser CAPEX, driven by expensive electrode/membrane materials; even with expected learning, the 2030 CAPEX remains material (c. €0.49–1.12 kW^{-1} across scenarios), and the economics hinge on low-cost renewable electricity (mid-30s €/MWh projected for onshore wind/solar by 2030–2050). These fundamentals make green hydrogen highly sensitive to financing conditions, power price volatility and utilisation factors.

On the demand side, the total cost of ownership remains above fossil comparators in transport and many industrial use cases, absent targeted instruments (e.g., CfDs on carbon or ammonia, mandates/procurement in mobility). It is worth noting that retail hydrogen prices are well above aspirational levels, highlighting the mismatch in pace across the value chain (producers, distributors, and users) as a brake on scaling.

Consistent with this, the Roadmap proposes CfDs and mandates as priority mechanisms to bridge the green premium for fertilisers, refining and heavy transport, while cautioning that public procurement alone cannot carry the market.

Infrastructure readiness and cost

Lithuania currently has no hydrogen refuelling stations; to meet EU TEN-T requirements (≤150 km spacing) it needs ~5 HRS by 2030, implying new capex and coordinated siting (Vilnius–Kaunas–Klaipėda corridor and borders).

For transmission, the Roadmap indicates no primary power-grid reinforcement is needed to meet the fertiliser sector's 2030 step, but the next demand phase (mid-2030s) would either strain the power network or require a first dedicated hydrogen pipeline. Comparative modelling shows that at larger volumes (50–100 kt p.a. and beyond) "pipe beats wire" on cost, pointing to a staged shift from local production near demand to dedicated H_2 pipelines and, by ~2040, linkage to a Baltic hydrogen backbone, all of which demand multi-year planning, permitting and finance.

At the distribution level, Lithuania's ~60% polyethylene gas grid may lower retrofit costs compared to all-metal systems, but this does not eliminate the need for standards on hydrogen quality, safety, and material compatibility to avoid embrittlement/fatigue risks.

Environmental aspects and social acceptance

Strategically, the Roadmap relies on ammonia as the dominant long-duration storage/import-export vector, leveraging Lithuania's fertiliser base. However, it explicitly flags high health and safety risks associated with large-scale ammonia storage compared with geological options, and calls for a national assessment of geological storage alternatives. The researchers also stress the EIA and permitting burden for complex chains, as well as the constraints from regional marine conventions (e.g., the Helsinki Convention, which prohibits sub-seabed CO_2 storage in the Baltic Sea), which shape feasible import/export or CCUS couplings. These factors can slow projects and increase community-acceptance hurdles unless they are proactively managed.

Critical raw materials (CRMs) for electrolysers

Supply risk for electrolyser components is a structural barrier in the 2020s. The Roadmap notes stack materials drive ~60% of electrolyser CAPEX today and anticipates cost declines only with new, less costly materials and economies of scale i.e., Lithuanian projects are exposed to global CRM availability and pricing until domestic/European manufacturing scales under EU industrial policy. This presents an investment risk for early movers and serves as a rationale for phased deployment and portfolio diversification in technologies.

Availability and cost of storage

For short-term buffers, pressurised tanks are mature but high-cost per tonne at scale; for seasonal and bulk storage, salt caverns are generally lowest-cost where geology permits, but Lithuania lacks proven cavern capacity today and must evaluate domestic and regional options. The Baltic study points to significant cavern potential in Latvia and Poland, suggesting a regional storage strategy tied to the Baltic backbone. In the interim, ammonia storage and logistics at Klaipėda provide a practical pathway (often without reconversion), but bring the safety/regulatory issues noted above.

Availability and cost of transport/import chains

Even where imports could be competitive, the regional analysis warns that long-distance ammonia or derivative logistics add emissions and cost (e.g., cracking losses), complicating RFNBO compliance and project economics; pipeline capacity may offer lower delivered costs, but construction by 2030 is challenging, and existing underground storage is primarily committed to natural gas. This again argues for phased domestic supply, early anchor off-takers, and ports/pipeline/rail investments prioritised for industrial end-uses rather than a premature, costly roll-out of automotive-grade distribution.

