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H_2-Derivatives Market Demand Analysis for Baltic Sea Ports - hydrogen derivatives for marine fuels

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Executive summary

The global shipping industry faces an urgent need to decarbonise to meet the International Maritime Organization's target of net-zero greenhouse gas emissions by 2050 and the EU Green Deal objective of climate neutrality within the same timeframe. Electrofuels, or hydrogen derivatives such as electroammonia, electromethanol, and renewable hydrogen, are all alternatives to conventional marine fuels. However, the readiness of fuel production, distribution, and port infrastructure varies significantly between fuel types and across regions.

This report, developed within the Interreg Baltic Sea Region H2Deri@BSP project, presents a comprehensive market analysis of hydrogen derivatives across eight countries bordering the Baltic Sea. It examines current and future demand, production capacities, infrastructure readiness, regulatory conditions, and import and export possibilities, providing a solid foundation for strategic decision-making by port authorities, energy companies, and policymakers. The analysis is based on an extensive literature review and desktop research covering more than 490 scientific and industry reports, 26 EU-level policies and regulations, national policy documents, as well as market outlooks. It also builds on stakeholder engagement through two structured surveys with responses from 28 ports and 13 energy companies, 14 semi-structured interviews, and two multi-stakeholder workshops. A mapping and synthesis exercise identified nearly 300 hydrogen-related projects across the Baltic Sea Region, of which roughly 240 are still in the planning or feasibility stage, according to open sources. Together, these efforts provide both a quantitative overview of current developments and a qualitative assessment of stakeholder perspectives on opportunities and barriers in the emerging hydrogen derivatives market.

The Baltic Sea Region is showing growing momentum towards renewable maritime fuels, yet hydrogen derivatives production and use remain at an early stage. EU regulations such as the FuelEU Maritime, the Alternative Fuels Infrastructure Regulation (AFIR), and the Emissions Trading System (ETS) are beginning to drive market formation, but the current policy and regulatory framework remain insufficient for large-scale deployment in near future. While binding Renewable Fuels of Non-Biological Origin (RFNBO) targets are expected to stimulate demand after 2030, delays in national implementation and fragmented policy signals continue to deter investment in many countries.

The results indicate that hydrogen-derived energy production in the Baltic Sea Region equivalent to around 338 TWh, corresponding to approximately 31 million tonnes of Marine gasoil (MGO), could be in operation beyond 2030 assuming that all mapped plans are realised. Projects having a start-up year until 2030 equals 150 TWh. With an estimated realisation rate of 7-25%, based on literature and workshop discussions, it is assumed that 14-50 TWh of electrofuels will be produced in 2030 (operational, projects in construction and introduction of new production).

Today, only about two percent of planned capacity is currently operational. Denmark, Germany, Finland, and Sweden account for more than 80 percent of the projected production. Denmark and Finland aim to become major exporters of electrofuels. Germany is focusing on developing import corridors and port conversion, while Sweden places emphasis on hydrogen for industrial and maritime decarbonisation. The Baltic States and Poland are still in early stages of development, though several ambitious hydrogen valley initiatives are emerging.

A few ports are taking leading roles in planning or implementing bunkering and storage infrastructure for renewable fuels. Both established bunkering hubs and new ports stand to benefit from the shift to future marine fuels. Existing ports are well positioned to remain central due to their infrastructure, expertise, and customer networks. At the same time, ports located near planned electrofuel production can emerge as new bunkering nodes, offering cost advantages through local supply. Together, these developments broaden the range of ports that may play key roles in the Baltic Sea Region's future bunkering landscape.

Ports and energy companies throughout the region broadly recognise electrofuels as a long-term necessity for decarbonisation but acknowledge that near-term business cases remain weak. High

production costs, investment risks, and uncertain offtake markets are seen as the main barriers, while weak regulatory provisions and funding schemes remain as additional major constraints. Many stakeholders stress the importance of public co-financing, long-term contracts, and offtake guarantees to reduce investment risks. There is also continued uncertainty regarding technology maturity and the eventual dominance of some fuels including hydrogen, methanol, or ammonia. A few ports offer limited bunkering of renewable fuels today, with an expected increase in the number of ports with bunkering capacity by 2030, primarily focusing on methanol and biodiesel. Hydrogen and ammonia are likely to follow but mainly beyond 2030. Policy and regulatory measures remain inadequate to support their large-scale deployment and market integration in short term. Stronger and more coherent frameworks and market mechanisms are needed to accelerate the scale-up of renewable hydrogen and H_2-derivates in the short, medium and long-term.

