Lithuanian Hydrogen Sector Development Roadmap and the Action Plan for its Implementation

Market Appraisal

AmberGrid EPSOG

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Country hydrogen strategy analogue 1: UK

UK hydrogen strategy: overview

The Hydrogen Strategy was published on the 17th April 2021, with the first progress report expected in early 2022

Energy resource and demand context

- **Supply**: In 2020, around 50% of the 98 GW of installed power capacity and 43% of power generation was renewables (wind, solar, biomass, hydropower). Gas is the primary fuel used for thermal power as coal has been declining rapidly and will will be phased out of electricity by 2025. New power builds include increased renewables, nuclear, gas, and gas with CCS facilities. Heating is largely provided through domestic gas boilers, with limited district heating. Transport relies on diesel and LPG with a small but increasing number of HGVs using CNG. Vehicle electrification is in its infancy, but 55% of vehicles are predicted to be electrified or hybrid by 2030 – when there is a ban on the sale of new petrol/diesel cars
- **Demand**: Since 2005 demand has been decreasing due to energy efficiency and declining industry, however with the increased electrification of transport and heating this is expected to rise- Baringa IP predicts that it will increase from 330TWh in 2020 to 480TWh in 2050. The economy is heavily geared towards the services sector, however there is some industry demand
- **Import/export:** The UK has been a net importer of electricity since 2010, with net imports of 7.6 TWh. Gas is primarily imported via pipeline from Norway but also shipped LNG from North America, while over 90% of crude oil demand is produced domestically in the North Sea

Targeted domestic use cases

- Targeted hydrogen fuelled domestic use-cases include: **Buses, HGVs, SAF (Sustainable aviation fuel), shipping, CHP, CCGTs, Hydrogen boilers, industrial fuel switching, oil refining & chemicals, buildings.** For passenger vehicles electrification is expected to dominate. However, for larger vehicles (such as heavy duty transport) hydrogen is expected to play a leading role – no specific targets have been set in relation to this, but phase out of sales of non zero-emission vans are from 2030, medium HGVs from 2035 and the heaviest HGVs from 2040. Rail decarbonisation is expected to take place primarily through electrification – with 38% of the track already electrified- with some battery and hydrogen input. The UK government have yet to commit to a decision on hydrogen in heating decarbonisation – it is expected in 2026. However, the UK's focus is expected to be primarily heat pump based – with a target of 600,000 new heat pumps installed per year by 2028.
- In the UK **10-27 TWh of hydrogen is currently produced**, predominantly for the petrochemical industry centred on the North Eastern Coast
- Specific **transport and heating hydrogen trials are already underway**. In 2023 there will be a trial of hydrogen power boilers, and the initiation of hydrogen transport hubs – e.g. Teesside and the Orkney Islands. Currently these are isolated neighbourhood trials in pilot phases

Approach to supply and infrastructure

- The UK is targeting a **'twin-track' approach, pursuing developments in both blue and green hydrogen**. Blue hydrogen projects are being planned within several CCUS clusters located around several existing heavy industry clusters, predominantly in the North of England and in Scotland. Four of such CCUS clusters are planned for before 2030. Green hydrogen coupled with abundant onshore and offshore wind resource is expected to play a role, though no preferred business model has been set out yet. Roll out may begin earlier in Scotland where onshore and offshore wind is abundant and transmission of electricity down to South of England is heavily constrained
- Pipeline transmission is in pilot testing. There is currently Health and Safety testing to assess the potential for 20 percent hydrogen blending into the gas network. A decision is to be made in 2023 about the technical, economic and safety potential of hydrogen blending

Import / export plans

- The UK **does not plan to import any hydrogen**, and aims to instead invest in internal production
- In the future, the UK **has signalled intent to export**, but has not set concrete targets surrounding this

Sources: [Uk Hydrogen Strategy, UK Heat and Buildings policy, UK Decarbonising Trasnport review, Baringa IP,

UK's hydrogen roadmap

The UK has high level qualitative goals

	Today	by 2025	By 2030	2035+
Production	Small scale electrolytic production	Large-scale CCUS enabled production in at least one location; electrolytic production increasing in scale	Several large-scale CCUS-enabled projects & several large-scale electrolytic projects	Increasing scale and range of production – e.g. nuclear, biomass
Use	Some transport (buses, early HGV, rail and aviation trials); industry demonstrations; neighborhood heat trial	Industry applications; transport (HGV, rail & shipping trials); village heat trial; blending (tbc)	Wide use in industry; power generation & flexibility; transport (HGVs, shipping); heat pilot town (tbc)	Full range of end users incl. steel; power system; greater shipping & aviation; potential gas grid conversion
Distribution	Direct pipeline, co-location, trucked (non-pipeline), onsite uses	Dedicated small-scale cluster pipeline network; expanded trucking and small-scale storage	Large cluster networks; large-scale storage; integration with gas networks	Regional or national networks & large scale storage integrated with CCUS, gas & electricity networks
Key actions & milestones	• **Launch NZHF early 2022** • **Phase 1 CCUS cluster decision 2021** • **Finalise low carbon hydrogen standard 2022** • **Finalise business model 2022** • **Heat neighbourhood trial 2023** • **Value for money case for blending Q3 2022**	• **Aiming for 1GW production capacity 2025** • **At least 2 CCUS clusters by 2025** • **Heat village trial 2025** • **Hydrogen heating decision by 2026** • **Decision on HGVs mid-2020s** • *Blue LCOH €52/MWh, green LCOH €94/MWh*	• **5 GW production capacity 2030** • **4 CCUS clusters by 2030** • *Pilot hydrogen town by 2030, pending heating decision* • *40GW offshore wind by 2030* • *9,000 jobs, €760 million GVA and €3.4 billion of private co-investment* • *42 TWh low carbon hydrogen* • *Blue LCOH €54/ MWh, green LCOH €74/MWh*	• **Sixth carbon budget** • *Could support 100,000 jobs & €11 billion GVA to the UK economy by 2050* • *250-460 TWh of low-carbon hydrogen by 2050* • *By 2050 blue LCOH €56/MWh, green LCOH €60/MWh*

LEGEND: **bold = target**, *italics = ambition*

Sources: UK Hydrogen Strategy; BEIS Hydrogen Production Costs 2021 Annex]

UK's Hydrogen regulation plan summary

UK is prioritising setting standards for hydrogen 'green-ness' and safety, with use-case specific regulation to follow

Category of regulation	Description	Status / timeframe
Production / supply	Rules for traceability of feedstock and certification of hydrogen as a green or partially green fuel	Early 2022
	Regulation of carbon capture and storage / blue hydrogen production	Early 2022
	Interventions to phase out carbon intensive hydrogen and transition to low carbon production methods	Call to evidence 2022
	Regulations of electrolyser production facilities	ISO 22734:2019
Transmission, distribution, and storage	Regulation of gaseous and liquid hydrogen transport on public roads	No plan
	Regulation of hydrogen injection in transmission and distribution networks	2023 decision
	Update of regulations for handling and storage of dangerous cargo in port areas	No plan
	Safety regulations for bottled hydrogen containers and bulk hydrogen tanks, and cryogenic storage	ISO under development
	Update regulation on the storage of dangerous substances to include gaseous and liquid hydrogen	Early 2022
Use case / point of use	Regulation of gaseous hydrogen use in industrial machinery and vehicles	Currently consulting
	Regulation of technical, construction and safety requirements for FCEVs	ISO 13985:2006
	Safety recommendations for emergencies and accidents concerning FCEVs	Consultation to start 2022
	Regulation of hydrogen vehicles repair and maintenance workshops	Consultation to start 2022
	Safety recommendation for gaseous and liquid hydrogen vehicle parking garages	ISO 13984:1999
	Regulation of gaseous hydrogen use in domestic appliances	Ongoing
	Update the regulation of health and environmental requirements in places of work for hydrogen	No plan
	Requirements for use in shipping as a fuel	2030, ISO/AWI 11326
	Requirements for use in aviation as a fuel / SAF alternatives	Published 2021
	Requirements for the combustion of hydrogen in boilers and furnaces	2026 consultation

Sources: ISO database, UK Hydrogen strategy

UK direct subsidy interventions (1 of 2)

The UK is funding through lots of dedicated small pots – for specific technological solutions

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
Net Zero Innovation Portfolio	Commercial	€840 million	Decarbonisation	Hydrogen innovation is one of the ten key priority areas in this portfolio – this feeds into future competitions
Carbon Capture and Storage Infrastructure Fund	Commercial	€840 million	CCUS technology	This is relevant for the UK prioritization of blue hydrogen as an approach to mass rollout of hydrogen
Phase 2 Industrial Energy Transformation Fund	Commercial	€265 million	Industrial energy consumption	Grant funding to support fuel switching technologies, inc. low carbon hydrogen
Zero Emission Bus Regional Areas (ZEBRA)	Commercial	€230 million	Public transport	Funding to help local transport authorities to purchase over 4,000 new zero-emission buses for city councils, either HFC or BEV & surrounding infrastructure
Net Zero Hydrogen Fund (NZHF)	Commercial	€200 million	Production facilities for low carbon hydrogen	Applies to co-investment opportunities, launching in 2022
Longer Duration Energy Storage Demonstration Competition	Pre-commercial	€57 million	Storage	Accelerate commercialisation of innovative longer duration energy storage projects
Low Carbon Hydrogen Supply 2 competition	Research & Development	€51 million	Supply & Storage	This aims to develop novel hydrogen supply solutions for a growing hydrogen economy, including storage solutions

Sources: UK Hydrogen Strategy

UK direct subsidy interventions (2 of 2)

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
Industrial Fuel Switching Competition 2	Pre-commercial	€46 million	Industrial fuel switching technology	Provides 100% funding for pre-commercial solutions. TRL 4-7
Red Diesel Replacement Competition	Pre-commercial	€34 million	Off-road machinery fuel switching technologies	Innovative technologies which support the switching of Non-Road Mobile Machinery from red diesel fuel. TRL 4+
Clean Maritime Demonstration Competition (CMDC)	Research & development	€19 million	Decarbonising marine transport	To accelerate the design of zero-emission marine vessels in the UK
HGV trials	Pre-commercial	€17 million	Heavy duty zero emission transport	Supported investigative trials for the feasibility of hydrogen long haul heavy road vehicles & comparison with battery electric vehicles
Green Fuels, Green Skies competition	Research & development	€13 million	Sustainable Aviation Fuels (SAF)	Production of a first-of-its-kind SAF plant in the UK
Hydrogen Transport Hub support	Commercial	€6.6 million	Hydrogen transport hubs	€2.5 million for Tees Valley, €4 million for Holyhead, Wales

Sources: UK Hydrogen Strategy

UK incentive based interventions

The UK has a strong history of RES roll out through incentivising innovation

Incentive name	Type	Budget + horizon	Applies to	Further details
Supplier Revenue certainty mechanism	Tbd – incentivising the production and use of low carbon hydrogen through the provision of ongoing revenue support	Contracts to be allocated Q1 2023	Tbd by government	3 options under consideration: fixed price, fixed premium and variable premium
UK Emissions Trading Scheme (UK ETS)	Cap and trade similar to EU ETS but with an additional support payment	Cap set to keep decreasing up to 2050	Energy intensive industries, the power generation sector and aviation	Potential expansion of to transport and domestic heating sectors is being considered
Renewable Transport Fuels Obligation (RTFO) certificates	Obligation on fuel suppliers to supply a percentage of fuel from RES, with the option to meet targets through: • Producing biofuels • Purchasing certificates (RTFCs) from other producers • Paying the Buy-out	Currently 0.5% RTFC mandate, increasing to 12.4% in 2032 Buy out price currently up to €5.9 / kg H2	Applied to all renewable fuels including biodiesels. Affects transport (road, aviation and marine) and NRMM	Blue and green hydrogen receive double RTFC support as 'Development' stage fuels

Sources: [Renewable Transport Fuel Obligation - GOV.UK (www.gov.uk), http://www.greengas.org.uk/governance/scheme-rules]

UK key projects and partnerships

Large scale blue and green hydrogen projects proposed but not financially closed

Project name	Proposed COD	Overview	Key figures	Partners involved
Orkney Islands – 'Hydrogen Islands'	2016	The Orkney Islands seek to become the global exemplar on green hydrogen integration. This portfolio of linked projects (Surf 'n' Turf, BIG HIT, DUAL port, HYDIME, HYSEAS III, HyFLYER) have combined to roll out iterations of hydrogen infrastructure, starting with electrolysers and storage, branching out to a whole integrated system, including Hydrogen powered ferries and aviation	• 1 hydrogen ferry operational • First-of-its-kind seafarer hydrogen training • 20 HFC vehicles • Heat in 2 buildings • €70 million total budget	Local Energy Scotland, Local Energy Challenge Fund, EU FCH-JU, EU Interreg North Sea Programme, Innovate UK, UKRI – Industrial strategy Fund, BEIS, Aerospace Technology Institute, Zeroavia
ITM Power – electrolytic Hydrogen Production	2023	Based in Sheffield, ITM Power are a world-leading manufacturer of PEM electrolysers, a technology for hydrogen production from water. The company's new Gigafactory is the world's largest electrolyser factory with a 1GW per annum capacity to produce renewable hydrogen for transport, heat and chemicals	• Largest Electrolyser factory in the world • 1GW per annum capacity	Gigastack project – funded by BEIS, working with Ørsted, Phillips 66 Limited and Element Energy
H100 Fife Neighbourhood trial	2023	This project will deliver the world's first hydrogen-to-homes gas network in 2023. The trial will provide hydrogen to 300 homes for heating and cooking on an opt-in basis, switching from natural gas. The hydrogen used in these trials will be produced locally from offshore wind power	• 300 homes • First-of-its-kind dedicated network	SGN, GDN, Cadent, NGN, WWU, Ofgem and the Scottish Governemnt
Whitelee Green Hydrogen	2023	ITM power to provide up to 8 tonnes of hydrogen a day, this uses renewable electricity from Whitelee Windfarm, and stores it to then be used by public buses in Edinburgh and Glasgow	• €7.9 million • 225 HFC buses • 20 MW electrolyser	ITM power, BOC, ScottishPower
Blue Hydrogen – Northern Endurance CCUS cluster	2023	Led by oil and gas majors this project aims to create an offshore carbon dioxide transport and storage network, and develop a large-scale blue hydrogen production plant that will connect to and decarbonize industrial sites through the Humber region	• Reduce Britain's industrial cluster CO2 emissions by 50%	BP, Shell, Eni, Total and Equinor, BEIS, National Grid
HyGreen Teesside	2025 (confirmation in 2023)	BP plans to set up a large-scale green hydrogen production plant in northeast England, generated from wind, water and solar energy	• 60MW electrolysis by 2025 • 500MW by 2030	BP

Sources: IEA, press articles

UK summary learnings for Lithuania

Although UK is more gas-led and more blue-focused, it offers a playbook of what a transport-based incentive would look like and will have a strong wind-to-hydrogen coupling similar to Lithuania

	Observation on UK	Observation for Lithuania
Energy supply and demand mix	▲ *The UK is **considerably more dependent on natural gas** than Lithuania, particularly for home heating, with biomass featuring much less. The UK is also primarily a service based economy but does possess **several industrial clusters where CCS infrastructure is planned** and some hydrogen economy for feedstock already exists.*	▲ *This combined with proximity to North Sea geology suitable for sequestration means the environment is better set for blue hydrogen compared to Lithuania,* ▲ *However, the large storage potential for the North Sea means in the longer term there is an opportunity to ship hydrogen to Norway or Denmark. Government de-risking will be required to achieve this due to long value chain involved*
	▲ *UK does however have a **similar renewable power trajectory, focused on onshore and offshore wind** with capacity to expand offshore wind production to feed electrolysers.*	▲ ***Business models for linking wind to hydrogen have not yet been established but should be monitored closely***
Ambition, targets and pathway	▲ *UK holds similarly ambitious power sector Net Zero by 2035 target, and the trajectory for wind deployment is clear. However a roadmap for flexible power is less clear and planned gas-CCS projects do not necessarily reconcile with net-zero-by-2035 target. Although close monitoring of gas-CCS for power is required*	▲ *Although close monitoring of gas-CCS for power is required, **Lithuania should be wary of it as an option for power preferred over hydrogen-to-power** for providing power flexibility in this context. Unlike UK it's gas fired power does not sit close to the industrial emitter in need of CCS: Orlen refinery. Hence ability to develop CCUS for power generation will be more costly due to lack of synergies*
	▲ ***Targets have focused on supply** and cluster development and avoided use case specific targets. **This has received criticism** for missing opportunity to instil investor confidence in long term markets for use cases.*	▲ *Lithuania may wish to set certain aspiration levels in consultation with industry, e.g. for transport (HGV) as example*

UK summary learnings for Lithuania

Although UK is more gas-led and more blue-focused, it offers a playbook of what a transport-based incentive would look like and will have a strong wind-to-hydrogen coupling similar to Lithuania

	Observation on UK	Observation for Lithuania
Ambition, targets and pathway (continued)	▲ ***Within heat**: UK's commitment to replacing boilers with heat pumps but keeping hydrogen and biomethane heating options open*	▲ *This approach makes broad sense for dealing with the portion of Lithuania's heating demand that cannot be served by biomass, primarily smaller towns using gas boilers and Lithuania could conduct similar pilots*
Ambition, targets and pathway (continued)	▲ *UK's RTFO certificates provide one of the most generous subsidies for hydrogen as a road transport fuel in the world but this is seen only as a **kickstarter incentive to promote production** rather than a long-term subsidy. However the market-based mechanism is in place for road transport fuels. A similar mechanism could provide confidence for investing in hydrogen HGV fleets*	▲ *A similar mechanism could provide confidence for investing in hydrogen HGV fleets*
	▲ *In addition the UK is mixing demand and supply-side incentives which will likely sit outside of the transport fuel mechanism and will likely be used to drive industry and grid-blending use cases.*	▲ *This **market-based-but-use-case-specific approach to demand side incentives appears sensible if Lithuania expects to foster biomethane or other low-carbon fuels to compete with hydrogen such as bioethanol for certain use cases***
	▲ *UK is using it's global strength in R&D to become leaders in later use cases, notably sustainable aviation fuels. While Lithuania will need to be more narrow in **targeted R&D efforts it could develop solutions specific to fertilizers or HGV logistics to foster exportable capability***	▲ *While Lithuania will need to be more narrow in **targeted R&D efforts it could develop solutions specific to fertilizers or HGV logistics to foster exportable capability***

Country hydrogen strategy analogue 2: the Netherlands

Netherlands hydrogen strategy: overview

Targets of 800 MW by 2025, 3-4GW by 2030. Ambition for green hydrogen

Energy resource and demand context

- **Supply**: Netherlands relies heavily on natural gas for power, including from its domestic Groningen gas field. In 2020, 14% of the power supply was from RES- there are substantial (21.5 GW) targets for offshore wind by 2030 (total installed power capacity expected to be 59GW), with coal due for phased out by the same date. Current policy targets reduction in gas consumption, including decommissioning of Groningen gas field
- **Demand**: Oil and gas amounted to 77% of final energy consumption. Demand was primarily driven by heavy industry, petrochemicals and chemicals. This makes industry grade heat consumption a large contributor to final energy demand vs EU average
- **Import/export:** the Netherlands has a high power and gas interconnection capacity, and was a net exporter of power in 2020, due to lower cost natural gas reserves. The Netherlands is an important transport hub for the trade of natural gas, oil, electricity and coal – it has extensive cross-border and subsea oil and gas pipelines and electrical interconnections. Dutch ports play a key role in global and regional energy trade

Targeted domestic use cases

- Targeted hydrogen-fuelled domestic use-cases include: **feedstock and heating fuel for the chemicals industry, heavy duty road transport, shipping and rail, and building heat**
- Transport electrification is expected to decarbonise passenger vehicles; the Netherlands is an EU leader with almost 200,000 EV's in use and over 50,000 EV charging stations (2019). Hydrogen is unlikely to play a significant role in rail decarbonisation as the network is already 75% electrified within the Netherlands. Hydrogen is recognised as the preferred standard solution for heavy duty vehicles by 2035
- The Netherlands is investigating **localised clusters of hydrogen home heating**. Clusters will be **focused around existing industry hydrogen demand** , acting as anchor load of production.
- Grey hydrogen is in widespread use in industry – with 100PJ is used each year

Approach to supply and infrastructure

- There is an explicit preference for zero-carbon Hydrogen. However, the Netherlands is one of a small number of EU countries where blue hydrogen is explicitly accepted a stepping stone to establish the technology. Green hydrogen production is being coupled with offshore wind and hydrogen transmission from wind turbine to shore is being investigated
- The national gas network may be used for the transport of hydrogen or other green gas. 2% blending is already achievable with minor adjustments, it is thought with further adjustments 10-20% is feasible. A review is currently being undertaken by Gasunie, the national network operator

Import / export plans

- The Netherlands continually stress that they wish to be part of an EU wide roll out of hydrogen, and hydrogen infrastructure, in part to unlock economies of scale, both from a supplier side and demand side point of view. The ports of Rotterdam and Amsterdam are engaging with feasibility and strategic studies involving import and export of both hydrogen and ammonia. Furthermore, MoUs have been signed with regions targeting green hydrogen export in order to guarantee the place of Dutch ports in the future global transport of hydrogen

Netherlands hydrogen roadmap

The Netherlands has high level qualitative goals

	Today	by 2025	By 2030	2035+
Production	- Feasibility study for linking hydrogen and offshore wind - Pilot green hydrogen and offshore wind linking project	- Expected 141m kgs per year of hydrogen for FCEV demand - Co-ordination with North Sea countries to prioritise offshore wind for green hydrogen	- Reduced production cost of 50% for green hydrogen relative to today - 19 TWh of 'green gas'- this includes biomethane	Gaseous energy carriers to provide at least 30% of final energy consumption – target not hydrogen specific
Use	- Pilot neighbourhood heating - Pilot retrofit of gas turbines running off hydrogen	- 15,000 FCEVs - 3,000 Hydrogen HGV - 50 new HRS (6 currently) - All new buses to be zero-carbon - Heating + building pilot projects	- 300,000 FCEVs (> # of HGVs) - 30% renewable fuels mandate for blending on inland shipping - Inland shipping has 150 ZEVs - 14% aviation renewable fuels	- Hydrogen FCEVs standard for goods vehicles - 100% renewable aviation fuels by 2050
Distribution	- Gas grid blending investigation - Supply chain review commissioned	- Aims to link green hydrogen production and industry clusters - Port of Rotterdam to identify import demand and gear up to be a future fuel hub	- Port of Rotterdam ~~is~~ established as a hydrogen trading hub	- Integrated EU hydrogen distribution network - Port of Rotterdam as focus for supplying all of Europe
Key actions & milestones	• **Preparatory program for the roll-out of hydrogen** • **Formation of the National Hydrogen Program** • **Planning for regional clusters** • **Identification of projects targeting IPCEI funding**	• **500 MW production capacity by 2025** • *Development of the demand for hydrogen* • *Development of regional infrastructure* • *Connection of regional clusters*	• **3-4 GW capacity by 2030** • *Connection to storage sites and expansion of infrastructure* • *Increased renewable electricity* • *Estimated cost to be 100-150 euros per avoided tonne of CO2*	• *No aspirations set post-2035*

LEGEND: **bold = target,** *italics = ambition*

Sources: [Dutch National Climate Agreement]

Netherlands hydrogen regulation plan summary

The Netherlands plan to implement particular regulations to coincide with milestones