LEGAL CONDITIONS

European Union framework and its influence

EU policy now provides a clear – if still evolving – legal framework for hydrogen. The EU Hydrogen Strategy (2020) set a long-term vision (6 GW of electrolysers by 2024; 40 GW by 2030, with a priority for renewable hydrogen) and launched the European Clean Hydrogen Alliance to mobilise investment. This vision is operationalised through the Hydrogen & Decarbonised Gas Markets package, which adapts gas-market governance to accommodate hydrogen and complements the Fit for 55/RED III targets. For Lithuania, the package matters in five concrete ways: (1) it enables hydrogen network codes and an ENNOH-type governance; (2) it discourages new long-term natural-gas contracts after 2049, steering investment to low-carbon gases; (3) it sets a cross-border blending cap of 5% from October 2025, limiting reliance on blending as a scale-up tool; (4) it recognises "low-carbon hydrogen" (e.g., blue) if ≥70% GHG reduction is achieved; and (5) it introduces tariff incentives (e.g., 75% discounts on production and storage fees for renewable gases and zero fees at interconnection points), which de-risk early projects and tilt infrastructure toward hydrogen.

In parallel, RED III imposes binding RFNBO shares in industry (42% by 2030, 60% by 2035) and transport (≥1% by 2030), which the Baltic study uses to size hydrogen demand and shows why Lithuania faces deficits unless domestic supply and/or imports scale a direct regulatory pull for projects.

How EU law is influencing national rules

Lithuania's sectoral Roadmap explicitly or implicitly translates EU obligations into national tasks: establish a certification system for renewable/low-carbon hydrogen, prepare health & safety (H&S) and environmental planning norms across production, transport, storage and use, incorporate zero-emission HGV targets into the NECP and law to enable pilots, and develop primary support mechanisms (e.g., carbon CfDs) for ETS-exposed industries. These actions align national regulation with RED III/ETS and the gas package, and are sequenced to 2030.

More broadly, the Roadmap's policy review ties Lithuanian planning and 2030 goals to the EU Hydrogen Strategy, the new Gas Package, and Fit for 55/RED III proposals, and calls for integrated network planning (gas–power–hydrogen) in line with EU requirements on TYNDP and decommissioning.

National law: support for low-emission hydrogen and the value chain

On market design, the Roadmap assumes Lithuania will reuse gas-sector governance for hydrogen transmission, permitted under the EU package, including the option to assign hydrogen tasks to a dedicated TSO subject to unbundling/certification, and adopt negotiated third-party access for producer connections. The EU-level tariff discounts and interconnection zero fees are expected to be passed through, resulting in lower delivered costs for domestic projects.

On public finance, the same document outlines a ~€1 bn (2022–2030) investment need and maps EU/national sources (Innovation Fund, Modernization Fund, JTF, InvestEU, EIB loans), with CfDs, mandates and targeted procurement proposed to bridge green premiums in fertilisers, refining and heavy road transport i.e., to operationalise RED III targets in Lithuanian law and programmes.

On infrastructure, the plan anticipates no HRS today → ~5 by 2030 to meet TEN-T ≤150 km spacing, and a staged approach to dedicated hydrogen pipelines as volumes rise—legal work that will require standards, permits and safety rules at the national level.

Regulatory constraints and to-dos

Two legal constraints recur in your files. First, the 5% cross-border blending cap (from October 2025) curtails the use of general gas grids for early large-scale offtake, nudging Lithuania toward point-to-point supply, dedicated pipelines, or ammonia logistics. Second, while salt-cavern storage is identified as the lowest-cost large-volume option in the EU, Lithuania has no proven cavern capacity. The Roadmap, therefore, treats ammonia as the dominant long-duration storage and import/export vector for now and calls for a national geological assessment and safety regulation.