The analysis suggests that the Baltic Sea Region will probably initially be a net importer of hydrogen derivatives. Self-sufficiency is constrained by limited direct investments and slow permitting processes as several countries focus on pilot project development until 2030. Cross-border collaboration will therefore be essential for cost-efficient scaling, particularly through shared port infrastructure and hydrogen corridors. Given current plans and policies, Finland and Denmark are well positioned to become leading exporters, while Germany and Lithuania may potentially emerge as important import and distribution hubs.

Hydrogen derivatives represent a critical component of the maritime sector's climate transition, but their widespread adoption in the Baltic Sea Region will depend on how the existing economic, financial, regulatory, infrastructural and market barriers are addressed. Stronger and more coordinated EU and national policy and regulatory frameworks are needed to establish stricter and longer-term sub-targets for electrofuels and to streamline permitting processes. Public risk-sharing mechanisms, including state-backed contracts for difference, long-term offtake agreements, and continued EU Innovation Fund support and other such initiatives, can help accelerate investment. Finally, enhanced cross-border cooperation, through hydrogen corridors, shared data platforms, and joint investment strategies, will be essential to ensure efficient deployment and avoid duplication of efforts.

If these measures are effectively implemented, the Baltic Sea Region could become a European frontrunner in green maritime fuels, achieving meaningful hydrogen-derivative deployment by 2030 and paving the way for full-scale adoption by 2050.

List of Abbreviation

AFIR	Alternative Fuels Infrastructure Regulation
CCS	Carbon capture and storage
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent, the standard measurement of GHG emissions in terms of the most common GHG, carbon dioxide (CO_2)
DNV	Det Norske Veritas, a global, independent Norwegian company that provides services across a variety of industries, including maritime, energy including shipping and energy.
EEDI	Energy Efficiency Design Index, a measure that sets minimum efficiency standards for new ships
e-MEOH	Electromethanol
e-NH_3	Electroammonia
ETS	Emission Trading System
GHG	Greenhouse gas
Green Shipping Corridors	A global maritime decarbonisation initiative for the development of zero-carbon emissions ships trade routes
HVO	Hydrotreated vegetable oil
H_2	Hydrogen
IF	Innovation Fund
IEA	International Energy Agency
IMO	International Maritime Organization, the United Nations specialised agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships.
LBG	Liquefied biogas (sometimes referred to as bio-LNG)
LBM	Liquefied bio-methane
LNG	Liquid natural gas
LPG	Liquefied Petroleum Gas
MeOH	Methanol
MEPC	Marine Environment Protection Committee
MGO	Marine gas oil
MDO	Marine diesel oil
MRV	EU system where ships must Monitor, Report and Verify their annual fuel use, CO_2 emissions, and transport activity
Net-zero GHG emissions	Removing an equal amount of CO_2 from the atmosphere as we release
NO_X	Nitrogen oxides
OPS	Onshore Power Supply
Power-to-X (PtX)	The process of converting electric energy to products, for example hydrogen derivatives
RED	Renewable Energy Directive
RFNBO	Renewable Fuels of Non-Biological Origin

RoRo	Roll-on/Roll-off vessel
SAF	Sustainable aviation fuel
SOFC	Solid oxide fuel cell

Content

1. Introduction

The chapter gives a background to decarbonisation in relation to the shipping industry, maritime regulations, energy, ship bunkering and port activities covered in this report. The aim and problem formulation addressed in this report are also presented.

1.1. Background

The International Maritime Organization (IMO) environmental target of net-zero GHG emissions by 2050 requires a comprehensive transformation of maritime energy systems (MEPC, 2023). One potential solution to achieve this target is the transition from fossil to alternative/renewable fuels such as electrofuels (e-fuels, power-to-fuel) (Brynolf et al., 2022). These fuels are a type of synthetic replacements or drop-in fuels, produced from hydrogen (H_2) and carbon dioxide (CO_2) that can directly substitute current fossil based alternatives like marine gas oil (MGO), marine diesel oil (MDO) or liquefied natural gas (LNG) as well as potential future use of fossil-based methanol and ammonia (Zincir and Arslanoglu, 2024). If their feedstocks originate from renewable sources, H_2-derivative fuels such as electrofuels are considered an environmentally favourable carbon-neutral alternative for the shipping sector (Gray et al., 2024). However, for their integration into future maritime energy systems to be successful, several challenges must be overcome before they can be implemented at scale.