Category of regulation	Description	Status / timeframe
Production / supply	Rules for traceability of feedstock and certification of hydrogen as a green or partially green fuel	In progress
	Regulation of carbon capture and storage / blue hydrogen production	No plan
	Regulations of electrolyser production facilities	ISO 22734:2019
Transmission, distribution, and storage	Regulation of gaseous and liquid hydrogen transport on public roads	Delivered 2016
	Regulation of hydrogen injection in transmission and distribution networks	In progress
	Update of regulations for handling and storage of dangerous cargo in port areas	In progress
	Safety regulations for bottled hydrogen containers and bulk hydrogen tanks, and cryogenic storage	ISO under development
	Update regulation on the storage of dangerous substances to include gaseous and liquid hydrogen	Delivered 2016
Use case / point of use	Regulation of gaseous hydrogen use in industrial machinery and vehicles	Delivered 2016
	Regulation of technical, construction and safety requirements for FCEVs	ISO 13985:2006
	Safety recommendations for emergencies and accidents concerning FCEVs	underway
	Regulation of hydrogen vehicles repair and maintenance workshops	Delivered 2016
	Safety recommendation for gaseous and liquid hydrogen vehicle parking garages	ISO 13984:1999
	Regulation of gaseous hydrogen use in domestic appliances	underway
	Update the regulation of health and environmental requirements in places of work for hydrogen	underway
	Requirements for use in shipping as a fuel	Established nationally
	Requirements for use in aviation as a fuel	If not EU wide, by 2023
	Requirements for the combustion of hydrogen in boilers and furnaces	underway

Sources: [PGS-15 directive NL, ISO website]

Netherlands direct subsidy interventions

Reliance on EU funding for lots of aspects, but with dedicated national support too

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
Groenvermogen (National Growth Fund)	R&D, pre-commercial	€338 million	Industrial use cases (includes steel, refineries and fertilizer)	• Hydrogen and green chemistry technologies allowing for scaling of decarbonization in chemical, transport and heavy industry
Climate budget	Pre-commercial	€60-100 million every year from 2023	Scaling up hydrogen technology for commercial readiness	• The focus will be on pilots, demonstrations, and roadmaps that are required for upscaling
DEI +	R&D	€76.6m, 25-45% of eligible costs, up to €15 million per project	Hydrogen Production Pilots are one of 8 categories for funding	• Aim is to accelerate cost reductions. Funding is for pilot project technology demonstrations
HER+	Pre-commercial	€50m, max per project €6 million	All use cases and low carbon fuels	• Projects that lead to cost-effective CO2 reduction are eligible for subsidy

Note to AmberGrid –this list is incomplete and we expect more entries to this table before we finalise this module

Sources: [Top Sector Energy Publication, Dutch Hydrogen Strategy]

Netherlands incentive based interventions

The Netherlands has an established support mechanism – the SDE++

Incentive name	Type	Budget + horizon	Applies to	Further details
SDE ++	• Variable feed-in premium mechanism • **Subsidises the unprofitable component of each technology** for up to 2k hours p.a. – capped at ¼ full load hours to ensure RES production • 12 – 15 year subsidy • Capped at €1064 / t of carbon dioxide for green hydrogen	• Multiple auction rounds, most recent had a budget of €5 billion • Awarded over 12-15 years, technology dependent	• Production of renewable energy or CO2 reducing techniques. • Specific category for green hydrogen. Blue hydrogen can compete in CCS category	• This is a **supply led mechanism** without limits/ demands on end-use • The SDE provides a **technology-differentiated subsidy payment** based on the average market value of a technology and is provided on top of market revenue • You receive a subsidy amount **per tonne of CO2** reduction • Project **still retains market price exposure (i.e. a one-way CfD)** and operational risk
EU ETS	• A cap is set on permissible GHG emissions. This cap is decreased over time – if more carbon is emitted then emission allowances must be traded/ purchased	• Cap set to keep increasing up to 2050	• Energy intensive industries, the power generation sector and aviation	• Expansion to transport and domestic heating sectors is being considered
Tax rebates for vehicles	• **Vehicle registration tax exemption** for zero-emissions vehicles • **Road tax exemption** for zero-emissions vehicles		• Zero emission cars	• For non-zero-emission cars the **system is progressive**, with different levels of CO2 emissions receiving different levels of registration tax

Sources: [Hydrogen Strategy, EAFO]

Netherlands projects and partnerships (1 of 2)

The Netherlands is supplying funding to, and getting involved in, large scale industry and infrastructure projects

Project name	Proposed COD	Overview	Key figures	Partners involved
BioMCN	operating	• First industrial scale biomethanol plant, uses sustainable raw materials including green hydrogen produced locally	• 20MW • 16.2 million tonnes of nitrogen and methanol products	- National government
WEVA	2023	• Construction of a hydrogen fuel cell inland cargo ship	• €4 million euros • Vessel will be 135 metres and 3700 tonnes	- Dutch government - Lenten Scheepvaaert - NPRC inland shipping corporation
Heating Rozenburg, Stad aan 't Haringvliet and Hoogeveen	2022	• Transferring homes from natural gas heating to hydrogen, on a dedicated hydrogen network. • Initially 6 homes will be connected, operational by 2022	• €10 million euros • Initial 6 homes	- Cooperatie Deltawind, Eneco, Gasunie, Greenpoint Group, Hydrgo, East West Wonen, South Holland, Stedin, Goeree-Overflakkee
Green Octopus	2035	• Project is a series of hydrogen pilots and hydrogen transport trajectories • Funded by FCH-JU in partnership with Horizon Europe (EU Horizon 2020) and Hydrogen Europe • Part of broader Hydrogne Backbone of 22,900km spanning continental EU countries	• Hydrogen backbone (2030) • Hydrogen infrastructure in ports (2025) • Onshore hydrogen production plant (2030) • Offshore hydrogen production (2030) • Interfaces/coupling hydrogen production to end users (2030) • Development/innovation (2030)	WatersofNet, and partners: Gasunie, Fluxys, Port Of Rotterdam, Port of Antwerp, Port of Zeebrugge, North Sea Port, Engie, Colruyt Group, VDL, Salzgitter, Bosch, Elring Klinger
Large scale green hydrogen production	2025	• Large scale green hydrogen plant is to be connected to the HyTransport.RTM pipeline that runs through the Port of Rotterdam	• 100MW initial electrolyser • 500MW expansion	Uniper, Port of Rotterdam

Sources: [Netherlands Hydrogen Strategy, Green Octopus, BioMcN, Port of Rotterdam]

Netherlands projects and partnerships (2 of 2)

The Netherlands is supplying funding to, and getting involved in, large scale industry and infrastructure projects

Project name	Proposed COD	Overview	Key figures	Partners involved
HEAVENN – first Hydrogen Valley	2025	• Northern Netherlands – combining RES, storage, generation and transport with industry and mobility offtake applications • Using hydrogen as combined heat and power for residential users	• €90 million - €20 million from EU • 30 subprojects	31 parties
Port of Rotterdam	2023	• Conversion park: 2 GW conversion park (industrial estate) planned for green hydrogen production • Offshore wind: 2 GW of offshore wind energy is linked ot the production of green hydrogen • Import plans focus on importing from South Europe, North Africa and the Middle East • Import terminals: Large-scale imports of hydrogen compounds are needed to provide Northwest Europe with adequate supplies of sustainable energy. Import terminal operational by 2030	• 2023: Backbone and Maasvlatke conversion park operational • 2023: Shell goes operational with 150-250 MW electrolyser on conversion park • 2025: H2-fifty's 250 MW electrolyser goes operational • 2025: Road transport expansion, with 500 hydrogen powered trucks targeted • 2026: Installation of H-vision operational • 2030: Import terminal, pipelines to Chemelot and North-Rhine-Westphalia operational	
NorthH2	2027	• Aims to link North Sea offshore wind to large scale production of 1 Mt hydrogen (initially at Eemshaven) to industry and HGV use cases through retrofitting natural gas pipeline infrastructure • Currently at feasibility stage	• 1 GW in 2027, 4 gigawatts by 2030, and 10+ gigawatts by 2040	- Equinor - Shell, Groningen Seaports - Gasunie - Groningen. - RWE

Sources: Port of Rotterdam, HEAVENN

Netherlands summary learnings for Lithuania

	Observation on NL	Observation for Lithuania
Energy supply and demand mix	▲ *NL has large industrial demand for hydrogen in the form of fertilizer plant and refineries, as well as potential hydrogen demand within it's steel industry. Industry is currently dependent on natural gas for feedstock and process heat*	▲ *NL is a good benchmark for ambition in decarbonising grey hydrogen consumption as industry feedstock*
	▲ *NL is targeting both blue and green through separate pots of funding with the intent to meet demand through green energy in the long term*	▲ *LT may wish to change policy towards accepting blue H2 in the short term to serve demand. This could be through domestic sequestration or international export*
Ambition, targets and pathway	▲ *NL has highly ambitious vehicle electrification targets and in particular H2-FCEV targets which expect FCEV deployment far beyond HDVs by 2030, though no explicit rationale for high share of FCEVs vs BEVs has been given*	▲ *Even early movers in Western Europe may have set targets without strong rationale for choice of technology*
	▲ *NL not yet considering H2P as gas-CCS is expected to fill this requirement for flexible power*	▲ *Lithuania will need to engage with H2P in order to reach 2035 targets without resorting to CCS infrastructure*
	▲ *NL seeking to maintain and grow their role as **a commodity transit hub of choice** for much of Northwest Europe's industrial input and output and is **pursuing projects specifically aimed at building out a hydrogen backbone** across NW Europe*	▲ *Lithuania should seek to exploit EU funding aimed at international projects between member states*
	▲ *NL not yet making decision on preferred import carrier (hydrogen, ammonia, synfuel) at Rotterdam*	▲ *Lithuania could wait to see what direction Rotterdam sets, given its outsized influence in European commodity flows*

Netherlands summary learnings for Lithuania

	Observation on NL	Observation for Lithuania
	▲ *There is a wide participation in cross-country MoUs with obvious import and export partners, as well as feasibility studies using EU money and more explicit recognition of developing the wider Benelux regional hydrogen economy*	▲ *MoUs can be used to establish working groups with other countries once an initial import/export philosophy has been conceived with a view to accessing funding for projects. This aligns with the stated political intention to further integration with EU member states*
Subsidy and incentive mechanisms	▲ *NL is taking a **system based supply led** approach to incentivising carbon abatement through a new hydrogen bracket in its SDE++ scheme for long term floor price for renewable energy* ▲ *This is coupled with funding for pilot infrastructure in industry use cases and tax rebates for transport vehicles to promote adoption*	▲ *Lithuania can take a supply or demand led approach but needs a cohesive response that recognises the need to provide a long term offtake for fuel producers and incentive schemes for capital expenditure among users*
	▲ *NL is targeting **the first of 24 EU's hydrogen valleys** currently in development in Europe, and has received €20m dedicated EU funding to develop this and a focus on integration of supply and multiple demand cases*	▲ *A similar valley centred around Achema or Orlen refinery could attract EU money*

Country hydrogen strategy analogue 3: Chile

Chile hydrogen strategy: overview

Chile's ambitious hydrogen strategy aims to scale domestic production by moving from existing use cases to harder-to-decarbonise sectors, then scaling to export levels

Energy resource and demand context

- **Supply**: Chile has c. 26GW of electricity generation capacity. The capacity mix is composed of hydropower (27%), coal (21%), gas (20%), wind (12%) and solar (11%). Solar capacity is expected to grow strongly expanding from around 4GW in 2020 up to nearly 20 GW by 2050
- **Demand**: Chile's energy consumption is weighted towards industry and mining (38%) and transportation (37%). Chile has a dominant mining sector, and is responsible for 1/3 of global copper output, in addition to concentrating 50% of the world Lithium reserves
- **Import/export:** Thanks to it's relatively low-cost renewables (solar LCOEs are comparable to Spain) and abundant space to develop them Chile is a net exporter of electricity but. Oil and natural gas are imported, with oil coming primarily through the Transandin pipeline to Bolivia

Targeted domestic use cases

- Targeted hydrogen fuelled domestic use-cases include **oil refineries**, **ammonia production**, **mining haul trucks**, **heavy-duty trucking**, **long-range buses** and **blending into gas grids** (up to 20%)
- Chile is planning on building the **worlds largest renewable fuels production plant,** with a focus on providing liquid fuels to support the transport industry. While there are currently just over 2000 EVs in Chile, public transport will be fully electrified by 2040 and electrification will compete with hydrogen. Chile has 841 electric buses currently operating – the second largest fleet in the world, behind China
- Hydrogen demand in Chile is approximately 58kt and is driven by the petrochemical refining sector. As a result, Chile aims to decarbonize sectors that currently rely on hydrogen as a feedstock, such as the chemical and petrochemical industries. Ammonia imports can be replaced with Chilean green ammonia

Approach to supply and infrastructure

- Chile is targeting green hydrogen, owing to its abundant renewable sources of electricity. By 2030 it is expected that 70% of power generation will be through RES- and that by 2050 the LCOE from renewables will be from €8-18 EUR/MWh. 300GW of renewable power capacity is projected to be needed by 2050 to meet their green hydrogen export goals
- There are plans to introduce blending into the gas grid of up to 20% by 2030. A detailed roadmap for subsequent important infrastructure milestones is being developed

Import / export plans

- By 2030-2035, Chile is not only expected to become self-sufficient in satisfying domestic hydrogen demand, but also become one of the major global hydrogen exporters, **exporting 13 times the amount of hydrogen consumed domestically and satisfying more than 4.5% of expected global hydrogen demand.** The exports are expected to take the form of **green ammonia** and **synfuels**

Sources: [Statistica, Chile's Hydrogen Strategy]

Chile's hydrogen roadmap

Chile aims to become the cheapest producer of green hydrogen globally

	Today	By 2025	By 2030	2035+
Production	- 20MW trials Linde synfuels plant	Leverage domestic base to develop a green ammonia production and exportation industry	Aim to have a large-scale production plant for synthetic fuel production	Exploit synergies and economies of scale to expand as a global supplier of clean fuels
Use	- Pilots in heavy duty trucks and long range buses - Blending trials in gas grids - Use in oil refineries and for local ammonia production	- Secure offtake and investment commitments for ammonia and hydrogen exports - Role out into mining trucks, long range trucks - Blending into the gas grid	- Ammonia for domestic shipping - Synfuels and e-methanol opportunities to increase	Domestic hydrogen demand to be driven by heavy-duty transport sector through 10% of mining trucks and bus fleets with FCEVs
Distribution	The foundations of the distribution system for Chile to be laid down. The existing gas network will be studied to consider blending	Roadmap for required knowledge for establishment of green hydrogen sector to be established	Start of global hydrogen exports	Take advantage of opportunities for further growth as global hydrogen demand increases, new technologies are developed and the export markets for clean fuels grows and diversifies
Key actions & milestones	• Domestic ramp up to satisfy hydrogen demand from existing and newly developed use cases • Export preparation	• **5 GW electrolyser capacity (operating or under development)** • *200 kton/year hydrogen production in at least 2 hydrogen valleys* • *Up to €4.4 billion of green hydrogen investment*	• **25 GW installed electrolyser capacity** • **Cost <€1.3/kg – Chile makes the cheapest green hydrogen globally** • *€2.2b/year – Chile is a global leader in hydrogen exports*	• *Creation of up to 100,000 new jobs* • *Estimated export market size of €21 billion for green ammonia, and €16.8 billion USD for green hydrogen*

LEGEND: **bold = target,** *italics = ambition*

Sources: [Chile Hydrogen Strategy]

Chile's Hydrogen regulation plan summary

CIVITTA

Baringa

Regulations in Chile for Hydrogen are expected to be adopted in three different stages – short term (2020-2024), medium term (2024-2028) and long-term (2029+). International standards to be used where possible

Category of regulation	Description	Status / timeframe
Production / supply	Rules for traceability of feedstock and certification of hydrogen as a green or partially green fuel	Planned
	Regulation of carbon capture and storage / blue hydrogen production	No plan
	Interventions to phase out carbon intensive hydrogen and transition to low carbon production methods	Carbon tax- in planning
	Regulations of electrolyser production facilities	ISO 22734:2019
Transmission, distribution, and storage	Regulation of gaseous and liquid hydrogen transport on public roads	No plan
	Regulation of hydrogen injection in transmission and distribution networks	No plan
	Update of regulations for handling and storage of dangerous cargo in port areas	No plan
	Safety regulations for bottled hydrogen containers and bulk hydrogen tanks, and cryogenic storage	ISO under development
	Update regulation on the storage of dangerous substances to include gaseous and liquid hydrogen	Under plan
Use case / point of use	Regulation of gaseous hydrogen use in industrial machinery and vehicles	No plan
	Regulation of technical, construction and safety requirements for FCEVs	ISO 13985:2006
	Safety recommendations for emergencies and accidents concerning FCEVs	In planning
	Regulation of hydrogen vehicles repair and maintenance workshops	No plan
	Safety recommendation for gaseous and liquid hydrogen vehicle parking garages	ISO 13984:1999
	Regulation of gaseous hydrogen use in domestic appliances	No plan
	Update the regulation of health and environmental requirements in places of work for hydrogen	No plan
	Requirements for use in shipping as a fuel	2030, ISO/AWI 11326
	Requirements for use in aviation as a fuel / SAF alternatives	No plan
	Requirements for the combustion of hydrogen in boilers and furnaces	No plan

Sources: [ISO database, Chile Hydrogen Strategy]

Chile's direct subsidy interventions

Chile has backed up ambitious supply targets with only limited subsidies

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
CORFO – Chilean economic development agency	Commercial	€44 million USD – already allocated to 6 projects	Green Hydrogen projects – 6 have been chosen	Funding available to support scalable and replicable green hydrogen projects in order to achieve the 1.5 USD/kg.hydrogen target by 2030
Chilean Clean Technology Institute	R&D	€170 million USD, subsidies to be paid out over a period of 10 years	Solar energy projects including storage technologies, low emission metal mining and advanced materials of Lithium	Fund to accelerate low-carbon transition in Chile with a particular focus on R&D support for non-profits & academics

Sources: [Chile's Hydrogen Strategy, CORFO Clean Technology Institute]

Chile incentive based interventions

Material incentives for green fuels are in development to go on top of a very limited €4.4 / t carbon tax

Incentive name	Type	Budget + horizon	Applies to	Further details
Oil Tax (Impuesto al petróleo)	Fuel excise tax	N/a	Road fuels	Fuel excise tax applicable to road fuels (According to the SII, the IEC represents 5.1% of the total tax revenue of the country)
Downstream carbon tax	Applied per tonne of co2	€4.4 per tCO2	Non-eco-friendly assets, such as boilers or turbines	Raised on emissions of local (MP, NOx, SO2) and global (CO2) pollutants from stationary sources such as boilers and/or turbines with a total thermal power rating of 50 MW or more at a given location
Green hydrogen quotas	Tbd – expected to be a quota to have a minimum percentage of 'green gas'	TBD by Government	TBD by Government	Introduction of mandatory green hydrogen quotas in hard-to-decarbonise sectors and end-use sectors
Tradeable renewable energy quotas between companies	10% of electricity used by companies must be from renewables. This can be certified by green certificates, which can be traded	N/a	All companies	Companies must draw 10% of electricity used from renewables. Companies are allowed to store obligations and surpluses for a calendar year and trade them between each other, creating a market for transferable green certificates

Sources: [Renewable Transport Fuel Obligation - GOV.UK (www.gov.uk), http://www.greengas.org.uk/governance/scheme-rules]

Chile's key projects and partnerships

Largest e-fuels factory in the world in preparation

Project name	Proposed COD	Overview	Key figures	Partners involved
Highly Innovative Fuels (HIF)	• 2022	• Pilot plant for green hydrogen production through an electrolyser powered by wind energy • Combined with carbon (captured from the atmosphere & biomass) via a synthesis process to produce green methanol and fuel for transport • Located in Cabo Negro, an existing port in Chile • Offtaker is HIF	• 350 t.p.a of green methanol • 25kt per year of green hydrogen • 3 MW demonstration pilot, scaling to 200 MW- which has been identified as optimal for unlocking commercial scale • €14.9m of CORFO funds	• Enel Green Power Chile • Andes Mining and Energy (AME) • Nacional del Petroleo (ENAP) • Siemens Energy • Porsche
HyEx	• 2024	• Pilot: fed by a 36 MW solar plant • Wider project: fed by a 2 GW solar plant. Half of the ammonia produced would be distributed to Enaex's ammonium nitrate plant and the rest supplied for fuel, green fertiliser production and the export market	• 26 MW industrial pilot for the generation of 3.2kt of green hydrogen • €8.4m	• Engie • Enaex
Hydra	• 2020	• Develop a new powertrain and refuelling system for mining vehicles to run on hydrogen instead of diesel	• €1.45m (of which €0.30m funded by CORFO)	• CSIRO • ENGIE • Mining3
Antofagasta Mining Energy Renewable (AMER)	• 2022	• Plans to use carbon capture technology for a CO2 source and combine this with green hydrogen to produce e-Methanol	• 60kt per year of e-Methanol • 80 MW electrolyser • €10.4m	• Air liquide • Offtaker is Antofagasta mining company
MoUs		• Germany: signed agreement to boost hydrogen cooperation • Netherlands: MoU signed with port of Rotterdam on green hydrogen • Singapore: MoU to facilitate green hydrogen co-operation • South Korea: MoU to expand cooperation on low carbon hydrogen • Belgium: MoU with ports to create green hydrogen corridor		

Sources: Green hydrogen for Glasgow - ScottishPower

Chile summary learnings for Lithuania

	Observation on Chile	Observation for Lithuania
Energy supply and demand mix	▲ *Low cost renewables enabled by favourable solar resource, strong land availability and favourable regime for investment (low policy and regulatory risk) underpin Chile's strategy to export green hydrogen. This philosophy has carried through to hydrogen project planning, with the strategy calling for the energy regulator and government energy ministry to collaborate to reduce project development risk for investors*	▲ *Levers to bring down the levelised cost of renewables in countries with already strong resource will make it challenging for Lithuania to compete for export demand against Chile, Saudi Arabia, Spain, North Africa, where solar or wind resource is strong and space for projects is abundant* ▲ *A defined route to market for early stage projects will hasten project investment. This could be provided for greening grey hydrogen or supply to public sector transport as this would not impact competition from e.g., other fuels within the private sector*
Ambition, targets and pathway	▲ *Targets are supply rather than demand led but delivering 5 GW by 2025 hinges on the development of international offtake agreements with either U.S. or Europe as domestic consumption targets are so far relatively vague and demand for greening grey hydrogen feedstock – no such agreements have been announced to date though MoUs have been established with Germany, the Netherlands, Belgium, Singapore and South Korea*	▲ *Secure offtakers are required for targets to be met and absence of offtake routes put targets at risk. International collaboration should have a targeted offtake idea/philosophy in mind*
	▲ *Heavy emphasis on BEVs over FCEVs for buses so far, combined with expectation of less than 10% FCEV share of HDVs post 2035 suggests Chile is not banking on hydrogen underpinning heavy duty transport in the near term*	▲ *Careful consideration required on optimal technology choice for buses and lighter categories of goods vehicles*

Chile summary learnings for Lithuania

	Observation on Chile	Observation for Lithuania
Subsidy and incentive mechanisms	▲ *Chile's CORFO's scheme has earmarked most of its funding for R&D industry partnership in order to develop niche capability in hydrogen-fuelled mining machinery*	▲ *Targeted R&D funds for fostering green hydrogen use cases over longer term*
	▲ *E-methanol plant using green hydrogen is adopting partnerships with automotive and petrochemical industry in order to deliver offtake agreements and provide use case for captured carbon*	▲ *Collaboration could be sought from Orlen to assess use of captured CO2 and promote synfuel production through hydrogen*