Where hydrogen policy intersects with CCUS, the feasibility study notes that CO_2 geological storage is currently forbidden by Lithuanian law, and recommends aligning with EU frameworks (CCS Directive 2009/31/EC) and international maritime regimes to enable CO_2 transport and offshore storage access critical for any blue hydrogen benchmarking pathway contemplated in the Roadmap.

What this means in practice (Lithuania-specific implications drawn from the sources)

- **Targets + pull:** RED III creates hard demand for renewable hydrogen in Lithuanian industry and transport; the Baltic study's quantification shows that without rapid domestic build-out and/or import arrangements via Klaipėda, Lithuania risks shortfalls against 2030–35 obligations.
- **Networks + tariffs:** The gas-package provisions (ENNOH, network codes, tariff discounts, interconnection fee waivers) provide the legal and economic basis to connect producers, plan hydrogen valleys, and ramp up transmission when volumes pass thresholds where "pipe beats wire."
- **Standards + certification:** National workstreams must deliver H&S rules, water-use planning for electrolysers, and certification/traceability consistent with EU RFNBO definitions – pre-conditions for bankable offtake and compliance.
- **Financing + instruments:** The Roadmap's CfDs/mandates proposals and mapped EU funds translate EU climate law into bankable support for Lithuanian plants and fleets, while keeping options open for blue hydrogen benchmarking (subject to CCUS legal alignment).

SUPPORT INSTRUMENTS FOR THE DEVELOPMENT OF A HYDROGEN ECONOMY

Lithuania's hydrogen policy architecture couples EU-level incentives with a national toolbox designed to *de-risk early volumes*, *close the green-premium gap* in anchor sectors (fertilisers, refining, heavy-duty transport) and *sequence infrastructure* from pilots to backbone. The Lithuanian Hydrogen Sector Development Roadmap & Action Plan is the core reference for instruments, volumes and funding mix to 2030, complemented by the NENS 2024 targets for the regional context.

1) Qualification of support instruments

The Roadmap proposes a layered mix of **market instruments**, **capital support**, and **regulatory price signals**:

- Contracts for Difference (CfDs) and mandates to underwrite low-carbon hydrogen use in fertilisers and refining and to accelerate HGVs/buses switching i.e., pay for verified emissions reduction or RFNBO compliance relative to fossil baselines. These are singled out as the *primary* scale-up tools for the second half of the decade.
- Capex co-funding for pilots and first-of-a-kind assets: electrolysers, HRS, hydrogen buses/HGVs, and the enabling works for hydrogen valleys (network connections, permitting). Early pilots are expected to carry a significant public cost share before transitioning to more competitive instruments (e.g., CfDs).
- EU tariff incentives from the Gas Markets package: 75% discounts on production and storage tariffs for renewable gases (incl. hydrogen) and zero fees at interconnection points, which lower

delivered costs for Lithuanian producers and shippers. National regulation is expected to allow negotiated third-party access for producer connections.

- Financial platforms and debt: structured use of EIB loans and EU financial instruments alongside grants to improve bankability of large industrial and infrastructure projects.

2) Level of subsidising/funding (documented amounts)

The Roadmap quantifies a ~€1.0 bn cumulative investment need for 2022–2030 in the Base Case (public + private), with an indicative public support envelope ≈€460 m (grants) and ≈€412 m (EIB loans) potentially accessible by 2030 across EU/national sources i.e., ~€0.87 bn of direct support and soft financing that can anchor the €0.99 bn investment plan.

Breakdown of uses within the ~€994 m investment plan illustrates where support is likely to land: fuel infrastructure (incl. storage) ~€530 m; electrolysers ~€240 m; HRS ~€74 m; OEM/consumption (buses, HGVs, rail) ~€159 m; plus smaller envelopes for renewables integration. This confirms the intent to fund both supply and demand sides, not just production.

3) Expected level of subsidising/funding (policy intent)

Looking forward, the same plan instructs the government to agree and legislate target levels of state co-funding and assemble a bid taskforce to maximise EU money, turning the above ranges into committed pipelines. It also calls for a policy group to choose the market-based mechanism (e.g., carbon CfDs, taxes) to scale hydrogen demand in industry and transport and to design the renewable power contracting model for electrolysers, all before large FIDs in the second half of the decade.