Variable technology readiness levels within H_2-derivative fuel value chains, combined with their highly contextual economic feasibility, makes adoption of any particular fuel challenging beyond special use cases (Styhre et al., 2024). For example, distribution of e-ammonia can build on pre-existing distribution and storage infrastructures, yet no bunkering facilities for ammonia exist today (Wang et al., 2023). Which fuel will come to dominate is uncertain with a diverse mixture of fuels likely to be embraced across the sector, although adoption rates could vary greatly between individual actors depending on their needs (Hellström et al., 2024). Moreover, the interrelated production, distribution and use of derivative fuels calls for a system perspective on fuel processes and logistics.

Another significant barrier that could hinder the uptake of derivative fuels is a lack of uncertainty on key variables impacting future demand (Stolz et al., 2022; Malmgren et al., 2023). This includes the implementation of market-based mechanisms to reduce costs and improve derivative fuel competitiveness (Gray et al., 2024; Kanchiralla, 2025), the degree of competition from other hard-to-decarbonise sectors like aviation (Gray et al., 2021) and potential policy decisions that favour alternative solutions, e.g. competitiveness of biofuels (Parsmo, 2025). Correspondingly, the growth rate of derivative fuel supply is unclear and impacted by uncertainties in market development. This leads to a fuel transition landscape that ultimately relies on investor decision making (Brynolf et al., 2022; Styhre et al., 2024). As a result, current estimates of carbon neutral fuel demand from the shipping sector in 2030 ranges from 10% to 100% of the total anticipated global production capacity (DNV, 2024).

A system outlook on the state of hydrogen derivatives in the Baltic Sea Region which considers several fuels, their feedstocks, supply chains, processes and handling is currently lacking. Without understanding these aspects of derivative fuel value chains, guidelines for fuel handling and storage remains difficult to establish despite it being needed. This impacts decision makers such as port authorities and terminal operators who are expected to handle, store, and supply these derivative fuels in the future.

To ensure supply chain readiness, port authorities, terminal operators, maritime fuel providers and energy suppliers require greater certainty regarding what derivative fuel demand looks like now and in the future, arming them with the knowledge and capability to assess their requirements and further develop sustainable strategies for H_2-derivative fuel production, bunkering and storage capabilities.

1.2. Aim and problem formulation

The aim of this report is to provide an assessment of the level of readiness for current and future H_2-derivates activities in the Baltic Sea Region. The purpose is primarily to offer a mapping and situational overview rather than to present recommendations, which will instead be developed in later stages of the overall project. The work conducted here will form a basis for other project activities and will be further developed by project partners. The report is intended to be useful not only for work on hydrogen derivatives but also for a broader range of analyses related to alternative fuels and energy transition in the region.

This report includes the following activities:

- An assessment of the current and potential future demand for hydrogen and its derivatives (e.g., hydrogen, ammonia, methanol, synthetic fuels) in the Baltic Sea Region.
- A mapping of existing and planned hydrogen production.
- An assessment of the feasibility of exporting and importing H_2-derivatives to and from the Baltic Sea Region.
- A forecast of future market growth based on policy trends and investments.
- Identification of gaps in distribution networks that could hinder market growth.

The assessment will include a comprehensive overview of current hydrogen strategies in the Baltic Sea Region and a mapping of existing and planned electrofuel production, supply, and demand across different countries. The expected future development of H_2-derivative value chains within the region will also be evaluated, with the understanding that detailed projections for specific time periods (e.g., 2030, 2035, 2040, 2045) are not feasible at this stage due to uncertainties in technological, policy, and market developments. Further, during the interviews and surveys performed as part of the study, it turned out to be difficult for respondents to relate to the distant target years, which resulted in the time aspects used in this report: today, 2030 and beyond 2030. This time perspective also fits well with estimated timelines for ongoing electrofuel projects mapped in this report, with few projects intended to be realised after 2030. The present uncertainties are simply too great.