Country hydrogen strategy analogue 4: Australia

Australia hydrogen strategy: overview

Aiming for export - starts with 57 nationally coordinated government actions

Energy resource and demand context

- **Supply**: Renewable resources make up 24% of Australia's power generation – 9% solar, 9% wind and 6% hydropower. The remaining power is generated by fossil fuels: coal generates 54%, gas 20% and oil 2%. It is predicted that the share of renewable power will increase significantly in the coming years, with the main electricity grid expected to surpass 50% RES by 2025. Australia's power demand is approximately 250 TWh per year
- **Demand**: Industry and mining represent 30% of energy demand, with transport a further 28%. Coal and Uranium are mined extensively, and this a significant contributor to the Australian economy
- **Imports:** Australia imports totaled 680 TWh, these are predominantly refined products and crude oil
- **Exports:** Australia is a major energy exporter- exporting 75% of its energy output, amounting to 4400 TWh. Australia is the worlds largest exporter of coal and LNG. They also export large quantities of Uranium for nuclear power

Targeted domestic use cases

- Targeted hydrogen fuelled domestic use-cases include: **using clean hydrogen for industrial feedstocks and heating**, **blending of hydrogen in the gas network** and **heavy-duty transport**. However, the primary target use-case is **mass export of green hydrogen** to Asian markets
- Australia is considering hydrogen-to-power, with two new large gas turbines (1GW) being commission with hydrogen ready technology – and mandates to blend up to 5% hydrogen by 2025. There is limited support for light vehicle transition, with currently only 4 HRSs and 30 FCEVs, there are currently 8,700 electric cars in Australia – significantly lower than other comparable nations
- Australia seeks to support technology development, identification and removal of policy barriers, and setting up processes and partnerships to facilitate industry growth. The will be **rolled out through regional hubs- 7 such hubs** have been funded by the Australian government and are targeted to coal hydrogen ecosystem producing regions

Approach to supply and infrastructure

- Australia is targeting renewable hydrogen – produced from wind and solar power. It is estimated that **3% of Australia could be suitable for green hydrogen production**, with combination of available RES and water. Blue hydrogen is also in development
- Australia's energy system is transitioning from a centralised, fossil-fuel based system to a decentralised, renewables based system
- Pipeline transmission and gas network blending is in development. Some distribution networks are experimenting with blending hydrogen up to 10% with natural gas in the grid

Import / export plans

- Australia is targeting a **large-scale future opportunity for the export of clean hydrogen**. Their long-term goal is to be one of the top three exporters of hydrogen to Asian markets. Australia believes it is well-placed to do this due to it's track record in building large-scale energy industries and its reputation as a proven partner to Asia's biggest energy importers. By 2050 Japan alone intends to import 10 million tonnes of hydrogen per year, The Republic of Korea, China and the US will also have millions of FCEVs – these are all targets in the sights of Australia

Sources: [Australian Energy Statistics 2020 Energy Update Report, AER Information Paper - Regulating gas pipelines under uncertainty - 15 November 2021.pdf, Renewables | energy.gov.au, Overview | Geoscience Australia (ga.gov.au)

Australia's hydrogen roadmap

Predominantly state based initiatives to build up significant green hydrogen exports

	Today	By 2025	By 2030	2035+
Production	- Blue hydrogen from brown coal & CCS pilot plant - Green hydrogen pilots	- Steadily increase green hydrogen production & focus on renewables infrastructure roll-out to support green hydrogen	- Synthetic fuels by 2030 - Clean hydrogen costs are expected to decline to between €1.3 and €2.5 / kg by 2030	- AUS could produce up to 18Mt of green hydrogen by 2050 - Green ammonia for fertilizer exports
Use	- Role out of hydrogen bus pilots - hydrogen refuse truck pilot - Pilot HRS projects	- Hydrogen trucks - Hydrogen buses - Industrial feedstocks - Remote area power systems - Nine hydrogen blending projects operational by 2025	- Residential heating - Demonstrate rail use case - Mining vehicles will be hydrogen powered at scale - Prolong and redevelop existing ammonia infrastructure	- International shipping & aviation will move towards decarbonization – Australia hope to provide clean ammonia or pressurized/ liquefied hydrogen/ e-Kerosene for use in these sectors
Distribution	- NSW allows blending of hydrogen and biomethane into the grid - Hyp SA blending 5% green hydrogen in its gas grid for 700 homes	- Begin exports by 2025 - Grid firming services ramped up - Roll-out of HRS clusters - Invest in hydrogen-capable pipelines where existing network upgrade is required	- Roll-out of intercity HRSs - Gas networks are targeting 100% hydrogen in some regions of the network by 2030	- Exist as an international hydrogen export hub
Key actions & milestones	• Public sector investment: €800m, Private sector investment: €1b • Principle aims are to build demand, to achieve low-cost hydrogen production at scale, and to reduce delivery costs of hydrogen	• *Conduct salt cavern analysis for CCS locations* • *Establish route to hydrogen exportation* • *Establish government-government agreements, JVs, long-term pay agreements*	• *Gas networks and appliances converted to 100% hydrogen* • *Western Australia has a 100 GW of RES for hydrogen production by 2030 ambition*	• *16,000 new industry jobs + 13,000 new construction jobs* • *€32 billion in additional GDP by 2050*

LEGEND: **bold = target,** *italics = ambition*

Sources: [State of Hydrogen (industry.gov.au)]

Australia's Hydrogen regulation plan summary

Regulations in Australia for Hydrogen are expected to be adopted in three different stages – short term (2020-2024), medium term (2024-2028) and long-term (2029+). International standards to be used where possible

Category of regulation	Description	Status / timeframe
Production / supply	Rules for traceability of feedstock and certification of hydrogen as a green or partially green fuel	In development
	Regulation of carbon capture and storage / blue hydrogen production	In planning
	Interventions to phase out carbon intensive hydrogen and transition to low carbon production methods	No plan
	Regulations of electrolyser production facilities	ISO 22734:2019
Transmission, distribution, and storage	Regulation of gaseous and liquid hydrogen transport on public roads	No plan
	Regulation of hydrogen injection in transmission and distribution networks	Planning
	Update of regulations for handling and storage of dangerous cargo in port areas	No plan
	Safety regulations for bottled hydrogen containers and bulk hydrogen tanks, and cryogenic storage	ISO under development
	Update regulation on the storage of dangerous substances to include gaseous and liquid hydrogen	No plan
Use case / point of use	Regulation of gaseous hydrogen use in industrial machinery and vehicles	No plan
	Regulation of technical, construction and safety requirements for FCEVs	ISO 13985:2006
	Safety recommendations for emergencies and accidents concerning FCEVs	In planning
	Regulation of hydrogen vehicles repair and maintenance workshops	No plan
	Safety recommendation for gaseous and liquid hydrogen vehicle parking garages	ISO 13984:1999
	Regulation of gaseous hydrogen use in domestic appliances	In planning
	Update the regulation of health and environmental requirements in places of work for hydrogen	No plan
	Requirements for use in shipping as a fuel	ISO/AWI 11326
	Requirements for use in aviation as a fuel / SAF alternatives	In planning
	Requirements for the combustion of hydrogen in boilers and furnaces	In planning

Sources: [CSIRO Hydrogen Roadmap]

Australia's direct subsidy interventions

The Australian Government has committed €760 million to the development of its hydrogen economy

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
Clean Hydrogen Industrial Hubs	Pre-commercial & commercial	€292 million	• Funding available for feasibility studies and project roll-outs	• Aims to drive down the cost of clean hydrogen faster
ARENA	Commercial	€189 million	• Renewable energy production	• 3 10 MW electrolyser plants have so far been funded – supported by a declaration of intent between Germany and Australia
Advancing Hydrogen Fund	Commercial	€189 million	• Advancement of green hydrogen	
Future fuels fund	Commercial	€158 million	• Investment in electric transport & HRSs	• The largest part is to flow into the expansion of electric car charging infrastructure and the establishment of hydrogen filling stations. However, there will be no direct purchase incentives.
Australian research council	R&D	150 hydrogen related projects funded so far, 70% between €189,000 - €378,000	• Emissions reduction research	• The Australian Research Council (ARC) has supported research activities that include elements of the hydrogen supply chain in a significant or sole manner or as part of a wider research effort into a lower emissions economy

Sources: [Aus hydrogen strategy]

Australia's incentive based interventions

Australia introduced a short-lived carbon tax in 2011, which was later repealed in 2014. It is not known if plans to reintroduce one are under development

Incentive name	Type	Budget + horizon	Applies to	Further details
New South Wales – electricity network charge exemption	90% exemption from electricity network charges	N/a	Green hydrogen producers	Applicable only if green hydrogen pilots are built in areas of the grid with spare capacity
New South Wales	Exemptions for green hydrogen production from government scheme charges	N/a	Producers of green hydrogen	This reduces the electricity bills by providing exemptions from some of the added levies
R&D tax incentive scheme	Tax offset for a company's R&D expenditure	For larger entities (with a turnover above €12.6m) the offset amount will depend on whether the company's R&D "intensity", being the proportion of their R&D expenditure compared to their total annual expenditure, is above or below 2%	R&D efforts – green hydrogen technology is in the approved list of R&D activities	To access the incentive, a company must make sure: • it is an eligible entity; • the activity undertaken is an eligible "core" R&D activity; • all R&D activities are registered with the Department of Industry, Science, Energy and Resources; and • it complies with reporting and documentation requirements.

In the Hydrogen Strategy the following incentives were mentioned, but as of yet have not been implemented:
- **Incentive scheme regarding use of hydrogen as an industrial feedstock**
- **Implement regulations that provide appropriate compensation for grid firming services from electrolysis**
- **Mandate local and low emissions fuel supply targets**

Sources: [Renewable Transport Fuel Obligation - GOV.UK (www.gov.uk), http://www.greengas.org.uk/governance/scheme-rules]

Australia's key projects and partnerships (1 of 2)

More than 30 pilot projects have so far been carried out across Australia

Project name	Proposed COD	Overview	Key figures	Partners involved
Pilbara hydrogen hub	2023	• Australian Government is funding Yara Pilbara Fertilisers and ENGIE Renewables to develop a 10 MW electrolyser project to produce renewable hydrogen at Yara's existing ammonia facility in Karratha, Western Australia. This project will see clean hydrogen used to make clean ammonia for global export. • This project will have an on-site facility of photovoltaic panels and a battery storage system that will allow the plant to operate without being connected to the main electrical grid	• 10 MW electrolyser • €27m ARENA grant • 625 tonnes green hydrogen • 3.7kt of renewable ammonia	Yara, Engie, ARENA
Latrobe valley	2021	• Hydrogen energy supply chain development. Current project is focusing on blue hydrogen using local coal. In particular there is a focus on building up the supply and transport chain, and liquefication	• €315m • So far 1 tonne of hydrogen has been produced	Victorian government, Australian government, the Japanese government & Australian & Japanese industry players
AGIG hydrogen park	2024	• The Australian Hydrogen Centre will assess the feasibility of blending renewable hydrogen into gas distribution networks (in the near term) and of transitioning to 100% hydrogen networks (over the long term)	• 700 houses with 5% blended hydrogen since May 2021 • €2.6m	ARENA, South Australia's Dept. Energy and Mining, Victoria's Dept. of Energy, Land, Water and Planning, AGN, Ausnet, Engie and Neoen
Arrowsmith Hydrogen project	Phase 1 – 2022	• Renewable hydrogen production plant. Planned in 2 stages: stage 1 is a pre-commercial 50 MW electrolyser to produce 25 tonnes of hydrogen a day. Stage 2 would increase production to 110 tonnes a day. There is a 20 year offtake agreement in place with Top Group for FCEVs	• 50 MW electrolyser • 25 tonnes of hydrogen per day • Secured offtake agreement	Infinite Blue Energy, PetroFac, Top Group

Sources: Green hydrogen for Glasgow - ScottishPower

Australia's key projects and partnerships (2 of 2)

MoUs have been developed to progress the hydrogen economy

Project name	Proposed COD	Overview	Key figures	Partners involved
MoU between two Australian companies and four Japanese companies for green hydrogen production	n/a	• Project to jointly implement a feasibility study of the Central Queensland Hydrogen Project. This project will produce hydrogen on a large scale using renewable energy, liquefy it at the Port of Gladstone, Queensland, Australia, and then export the liquefied hydrogen to Japan	• 100t of hydrogen per day by 2026 • 800t of hydrogen per day by 2031	Iwatani Corporation, Kawasaki Heavy Industries, Ltd., Kansai Electric Power Co., Inc., and Marubeni Corporation with Stanwell Corporation Limited and APT Management Services Pty Ltd.
(MoUs signed)		• Singapore: accelerate low-carbon hydrogen • Rotterdam: signed with Western Australia for hydrogen • Germany: accord on hydrogen cooperation		

Sources: Green hydrogen for Glasgow - ScottishPower

Australia summary learnings for Lithuania

	Observation on Australia	Observation for Lithuania
Energy supply and demand mix	▲ *Low cost renewables enabled by favourable solar, wind and water resource, and favourable international energy market position as a traditional energy exporter power to the Asian markets underpins Australia's strategy to export green hydrogen*	▲ *While it may be challenging for Lithuania to adopt this strategy due to lower renewables resource it could established international export-import relationships with its neighbours as it has done with natural gas*
Ambition, targets and pathway	▲ *Australia plans to create green ammonia for the fertiliser industry, and has plans to export this capacity internationally. In particular long-term they expect that the cost of ammonia will be internationally competitive* ▲ *Australia are experimenting with integrated green ammonia production and battery integrated systems, co-locating RES with ammonia production so as to avoid using and adding capacity to the electricity grid*	▲ *Lithuania's own green fertilizer roadmap should assess relative value of green ammonia imports as an alternative to domestic ammonia production* ▲ *Colocation of hydrogen and wind/solar could be investigated as a solution to avoiding major grid upgrades required to deliver hydrogen demand*
Subsidy and incentive mechanisms	▲ *New South Wales incentives target location of green hydrogen production at preferable points in the electricity network to minimise congestion and system instability* ▲ *Australia has a heavily state based approach to the hydrogen strategy rollout, with each state taking a different approach and setting differing targets, routes and strategies*	▲ *Litgrid could assess and articulate value of using preferable supply locations (once expected demand and supply infrastructure roadmap is established by this work) in order to inform policy on production zones* ▲ *Less applicable to Lithuania's size given less involvement in energy policy from devolved authorities*

Country hydrogen strategy analogue 5: Portugal

Portugal hydrogen strategy: overview

Portugal's ambitious hydrogen strategy aims to accelerate the decarbonisation of its economy, create green job opportunities and position the country as a major green hydrogen exporter

Energy resource and demand context

- **Supply**: Annual power generation of 54 TWh in 2020, this is from 21GW of installed power capacity. The capacity mix is dominated by hydro and pumped storage (34%), followed by 27% wind capacity. Thermal capacity is predominantly gas, which accounts for 22% of the overall capacity mix. Significant increases in the capacity of RES technologies are planned, with ambitions for 19.1 GW of solar and 14.8 GW of onshore wind by 2050. in 2050, 80% of power generation is projected to come from RES. 76% of Portugal's primary energy supply is from fossil fuels
- **Demand**: Annual power demand is 49 TWh. The commercial and public services sectors (including agriculture) consume most of the electricity demand (71%). 56% of building energy demand is electrified
- **Import/export:** Portugal shares an interconnector with Spain – traditionally the imports / exports follow seasonal flows, with exports increasing in Winter. With the exception of 2016-2019, Portugal has been a net importer of electricity. Portugal does not mine or produce coal, crude oil or natural gas, and is reliant on imports for these commodities

Targeted domestic use cases

- Targeted hydrogen fuelled domestic use-cases include: **transport**, **industry**, **electricity and heat**, and **synfuels** whilst also stabilising the electricity system. The 5 aspects which are being targeted are power-to-gas, power-to-mobility, power-to-industry, power-synfuel and power-to-power. Electric vehicles are going to compete for decarbonisation of light vehicles – Portugal already has 34,000 electric vehicles in use, with this expected to rise to 655,000 by 2030. FCEVs are expected to number between 53,000 and 264,000 by 2030 – these are expected to be partly through the roll-out of HFC buses
- In Portugal, hydrogen is currently derived entirely from fossil fuels and its consumption is driven by the industrial sector, in particular refineries
- Portugal is **embarking on one of the current largest electrolyser production facilities in the world** with their 1 GW development in Sines. With this development they aim to jumpstart the Portuguese hydrogen economy by implementing the necessary infrastructure and reaching a critical mass. Sines was previously the location of a large coal plant, which closed in 2020

Approach to supply and infrastructure

- Portugal is targeting green hydrogen, with **no mention of blue hydrogen in its hydrogen strategy**. Their strategy is to leverage solar energy as a factor for competitiveness
- Assumed that existing gas infrastructure will be used for hydrogen infrastructure. Feasibility study suggests that up to 22% hydrogen can be blended into the grid without impacting the calorific power of the gas in the grid. Aims to prolong the useful life of existing infrastructure

Import / export plans

- Portugal has **set targets for export green hydrogen**. They have **signed MoUs** with multiple nations to signal intent to further the green hydrogen economy on an international level

Sources: [EN-H2, Baringa Portugal IP, IEA]

Portugal's hydrogen roadmap

Portugal released their hydrogen strategy in May 2020

	Today	by 2025	By 2030	2035+
Production	- Begin implementation of 1 GW green hydrogen project in port of Sines	- 250-550 MW production	- 2 GW capacity installed in electrolysers	- 5 GW by 2050
Use	- Implement decentralized pilots in different economic sectors	0.5-1% use in industry, 0.1-0.5% in road transport, 1-2% final energy consumption	2-5% use in industry, 1-5% in road transport, 3-5% in maritime transport, 2-5% final energy consumption	20-25% consumption in industry, 20-25% in road transport, 20-25% in maritime transport, 15-20% final energy consumption by 2050
Distribution	- 0% grid blending - 1 HRS	- 1-5% green hydrogen in the gas grid - 10-25 HRSs	- 10-15% hydrogen injection in the natural gas network - 50-100 HRSs	- 75-80% green hydrogen in the gas grid by 2050 - 1000-1500 HRSs by 2050
Key actions & milestones	• **Develop the necessary regulatory and support framework for the implementation of hydrogen projects at variable scales across different sectors** • **Ramping up funding attempts – e.g. submit IPCEI funding** • **Support training and professional hydrogen development**	• **250-550 MW electrolyser capacity** • **Review the original hydrogen strategy targets and update** • *Consolidate the national regulatory and support framework, strengthen hydrogen production competencies and capacity, and increased the roll out of projects*	• **1.6-2.6 GW electrolyser capacity** • *8500 – 12000 new jobs* • *€7 b investment in hydrogen production, €900m to investment and production* • *€300-600 million reduction in natural gas imports & €180 million reduction in ammonia imports* • *51% of hydrogen expected to be used in industry, 36% is expected to be exported*	• **10.5 GW electrolyser capacity by 2050** • *Complete the development of a national hydrogen market, including the export and internationalisation dimensions* • *Domestic hydrogen demand will be driven by use in aviation (53%), manufacturing (19%) and shipping (18%). Exports to reduce to 12% of total hydrogen production*

LEGEND: **bold = target**, *italics = ambition*

Sources: [En-H2]

Portugal's Hydrogen regulation plan summary

Portugal currently has limited regulation on hydrogen. This is a key focus of their next steps for the hydrogen roll out

Category of regulation	Description	Status / timeframe
Production / supply	Rules for traceability of feedstock and certification of hydrogen as a green or partially green fuel	Published 2020
	Regulation of carbon capture and storage / blue H2 production	No plan
	Interventions to phase out carbon intensive hydrogen and transition to low carbon production methods	No plan
	Regulations of electrolyser production facilities	ISO 22734:2019
Transmission, distribution, and storage	Regulation of gaseous and liquid hydrogen transport on public roads	No plan
	Regulation of hydrogen injection in transmission and distribution networks	In development
	Update of regulations for handling and storage of dangerous cargo in port areas	No plan
	Safety regulations for bottled hydrogen containers and bulk hydrogen tanks, and cryogenic storage	ISO under development
	Update regulation on the storage of dangerous substances to include gaseous and liquid hydrogen	No plan
Use case / point of use	Regulation of gaseous hydrogen use in industrial machinery and vehicles	No plan
	Regulation of technical, construction and safety requirements for FCEVs	ISO 13985:2006
	Safety recommendations for emergencies and accidents concerning FCEVs	No plan
	Regulation of hydrogen vehicles repair and maintenance workshops	No plan
	Safety recommendation for gaseous and liquid hydrogen vehicle parking garages	ISO 13984:1999
	Regulation of gaseous hydrogen use in domestic appliances	No plan
	Update the regulation of health and environmental requirements in places of work for hydrogen	No plan
	Requirements for use in shipping as a fuel	ISO/AWI 11326
	Requirements for use in aviation as a fuel / SAF alternatives	Ongoing
	Requirements for the combustion of hydrogen in boilers and furnaces	Ongoing

Sources: [ISO database, EN-H2]

Portugal direct subsidy interventions

MoU has also been signed with EIB to help Portugal with hydrogen

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
The Operational Sustainability and Efficiency Program concerning the Use of Resources	Commercial	€2.6 b	• Supporting the transition to a low carbon economy in all sectors; • Adaptation to climate change and risk management and prevention; • Environment Protection and promotion of resource efficiency	Supports projects for the production, distribution and consumption of energy from renewable sources, including hydrogen
Portugal 2030 (PT2030)	Commercial	€400-450m reserved for hydrogen	• Hydrogen	Funding from EU. Funding will initially be directed at supporting production, transport and distribution infrastructures projects, and subsequently at the decarbonisation of specific sectors (industry, transport) through hydrogen
The Environmental Fund (FA)	Research & development	€62m – from carbon tax and ETS allowance auctions fund this	• Produce gases of renewable origin	Supports research projects aimed at decarbonising the economy
The Blue Fund	Commercial	€50m	• Maritime decarbonization and stewardship	Finances public policies aimed at developing the maritime economy through support for scientific and technological research and technological start-ups, and will have a key role to play in supporting innovation for Portugal's hydrogen strategy
The Innovation Support Fund (Fundo de Apoio à Inovação)	Pre-commercial	€6m	• Promoting renewable energy and energy efficiency – includes hydrogen	Supports innovation, technological development and investment. Financial incentives will cover innovative pilot or demonstration projects

Sources: [En-H2]

Portugal incentive based interventions

Clear increases on carbon signalled, with support for hydrogen production earmarked to arrive

Incentive name	Type	Budget + horizon	Applies to	Further details
EU-ETS	A cap is set on permissible GHG emissions. This cap is decreased over time – if more carbon is emitted then emission allowances must be traded/ purchased	• Cap set to keep increasing up to 2050	• Energy intensive industries, the power generation sector and aviation	Expansion of to transport and domestic heating sectors is being considered
Differentiated tariff treatments	Exemption from payment for access to the natural gas grid	• Ongoing	• Hydrogen	Only exempt if it does not add excessive burden to the grid in that location
Hydrogen production support	Variable premium on natural gas, coupled with auctions for green hydrogen production and injection into gas networks	• First auction to be announced early 2022	• Green hydrogen production	
Autonomous tax	Tax on vehicles	• 0% for EVs, between 10-35% for petrol cars (depending on cost of car)	• Vehicles	Personal vehicles fuelled by fossil fuels receive higher taxation rates than low – emission vehicles
Fees on consumers travelling by air or sea	Applied per passenger	• €2-2.50 per passenger	• Passengers travelling by air or sea to or from Portugal	