The NENS 2024 adds quantitative ambition, targeting 1.3 GW of electrolysis and ~129 kt/yr of green hydrogen by 2030, and states that to increase competitiveness, "separate funding measures need to be prepared" for hydrogen and its derivatives. This language signals a high expected support level consistent with CfDs/mandates and capex aid outlined in the Roadmap.

4) Planned support programmes (grant windows and instruments)

The Roadmap catalogues EU and national envelopes relevant to Lithuania's 2030 plan, including:

- Innovation Fund (grants for near-market demonstrations), Modernisation Fund, Horizon Europe, InvestEU, Just Transition Fund, Connecting Europe Facility, Recovery & Resilience Facility, and EU Structural Funds – with illustrative allocations adding up to ~€460 m grants and ~€412 m EIB loans that Lithuania could realistically mobilise by 2030.

- Smaller EU instruments helpful for preparation/roll-out – ELENA, LIFE (CET and Climate strands), I3 – with typical co-funding rates (e.g., ELENA up to 90% of development costs; LIFE ~60%; I3 up to ~70% for TRL6–9), intended to accelerate project development and de-risk first deployments.

At the national level, the Action Plan highlights pilot schemes (HGVs/HRS; hydrogen buses in the five largest cities), hydrogen valleys (Kaunas–Jonava; Klaipėda–north corridor), and the planning of the first dedicated H_2 pipeline – all of which are expected to draw on the EU/National mix outlined above.

5) How support is distributed (who gets what, and when)

The distribution logic is sequenced:

1. Pilots (now–mid-2020s): heavy capex grants for HRS, municipal buses, early HGV fleets, and MW-scale electrolysers colocated with off-takers. Grants cover a large share of first-of-a-kind CAPEX to prove operations and create demand signals.

2. Scale-up (late-2020s): CfDs/mandates take over as the main *operational* support to pull volumes in fertilisers/refining and to keep fleet TCO competitive; EIB loans/InvestEU complement grants for network and storage.
3. Networks (2030s): shift from electricity-grid reinforcement to dedicated hydrogen pipelines as volumes cross the 50–100 kt/yr threshold; EU tariff incentives (75%/0% rules) and cross-border provisions lower delivered costs and support Baltic backbone integration around 2040.

This distribution mirrors Lithuania's geography: Kaunas–Jonava (fertilisers) and Klaipėda–Mažeikiai–Šiauliai/Panėvėžys (refining/port, mobility corridors) as early hydrogen valleys, then network interconnection.

6) Why support is critical (regional compliance and deficits)

RED III's binding RFNBO shares create a hard demand pull; regional modelling shows that Lithuania faces a 2030–35 hydrogen deficit without rapid domestic supply and/or imports – hence *why* Lithuania's Roadmap front-loads grants and designs CfDs/mandates to meet obligations while infrastructure ramps.

HYDROGEN ECONOMY DEVELOPMENT SCENARIOS

Lithuania's hydrogen build-out will be paced by four practical indicators: renewable power headroom, compliance pressure from EU law (RFNBOs), the readiness of enabling assets (electrolysers, HRSs, pipelines, storage, early fleets), and the depth/credit of anchor off-takers. The documents you shared allow us to bound each element and then assemble three internally consistent scenarios to 2030.

Indicators that determine the pace of development

Renewables potential (power headroom for electrolysis)

The Roadmap assumes ~7 GW of renewables by 2030 (≈3.6 GW onshore wind, 1.4 GW offshore wind, 2 GW solar), yielding ~16.3 TWh available for hydrogen after serving other loads; by 2050, available headroom tightens to ~11.2 TWh unless additional RES or imports are developed. Competitiveness requires €35–40/MWh power to electrolysers.

A system study ("Lithuania 100") corroborates the RES step-up to 2030 (land wind to ~4.5 GW; solar to ~4.1 GW; offshore wind to ~1.4 GW) and quantifies electrolytic H_2 power demand in an optimistic 2030 case at ~6.5 TWh to produce ~130 kt H_2.