The aim of the report has been achieved by compiling the current state of the art knowledge from literature and synthesising new knowledge through literature, surveys, interviews, and workshops mainly with port authorities, terminal operators, energy companies and energy infrastructure providers. The process aims to facilitate collaboration between key actors and support the removal of barriers to the adoption of sustainable fuels in the shipping sector in the Baltic Sea Region.

One important but very challenging aspect of the market demand analysis concerns the expected types of H_2-derivatives, the amount of energy required, and their production locations. This is addressed in this work by developing and providing a scenario tool, *IVL H_2-derivatives scenario tool*, based on all projects and initiatives around the Baltic Sea for the time span up to 2030, and beyond 2030. Scenarios can thus be created based on estimations of project realisation rate, resulting in estimations of fuel mix and energy production for the Baltic Sea Region. A link to the online tool can be found here: link.

The report is structured as follows. Chapter 2 describes the methods used in this report. Chapter 3 includes the state of the art focusing on global and European outlooks for hydrogen-based marine fuel development, and policies and regulation that are expected to impact the future market of renewable fuels in Europe. A summary of the results from interviews, surveys and workshops with ports, energy companies and other relevant actors is found in Chapter 4. The H_2-derivatives landscape around the Baltic Sea is in focus in Chapter 5, including status of current H_2-derivatives and future forecast, a summary of supply and demand for the region, and a description of expected export or import balance. Finally, concluding remarks is included in Chapter 6.

2. Methodology

The used methods in this report are described below including desktop research, literature review, international and national workshops, surveys and interviews with ports and energy companies.

2.1. Literature review and desktop research

The state of the art knowledge presented in the report has been gathered in a three-step process. First a literature review was conducted to identify academic papers within the field of market analysis for renewable marine fuels, followed by a desktop research study used to gather data, reports and outlooks from the industry. In combination with these two approaches, relevant texts, reports and local legislation and governmental assignments were received from project partners and associate partners[1].

The literature review was performed to capture the state of knowledge on market development for marine fuels in the Baltic Sea region. In particular, the review seeks to capture insights into the role of conventional fuels, alternative fuels (e.g., LNG, methanol, ammonia, hydrogen and derivatives, biofuels), and renewable marine fuel options in the Baltic context. Scopus and web of science was used to identify literature and the search terms as well as number of hits can be found in Figure 1. The search for academic literature was performed iteratively to find a relevant search string. A list of reviewed material is found in Appendix A.

Sources were included if they, 1) Contained forward-looking assessments (scenarios, projections, or market outlooks) for marine fuels, 2) Focused on the Baltic Sea Region specifically, or on European/global assessments with relevance for the Baltic context, or 3) Addressed market drivers such as regulatory frameworks, cost competitiveness, technology readiness, or infrastructure availability. Exclusion criteria applied to sources that 1) Focused solely on technical aspects without market perspective, or 2) Were limited to single-company strategies without broader market implications.

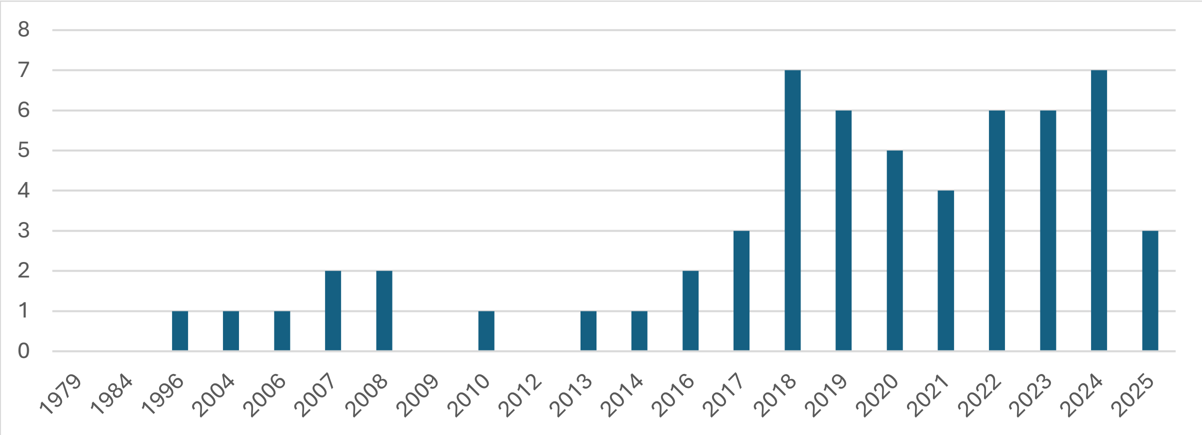

Figure 1. Number of relevant articles by year. A total of 133 articles was identified (peer-reviewed and press).