Sources: [Linklaters hydrogen information Portugal, EN-H2]

Portugal key projects and partnerships (1 of 2)

Portugal's planned project in Sines is the country's biggest green hydrogen project

Project name	Proposed COD	Overview	Key figures	Partners involved
H2Sines/ Green Flamingo	2022	• Develop a green hydrogen project to test synchronised capabilities for green hydrogen along the entire value chain, including production, transportation, distribution and demand • First phase is the installation of a 10 MW pilot project, second phase (before 2030) is 1 GW • Offtake is aimed at industry – in particular the Petrogal refinery & gas grid injection	• 5 GW electrolysers • €3.5 b • 200,000 tons/year of green hydrogen by 2025 • 465,000 tons/year of green hydrogen by 2030	• Resilient Group • Vopak • Anthony Veder • H2B2 • ABN-AMRO • Vestas • EDP • Galp
Green Ammonia production facility in Sines	2022	• Create a green ammonia plant in the area of Sines using Green Hydrogen from Fusion Fuel's DC-PEH technology	• €136 m • 10,250 tons/year of green hydrogen • 55,000 tons/year of green ammonia	• Fusion Fuel (and others)
Offshore energy hydrogen production		• The development and commercialisation of a modular and standardised system to produce green hydrogen • The joint development and commercialisation of this technology will allow the partners involved to strategically position themselves in the hydrogen value chain, specifically through the provision of engineering and services worldwide and by the ability to reproduce this business model	• €0.67 m	• EDP NEW • EDPI • CEIIA • USN • TechnipFMC • LusoTPFMC • WavEC
FLEXnCONFU	2020	• Demonstrate the flexibility of combined cycle power plants, using hydrogen, or an ammonia carrier, as energy storage elements • Evaluate the compatibility of the combustion system with unconventional fuels • Survey the needs for flexibility and reference with other assets, determining the economic and environmental rationale of P2H (power-to-Hydrogen) and P2A (power-to-Ammonia) solutions • Demonstrate hydrogen injection in gas pipelines and for mobility	• €12.6m (70% EU financing) • 1 MW PEM • Production target is 18 kg/h	• EDP + 21 partners

Sources: En-H2

Portugal key projects and partnerships (2 of 2)

Portugal's planned project in Sines is the country's biggest green hydrogen project

Project name	Proposed COD	Overview	Key figures	Partners involved
Toyota & Caetanobus partnership	Demo 2019	• Toyota providing its HFC tech to Portuguese bus manufacturer Caetanobus SA • This is for the production of hydrogen fuel cell city buses • Currently available for purchase	• Export buses to Europe • 2 operational within Portugal	• Toyota • Caetanobus
MoUs with the Netherlands, Morocco and Canada	2021	• Netherlands: Agreement to co-operate bilaterally in the green hydrogen space • Morocco: MoU for development of green hydrogen • Canada: agreement to cooperate on the blue economy		• Respective governments

Sources: En-H2

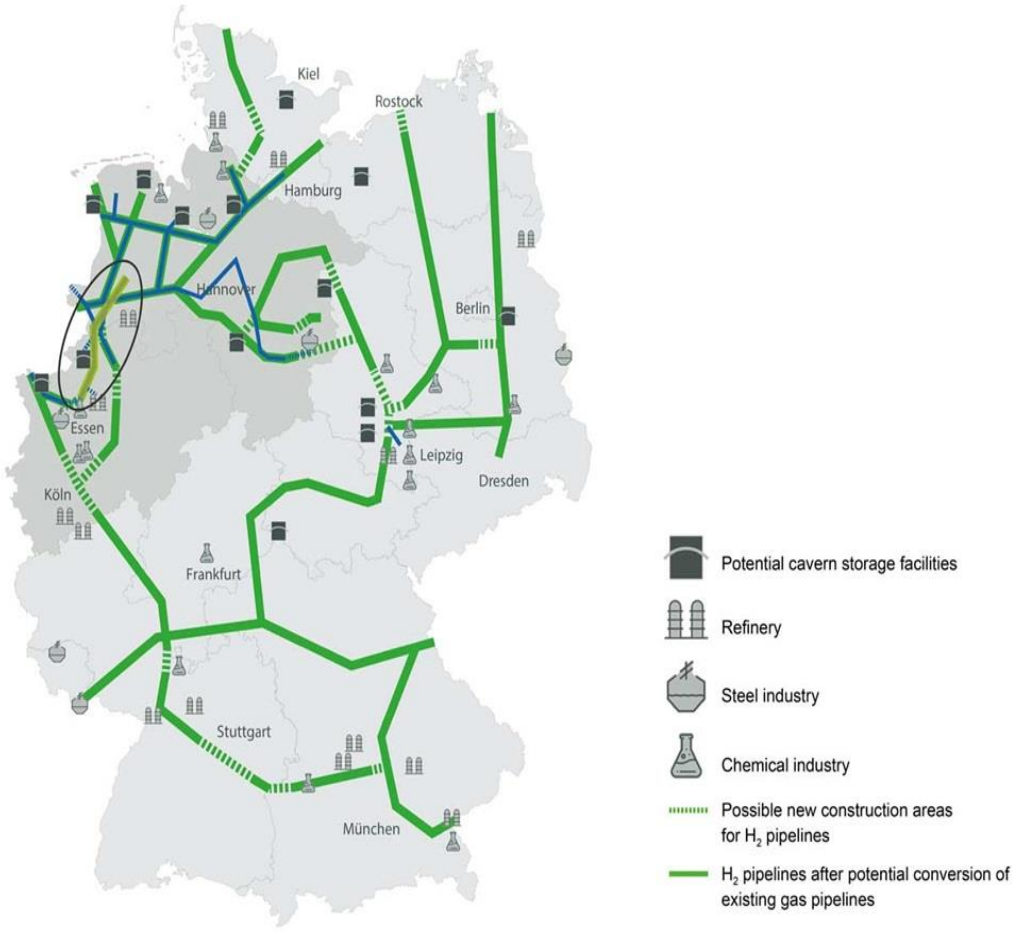
Portugal summary learnings for Lithuania

	Observation on Portugal	Observation for Lithuania
Energy supply/ demand mix	▲ *Portugal have abundant and cheap renewable sources yet are not expecting to be competitive in global exports. Expected that domestic hydrogen production will reduce Portugal's dependence on fossil fuel imports*	▲ *Lithuania have limited renewables compared to Portugal, unlikely to compete in global hydrogen exports. Potentially need to consider hydrogen imports to reach full hydrogen decarbonization scenario*
Ambition, targets and pathway	▲ *Early activity in hydrogen-to-power scenarios in order to provide grid flexibility solutions, which aligns with absence of CCS in decarbonisation strategy*	▲ *Lithuania will also need to consider hydrogen-to-power and technology developments in order to meet 2035 Net Zero power targets without using CCS*
Subsidy and incentive mechanisms	▲ *Sines GW project is taking phased approach whereby 100 MW is being contarcted initially with plan to expand to 1 GW for export*	▲ *Major projects can serve demand in a phased way that de-risks both project and demand offtake e.g., by having an initial use case based on partially replacing grey hydrogen but with appropriate permitting and site selection fit for for future expansion*
	▲ *Portugal pairs auction incentives for green hydrogen production with national grid blending offtake – with associated targeted tax rebates. They are targeting expansion of green hydrogen production with grid blending*	▲ *Although grid blending is attractive as a means of providing early demand, Lithuania's gas grid primarily serves industrial processes and careful coordination with major users (Achema, Orlen) would be required prior to any significant blending volumes*
	▲ *Small fees for using marine and aviation*	▲ *Such fees could be used to fund R&D efforts for longer term use cases in aviation, marine, and heating*
	▲ *Tax rebates for low carbon vehicles*	▲ *Could provide an incentive to switch that compliments rather than overlaps with any future EU regulation of transport fuels*

Country green hydrogen strategy analogue: Germany

Germany Hydrogen Map

The aim is to build an ambitious hydrogen network to connect surplus RES to industrial hubs, and significant import capacities



Source: FNB-Gas. The map shows the "visionary H2 network" as well as the state of discussion of the currently discussed network development plan.

Key insights

- Strategy published in 2020, major update in 2022 to account for any technological and economic developments
- H_2 demand is forecasted in industry hubs in the western and southern parts of the country, and southeast in Saxony. Steel and chemicals highlighted as key hydrogen users in the horizon up to 2050
- Wind potential is mostly in the north of the country, best zones for wind development partly overlap with potential underground sites
- Significant import flows predicted and the country started the *H2Global* to secure relatively cheaper H_2 in some African countries (Morocco, South Africa and Namibia in particular), Russia, Chile, Australia
- In addition to countries above, Nordic, Baltic, and Mediterranean Sea regions identified as potential H_2 supply geographies
- Germany expects to import up to 58% of hydrogen by 2050, producing only 42% for its needs
- Natural gas infrastructure to be adapted to H_2 to connect import and electrolyser capacities to the industrial zones. Main points of import (both H_2 and ammonia) will be Hamburg and Wilmeshaven
- H_2 strategy to be reviewed annually by a board of stakeholders and submit recommendations for strategy update

German green hydrogen strategy: overview

Key assumption: H2 to become regionally and globally traded commodity in the next 10 years

Energy resource and demand context

- Country to become carbon-neutral by 2045, which is earlier than most of EU or Paris-agreement countries
- Energy mix: fossil fuels with oil accounting for 36%, natural gas for 24% and coal for another 18% while of renewable energy sources wind is the most important with 9%, solar 3% and biofuels <1%. Nuclear stands at <1%
- Electricity mix: wind (24%), coal (24%), gas (16%); solar (9%), hydro (3%) and others (9%)
- In 2030, 350GW of wind and solar will be installed with additional 70GW of offshore wind being planned by 2045

Targeted domestic use cases

- Key industries: automobiles, machinery, chemicals, electrical equipment. Germany is Europe's 1st chemical product manufacturer, 2nd oil refiner, 2nd steel producer, and 3rd biggest ammonia producer.
- Most of hydrogen used is grey, used by the petrochemical sector and basic chemicals production (ammonia and methanol)
- Priority for green hydrogen is for hard-to-abate sectors: steel and chemicals. Significant encouragement will be given to the transition of heavy-duty trucks carrying over 20 tons and public transportation to hydrogen fuel-cells
- Heavily industrialized west (North-Rhine Westphalia, Lower Saxony) and south (Bavaria, Baden-Wurttenberg) are front runners who received 62% of Federal Hyland funding competition.

Approach to supply and infrastructure

- Germany recognizes exclusively green hydrogen as sustainable in the long-term. Blue hydrogen is labeled as unsustainable and undesirable in the long-term, its use being primarily transitional in the short-term
- Natural gas network and storage will be gradually repurposed and strengthened for hydrogen. Germany has a large resource of saline caverns suitable for hydrogen storage
- Hydrogen interconnectors with the Netherlands and the UK are planned as part of the EU hydrogen backbone

Import / export plans

- Germany to become largest European consumer of H_2 and by 2050 it expects to meet only 42% of its domestic needs (North Rhine-Westphalia – only 17%).
- The country intends to leverage its existing H_2 know-how to become a global H_2 technology leader
- Several MoU's signed with Russia, Morocco, and Namibia. Germany specifically views Africa as a source of green hydrogen, (€200M already invested in South Africa). Baltic Sea countries alongside some Mediterranean and North sea countries have been identified as potential sources of hydrogen production. Germany would provide consumers, investors and suppliers

German green hydrogen roadmap

The aim is to create a green hydrogen market through the incentivization of current producers and consumers to switch to green hydrogen, expand the transmission grid and foster new demand

	Today	By 2025	By 2030	2030+
Demand use cases	First globally hydrogen-fuelled trainline in Lower Saxony	Inviting and strengthening companies making products for the hydrogen economy (e.g. fuel cells) Pilot projects in chemical product, transportation and oil refining sectors, including first-ever green steel	Significant retrofitting of fossil-fuel based manufacturing facilities Permitting only CO2-neutral cars Expansion of hydrogen use in steel and cement	Trials of hydrogen use in glass production
Supply and distribution	Hydrogen as a by-product of steel making Testing of CCU facilities that combine CO_2 with hydrogen to produce useful hydrocarbons Hydrogen production via fermentation in wastewater plants	New gas plants have to be H_2 ready Seek adjustment of EU state-aid rules to boost H_2 funding outside of EU Ramp-up of hydrogen production in step with the completion of key projects Port facilities able to do storage and gasification of hydrogen using RES Natural gas as transitionary energy-source between coal phase-out and RES adoption	Introduce quotas for green hydrogen and "green base substance" procurement Development of a hydrogen-adapted grid 1,2M tons of blue-hydrogen based ammonia imports from Russia via ships	Hydrogen hubs around large storage facilities, users and producers of hydrogen to pool demand and supply, thus, improving green hydrogen's economic viability

Legend
- Pilot
- Scale up

Phases

Phase 1 (2020-2025)
- Over €10B in investments into creating new hydrogen projects to boost demand, encourage green hydrogen production and create a supply network
- Review the current legislation to reflect the changing status of H_2

Phase 2 (2026-2030)
- Revising KPIs and updating H_2 policy following review of phase 1, evaluating the successes of current projects
- Guide development of new international rules such as on competition rules and imports of hydrogen from non-EU countries.

Phase 3 (2030+)
- Continue bolstering the hydrogen economy with respect to its more mature-state and create new funding and legislation to reflect H2's broader adoption in the industrial and transport sectors
- Encourage German technology exports and new international partnerships

Sources: German Coalition Agreement 2021, Federal Ministry for Economic Affairs and Energy

German green hydrogen targets

CIVITTA Baringa

Hydrogen projects have reached market viability stage in Germany and large technological adaption is envisioned in the next 10 years with ambitious goals set by Federal States themselves

	Today	by 2025	By 2030	2030+
Demand use cases	55TWh of hydrogen are used in industry	€50M for R&D and testing of H_2 fuel cell applications in aviation and shipping	€10B investment to make steel green	€30B investment to make steel green until 2050
	7% of hydrogen produced via electrolysis	SALCOS initiative of €900M public investment for using hydrogen in steel manufacturing (public financing limit 50%)	11000 heavy-duty hydrogen-fuelled trucks in North-Rhine Westphalia alone	
	91 refuelling stations	€1,5B subsidies for purchases of alternative fuel vehicles	3800 hydrogen fuel-cell buses in North-Rhine Westphalia alone	
		100 H_2 refuelling stations	2% kerosene (produced by combining H2 with C2) mandate in jet-fuel	250 refuelling stations necessary in 5 North German Lands[1] alone to provide adequate coverage
			400 refuelling stations by 2027	
Supply and distribution	Point-use cases for hydrogen	500MW electrolysis capacity in northern Germany, 100MW in North Rhine-Westphalia	1,5-2€ / kg green H_2 imports from Namibia	
		€290M investments in connections with the Netherlands by 2025	10GW Electrolysis capacity producing 14TWh of hydrogen, however the German Energy Agency pilot study assumes 15GW will be in installed in Germany	15GW Electrolysis capacity by 2035
		2,4GW of gas capacity will come online in 2022/23 that will have to be H_2 ready, adding to current gas capacity of 27,2GW	1300km of hydrogen-adapted pipelines	
			1000 fuel-cell dedicated waste trucks in North-Rhine Westphalia	
Targets	Currently 7,7GW of installed offshore wind	€9B investment in domestic H_2 adaptation until 2026	Complete coal-phase out by 2030	€14B GDP contribution and 373300 jobs by 2050 if domestic hydrogen production reaches the predicted 42%
	Currently 49GW of installed solar energy	€2,9B investment in international H_2 production	80% of electricity from renewable sources	
	2% of land dedicated to wind parks		90-110TWh demand of hydrogen in 2030	
	New commercial buildings have to have solar PV		Target 30GW Offshore wind	Target 70GW Offshore wind by 2045
			Target 120GW Onshore wind in northwest and east	After 2045 pipelines and power stations can only be used if they run on non-fossil fuels
			Target 200GW solar power in the south	155TWh H2 needed to decarbonize industry

[1] *Bremen, Hamburg, Schleswig-Holstein, Lower Saxony and Mecklenburg Vorpommern*

Sources: Cleanenergywire, CMS, Federal Ministry for Economic Affairs and Energy, Bloomberg, SPGlobal, Wuppertal

Germany | regulation plan summary

German strategic hydrogen direction is set on a federal level but specific policies are proposed on the state level with numerous independent decisions taken by private businesses

Category of regulation	Description	Status / timeframe
The Federal Hydrogen Strategy	Provides the funding options for hydrogenation of the economy: package for the future, H2Global, Energy and Climate Fund; however, the specific funding mechanisms are laid out by specific agencies	A new strategy is to be created in 2022
	Details incentive mechanisms that are in the pipeline, such as carbon contracts for difference that shield private enterprises from risks associated with H_2 adoption, green steel licencing and green procurement quotas	
	The strategy does not outline specific goals rather it focuses on the sums of money to be spend for various purposes	
	Clearly states that only green hydrogen is acceptable and that the country will be a net importer of hydrogen	
	Elaborates on the sources of hydrogen imports, noting the particular importance of the Baltic and North sea regions	
	Covers the investments in R&D to retain Germany as the leader of hydrogen technologies worldwide	
	Special attention is paid to the Hydrogen Council, the oversight body of the Strategy, which will submit recommendations annually, amend objectives and identify opportunities	
The Federal States' Strategies	Strategies were made by certain individual states, but some were made as a collaboration between a grouping of states from a certain region (e.g. east, north)	These strategies have different expiration dates dependent on the federal legislation
	These establish concrete objectives for hydrogen adoption (e.g. North Rhine Westphalia 3800 fuel cell buses by 2030 or 1000 collection bins for hydrogen fuel cells or in the North German states the emphasis on good port infrastructure and excess wind power), local strengths and competences, H_2 adoption priority areas and list of projects currently being developed	
The German Government Coalition Agreement	Outlines the goal to greatly increase renewable energy targets for wind (offshore to 30GW and onshore to 120GW, dedicate 2% of territory to wind parks) and solar	Valid until a new government is expected
	Recognizes that natural gas will be an important transitionary source of energy until RES catch up in market prices and generational capacity to fossil fuels	
	Boosted hydrogen targets from 5TWh by 2030 to 10TWh by 2030, declaring that hydrogen is a crucial resource necessary to decarbonize industry	

Sources: Federal Ministry for Economic Affairs and Energy, CMS

Germany direct subsidy interventions

Large investments are made into R&D and commercialization of scientific innovations

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
Package for the future (2020)	• Full scale commercialization	€9B	• Businesses	Speeding up the market rollout of hydrogen technology in Germany and for fostering international partnerships
National Innovation Programme on Hydrogen and Fuel Cell Technology	• R&D	€1,4B until 2026	• Research Institutions • Businesses	Programme for research and development funding
Decarbonisation programme	• Full scale commercialization	€1B until 2023	• Retrofitting for businesses	Funding is for investment in technologies and large-scale industrial facilities which use hydrogen to decarbonise their manufacturing processes
H2Global	• Full scale commercialization	€900M first deliveries in 2024, the program will run for 10 years (included in €9B 2020 package)	• Production in foreign countries	Support investments in the production of renewable hydrogen (electrolysers over 100MW) in non-EU countries
Regulatory Sandboxes for the Energy Transition	• Full scale commercialization	€600M until 2023	• Research Institutions • Businesses	Speeding up the transfer of technology and innovations from the lab to the market, not least for hydrogen solutions
Energy and Climate Fund	• R&D	€510M until 2023	• Research Institutions • Businesses	Support for practice-based energy research on green hydrogen

Sources: Federal Ministry for Economic Affairs and Energy

Germany incentive based interventions

Incentive based mechanisms in Germany are being considered particularly in the industrial sector aiming to combine government guarantees, quotas and labels to incentivize producers to adopt H_2

Incentive name	Type	Budget + horizon	Applies to	Further details
Carbon Contracts for Difference	• Price guarantees for companies to install green technologies to make them competitive with carbon-intensive technologies	• Proposed but not legislated therefore no specific sum of funding • White paper released April 2021	• Aimed at steel and chemical industries	• Similar to CfDs against power prices for solar and wind • Stabilised the long-term price of carbon experienced by industrial emitters and hence provides confidence to invest in low-carbon initiatives
Quota for climate-friendly substances	• Proposed in the current national hydrogen strategy	• Being considered • No specific sum provided	• Base substances, namely steel and lead	• The Federal government using its procurement power to incentivize companies to produce important base substances in a climate-friendly way
Climate-friendly label for green substances	• Proposed in the current national hydrogen strategy	• Being considered • No specific sum provided	• Base substances, namely steel and lead	• Clear labels for base substances and industrial goods produced in a climate friendly way
H2 blending in the natural gas grid	• Regulation	• By 2045 natural gas to be completely phased out and pipelines retrofitted	• H_2 blending in natural gas	• Natural gas can be blended up to 8% (the highest in the world) if there is no CNG filling station connected to the market

Sources: Federal Ministry for Economic Affairs and Energy

Germany key projects and partnerships

CIVITTA Baringa

Germany has over 60 projects which span green hydrogen creation, storage, distribution and adoption

Project name	Proposed COD	Overview	Key figures	Partners involved
H2 Mobility	2023	• "H2 supply suitable for everyday use shall be created not only for densely populated areas and main traffic arteries, but also for rural areas. The objective is to offer an H2 station at least every 90 kilometres of motorway between densely populated areas. Drivers of fuel cell powered vehicles will have at least 10 hydrogen refuelling stations available each from 2023. Thus zero tailpipe emission H2-mobility is becoming increasingly attractive for customers."	• 100 refuelling stations in 7 majors German metropolitan areas with another 300 planned in the next 4 years • €350M investment	- Air Liquide (industrial gases) - Daimler (automobiles) - Linde (chemicals) - OMV (oil, gas and petrochemicals) - Shell (oil) - Total (oil)
AquaVentus offshore wind-to-hydrogen	First phase – 2025 (30MW electrolyser) Last phase – 2035 (5GW electrolyser & dedicated pipeline)	• "The project comprises offshore wind farms. They shall be built initially offshore the German island of Helgoland and in the further course of the project at the Dogger Bank sandbank by 2035. From the electrolysis plants the green hydrogen shall be transported via a dedicated pipeline system to Helgoland and in the final stages of the project further on to the German mainland."	• 5GW Electrolyser capacity by 2030 and 10GW by 2035 • 1 millions tons of hydrogen by 2035 • €135-345M investment	- RWE (electric generation) - Shell (oil) - Siemens Gamesa (renewable energy) - Vettanfall (energy) - Northland Power (electric generation)
Bad Lauchstädt Energy Park	2026	• "Renewable electricity will be converted into hydrogen by electrolysis and supplied to the chemical industry plants in neighbouring Leuna via a 20-kilometre gas pipeline In addition storage facility in a salt cavern is being built	• 40MW electrolysis • 50 million m^3 storage facility • €140M investment	- ONTRAS (gas transmissions) - Uniper (energy) - VNG Gasspeicher (natural gas)
Get H2	Electrolyser operational by 2023 135km pipelines ready by 2024 Links with the Netherlands by 2025 Storage facilities operational in 2026	• Implementation of several projects in Germany encompassing the production, transport and storage of green hydrogen • "Besides implementing a public hydrogen infrastructure, the specific aim of the project is to develop electrolysis through large-scale deployment and thus reduce the cost of producing green hydrogen. Based on the existing natural gas pipeline network, the GET H2 Nukleus project has the potential to green light a regulated hydrogen infrastructure in Germany." • The overall project has a CO2 avoidance potential of up to 16 million tonnes by 2030	• 100MW Electrolyser capacity and additional 200MW if necessary • Hydrogen storage at salt caverns in North-Rhine Westphalia • 135km of pipelines able to transport 100% H2	- RWE Generation (electric generation) - Nowega (transmissions system operator) - OGE (gas transmissions) - Gascade (gas transmissions) - BP (oil) - BASF (chemicals) - Stadtwerke Lingen (electric utilities) - Hydrogenious Technologies (hydrogen transport and storage)