Execution of EU requirements (demand pull)

Under RED III, at least 42% of hydrogen used in industry by 2030 must be RFNBO (rising to 60% by 2035) and ≥1% of transport energy in 2030 must be RFNBOs. The Baltic study converts this into tonnage needs for the region and shows a tight balance for Lithuania unless domestic supply/imports scale.

Availability of enabling assets.

- Electrolysers: 2030 Base Case ~300–350 MW (≈~30 kt/yr low-carbon H_2); up to ~1.2 GW in a High case. Associated RES needs are ~450–1,750 MW in 2030.
- Pipelines: pilots feasible via the existing electricity & gas network in the 2020s; dedicated H_2 pipelines become economic in the 2030s, with Baltic/EU backbone around 2040.
- Storage: ammonia is the dominant long-duration/storage and trade vector (near-term), with short-term buffers via pressurised tanks; geological H_2 options need assessment.

- HRSs & fleets: to meet TEN-T ≤150 km spacing, Lithuania needs ~5 HRS by 2030; Roadmap flags 50–100 H_2-HGVs by mid-2020s and buses in 5 cities as early adopters.

Off-takers (industrial anchors)

Early demand clusters around fertilisers (Jonava) and the refinery (north-west); a first hydrogen valley is foreseen around Kaunas–Jonava, with a second around Klaipėda/Mažeikiai, later linked by pipelines.

Three scenarios to 2030

The scenarios below align with your sources' ranges and assumptions. They differ by RES deliverability, policy execution, and asset timing.

1) Optimistic (fast alignment of policy, RES and anchor projects)

What happens:

- Electrolysers reach ~1.0–1.3 GW by 2030 (consistent with the upper bound of Roadmap "High" and the NENS direction of travel). Green H_2 output ~100–130 kt/yr supported by ~6–7 TWh of power to electrolysis (Lithuania 100 optimistic).
- HRS network (≥5 stations) complete on TEN-T; buses deployed in 5 major cities; >100 HGVs in operation; first dedicated H_2 spur scoped/consented linking Jonava–Kaunas assets, with port-side ammonia logistics in Klaipėda.
- RFNBO compliance is met domestically in priority sectors (fertilisers share, refinery pilots, early mobility), avoiding a 2030 deficit.

Why it holds: RES additions are delivered on time; cheap power contracts (≈approximately €35–40/MWh) are available; support instruments (CfDs/mandates, grants) are executed early; permitting is predictable.

Risks: Tight OEM/CRM supply chains; grid bottlenecks if pipeline timing slips.

2) Neutral (Roadmap Base Case)

What happens:

- Electrolysers ~300–350 MW; low-carbon H_2 ~26–30 kt/yr; ~15% of ammonia enabled by low-carbon H_2; HRS = ~5; 50–100 HGVs; buses in 5 cities. Seasonal storage provided by ammonia; no major pipeline yet (electric grid carries early growth).
- RES headroom is sufficient through 2030; further ambition deferred pending additional RES/network upgrades.
- EU obligations: industry and transport RFNBO shares are largely met in priority sites, with the remainder managed via scheduling and (if needed) modest imports.

Why it holds: This is the "ambitious but appropriate" path sized to proven offtake and domestic RES trajectory.

Risks: Any slippage in bus/HGV procurement or HRS siting squeezes the transport RFNBO slice.

3) Pessimistic (delays in RES, permits and support execution)

What happens:

- Electrolysers ≤300 MW; fertiliser conversion 0–10% by 2030 (Roadmap "Low" allows 0% if funds or OEM capacity are delayed); low-carbon H_2 ≈15–20 kt/yr; HRS ≤3; pilots remain small-scale and geographically fragmented.

- Pipelines deferred; ammonia storage/logistics still the main long-duration option; greater reliance on grey H_2 persists in industry.
- EU obligations: Lithuania faces a RFNBO compliance gap and must rely more on imports/credits or accept penalties.