The desktop research was conducted from spring to fall of 2025 and focused on market outlooks, forecast and public projects in the region, and included sources such as journal articles, reports, white papers, press releases and databases. The approach followed a snowball methodology, where references in identified reports and materials were reviewed for potential inclusion. Identified major

[1] In total, 132 reports were received from partners and associated partners that also been used as background material and as report references. This, together with the active participation on monthly meetings, workshops etc. indicates how active the project partners have been through the whole market analyses process.

reports in the field has been utilised to find both additional reports and databases. The final review material includes over 320 reports (industry and authority), articles and strategies as well as numerous press releases or similar shorter inputs regarding specific projects and initiatives. Suggestions on the inclusion of further material were gathered from partners and associated partners as well as during workshops, interviews and survey.

The review is limited by the availability and transparency of market outlooks. Many industry reports do not publicise data and/or methodology for the assessment. Furthermore, methodological differences across studies (e.g., assumptions on carbon pricing, technology costs, or fuel availability) complicate direct comparison. The review therefore emphasises relative trends and qualitative insights rather than precise numerical projections.

Most of the information regarding on-going projects is taken from grey literature (web pages, press releases), but has been discussed directly with relevant stakeholders and should be viewed as a living document. National plans and strategies for energy and/or H_2-derivaties were primarily collected through partners and associated partners. Results from previous and ongoing national and international projects were also examined for example Blue Supply Chains, CHESS, H2AMN, Nordic Road Map, etc. Within the desktop research we identified individual projects per country in a systematic manner.

Another aspect included in the analysis is EU-level policies and regulations. 26 regulatory documents at EU-level have been reviewed, each having a direct or indirect impact on the formation of the hydrogen and its derivatives market in both the short and long term (see Table 1 for a detailed list of the documents reviewed). These documents, dated between 2020 and 2025, comprise communications, directives, regulations, and other relevant initiatives supporting the uptake of green hydrogen. The documents were identified using a snowball method, starting from key policies and regulations related to maritime transport and ports. Preliminary observations related to regulatory trends were presented and discussed with project partners and associated organisations, providing space for input and feedback.

Further, all partners in H_2Derivatives were asked to identify and provide the IVL project group with reports, scientific papers, national plans and studies, governmental assignments, etc. that included information on the current situation and plans for future fuel production, bunkering and fuel infrastructure. This enabled the identification of important data and information in local languages that would have been difficult to find otherwise.

2.2. Survey studies

To generate an overview of current and planned capacities for handling H_2-derivates, we conducted two structured surveys during the summer and fall of 2025. The surveys targeted two distinct stakeholder groups: 1) energy companies engaged in production (or planned production), trade, bunkering and/or distribution of hydrogen and hydrogen-derived fuels, and 2) ports with existing or potential roles in the transshipment of such fuels. The surveys were designed to capture both quantitative and qualitative data. Both surveys included open-ended questions to allow respondents to elaborate on perceived challenges, opportunities, and enabling conditions for H_2-derivate trade. The surveys were distributed electronically to a selected sample of energy companies and ports identified through partner networks (both companies to include and the contact details of the respondents), industry networks, previous project collaborations, and publicly available information on hydrogen initiatives.

Survey of ports

The survey to ports was conducted to map existing port capacities and planned expansions or upgrades for transshipment of H_2-Derivatives infrastructure, including storage facilities, terminal setups, onshore power supply, electricity grid capacity, and bunkering activities. The respondents' view of main drivers for developing renewable fuels, and potential future shipping fuels were also covered. The port survey captures a range of ports varying in size, geographic location, and degree of current involvement in hydrogen-related activities.

In total, the survey was distributed to 49 ports and terminals of which 28 responded. Positions of respondents included CEO, CCO, advisor to CEO, business development manager, head of development, head of renewable energy, environmental manager, and similar. All partners and associated organisations to the H_2Derivatives-project participated, as well as additional ports of importance, see Figure 2. The 28 responding ports were located in the following countries: Sweden 10, Germany 5, Denmark 5 Finland 2, Latvia 2, Poland 2, Lithuania 1, and Estonia 1.