Sources: Federal Ministry for Economic Affairs and Energy, CMS, Geth2.de, H2me

Germany summary and learnings for Lithuania

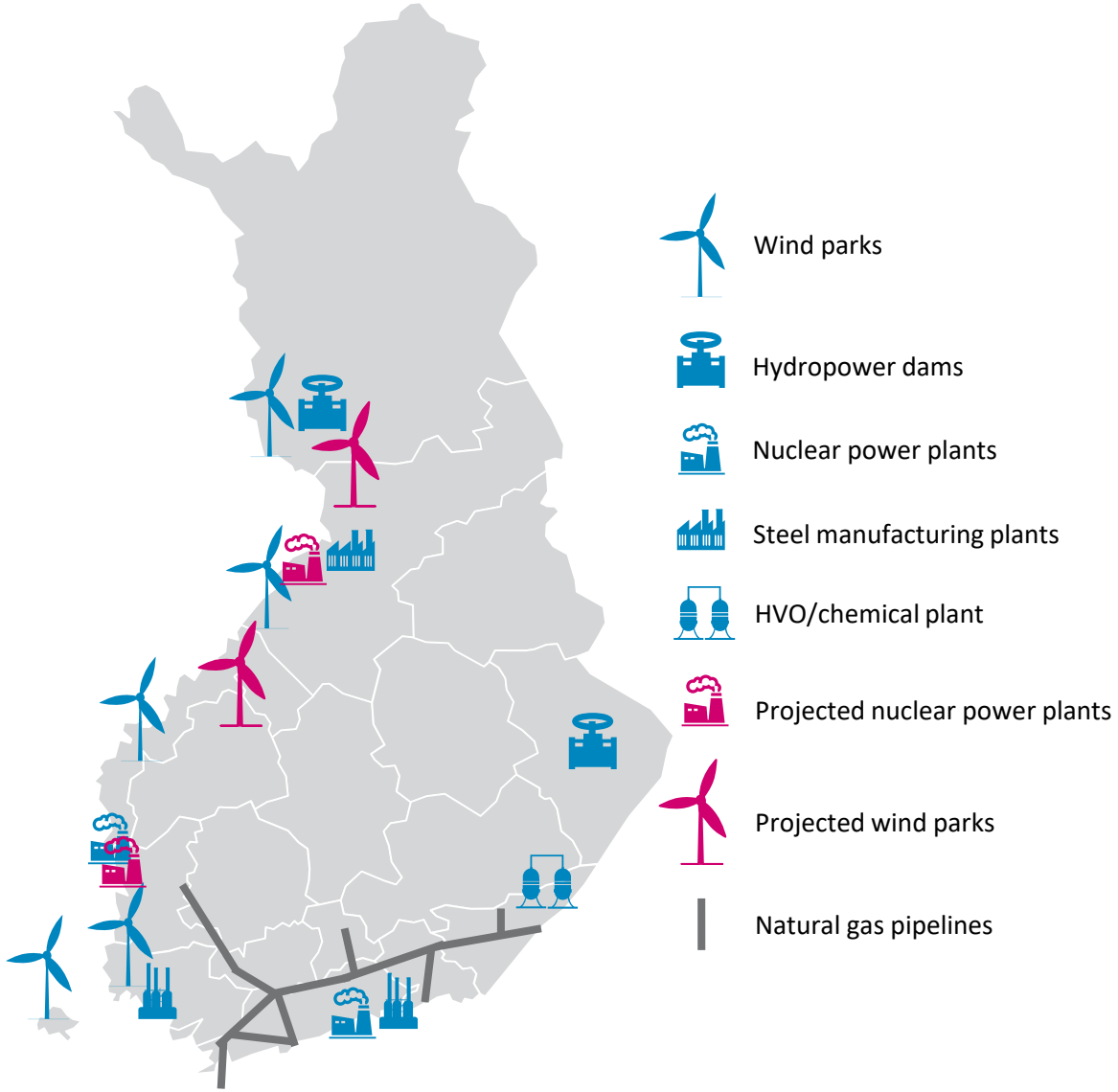
Germany has ambitious targets for H_2 adoption, which can be useful for Lithuania as it can utilize German private and public funding for local H_2 production and eventual export

	Observation on Germany	Observation for Lithuania
Energy supply and demand mix	▲ Germany is a net importer of energy (importing up to 50% of its needs) and will reman so ▲ German demand for H2 will increase (industry alone will need 10TWh more by 2030), thus it will be a net importer of H_2	▲ If Lithuania plans to be an exporting country, Germany will be a significant export destination, but current German public and private efforts/investments are focused on Russia, Australia, Chile, southern Africa and the Middle East, where low cost resource is expected
Ambition, targets and pathway	▲ Certain states, like North Rhine Westphalia aims to introduce H_2 trucks and public transport at a large scale (11k H_2 powered trucks and 3.8k buses), which will foster the development of H2 refuelling network and create demand for H_2. Federally, 400 refuelling stations are planned ▲ North Rhine Westphalia also envisions 1000 hydrogen fuel cell collection bins which are important considering the fact that fuel cells require REM and if untreated are dangerous to the environment	▲ Largest economy in Europe is betting on substantial conversion of trucks, public transport and other heavy duty vehicles from fossil fuels to H_2 ▲ A refuelling network can be built in partnership with logistics companies, for heavy duty vehicles which can be expanded for lighter vehicle use ▲ Lithuania can consider developing more niche use cases (e.g., waste collection) where larger hdroegn economy already exists e.g., where there is a hydrogen powered bus network or industrial demand
Mechanisms and interventions	▲ Large investments (€900M) and efforts to change EU competition rules are also made by the Federal Government and private companies to develop hydrogen outside the EU ▲ Private companies (Siemens, Uniper) are pursuing options to source blue hydrogen from non-EU countries ▲ Germany's proposed approach to carbon CfDs for industrial emitters under ETS will encourage investment in making grey hydrogen green among industrial emitters	▲ Lithuanian exports of H_2 to Germany will be competing with the world, not only other EU states ▲ Lithuanian government could aim to capture a share of those investments, not only in production, but also R&D and the creation of sophisticated H_2 technologies, leveraging Lithuanian manufacturing strengths ▲ If Lithuania desires H_2 imports collaboration with Germany on setting common prices, creating a common import infrastructure ▲ Lithuania may adopt such an approach for it's grey hydrogen and ETS-regulated heavy industry more broadly but such a scheme will be novel and may take time to design effectively. However, the relatively small number of major industry emitters means a scheme could face less barriers to effective design in Lithuania

Country green hydrogen strategy analogue: Finland

Finland Hydrogen Map

Hydrogen ambitions are small, playing a limited role in decarbonization of industry and transport



Key insights

- The natural gas grid is build in the industrialized and densely populate south near the Gulf of Finland while continuously expanding wind generation capacity is focused in the western part of the country, the Gulf of Bothnia
- The country does not have any salt rock caverns which are useful for long-term storage of hydrogen, only short-term storage in lined rock caverns (LRC) is possible
- Currently there is no dedicated H_2 pipeline, thus, the most promising method of transmission in the short term is ADR vehicles (trucks able to carry hazardous payloads) carrying 2,000kg of H_2 until a dedicated pipeline is built or existing one adapted
- Security is also addressed in Finland with the acknowledgement that pipelines can be prone to intentional or unintentional malfunctions with the Gulf of Finland between Finland and Estonia being of particular importance due to Finnish military's concerns
- The south contains the most important users of hydrogen in the form of HVO and oil refining facilities with most of electrolyser capacity today being near these factories connected by small individual H_2 dedicated pipelines
- Hydrogen is not seen as a flexibility provider to the electricity system rather emphasizes the importance of interconnectivity with the Nordic and continental European electricity grids
- The NECP (National Energy and Climate Strategy) has not set any objectives or supporting measures specifically related to hydrogen. In Finland, there are no technology-specific policies to promote fuel cell vehicles and hydrogen refuelling stations infrastructure. Driven by ambitious climate targets, the deployment of H_2 will be fully guided by the market

Finland green hydrogen strategy: overview

With the aim to become the first country in the world to become carbon neutral H_2 will serve niche cases where other options to fossil fuels are limited

Energy resource and demand context

- The energy supply is based on oil (34%), nuclear (20%), hydropower (14%) and coal (13%)
- The electricity supply is heavily dependent on nuclear (34%), hydropower (23%), other renewables such as biogas and peat (16%) and wind (11%)
- 24% of electricity is imported of which 69% comes from Sweden and 26% from Russia, in these two countries coal, oil and gas accounted for 2% of the electricity mix in Sweden and 59% in Russia
- The largest industries are electronics (21.6%), machinery, vehicles and other engineered metal products (21.1%), forest industry (13.1%), and chemicals (10.9%)
- Hydrogen strategy is set to be published not as a standalone document but as a part of a larger climate transition paper in 2022

Targeted domestic use cases

- Before 2030 hydrogen's primary use will be in the industrial sector, particularly petrochemicals, HVO but long-term hydrogen production is hoped to be expanded as an avenue to optimize and utilize
- H_2 is widely used in the Finnish industrial sectors primarily in oil refining and biofuel sectors, accounting for 2% of national energy consumption
- Because electric vehicles have became the green alternative in public transit and light vehicles, and because a hydrogen-refuelling grid has not been successfully established despite investments, H_2 fuel cells will be prioritized in long-distance, heavy payload vehicles (partnership with Toyota)
- 90% of Finland's heating is done via biomass and electricity, thus, H_2 can only play a limited part

Approach to supply and infrastructure

- Because Finland intends to become the first country in the world to become carbon-neutral by 2035 it does not accept grey or blue hydrogen as possible intermediaries before full-scale adoption of green H_2
- Hydrogen demand will be distant from hydrogen supply both within Finland and with respect to the EU; the supply will be concentrated in the north-western part of Finland while demand is in southern Finland and across the Baltic in Germany and Poland
- The current gas network is insufficient as it only covers the southern part of Finland, thus, the Swedish H2 grid will be used to send hydrogen via Sweden and Denmark to continental Europe and a dedicated pipeline connecting northern Finland with Estonia is suggested

Import / export plans

- According to Gasgrid (state-owned natural gas transmission operator) and Guidehouse (a consultancy) the country intends to utilize its large wind power potential to develop hydrogen export capabilities with Germany and to a lesser extent Poland, intended as primary markets with 75TWh of unmet demand by 2030 (€4B euro potential export market)
- However, Business Finland (an arm of the economy ministry) states that exports will not be possible despite strong fundamentals (large renewable production capacity and industries consuming H_2 at great quantities) as market uncertainties make big investments unappealing
- Competition for the German market is seen as tough because green H_2 generation and transportation prices are very similar in the Baltic region: Finland €2,2/kg, Sweden €2,1/kg and Estonia €2,4/kg. Because margins are small, other factors such as permitting, taxes and regulations will produce the competitive advantage for exporting countries

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Finland green hydrogen roadmap

Hydrogen ambitions will be achieved solely market mechanisms investment and no central hydrogen strategy until 2022 Q2

	Today	by 2025	By 2030	2030+
Demand use cases		Increase of hydrogen use in the oil and chemical industries as Neste is planning to expand their HVO production P2X chemical plants in industrial plants where H_2 and CO_2 as by-product are readily available Polymers and specialty chemical production using green hydrogen and CO_2 by VTT Production of synthetic biomethane	SSAB steel refinery will offer green-steel by 2026 250000 electric and hydrid cars by 2030	Replacement of blast furnaces in steel facilities with electric arc furnaces by 2040 sector wide
Supply and distribution	Only two H_2 pipelines both in factories Using excess heat produced by generation of H_2 for district heating by Elematic and TSE	Testing of storage solutions, particularly lined rock caverns (LRC) Studies on repurposing natural gas pipeline infrastructure for H_2 use Hydrogen transport by tube trailers, able to carry payload of 2000kg	Hydrogen prices are expected to fall due to cheaper electrolysers being produced at larger quantities and sizes EU Commission assumes part of H_2 in industry will still not be green by 2030 With sufficient demand – dedicated H_2 pipelines will be built (earliest possible by 2030) Hydrogen valleys/villages in places where hydrogen production occurs in industry because that electrolysis capacity can be used for transport	Finland joined the European Hydrogen Backbone, a plan between 21EU countries to develop 40000km of H_2 transmission network by 2040

Legend
- Pilot
- Scale up

Phases

Phase 1 (2020-2022)
- **The private sector and public investments in R&D created strong examples and niches for the hydrogen economy, which can be used in the hydrogen strategy to be passed in 2022 Q2**
- **Private investments have also shown the legislative improvements needed for a functioning of a H_2 market**

Phase 2 (2022-2030)
- Developing a legislative basis for future hydrogen applications especially with regard to modes of H_2 transportation and electrolyser operation (combustion in furnaces, injection into the gas grid)

Phase 3 (2030+)
- Reviewing KPIs and setting new objectives in light of new economic and technological developments alongside the success of the green transition domestically and the development of the hydrogen economy globally

Sources: Ourworldindata, Statista, Ministry of Economic Affairs and Employment of Finland, European Commission, Gasgrid/Guidehous, Business Finland

Internal note: with this and previous slide please take license to resize or split timeline differently depending on how the source strategy itself articulates it

Finnish green hydrogen targets

Business Finland study establishes a conservative view of hydrogen uptake while Gasgrid/Guidehouse project Finnish green energy potential to be the key to green H_2 production

	Today	by 2025	By 2030	2030+
Demand use cases	2 H_2 refuelling stations 20 H_2 buses in Kerava since 2019, town of 34500 people and a dedicated solar plant for electrolysis	21 H_2 refuelling stations Expansion of UPM Bioverno facility and output by 50000t of biodiesel	EU study: 32-68 refuelling stations for 17400-34800 H_2 fuelled cars (government objective: 50000 gas fuelled cars) EU study: 0-90 buses, up to 1740 trucks and 2-8 hydrogen fuelled trains Expansion of UPM Bioverno facility and output by 50000t of biodiesel 6TWh of H_2 national demand driven by industry	13TWh of H_2 national demand by 2035 19TWh of H_2 national demand by 2040, 13 of which from industry, 3 from transport, 1 from heating and 1 for power 30TWh of H_2 national demand by 2050, 17 of which from industry, 6 from transport, 4 from power and 4 from heating 450-550 MW electrolysis input to decarbonize SSAB steel mill
Supply and distribution	Production of H_2 as by product of burning methane (CH_4) to extract CO_2 for industrial uses Research into alternative gases done by a consortium of businesses given €10M funding by Business Finland 130MW capacity SMR in Porvoo producing 48000t of H_2	*Technical maximum of supply: 50TWh* 88M from EU Commission to decarbonize Neste's Porvoo refinery Electrolyser APEX costs are expected to fall to €0,5M/MW driven by mass production (33% decrease from today) EU study: 320-1120MW electrolyser capacity	*Technical maximum of supply: 150TWh by 2050* Electrolyser APEX costs are expected to fall further to €0,2M/MW	
Targets		Depending on the level of H_2 uptake, the economy would benefit by €270-900M 2730-8850 jobs would be created Reduction of 1,2 – 3,6 Mt of CO_2 50% of energy from renewables	Domestic Finnish hydrogen market is projected to be €2B by 2050 Waste heat from electrolysis can meet 15% of district heating demand	

Sources: Ourworldindata, Statista, Ministry of Economic Affairs and Employment of Finland, European Commission, Gasgrid/Guidehous, Business Finland

Finland hydrogen regulation plan summary

Three studies detail plans for hydrogen adoption in Finland, ranging from presenting a scenario where H2 an ambitious exporter to a pessimistic importer role

Category of regulation	Description	Status / timeframe
Gasgrid/Guidehouse	A study by the national Finnish gas grid operator (Gasgrid) and an American consultancy (Guidehouse) argues that Finland can become a net exporter of hydrogen quite rapidly by leveraging its massive wind power resources and capturing a large share of the German demand	Published 2021 Q4
	The paper argues that Finland has the technical maximum to produce up to 150TWh of hydrogen by 2050, stating that today there is 10 times more wind park capacity under construction than in operation, citing this momentum as evidence of massive possible future hydrogen operations	
	The H_2 would be transported from northern Finland to continental Europe via Swedish pipelines and a dedicated pipeline connecting Finland to Estonia	
European Commission	A study commissioned by the European Commission predicting the role of H2 in the decarbonization of the Finnish economy, presenting a middle path to Gasgrid/Guidehouse and Business Finland models	Published 2020 Q2
	Rather than establishing goals or areas where H_2 should be adopted, the report presents certain ranges for which sectors will adopt hydrogen how much	
	According to this study, Finland will have between 0,3 and 1,1GW electrolysis capacity that will fuel 2-8 trains, 17400-34800 H_2 cars and 0-90 buses	
	Hydrogen will play only a marginal role in the Finnish green transition as it will not be used as a stabilizer in the power system, which instead would be improved by expanding it to have more interconnections with other EU countries and H_2 adoption by the industry will be slow	
Business Finland	The roadmap evaluates current hydrogen use in Finland and observes that Finland will be a net importer of hydrogen	Published 2020 Q3
	The primary of hydrogen will be the steel sector which will decarbonize in the 2030s	
	Planned RES powered electrolysis capacity will not be enough to transition all of current grey hydrogen to green	
	Hydrogen will be transported by Europe-largest heavy-duty trucks, until there is more market demand for H_2	

Sources: European Commission, Business Finland, Gasgrid/Guidehouse

Finland direct subsidy interventions

There is no published hydrogen strategy thus avenues for hydrogen funding are not identified and green H_2 is treated as a commodity whose adoption will depend on its price in a free market

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
Energy Aid	• Scale up	• Contribution of minimum €10000 (no upper limit) • No expiration for the program	Anything that promotes the production and use of renewable energy, energy saving, more efficient production or utilization of energy	The aim of energy aid is to promote the development of innovative solutions for replacing the energy system with a low-carbon alternative in the long term

Sources: Business Finland

Finland incentive based interventions

The initiatives are focused on encouraging consumers to become more conscious of green alternatives and make them more financially acceptable

Incentive name	Type	Budget + horizon	Applies to	Further details
The Act on Guarantees of Origin for Energy	• Certificate	• Prices and budget will be set early 2022 • Operational from April 2022	• Gases and hydrogen produced in Finland regardless of whether the gas is injected into the transmission network or produced outside the natural gas network	Guarantees of origin help the user to ensure that the energy used has been produced from renewable energy sources
The cancellation of the vehicle tax on hydrogen and electric cars	• Tax exemption	• Effective 1 January 2022	• Cars and vans	The car tax rate for passenger cars and vans fully powered by electricity or hydrogen is 0, otherwise it is between 12.2% and 48.8%

Sources: Business Finland

Finland key projects and partnerships

The private sector boasts large financial commitments and technological know-how in hydrogen

Project name	Proposed COD	Overview	Key figures	Partners involved
Porvoo refinery green hydrogen production and carbon capture & storage	2030	• The Porvoo refinery is one of the largest in Scandinavia, producing over 240,000 barrels a day with an annual capacity of 13 million tonnes. • Carbon capture and storage (CCS) and electrolysis solutions that allow decarbonisation of production at the refinery	• Reducing CO2 emissions by 400,000 tons a year • €88M investment	- Neste Oil (oil) - European Union (public body)
P2X Solutions: first industrial scale green hydrogen production plant	Operational by 2024	• It will run on electricity produced by renewable energy, and captured carbon dioxide emissions from a Finnish industrial plant • Aims to produce synthetic biofuel from the green hydrogen and caught carbon dioxide	• 20MW electrolyser capacity • €46M investment	- Hitachi ABB Power Grids (energy) - Sweco (engineering)
Wartsila: adoption of hydrogen as a viable engine fuel for ships	An engine and plant concept for pure hydrogen operation ready by 2025	• Gas engines in development for highly flexible operation in marine capable of rapidly ramping up or down in power	- N/A	- Knutsen OAS (shipping) - Repsol Norway (oil) - Equinor (oil) - Singapore Port Authority (public body)
Power to gas project	Planned to be commissioned in 2025	• Synthetic carbon-neutral gas is produced by utilising raw materials obtained from the Vantaa waste-to-energy plant: electricity, water and carbon dioxide. • The produced gas is used for replacing natural gas at heating plants, which are needed for heating in the coldest winter periods. Gas can be stored cost-effectively in the natural gas network in order to have a sufficient amount of gas available	• 10MW installed capacity	- Vantaa Energy (heat) - Wartsila (manufacturer of sustainable energy and shipping products)

Sources: Ourworldindata, Statista, Ministry of Economic Affairs and Employment of Finland, European Commission, Gasgrid/Guidehous, Business Finland, VTT, Neste, P2X

Finland summary and learnings for Lithuania

Although Finland has no outlined hydrogen strategy, several measures taken by private enterprises have shown the market-applicability for these uses of H_2 and potential in Lithuania