Why it happens: grid constraints, slow siting for HRS, support measures not finalised, OEM supply chain bottlenecks, and higher power prices than the €35–40/MWh needed for competitive electrolysis.

RECOMMENDATIONS

Lithuania can accelerate its hydrogen economy by sequencing policy, power, projects and pipes around a bankable anchor offtake, while de-risking capital through clear regulation and long-term contracts.

Activities to accelerate development

1) Lock in low-cost renewable power for electrolysis.

Electrolyser OPEX is dominated by electricity; competitiveness hinges on sustained €35–40/MWh-class power to electrolysers and high utilisation. The Roadmap assumes dedicated RES tied to electrolysers and shows that each 1 MW of electrolysis needs ~1.4–1.6 MW of RES (mostly wind). Prioritise long-term RES contracting (direct PPAs or hybrids with flexibility) to deliver predictable input costs and lower WACC.

2) Move first with bankable anchor projects and "hydrogen valleys".

Concentrate early build-out where demand is proven: Kaunas–Jonava (fertiliser) and Klaipėda–Mažeikiai–Šiauliai/Panėvėžys (refinery/port). Stage 1 (pre-2030) focuses on on-site/near-site electrolysers and local distribution; Stage 2 (2030s) adds the first dedicated H_2 pipeline once the next demand phase materialises; Stage 3 (~2040) links into a Baltic hydrogen backbone. This sequence avoids overbuilding the power grid and matches infrastructure to volume.

3) Deliver the minimum refuelling backbone early.

To meet TEN-T spacing, plan and commission ≈5 hydrogen refuelling stations by 2030 along the Vilnius–Kaunas–Klaipėda corridor and borders, aligned with municipal bus conversions and early HGV pilots. Treat these as programmatic deployments (standardised design, batch procurement) to compress timelines and unit costs.

4) Choose storage pragmatically: ammonia now, geology assessed in parallel

Use ammonia as the dominant long-duration storage and import/export vector this decade (often without reconversion), while short-term buffers rely on pressurised tanks. In parallel, commission geoscience assessments and regional options for salt cavern storage (notably in Latvia and Poland, where potential is identified) to support scale beyond 2030.

5) Tighten the legal spine for cross-border carbon management (blue benchmarking & CCUS links).

Even if national policy prioritises green hydrogen, the Feasibility Study recommends aligning CO_2 transportation law (full, accurate CCS Directive transposition; mode-specific CO_2 transport rules) and ratifying international maritime instruments (London Protocol amendments) to enable export of captured CO_2. This improves strategic optionality for industrial decarbonization and future benchmarking.

6) Industrialise cost down: standardisation and modular delivery

Given that electrolyser stacks account for ~60% of CAPEX, standardise specifications, aggregate demand, and run technology-neutral tenders (PEM/alkaline) to capture OEM learning effects and reduce integration costs. Pair with EIB debt and government-backed long-term offtake contracts to lower financing spreads.

7) Plan networks on "pipe beats wire" economics at scale

Roadmap comparisons indicate that for 2050 needs, pipeline CAPEX is approximately twice as cheap as powerline CAPEX to transport equivalent energy for hydrogen value chains. Begin corridor safeguarding and permitting now so that a first dedicated line can follow the next demand tranche in the mid-2030s.

Actions to mitigate investment risks

1. Power price & utilization risk → long-term contracting + operational flexibility.

Use government-backed 10–15-year contracts (e.g., CfD-like) for renewable power to electrolysers to reduce WACC (as assumed in the Roadmap). Complement with dispatch optimisation (avoid peak prices) to improve effective input cost.

2. Technology & supply-chain risk (CRMs, OEM slots): phased, diversified procurement.

Mitigate stack/CRM exposure by (i) phasing capacity into tranches, (ii) dual-sourcing technologies (alkaline and PEM), and (iii) standardising balance-of-plant to enable competitive bidding. Reserve OEM slots early and leverage EIB/InvestEU to backstop supply schedules.