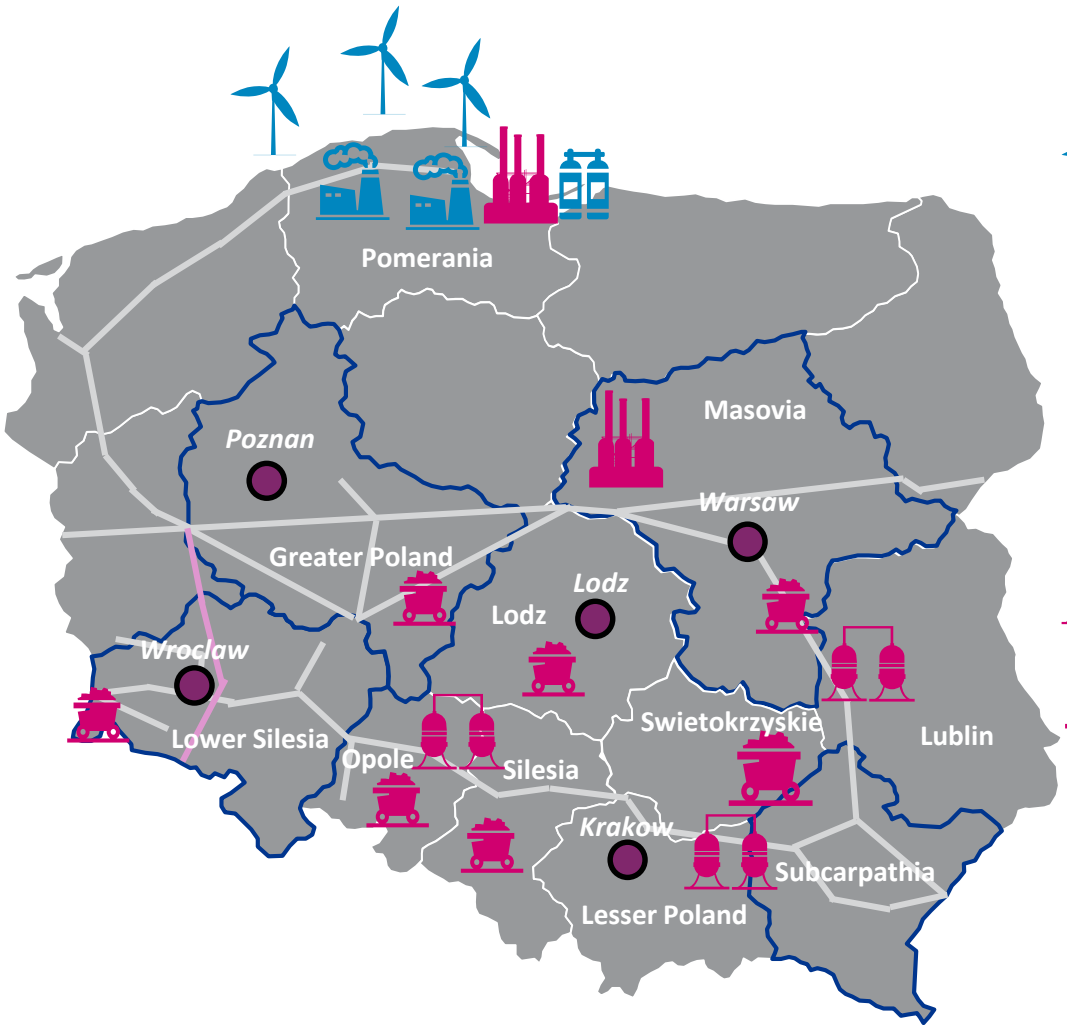
	Observation on Finland	Observation for Lithuania
Energy supply and demand mix	▲ Finland has a similar energy trajectory and geography to Lithuania: large reliance of wind power on the western part of the country situated far away from urban and industrial centres, with proven industrial hydrogen demand and low reliance on natural gas for heating and power ▲ The first electrolysers will be placed in industrial parks next to major factories, but eventual electrolyser distribution is unclear	▲ Lithuania could consider the production H_2 locally on industrial facilities especially in industrial parks where there is demand for H_2 and O_2 (by-products of H_2 production)
Ambition, targets and pathway	▲ The priority is given to heavy duty trucks and public transit recognizes the competitive advantage electric battery vehicles have in light vehicle sector. Finland leverages its heavy duty trucks to transport H2 in initial phases of H2 adoption as they are the largest and can transport the most in the EU ▲ H_2 public transit has been introduced in a town of 35,500 people, fuel for it being generated by small-scale PV solar	▲ Lithuania is facing difficulties meeting its objectives to decarbonize its transport sector and adoption of H_2 technologies in heavy duty trucks and public transit could allow to solve distance and payload issues associated with electric vehicles ▲ Lithuania has 7 towns with population of over 35,000 people (Vilnius, Kaunas, Klaipėda, Šiauliai, Panevėžys, Alytus and Marijampolė)
	▲ Hydrogen production using heat created as by-product of residential heating and in manufacturing facilities in industrial parks can serve as a way to monetize otherwise wasted heat and create a potential source of energy, which can be readily used in industrial facilities	▲ Providing district heating through utilizing heat which occurs as a by-product of H_2 production can be an important step towards establishing a circular economy and would not require large investments or a national grid and can be most applicable in industrialized and urbanized parts of the country
Mechanisms and interventions	▲ The Finnish government has thus far expected H_2 uptake to occur due to market forces, encouraging research, but there has been a lack of direct funding for near-commercial pilots ▲ Currently, three stakeholder groups have presented three narratives for H_2 development (optimistic, pessimistic and in-between) explaining why there is no direct funding at the moment with the government keeping its options open and leaving room for setting hydrogen targets in the future	▲ Ambitious climate and hydrogen action should be underpinned by financing and significant legislative and regulatory efforts
	▲ Finnish OEMs with global clout are key participants: Wartsila (engines) and Neste (refining)	▲ Hydrogen is an opportunity for Achema, Orlen and other heavy industry to export capability, both themselves and their supply chains

Country green hydrogen strategy analogue: Poland

Polish Hydrogen And Energy Map

CIVITTA Baringa

Future Polish green and nuclear power generation will be concentrated in the north while most of its demand is in the south, to remedy this it will utilize power plant on-site generation



- Projected offshore wind power plants
- Projected 2/6 nuclear power reactors
- Projected CO2 terminal
- Current oil refineries
- Current fertilizer producers
- Current coal power plants
- Hydrogen Valleys 1 left TBD by the government
- Natural gas pipelines
- Projected north-south natural gas pipeline

Key insights

- Two nuclear reactors and all offshore wind capacity in the north of the country
- Most of existing power generation in the form of coal mines and coal power plants are in the south
- Most of the industry that requires or will require hydrogen, are in the south and centre
- As is, there are comparatively few links between north and south as opposed to east and west
- A new pipeline expansion that connects Polish LNG terminals with Croatian LNG, that can be used to transport blended Hydrogen
- Poland to encourage innovation and hydrogen adoption by establishing hydrogen valleys in industrialized states of the south
- Polish plans for full carbon neutrality are vague and less ambitious than the rest of the EU's, consequently, it views low-carbon (blue) Hydrogen as viable too
- Initially hydrogen production will be dispersed: small electrolysers serving local needs, however, in the long-term larger electrolysers based specifically in the north and accompanying infrastructure will be considered if there is demand

Sources: Polish Ministry of Energy, Polish Ministry of Climate and Environment

Polish green hydrogen strategy: overview

Green, blue, and pink Hydrogen will all be used to achieve hydrogen self-sufficiency

Energy resource and demand context

- Poland currently mostly utilizes coal (45%), oil (32%) and gas (17%) as its sources of energy while renewables: wind, solar and hydro together make up only 4% of the Polish energy mix with biofuels making up 1%
- Electricity in Poland is derived from coal (70%), gas (10%) and wind (10%)
- Energy demand is split between transport (31.8%), households (25.8%) and industry (25.8%) with the agriculture sector taking only a minor share of all national energy (11.1%); within the manufacturing sector electronic appliances, cars and aviation being the most important
- Poland imports 66% of its natural gas and 20% of its coal; RES alongside nuclear resources are meant to improve its energy import/export balance
- Hydrogen strategy was published in December 2021 with a new Hydrogen Law set to be published in 2022/23 that will propose new hydrogen laws

Targeted domestic use cases

- Hydrogen is expected to serve as a crucial fuel in transport and feedstock in industries where electrification may be impossible
- Grey hydrogen is already heavily utilized in industry with 90% of hydrogen used for ammonia and methanol production, and oil refining processes
- Initially, Poland envisions to invest resources into R&D of various hydrogen-based projects, such as fuel-cells, small power generators alongside small electrolysers and hydrogen-adoption for vehicles
- Current demand is 1,3M tons/year with 4 companies controlling 59% of its production of which 32,3% is controlled by Azoty (chemicals), Lotos and Orlen making up 15,2% (oil) and Koksownie i Przyjazn controlling another 11,5% (coking)

Approach to supply and infrastructure

- Poland views hydrogen produced from green (RES), pink (nuclear) and blue (fossil fuel-derived with CCS) hydrogen as desirable
- Hydrogen will initially be transported by roads and rail, but over time existing gas infrastructure or dedicated hydrogen pipelines will be used. The infrastructure projects will be developed in tandem with the European Hydrogen Backbone initiative[1]
- There are discussions of “on-site” P2X conversion of solar and nuclear energy; wind energy would be used to generate hydrogen for “green-ports” and hydrogen-based vessels
- Hydrogen valleys will serve as ecosystems which will build a value chain in the hydrogen economy such as production, transport, storage and end-use of hydrogen in industry. R&D and investment projects will be carried out that will enable the exchange of information and experiences. The valley model is based on shortening the distance between supply and demand providers

Import / export plans

- Poland does not intend to be neither an exporter or an importer of hydrogen, expecting instead to be 99.4% self sufficient
- By 2026-7 Poland expects to establish a strong system of patents and hydrogen-IP, that will make it an exporter and leader of hydrogen technology

[1] *Adapting current pipelines to hydrogen is €0,8M/km while new lines cost €2,5M/km*

Polish hydrogen roadmap

CIVITTA Baringa

Initial phase 1 investments in R&D will be supplemented by a ramping of capacity for electrolysis, hydrogen-transportation and fuel-cells in phase 2 and more ambitious projects will occur 2030+

	Today	by 2025	By 2030	2030+
Demand use cases	Poland is 1 of 3 EU countries (out of 27) that do not apply CO2 taxation on vehicles	Manufacturing of hydrogen-fuelled buses in Poland (up to 500; made by Solaris) Pilot hydrogen initiatives across chemical, steel and refining sectors R&D support for the development of 10-250kW co-firing gas-hydrogen systems for non-industry use A facility to purify hydrogen to fuel-cell grade	The establishment of hydrogen valleys that foster a "hydrogen economy" Support for rollout of 10-250kW co-firing gas-hydrogen systems for non-industry use R&D for lightweight tanks and salt caverns for hydrogen storage	
Supply and distribution		Research of hydrogen storage 50MW production of hydrogen from water, biomass, biomethane and biogas through electrolysis, gasification and steam reforming Commissioning P2G 1MW capacity	Hydrogen transportation by road and rail Ramping up electrolyser capacity (up to 2GW) to insure hydrogen-independence	Gas blending of 10% in the gas grid Construction of dedicated hydrogen pipelines between hydrogen valleys and studies on the viability of international pipelines

Legend
- Pilot
- Scale up

Phases

Phase 1 (2022-2025)
- Conduction feasibility studies and specific directives for various sectors of the economy
- Creation of a centre of excellence - support R&D
- Establish legislative base governing hydrogen policies and financial incentives – a Hydrogen Law in 2022/23

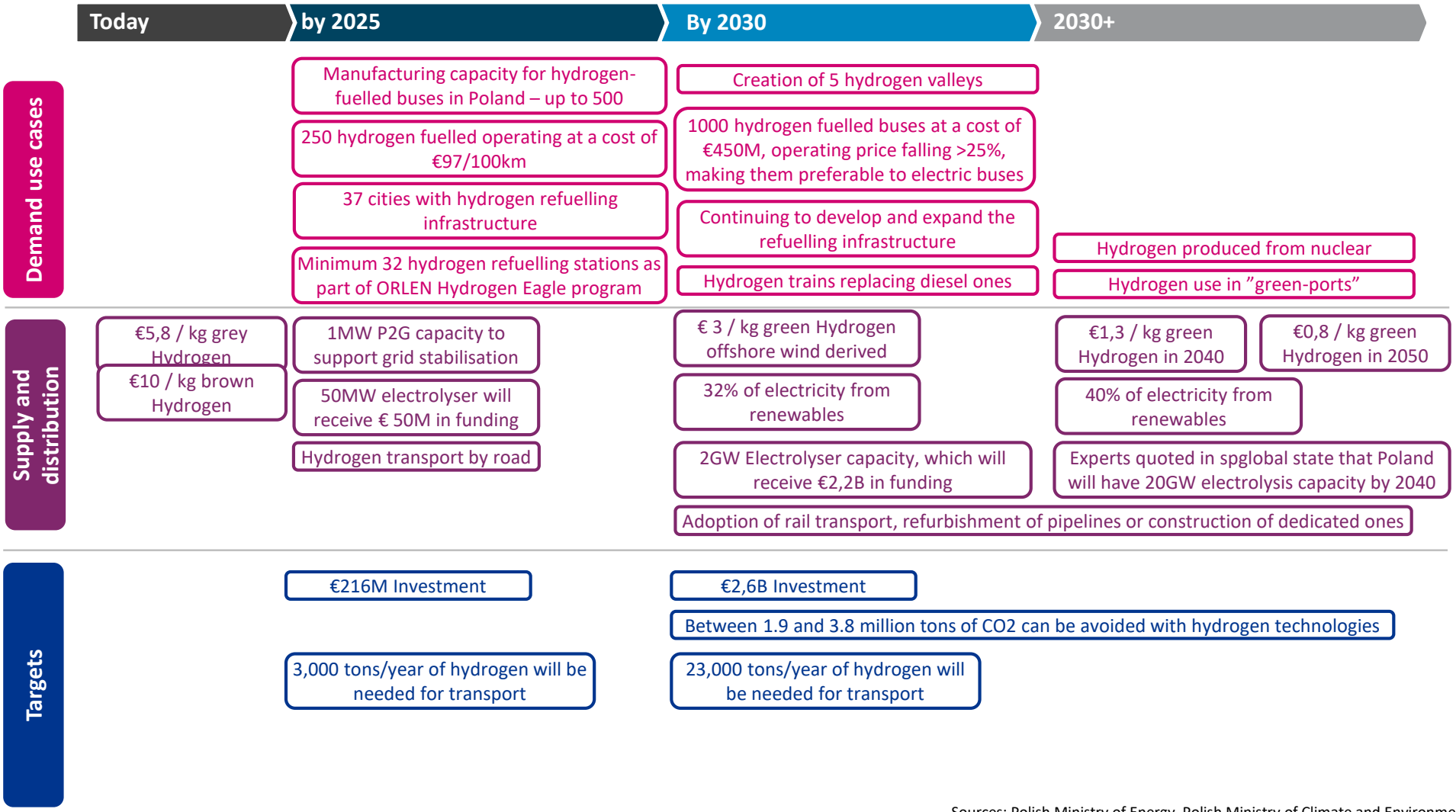
Phase 2 (2025-2030)
- KPIS for 2030+ will be evaluated and revised
- Supporting financial and technological readiness of decarbonisation

Phase 3 (2030+)
- Strategy evaluation and potential revision
- Revaluation the pace of hydrogen-adoption in the light of current commitments and targets for full decarbonization in the "second half of the twenty-first century"

Sources: Polish Ministry of Energy, Polish Ministry of Climate and Environment

Polish hydrogen targets

Building capacity towards sub €1/kg green hydrogen



Sources: Polish Ministry of Energy, Polish Ministry of Climate and Environment

Polish hydrogen regulation plan summary

The Polish legislative base will be overhauled in 2022 by the forthcoming Hydrogen Law, the current hydrogen strategy establishes targets with some input from regional governments

Category of regulation	Description	Status / timeframe
Hydrogen Strategy	The Hydrogen Strategy was published in December 2021, outlining the major objectives for hydrogen, including proven and future use-cases	Published in 2021
	The strategy states that Poland will be Hydrogen self-sufficient and that it accepts both green and low-carbon hydrogen (blue) as desirable as Poland is investing in CCU and CCS facilities and views blue hydrogen as less risky	
	The current aims rely on encouraging investment in R&D via hydrogen valleys to establish Poland as a net exporter of hydrogen technologies and make current Hydrogen uses less financially costly	
	Establishes broad electrolyser target of “up to 2GW” nationally on the supply side and encourages the up-take of Hydrogen by encouraging its use in public transit, trains and co-firing gas-hydrogen generators	
	State company ORLEAN is a significant tool for developing hydrogen supply within the country by establishing a refuelling network across the country	
	The strategy also proposed laws which should be amended in the future through a dedicated legal base for Hydrogen	
Hydrogen Law	A clear definition of whether hydrogen is subject to the rules of the Energy Law will be provided, including first of all the rule of separating the distribution activity from generation and sale of energy to end-users	Planned in 2022
	Laws concerning the use of hydrogen in transportation and logistics will be clarified to cover refuelling stations and fuel quality	
	Hydrogen will become included in the Law on Promotion of Electricity as a fuel	
Sectoral Agreement	Signed between various government organizations, businesses and scientific organisations that establish common priorities, objectives and specific matters on which collaboration is needed to find market niches for Polish Hydrogen	First signed in 2021
	Within these agreements the regions commit to achieving certain goals in promoting a hydrogen economy: scientific institutions and the government state which technologies can be exported due to a Polish market advantage and regional governments commit to certain electrolyser targets	

Sources: Polish Ministry of Energy, Polish Ministry of Climate and Environment

Poland direct subsidy interventions

Money originating from the EU and the Polish government is used to fund business implementation of a hydrogen economy mainly transportation

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
National Economic Recovery Plan	• Launched 2021	800M euros	Entrepreneurs Public administration institutions	Supporting vehicles charging infrastructure and hydrogen refuelling infrastructure alongside generation, storage and transportation of green or low-carbon hydrogen
New Energy Programme of the National Fund for Environmental Protection	• Launched in 2021	132M euros until 2026	Businesses	The program's support is directed to enterprises to implement technologies for production, transport, storage and use of emission-free hydrogen.
Green Public Transport Program (Phase I)	• Launched in 2021	70M euros	Public administration institutions	The program aims to reduce the use of emissive fuels in public mass transport by increasing the share of the fleet of buses using hydrogen
Hydrogenation of the Economy	• Launched in 2021	22M euros	Entrepreneurs Business environment institutions Scientific entities Public administration institutions	Support will be directed for the implementation of innovative projects related to hydrogen technologies
Support for Electric Vehicles	• Launched in 2021	NA	Businesses Public governance bodies	Supporting vehicles charging infrastructure and hydrogen refuelling infrastructure

Sources: Polish Ministry of Energy, Polish Ministry of Climate and Environment

Polish incentive based interventions

Current incentives are limited as Poland is taking only the earliest steps in developing a market for hydrogen and policies governing it

Incentive name	Type	Budget + horizon	Applies to	Further details
Income Tax write-offs for hydrogen vehicles	• Tax reduction	• No set amount • To be announced in 2022	• Personal vehicles	The current wording of the Income Tax Act provides for more favourable rules of depreciation write-offs for electric vehicles and not hydrogen vehicles; this will be changed

Sources: Polish Ministry of Energy, Polish Ministry of Climate and Environment

Poland key projects and partnerships

Investments in hydrogen are made by large oil companies, focusing on transport applications

Project name	Proposed COD	Overview	Key figures	Partners involved
Hydrogen production and use in the local economy	2021 (operational)	• "The project provides for the construction of a plant for the production of fuel-cell grade hydrogen, logistics infrastructure, and hydrogen refuelling stations. Initially, the fuel will be distributed primarily for use in public and freight transport. The Company has already signed agreements with local governments as potential customers for the hydrogen."	• 170kg/h of purified hydrogen with potential to increase up to 600kg/h	- ANWIL (chemicals) - Association of Upper Silesia (public governance) - Krakowski Holding (public governance) - City of Płock (public governance)
Electrolysis capacity creation	2025	• "An aim to build a large-scale unit for the production of green hydrogen. The Pure Hydrogen project comprises a hydrogen purification unit with distribution and refuelling infrastructure."	• 100 MW capacity • 300 M euro investment	- Lotos (oil)
Hydrogen Eagle	2030	• "The program provides for the construction of six new RES-powered hydrogen hubs: two in Poland, two in the Czech Republic, and one in Slovakia, one undecided including plans to build a hydrogen electrolysis plant to which electricity will be supplied from the Baltic Power offshore wind farm. The scheme also envisages the construction of three plants for converting municipal waste into low-emission hydrogen"	• 50,000 tons of hydrogen per year and 100 hydrogen refuelling stations in Poland, Czechia and Slovakia	- ORLEN Group (oil)
Hydrogen as an alternative fuel	NA	• "PGNiG's hydrogen research programme unveiled in May 2020 provides for the production of hydrogen, including green hydrogen using renewable energy sources, hydrogen storage and distribution, and industrial applications."	• Creation of a pilot hydrogen refuelling station	- PGNiG (oil) - Toyota (vehicles)

Sources: Polish Ministry of Energy, Polish Ministry of Climate and Environment LOTOS, ORLEN, PGNiG

Poland summary and learnings for Lithuania

In the period 2021-2030 Poland will lay the legislative and economic foundations for adoption of low-carbon hydrogen in its transport and industrial sectors

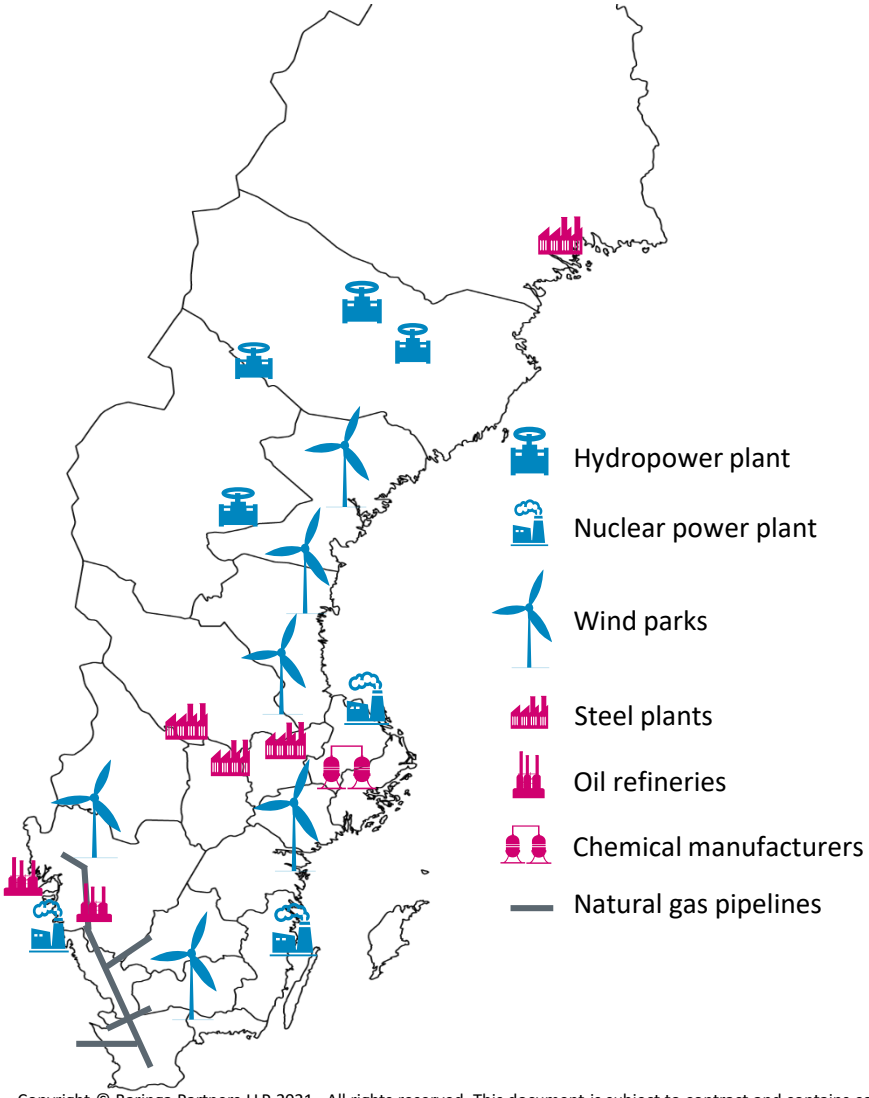
	Observation on Poland	Observation for Lithuania
Energy supply and demand mix	▲ Poland has historically relied on coal and will do so until the 2030s when more wind and nuclear power capacity comes online, hence, blue hydrogen will be accepted and the captured CO2 used for industrial purposes in the medium-term	▲ Since Lithuania has significant gas capacity, blue hydrogen can be also assessed, particularly if it is required to import/export with Poland, which is likely if access to demand in Germany is sought ▲ The Polish government envisions small electrolysers next to industrial facilities, that do not require significant infrastructure investments, hence, Lithuania could consider a gradual increase in electrolyser capacity, undertaking small steps which would limit risk
Ambition, targets and pathway	▲ The government plan to use Hydrogen buses in cities over 100,000 people in order to create use cases with some economy of scale. ORLEN as part of its Hydrogen Eagle initiative is building a min. of 32 refuelling stations across Poland and 68 in Czechia and Slovakia.Station locations are uncertain and priority will be given to cities	▲ A similar program would be applicable to Vilnius, Kaunas, Klaipėda, Šiauliai and Panevėžys. However it is unclear when Lithuanian Hydrogen vehicles will be able to transit Poland due to lack of information on the location of the refuelling network
	▲ Poland aims to become a market leader in hydrogen technology leveraging its strong universities and industrial familiarity with Hydrogen ▲ The network of hydrogen valleys will foster technological development and strategic partnerships between companies	▲ Hydrogen valley or cluster idea can be applicable to Lithuania especially in regions with strong technical learning facilities and demonstrated demand for hydrogen: Kaunas and Klaipėda
	▲ The wide distribution of small electrolysers across Poland in various hydrogen valleys next to the end users of hydrogen until there is established demand for hydrogen will not require large sums of investment in an Hydrogen transport network	▲ Any decision on economic zones for hydrogen supply requires evaluation of the *benefits to production cost from economies of scale* vs *cost of building hydrogen transport infrastructure*.
	▲ Poland plans to develop the hydrogen economy slowly, focusing on R&D and observing global trends	▲ Some risk that Lithuania may not be able to have a Poland hydrogen import/export corridor in the near term
Mechanisms and interventions	▲ Poland is not exclusively committed to green hydrogen but also is interested in low carbon production	▲ Lithuania could consider blue hydrogen depending on how public perceptions and costs of both blue and green evolve
	▲ Poland encourages hydrogen development in the public sector through the so-called “sectoral agreements” that express aligns strategic objectives and goals of state and science institutions and businesses	▲ Lithuania’s Hydrogen Platform provides a similar forum for sharing experiences and potential projects within Lithuania and across the EU