3. Market & offtake risk: anchor contracts and mandates where abatement is highest.

Prioritise fertilisers and refining with long-term offtake (volume and quality) and consider CfDs/mandates to bridge the green premium in these ETS-exposed sectors. Couple mobility support with municipal procurement (buses) and early HGV corridors to stabilise station throughput. Regional analyses show RED III compliance pressure; firming domestic offtake avoids deficits.

4. Infrastructure timing risk: "no-regrets" sequencing and corridor safeguarding.

Defer expensive transmission choices until volumes justify them: start with on-site/near-site production, then trunk H_2 pipelines as demand crosses thresholds, with route protection and permitting advanced early to avoid bottlenecks. The Roadmap's staged build (pre-2030 → 2030s → 2040 backbone) should be embedded in spatial plans.

5. Storage & safety risk: dual-track storage strategy with robust H&S.

Rely on ammonia for seasonal storage/import-export in the 2020s while conducting a geological storage programme (domestic assessment + regional caverns access) and strengthening H&S/EIA regimes around large ammonia inventories and port logistics.

6. Legal/regulatory risk: complete and clarify frameworks for CO_2 and hydrogen.

Implement precise CCS Directive transposition (definitions, dispute resolution for transport networks), dedicated CO_2 transport rules (pipeline/maritime/rail/road), and align with international law (London Protocol) to enable cross-border CO_2 shipping from Klaipėda – critical given the prohibition of domestic geological storage in NENS 2024.

7. Delivered-cost risk for logistics: choose the right vector per use-case.

Minimise reconversion penalties by using ammonia directly where feasible; where hydrogen is needed at scale inland, use pipelines rather than long logistics chains (trucks/rail) once volumes justify. The regional study also underscores the role of salt-cavern hubs (Latvia/Poland) in stabilising supply for refineries/ammonia plants.

8. Development & permitting risk → programmatic delivery with standard designs.

Batch HRS and electrolyser deployments using repeatable designs and pre-agreed technical standards; establish one-stop permitting for hydrogen/RES/hubs to compress timelines and reduce soft costs that inflate LCOH. The LCOH study confirms how quickly electricity and soft-costs dominate economics.

Strengthen the Research and Development Activities on Hydrogen in Lithuania

Lithuania's hydrogen R&D ecosystem is anchored in a network of strong academic and applied-science institutions led by the Lithuanian Energy Institute (LEI), with complementary expertise at Kaunas University of Technology (KTU), Vilnius University (VU), Vilnius Gediminas Technical University (VILNIUSTECH), and Vytautas Magnus University (VMU). Together, they form a coherent research and innovation landscape that encompasses the entire hydrogen value chain, from materials science and electrochemical conversion to combustion applications and socio-economic research (Figure 5).