Country green hydrogen strategy analogue: Sweden

v. Feb 11, 2022

Swedish Hydrogen And Energy Map

Green H_2 to provide competitive advantage in steel and manufacturing, new piped H2 network to be created linking industrial areas to RES electricity surplus areas and neighbouring countries



Key insights

- Currently less than 1% of H_2 is fossil free. Sweden aims to become carbon-neutral by 2045.
- Most of projected wind capacity is onshore near populated and industrialized areas in the centre/south
- Most of the industrial capacity concentrated in the centre and south with a large steel cluster in the centre, west of Stockholm, and 80% of Swedish oil-refining in the southwest near Goteborg.
- Natural gas network present only in the south, connecting Malmo with Goteborg with a link to Denmark. Sweden; however, intends to utilize the *European Hydrogen Backbone* Initiative to reuse sectors of the current natural gas pipelines and building dedicated H_2 pipelines to connect southwestern Sweden with Stockholm and eventually connect with Finland across land and across the Bay of Bothnia.
- In the remaining legacy network biogas could be potentially used. In the short term (until 2030) trucks and eventually rail will be used.
- Industrial clusters will be created with the goal of spreading a possible overcapacity of H_2 production through concentrated infrastructure investments connecting producers with consumers, in addition, the by-products of hydrogen production: O_2 and heat production to create potential benefit.
- Placement of electrolyser capacity to be determined on a case by case basis with key considerations being electricity demand of electrolysers, strength of relevant sections of the electricity network and potential investment needs into the H_2 transportation infrastructure.
- Large RES production capacities need to be reached before H_2 for electricity grid stabilisation is used, indeed H_2 can contribute to national security.
- The Swedish government expects green H_2 to provide a competitive advantage in green steel and manufacturing of sophisticated hydrogen products.
- The industrial adoption of green H_2 will be led by market forces and companies' green consciousness while the government will provide large quantities of green power and H_2 infrastructure.

Sources: Swedish Energy Agency

Swedish green hydrogen strategy: overview

Almost all of electricity is Sweden is produced using renewable sources and it is a net electricity exporter, which will allow it to potentially become exporter of green H_2

Energy resource and demand context

- Sweden is a net electricity exporter, able to export 16% of its output with that share of exports projecting to remain the same
- Energy is primarily attained from hydropower (30,4%), oil (25,5%), nuclear (22,3%) and wind power (11,6%)
- Electricity mix has three main components: hydropower (44,6%), nuclear power (30,2%) and wind power (16,4%), combined total of 91%
- By 2030 wind production particularly on land is projected to account for 33% of Swedish electricity production and by 2050 wind will account for 46% of production and solar will account for 4%; however, both hydropower and nuclear will also grow in absolute numbers of output with nuclear producing 44,8TWh in 2030 and 53,3TWh by 2050 and hydropower will slightly increase from 67,1TWh to 68,6TWh
- The hydrogen strategy was submitted to government approval November 2021, having been in the process of drafting since 2021 Q1.

Targeted domestic use cases

- Current H_2 use is 180 000 t, the largest users are the refinery (72%) and chemical (27%) sectors, metallurgy, plastics and food account for the remaining 1%; however, in the future it is projected to be dwarfed by steel refining which alone will consume 1 200 000t of H_2, vehicle manufacturers have been identified as willing potential users of comparatively more costly green steel
- Manufacturing is dominated by sophisticated goods, like machinery, chemicals, guns, and cars, alongside older industries like wood, paper and steel, thus, hydrogenation of green steel can help reduce CO_2 emissions across the value sector of steel (cars, guns, machinery)
- Oxygen and heat are by-products of H_2 generation and Sweden sees many potential uses for both: heat can be in district heating while oxygen could be utilised in industrial processes, hospitals, aquaculture and for environmental restoration of damage caused by eutrophication in the Baltic sea

Approach to supply and infrastructure

- Desirable to develop H_2 production at the same time as renewable energy sources as the most important part of hydrogen's adoption would be low electricity prices and H_2 production would guarantee a market for renewable electricity at all times of day
- Lined rock caverns have been identified as the most accessible and already proven method of H_2 storage in Sweden; however, possibilities to store the gas outside of Sweden in other Nordic countries in their salt mines is also being studied
- H_2 storage locations depends on private actor joint-initiatives that may make large-central facilities preferable to H_2 storage near end-use facilities
- For H_2 volumes less than 10t/day and distances less than 200 km trucks are more economical otherwise pipelines are preferrable

Import / export plans

- The intention is to produce "fossil-fuel free H_2" with the emphasis on solar and wind powered electrolysers due to ambitions to become carbon-neutral by 2045, five years earlier than EU/Paris goals. Blue H_2 will be used by oil refineries which under Swedish plans will invest in CCU
- Sweden is studying several scenarios: in scenario where fossil fuels become more expensive and RES expansion is rapid, it would become a net exporter to the EU, however, its current aim is to achieve self-sufficiency but numerous issues will need to be overcome
- The aim is to export hydrogen-related services and climate-smart products
- Volvo and Daimler have agreed to collaborate and become global leaders in the manufacturing of fuel cells

Swedish hydrogen roadmap

Hydrogen will be adopted where it is economic and not efficient to switch to electricity

	Today	By 2025	By 2030	2030+
Demand use cases	Studies carried out to assess locations for e-fuel plants (input of H_2, CO_2, methane, etc.), that could sell O_2 and heat by-products	Studies on combined aviation fuel, heat and power plants	Transport will not play a significant role in reducing Swedish CO_2 emissions except heavy duty trucks	Carbon-free steel by 2035
		Construction of wind-to-methanol plants by Liquid Wind	3 total wind-to-methanol plants across Scandinavia by Liquid Wind	
		A large increase of H_2 use by industry is not expected immediately, after 2024 numerous H_2 projects come online		
	Pilot projects of HYBRIT: an initiative to transition to fully green steel	Support for H_2 in aviation and shipping, technology is not expected to reach wide-spread adoption until 2030s or 2040s		
		40-50 H_2 refuelling stations across Scandinavia, 15 of which are in Sweden	Industry will most likely remain the most significant user of H_2 with some use-cases in transport and other applications	
Supply and distribution		Hydrogen distribution via trucks	H_2 produced from green sources will become competitive with blue H_2 between 2025-2040	
			On the western coast a H_2 pipeline could be built, elsewhere trains are used	Difficult to predict the distribution network but by 2050 a full-scale network is established
	$100m^3$ H_2 storage facility built in a mine	International storage options are examined and more domestic studies completed	More LRC storage constructed alongside storage in ammonia and e-fuels	By 2050 more underground reservoirs are constructed alongside ammonia infrastructure and storage in ports as fuel for ships

Legend

- Pilot
- Scale up

Phases

Phase 1 (2022-2025)

- Adoption of a hydrogen strategy that establishes national objectives and legislative H_2 measures
- Observing the progress of pilot initiatives and market adoption of green H_2

Phase 2 (2025-2030)

- Scale up of hydrogen use for industrial purposes and studies on energy islands
- Observing global technology trends and making Sweden a market leader of hydrogen-based technologies

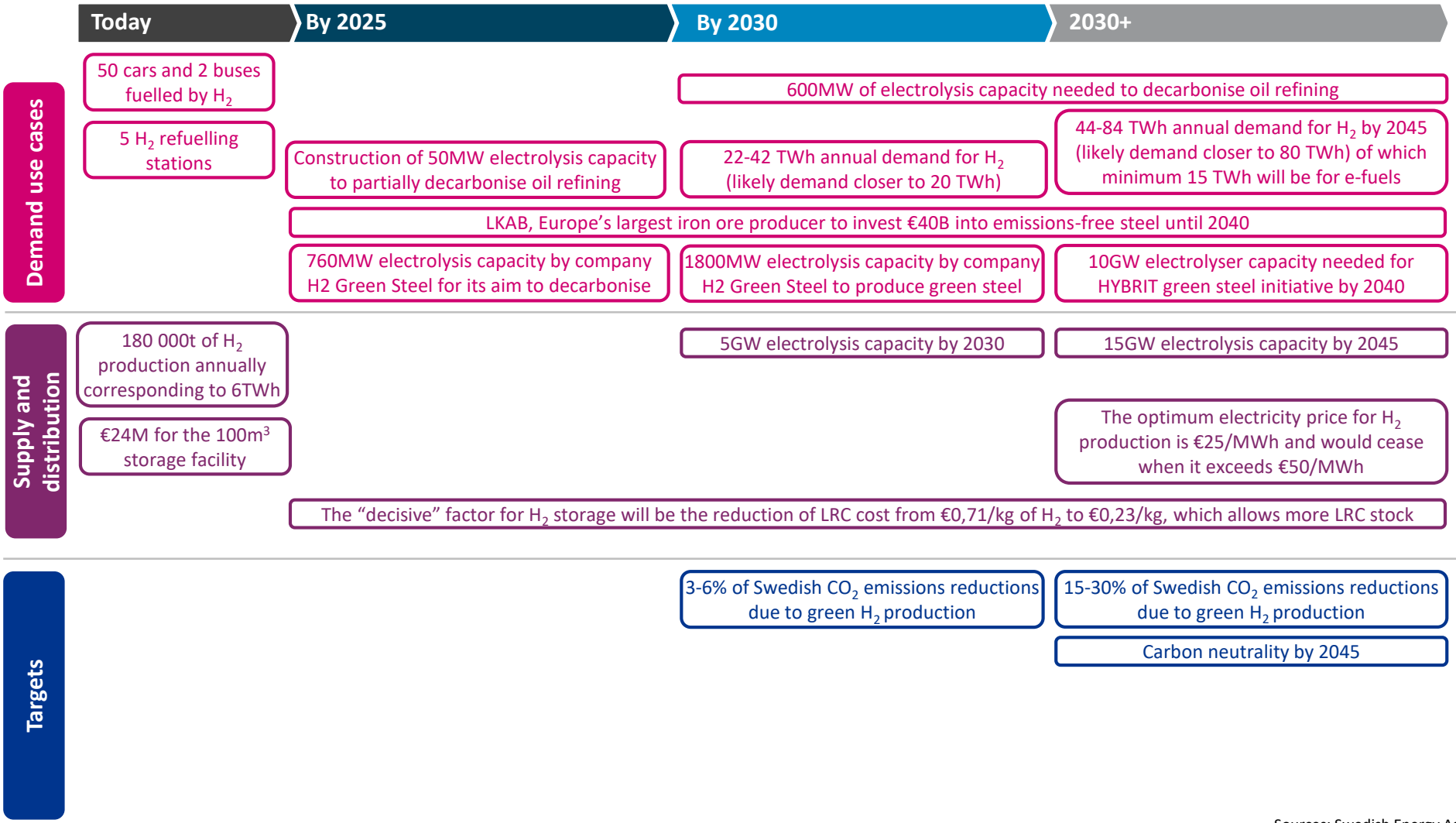
Phase 3 (2030+)

- Fostering H_2 adoption in the steel sector and continuing R&D for e-fuels
- Collaboration with European partners on creating a common H_2 network
- Depending on market forces, becoming a hydrogen exporter

Sources: Swedish Energy Agency

Swedish hydrogen targets

Building capacity towards full industrial decarbonization by 2045



Sources: Swedish Energy Agency

Swedish hydrogen regulation plan summary

The Swedish hydrogen strategy was proposed to the government 2021 Q4 with national objectives alongside considerations of forces outside of Swedish government control

Category of regulation	Description	Status / timeframe
Hydrogen Strategy	The Hydrogen Strategy was commissioned by the government to be prepared for 2021 Q3 but it was submitted to the government only in 2021 Q4	Published in 2021
	The strategy considers several development options for hydrogen in Sweden, all of them highly dependent on factors outside national control, such as the price of electrolysers, developments in technology, progress in creating supply, demand and infrastructure able to transport H_2 at a large scale worldwide	
	The document describes the close two-way relationship between hydrogen and electricity prices, that electrolysis may drive up electricity prices, however, low prices are necessary to make green H_2 competitive	
	Significant goals for hydrogen generation are outlined, driven primarily by industrial developments in the steel sector with some additional uptake by transportation	
	Hydrogen will benefit the Swedish economy primarily as an input for higher value added goods, like steel, petrochemicals and eventually e-fuels	
	The document details the intent to have completely green steel by 2035 and become a carbon-free hydrogen technology manufacturing hub	
	An important role is played by major private and state-owned enterprises in developing hydrogen projects	
	Financial and legal mechanisms of the EU are reviewed and potential sources of hydrogenation of the economy are proposed	
Strategy for fossil free competitiveness	Fossil Free Sweden, together with industry and transport sectors, has developed 22 roadmaps for fossil-free competitiveness, that are now to be implemented	Published in 2020
	The focus is on refining industry products within the country's borders, rather than producing and exporting hydrogen to other countries	
	Expansion of the hydrogen infrastructure in the country can be accelerated by establishing cross-sectoral local and regional hydrogen clusters. They can be established where existing industries use or will use hydrogen and where infrastructure such as ports and railways already exist	

Sources: Swedish Energy Agency, Fossilfrittsverige

Sweden direct subsidy interventions

Instead of direct subsidies the government focuses on market solutions by guaranteeing bonds and loans while encouraging the green transition more broadly rather than H_2-specific investments

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description	Applicability to Lithuania	Observation on adopting in Lithuania
Green bonds	• Launched in 2013	Funded 8,6B euros annually	Cities Municipalities	Green bonds to institutional investors to fund green loans for investment projects undertaken by local and regional governments	✓	Applicable to Lithuania
Climate Leap (Klimatklivet)	• Launched 2016	130M euros budget in 2018 No set expiration date	Companies Organisations Foundations	An investment programme for local and regional initiatives to reduce carbon emissions and emissions of other gases that impact the climate	✓	Applicable to Lithuania
Swedish Export Credit Corporation green guarantee scheme	• Launched in 2020	Maximum loans of 48M euros	Companies	Eligibility for the guarantee is broad. It applies not only to financing for Swedish exports but also to any financing or working capital for an investment in the "climate transition" made by a local company with "direct or indirect exports"	✓	Applicable to Lithuania
Nordic Hydrogen Corridor	• 2017-2022	20M euros budget	Cities and municipalities	Work with the most promising locations to ensure that there is sufficient demand before taking investment decisions and moving the initiative over to the execution phase.	✓	Applicable to Lithuania

Sources: Swedish Energy Agency, Kommuninvest, Fuelcellsworks, Naturvardsverket

Swedish incentive based interventions

The incentives are geared towards purchasing and maintaining low carbon vehicles

Incentive name	Type	Budget + horizon	Applies to	Further details	Applicability to Lithuania	Observation on adopting in Lithuania
Bonus for low emissions cars	• Subsidy	• Up to €6700 bonus per vehicle purchase • Effective since 2018 Q3	• Personal and company light vehicles	Applies to low emissions vehicles such as electric and hydrogen	✓	Applicable to Lithuania
Climate bonus	• Subsidy	• €8,7M allocated to cover charging infrastructure installation costs • Effective since 2018	• Households	Covers up to half of hardware and installation expenses	✓	Applicable to Lithuania
Ownership tax benefit	• Tax exemption	• ”Super green” cars exempt from the registration tax, amounting to €170 annually	• “Super green” vehicles	Only effective for 5 years after the car registration	✓	Applicable to Lithuania

Sources: European Alternative Fuels Observatory

Sweden key projects and partnerships

Interest in hydrogen is led by steel and vehicle conglomerates aiming to create uses for hydrogen throughout the value chain

Project name	Proposed COD	Overview	Key figures	Partners involved
HYBRIT	Production of steel to begin in 2024	• "Vattenfall has joined forces with mining company LKAB and steel manufacturer SSAB to, in principle, remove the impact the Swedish steel industry has on the climate. Together the companies have set up the joint venture company HYBRIT 2017. The objective is to have a completely fossil-free process for steel manufacture by 2035. A successful HYBRIT project will mean that Sweden's CO_2 emissions can be reduced by 10%"	• 5M tons of steel a year, doubling current Swedish output • 1800MW electrolyser • €2.4B investment • 1 500 direct and 10 000 indirect jobs	- Vargas (investment firm) - Scania (vehicle production) - EIT InnoEnergy (investment firm) - Societe Generale (bank) - Morgan Stanley (bank) - SSAB (steel manufacturing) - LKAB (mining) - Vattenfall (state power firm)
Hydrogen storage	Ready and operational between 2022 and 2024	• "A construction of a rock cavern storage facility for fossil-free hydrogen gas on a pilot scale next to HYBRIT's pilot facility. Storage is being built approximately 30 metres below ground. Building it underground provides opportunities to ensure the pressure required to store large amounts of hydrogen in a cost-effective way."	• €24M investment • 100m^3 H_2 storage	- SSAB (steel manufacturing) - LKAB (mining) - Vattenfall (state power firm)
Largest fossil-free hydrogen facility	First hydrogen production in 2023	• "Ovako is investing in hydrogen production in Hofors for a fossil-free steel production facility. The plan is to use hydrogen in all of Ovako's units. The project is also expected to build hydrogen infrastructure for fossil-free freight using fuel-cell trucks in the future. The long-term plan is for local hydrogen production to be used in all of our units where steel is rolled by 2030, provided that there is a good supply of fossil-free electricity."	• €17M investment • Reduction of CO_2 emissions by 50% • 17MW electrolyser producing 3500m^3 H_2 per hour	- Volvo Group (vehicles) - Hitachi ABB Power Grids Sweden (power and utilities) - H2 Green Steel (steel) - Nel Hydrogen (H_2 production, storage and logistics)
GKN Aerospace H2JET	Program lasting until 2023	• "By validating component technologies for H_2 combustion engines, H2JET will speed up the development of vital international engine and aircraft demonstrator programs such as the Clean Aviation Partnership in the recently launched EU program Horizon Europe. The focus is on light-weight design and advanced manufacturing technology."	• €2,4M investment	- GKN Aerospace (automotive and aerospace) - Swedish research institutes (public research)

Sources: Swedish Energy Agency, Cleannergywire, Reuters, SSAB, GKN Aerospace

Sweden summary and learnings for Lithuania

The emphasis on public private partnerships highlights the importance of the private sector driven interest in the hydrogen economy

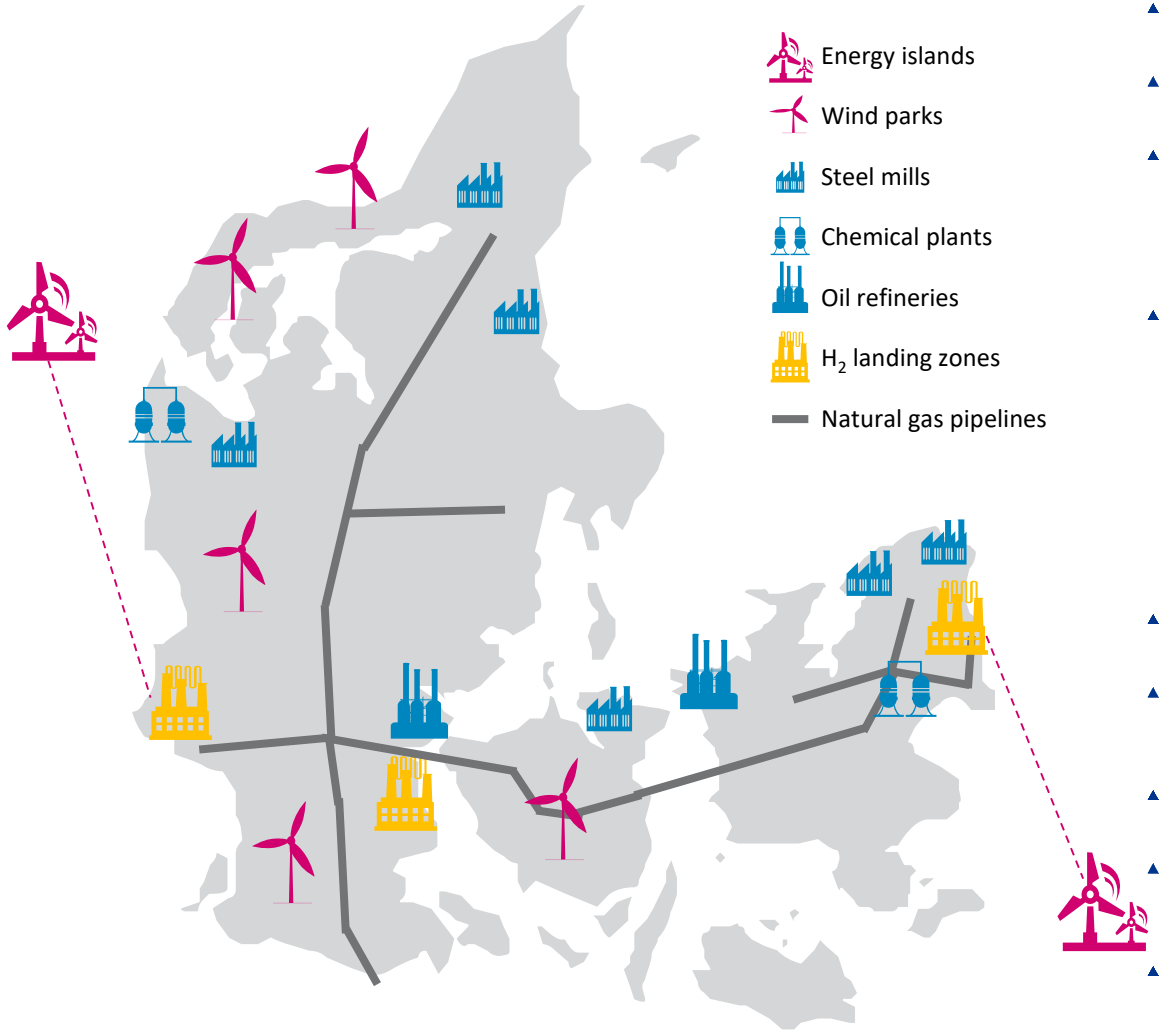
	Observation on Sweden	Observation for Lithuania
Energy supply and demand mix	▲ Green H_2 will require a lot of renewable power and, it the hydrogen strategy is fully implemented, electricity export from Sweden might be reduced and/or Swedish electricity export prices will increase. ▲ H_2 adoption is driven by private-public partnerships that emerge due to the strong renewable energy capacity and geographical distribution of both electricity demand and supply	▲ Energy self-sufficiency even more important, less likely H_2 production from cross-border electricity. ▲ Private partners can be engaged along the value chain, including finding consumers for by-products of H_2 production such as oxygen and heat
Ambition, targets and pathway	▲ Even though Sweden does not have a natural gas grid, it intends to construct a hydrogen-based grid in the long-term, potentially linking with Finland in addition to Denmark	▲ Sweden recognizes possibility of international H_2 trade opportunities via pipelines in the north of Europe, between Finland and Germany – two countries that Lithuania is interconnected with currently.
	▲ Sweden pays attention and wants to monetize oxygen and heat as by products	▲ While these are not big value pools for H_2 projects, they can be useful in the near term in contributing to public acceptance of hydrogen through demonstrating its contribution to wider economy ▲ Achema/Orlen can act as anchor tenants for use in other nearby processes
	▲ The Swedish government considers hydrogen as an important feedstock for the production of high-end products, such as green steel, fuel cells and automobiles	▲ Production of green ammonia can act as a stimulus to reduce reliance on ammonia imports and thereby increase its share of the fertilizer value chain
	▲ There is a “package” of road transport incentives that complement each other: green vehicle bonus, registration tax rebate and charging infrastructure funding	▲ A comprehensive package of H_2 transport should be adopted that eases all aspects of owning a renewable-fuelled car: purchasing, registration, maintaining and selling
Mechanisms and interventions	▲ Collaboration across borders a potential avenue to alleviate domestic storage facility shortages alongside native mining companies whose expertise can be used for discovering storage potential	▲ In an addition to geological surveyors, native mining companies can be used to investigate / realise geological storage potential, as LKAB are doing in the pilot slat cavern storage facility
	▲ By prioritising a longer term perspective Sweden can plan and put in place policies that allows it to begin working towards those outlined goals, accumulating expertise and investments	▲ Lithuanian objectives should consider various scenarios but already put in place a clear vision of hydrogen’s place in the national economy
	▲ Sweden is promoting collaboration in the whole hydrogen economy ecosystem from suppliers to consumers	▲ The business community should be engaged by public companies to develop initiatives where H_2 can give a long-term market advantage

Country green hydrogen strategy analogue Denmark

v. Feb 11, 2022

Danish Hydrogen and Energy Map

The country aims to use its large wind energy capacity to produce H_2 in a centralized location that will be distributed nationally



Key insights

- In line with the Paris targets, Denmark aims to achieve net zero emissions by 2050. End of fossil fuel extraction also by end of 2050.
- Denmark does not have a single H_2 strategy, therefore, insights came from various proposals and private initiatives.
- There are two oil refineries in the country both near the Baltic sea, one on the populous island of Zealand and the other on the mainland. The steel refining is concentrated in northern Danish mainland and the northern Zealand. The chemical industry is in the suburbs of Copenhagen and in the north-western part of the country.
- Denmark sees itself as a ”green powerhouse”, an early pioneer of green technology, able to produce large amounts of green energy and innovative technology for export. **1GW electrolyser capacity by 2030** planned in Fredericia (*HySynergy*) 80% of which will be used in industrial feedstock, **1.3GW electrolysis plant** in the Copenhagen area (*Green Fuels for Denmark*) to procure green H_2 for e-fuels for industry, trucks, and ships and **1GW facility** in Esbjerg (*H2 Energy Europe*) to replace all Danish imports of fertilizer, fulfil 1/3 of heating needs in Esbjerg and provide fuel for transport. These three locations are deemed “H_2 landing zones” because it is simpler and faster to develop hydrogen value chains in a single location.
- Copenhagen Airport aims for e-kerosene to make up 30% of its fuel consumption by 2030.
- Due to Denmark’s location: near gas infrastructure in the North sea and abundant oil and gas aquifers – CCS is seen as a viable path towards turning sectors of the economy “low carbon”. But H_2 production is only green.
- E-fuels are seen as a viable sector for the use of green H_2 as Denmark aims to use pure and blended H_2 truck, plane, ship, and potentially automobile fuels.
- Energy islands will be surrounded by giant amount of wind parks and will serve as hubs that can create better connections between energy generated from offshore wind and energy systems in the regions around the sea.
- The excess electricity produced by energy islands in the North and Baltic Seas will be sold to Germany and other European countries while options for conversion of this power to hydrogen will be explored, especially once power supply becomes exceedingly large.

Danish green hydrogen strategy: overview

Currently hydrogen is little-consumed in Denmark in industrial processes or as fuel, however, long-term excessive green energy capacity will allow for PtX solutions to become crucial

Energy resource and demand context

- Denmark's main electricity sources are: wind (56%), biowaste and biogas (18%), coal (15%), solar is at 4%, oil at 4% and gas at 4% as well.
- Total energy mix is made up of oil (47%), wind (26%) and gas (15%) while coal is at 6%, biowaste and biogas at 3% and solar at 2%.
- The country has targets in place for renewable energy to cover 100% of electricity and 55% of overall consumption by 2030, thus, making it electricity independent by 2030 and energy independent by 2050.
- Since 2013 Denmark's North Sea gas and oil extraction has fallen below sufficiency levels, making it a net importer of energy.
- The Danish economy is heavily focused on services, which accounts for 75% of GDP, out of manufacturing the most significant are wind turbines, machinery, chemicals, pharmaceuticals, steel and transport equipment, several of these industries (e.g. steel) can be moved towards carbon neutrality by the introduction of green H_2.

Targeted domestic use cases

- Denmark aims to utilize hydrogen for heavy duty vehicles, public transit and in the processing industry to produce e-fuels, like kerosene which can then be used for transportation in particular but also chemicals and jet fuels. There are no official mandates for H_2 use, however, Copenhagen Airport, Maersk and other companies intend to begin using H_2 or e-fuels for transportation.
- Today, H_2 demand in Denmark is very low as few industries use it apart from oil refining, therefore, the adoption of green hydrogen would be about creating new rather than making the existing use of H_2 less carbon emitting: current incentives should encourage consumption rather than production of H_2 in order to raise the national demand when market incentives would boost supply.
- Green H_2 production is intended to replace all fertilizer imports by 2030.

Approach to supply and infrastructure

- Denmark aims to produce exclusively green hydrogen from its extensive wind energy sources.
- Blue hydrogen is not considered because of ambitious Danish targets to reduce CO_2 emissions by 70% by 2030 and green H_2 is a way of doing that.
- It is planned that the current gas network is adopted to transporting hydrogen or methanised hydrogen (C added onto H_4), that is especially needed long term for the ability to export hydrogen to Germany.
- Hydrogen production is likely to occur on a small scale in existing industrial parks and next to factories, however, three major hubs are planned on the western coast in Fredericia (1GW), eastern coast in Esbjorg (1GW) and Copenhagen (1.3GW) by 2030.

Import / export plans

- The Danish government acknowledges that is far behind other European countries in terms of investments into hydrogen and development of hydrogen projects (per capita investments are lower than in Germany, France or Spain), thus, in the hydrogen report released in October 2020 by DanskiEnergi it is encouraged to make larger investments and in particular to use its massive renewable energy potential.
- Within Denmark there is currently little demand for hydrogen, however, in both the Netherlands and Germany demand is high and is expected to increase as well, thus, exports of both H_2 and hydrogen technologies to these two countries would be possible once natural gas pipelines are converted and connected with Germany, but before that is achieved, hydrogen-based e-fuels can be used to export hydrogen-based products.
- Competition in central European market will be heavy, thus, Denmark hopes to gain a competitive advantage by utilizing its cheap and abundant excess wind energy while importing hydrogen from Australia or Africa may prove too costly and non-environmentally friendly.

Denmark green hydrogen roadmap

The hydrogen is underdeveloped in Denmark; however, private and public partnership led initiatives are aiming for ways to expand H_2 use and production

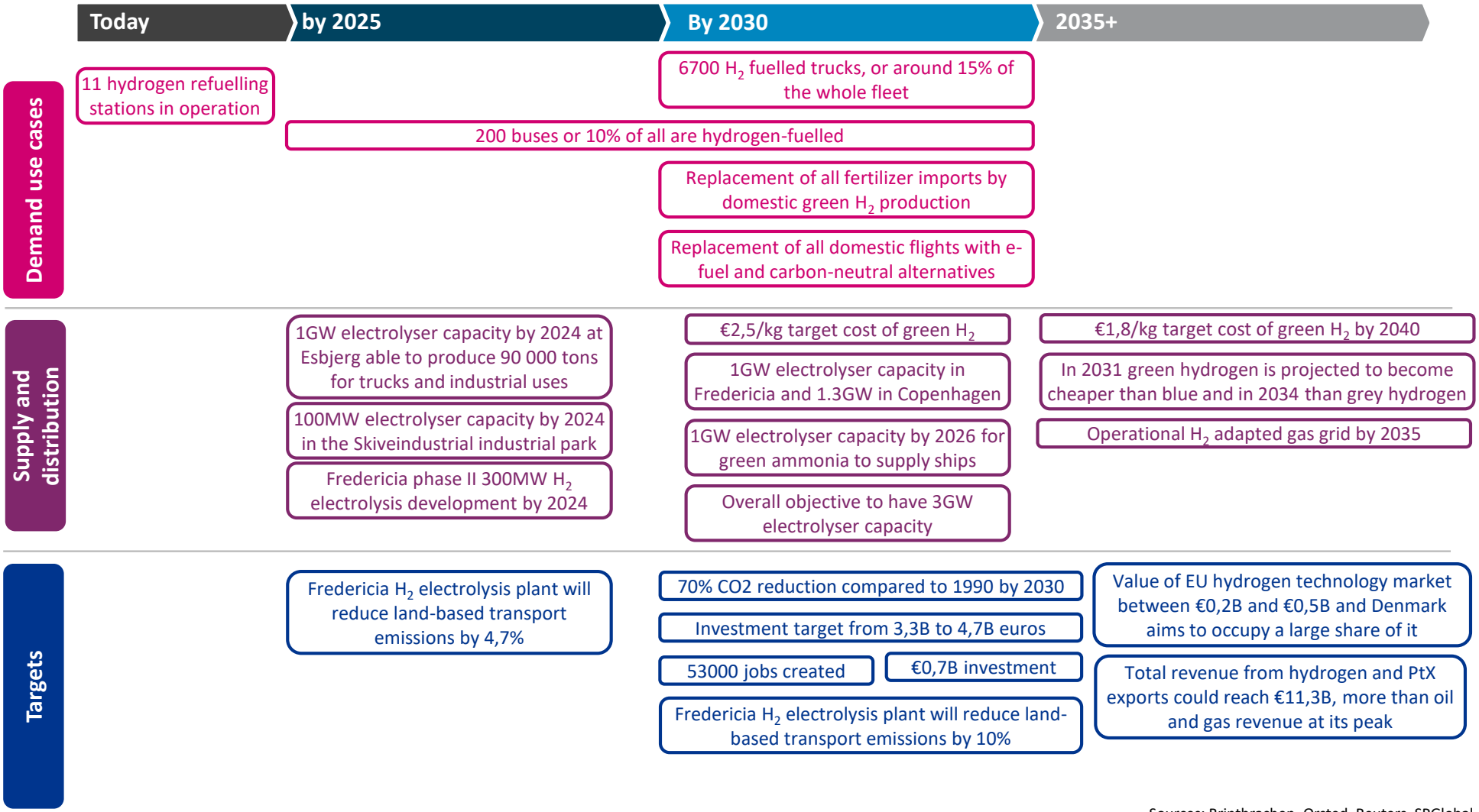
	Today	by 2025	By 2030	2030+
Demand use cases	Exclusively electric buses from 2021 Increased taxes on higher-polluting planes	Green flight options for consumers by 2025 Political aspiration to kickstart the production of green jet e-fuel by 2025	Fossil fuel free domestic flights by 2030 preferably by offsetting emissions, however, there is no technical solution yet End petrol and diesel car sales by 2030 Public transport carbon free before 2030 H_2 trucks becoming cheaper than diesel by 2028 according to McKinsey 5-10 ships using e-fuels, including world's largest ferry Copenhagen-Oslo	Cooperation between Maersk, Copenhagen Airport, Hyundai, etc to use green H_2 for fuel
Supply and distribution		Test electrolysers used for providing hydrogen for trucks and ships E-fuels produced by combining green H_2 and captured CO_2 produced domestically in Denmark	By 2030 e-kerosene will be competitive in aviation and shipping; its adoption requires no new technology Massive expansion of electrolyser capacity for use in e-fuels and industrial feedstock with plant to scale up facilities in Fredericia and Esbjorg as well as building an electrolysis plant in Copenhagen	A net exporter of PtX technology, products and services by 2035, especially to Germany The Energy Islands fully completed by 2033 with installed capacity of 12GW offshore wind
Phases	**Phase 1 (2021-2025)** ▲ **Establish a clear regulatory framework for hydrogen production and consumption** ▲ **Continue with massive renewable energy production facilities** ▲ **R&D on green hydrogen and PtX fuels**	**Phase 3 (2026-2030)** ▲ Begin the adoption of hydrogen on a national scale for trucking, aviation and shipping ▲ Encourage hydrogen consumption domestically	**Phase 3 (2030+)** ▲ Establishment of a hydrogen pipeline connecting Denmark with Sweden and Germany ▲ Becoming a large exporter of hydrogen technologies, services and products	

Legend
- Pilot
- Scale up

Sources: Brintbrachen, Orsted, Reuters, SPGlobal

Denmark green hydrogen targets

Hydrogen implementation will be led by the e-fuel sector, which will allow Denmark to meet its ambitious carbon-neutrality targets



Sources: Brintbrachen, Orsted, Reuters, SPGlobal

Denmark hydrogen regulation plan summary

Danish strategies provide few targets, however they agree on the importance of e-fuels in order to meet climate commitments

Category of regulation	Description	Status / timeframe
Brintbranchen (Hydrogen Denmark) Report	Hydrogen Denmark brings together all hydrogen and Power-to-X (PtX) stakeholders in Denmark. They are the main industry organisation for hydrogen and PtX, and represent the entire value chain from research to business, and from the production of renewable energy and energy technology such as fuel cells and electrolysis, to the use of hydrogen, methanol, ammonia and other electrofuels in, for example, the transport sector.	Published 2021
	The focus is on creating enough technical and logistical capacity to be able to export hydrogen, hydrogen products, services and technologies to other countries in particular Germany.	
	The report explores possibilities of combining large Danish wind power resources with PtX technologies in creating e-fuels, that can be used to reduce CO_2 emissions vehicles, aviation and shipping, sectors which have been historically difficult to decarbonize, and in the short term e-fuels can be an avenue of export.	
DanskEnergi (A non-commercial lobby organisation for Danish energy companies) Recommendation Paper	Denmark is positioned as a powerhouse of CCS because of its large empty oil and gas fields.	Published 2020
	In states that in Denmark, PtX is particularly relevant for decarbonising heavy transport (heavy-duty vehicles, aviation and shipping), and this will be essential in order to achieve the 70% reduction target.	
	Denmark has a small, open economy with foreign competition, and measures must be chosen carefully to ensure that Danish companies are not disadvantaged compared to foreign ones. It is therefore necessary to consider Danish competitiveness when determining national initiatives.	
	Proposes the 3GW target in order to satisfy the 2030 target for reducing Danish CO2 emissions by 70% compared to 1990 levels and a target of 1,2B euros of public investment is encouraged.	
Energinet (a public enterprise owned by the Danish Ministry of Climate) Strategic Action Plan	A claim that large-scale PtX will contribute to Denmark's national climate goal of a 70% reduction in carbon emissions by 2030.	Published 2019
	Green gases and fuels can either be consumed domestically or exported to other countries and thereby directly replaces fossil fuels. Access to carbon is a constraining factor, which is why there should be focus on utilizing all available carbon sources, both well-known and untested.	
	Green H2 will be focused in the "Landing Zones", which are defined as places of concentrated green RES generation, large electrolysers and large consumers, between which hydrogen could be transported via pipelines	

Sources: DanskiEnergi, Brintbranchen, Energinet

Denmark direct subsidy interventions

Direct subsidies are provided to green projects more generally rather than H2-specific and there is a large emphasis on having market-competitive projects that will create jobs in Denmark

Subsidy scheme name	Stage	Budget + horizon	Applies to	Description
Innovation Fund Denmark	• Scale up	260M euros annually Duration of the project funding 2-5 years	Research institutions Businesses	The purpose of Grand Solutions is to advance research, development, testing and validation of innovative solutions for the benefit of growth and employment in Denmark as well as to solve societal challenges
The Ministry of Climate, Energy and Utilities	• Scale up	69M euros annually	Research institutions Businesses Public bodies	Energy technology development and demonstration program, which supports the development of new efficient and climate-friendly energy technologies that can help make Denmark free of fossil energy in 2050. At the same time, the projects must develop Danish business potential for growth and employment
MUDP	• Scale up	18M euros total annually Between 60 000 and 600 000 per project	Research institutions Businesses Individuals	Aims to promote the development and application of new effective environmental solutions to priorities environmental challenges, while at the same time supporting growth and employment, through grants for the development, testing and demonstration of new environmental technology and grants for projects that can test new environmental technology on full-scale plants or on new construction projects
Promotion of energy-related export initiatives	• Scale up	Up to 200 000 euros	Companies	The Grant pool supports projects that can promote energy-related export initiatives while strengthening Denmark's government-to-government cooperation in new growth markets

Sources: Danish Energy Agency, Danish Shipping

Denmark incentive based interventions

Incentives exist only for domestic heating and electrolyser operators

Incentive name	Type	Budget + horizon	Applies to	Further details
Green Heating Incentive	• Tax exemption	• 2021-2026 first come first serve	• Homeowners • Private citizens	No charges for the costs of disconnecting from the gas network if the gas boiler is replaced with one powered by renewables, a subsidy is provided to purchase heat pumps
Public Service Obligation (PSO) exemption	• Tax exemption	• Beginning 2022	• Electrolyser operators	The government will phase out PSO tax on electrolysers making them more competitive

Sources: Danish Energy Agency

Denmark key projects and partnerships

Denmark aims to utilise its extensive gas and oil reservoirs and transport grid to promote CCS projects alongside leveraging wind power to produce green H_2

Project name	Proposed COD	Overview	Key figures	Partners involved
HySynergy	Phase 1 completed in 2022 Phase 2 completed in 2025	• 20% of capacity planned for direct use in zero-emission mobility and 80% of capacity planned as green feedstock to fuel refining processes • Electricity sourced from wind and solar, a contributor to grid balancing while O_2 to be used for the CO_2 capture process • Integrated heat recovery, usable for district heating • Initial CO_2 emission reduction potential from mobility and industry sector by 214,000 tonnes/year of CO_2	• 300MW electrolyser in 2025 • CO_2 emissions avoidance of 450 000 tons • 250M euros budget • Placement next to Fredericia oil refinery	- Everfuel (green energy and transport)
Project Greensand	Studies finalised 2021 Storage planned by 2025	• Project Greensand is currently validating the technical and commercial feasibility of permanent CO_2 storage in depleted oil and gas reservoirs in the Danish of the North Sea, starting with the Nini West Field • Building infrastructure and capabilities that will enable CO_2 captured in onshore facilities to be transported offshore for injection and storage beneath the seabed	• 4-8M tons of CO_2 per year capacity, contributing to 25-40% of Denmark's carbon reduction target • 26M euro investment from the government	- INEOS Energy (chemicals, oil and gas) - Wintershall Dea (oil and gas) - Maersk Driling (offshore drilling)
Project Bifrost	Tyra gas fields will restart production in 2023	• The project aims to reuse existing North Sea infrastructure while demonstrating CO_2 storage in a depleted offshore gas field. • Ørsted owns the pipeline infrastructure connecting the DUC offshore fields and installations to shore. It will conduct technical studies for repurposing of the existing pipeline infrastructure to CO2 transportation. • The Technical University of Denmark (DTU): DTU will be academic partner delivering technical studies.	• Storage of 3M tons of CO_2 per year • 10M euro investment from the government	- Noreco (oil) - Orsted (power) - DTU (university) - TotalEnergies (oil and gas) - Nordsøfonden (government trust)
H2RES	First electrolyser online 2024/5 Last stage 2030	• Green Fuels for Denmark is Denmark's most ambitious vision for the large-scale production of sustainable fuels and has a decarbonisation potential of 850,000 tonnes	• 2MW pilot electrolyser with plans for up to 1300MW electrolysers	- Orsted (power) - HOFOR (utilities)

Sources Noreco, INEOS, Reuters, Bloomberg, Westwood Energy

Denmark summary and learnings for Lithuania

Denmark's green transition will be led by public-private partnerships that maintain Danish economic competitiveness

	Observation on Denmark	Observation for Lithuania
Energy supply and demand mix	▲ Denmark plans to construct large "energy islands", which are able to supply green electricity to Denmark and neighbouring countries, however, solutions, including green H_2 are sought for the issue that peak-production hours in Denmark will coincide with peak production in Germany and the Netherlands	▲ Electrolysers offer a way to boost offshore wind capacity by allowing them to continue generating market-competitive energy even during off-peak hours ▲ Lithuania might consider centralized H_2 production near RES hubs
	▲ ORSTED is a clear leader in renewable energy generation and is a leader in hydrogen adoption	▲ An equivalent RES champion in LT could potentially be encouraged and expected to do the same
Ambition, targets and pathway	▲ A significant bet on PtX fuels, like e-methanol, ammonia and e-kerosene, which can be used as fuels in shipping, aviation and trucks ▲ It is predicted that a significant share of transport (15% of trucks and 10% of buses) will switch to H_2, mainly to kick-start demand and as a way to meet Danish 2030 carbon emission targets	▲ Denmark is a frontrunner, and Lithuania could study potential for e-fuels adoption by 2030 ▲ If Denmark is successful, their H_2 development model could be guiding LT decisions
	▲ There are plans to decarbonize certain key industries: fertilizers, oil refining, heating and transportation	▲ Synergies could be sought that allow electrolyser output to be used as industrial feedstock or fuel
Mechanisms and interventions	▲ The government investment schemes encourage green innovation more broadly and judges it based on its market viability, future competitiveness, the potential for export and the prospect for jobs creation	▲ Lithuania could encourage green technologies and hydrogen based on its market viability and potential for export alongside its social benefit to the society
	▲ The government retains a controlling share in numerous green projects, shielding private enterprises from excessive risk, but also bringing in private funding and talent	▲ Denmark is a potential business partner ▲ Private investments should always be sought, as the Lithuanian government alone should not govern and finance projects
	▲ As a small, open-to-trade, export-focused welfare state, Denmark states that any green innovations cannot hinder its competitive advantage or reduce the attractiveness of its brand	▲ Lithuania should not pursue vanity projects and prioritize market competitiveness