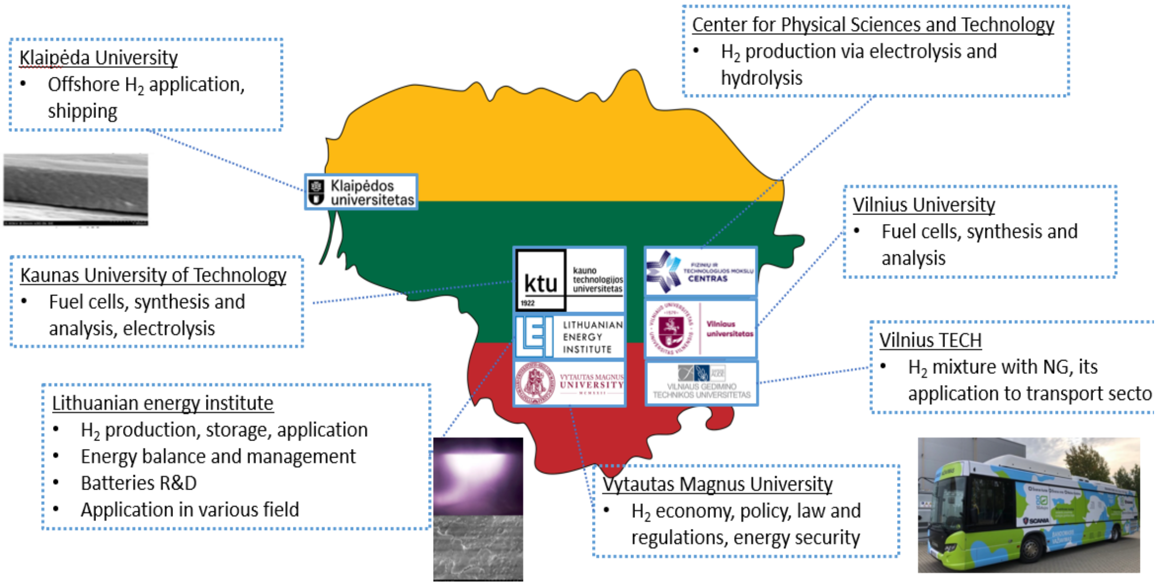

Figure 5. R&D activities on hydrogen in Lithuania.

Lithuanian Energy Institute (LEI)

Founded in 1956 and now a member of RTO Lithuania, LEI is the country's principal applied-energy research organisation. Its Centre for Hydrogen Energy Technologies leads experimental work on hydrogen generation, storage and synthetic-fuel synthesis. Notable projects include:

- Hydrogen generation via aluminium and magnesium hydride hydrolysis (patent PCT/IB2018/0522123), enabling on-demand hydrogen production from Al + H_2O reactions.
- Metal hydride research (Mg_2NiH_4, MgH_2–Ni–MgH_2 layered systems) for solid-state storage, smart windows and catalytic CO_2 methanation.
- LEI participates in 26 H2020 projects, including coordination roles in EURATOM and Clean-Energy clusters, and is active in Horizon Europe proposals (11 in CL5). It also contributes to the BALTICSEAH₂ cross-border Hydrogen Valley (2023–2029), which targets 48 500 t H_2 per year by 2030 across six industrial use cases (methanol, ammonia, chemicals, plastics, refining).

Kaunas University of Technology (KTU)

KTU focuses on materials and electrochemistry for Solid Oxide and Proton Conducting Fuel Cells (SOFC/PCFC). Its long-running "ProFC" programme (2012–2022) developed multifunctional thin-film nanocomposites and patented ion-conductive, catalytically active membranes (LT 6354 B, 2017). Current Horizon-linked projects explore mass-transfer and catalytic processes in single-chamber SOFCs, strengthening Lithuania's role in high-temperature fuel-cell research.

Vilnius University (VU)

The Nanoionics Laboratory investigates oxygen, proton, lithium, and sodium transport in solid electrolytes and develops superionic ceramics for SOFCs, solid-state batteries, and gas sensors. Its international publication record (e.g., *Electrochimica Acta 2018, 2020; Solid State Ionics 2019*) positions VU among Europe's advanced materials hubs for electrochemical devices.

Vilnius Gediminas Technical University (VILNIUSTECH)

The Faculty of Transport Engineering conducts modelling and experimental research on CNG/H_2 blends in spark-ignition engines. A sophisticated test bench (Nissan HR16DE engine, AVL instrumentation) enables optimization of combustion efficiency and emissions, providing applied insights into the transitional hydrogen mobility pathway.

Vytautas Magnus University (VMU)

VMU complements the technical R&D with social science and legal studies on the integration of renewable-energy prosumers, energy-justice theory and energy-security assessment. Its Energy Security Research Centre builds evaluation methodologies for the Baltic region, while the Law Faculty analyses EU-level regulatory compatibility for hydrogen and renewables.

Integration and Outlook

Lithuania's hydrogen R&D spans the full TRL 1–9 spectrum – from LEI's fundamental materials synthesis and reaction kinetics to VILNIUSTECH's engine trials and LEI's planned demonstration site. Cross-institutional cooperation, especially under BALTICSEAH$_2$, connects national laboratories to European industrial consortia. Despite its modest scale, the country's research base is diversified and internationally networked, positioning Lithuania as an emerging Baltic centre for hydrogen materials, solid-oxide technologies, and sustainable mobility integration.