Figure 2. Target ports that received the survey "The future of marine fuels in ports in the Baltic Sea".

Survey of energy companies

The survey to energy companies focused on identifying current and future fuels offerings and geographical coverage for delivery, and the respondents' ongoing development project in H_2-Derivatives. Questions also covered bunkering of fuels, electricity grid capacity, market segments for fuel distribution, driving forces for fuel production and necessary changes for increased production of renewable maritime fuels. All partners and associated organisations to the H_2Derivatives-project as well as additional energy companies of importance received the survey. The company names and main geographical distribution are shown in Figure 3.

In total, the survey was distributed to 34 energy companies, out of which 13 responded. Positions of respondents included CEO, business developer, R&D engineer, marine business development manager, head of technology, and similar.

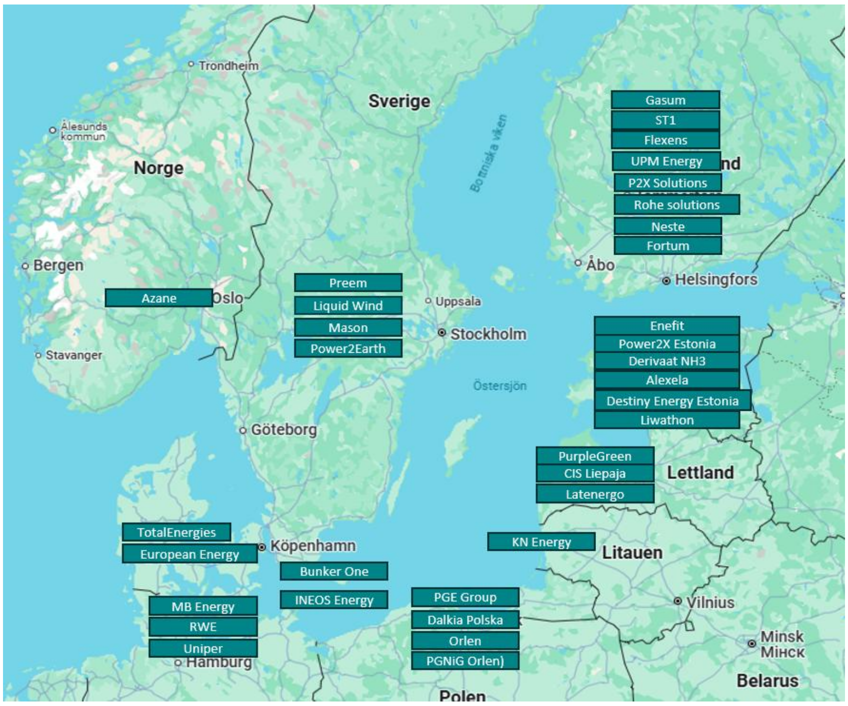

Figure 3. Target energy companies that received the survey "Energy companies around the Baltic Sea".

2.3. Interviews

As a complement to and in-depth analysis of the survey responses, semi-structured interviews were also conducted with a selection of ports and energy companies. The selection was based on their active role in the H_2Derivatives project or because of their importance to bunkering operations around the Baltic Sea. The following areas were covered with questions: Current and future fuels, Infrastructure and logistics, Driving forces and strategy, Customers and demand, Challenges and obstacles for renewable fuels for shipping and the Future. Interviews lasted between 30 minutes and one hour were carried out with eight ports and six energy companies and energy infrastructure providers. The interviewed companies were Port of Luleå, Port of Piteå, Port of Esbjerg, Port of Helsinki, Port of Kiel, Port of Klaipeda, Port of Ventspils, Port of Hamburg, Gasum, Uniper, Nordion Energy, Vattenfall, Bunker One and Interterminal.

2.4. Workshops and monthly meetings with partners

The results presented in this report has been collected and developed in close dialogue with experts from the project consortium. The information was gathered through written input, monthly project partner meetings, a dedicated international workshop with the consortium, and a workshop with Swedish actors with experts beyond partners and associated organisations.

Monthly meetings

Six monthly meetings with partners were arranged between April and October 2025. The purposes with the meetings were to inform about progress, planned and completed activities, as well as request input and feedback regarding data sources and preliminary results. Between 12 and 37 representatives from partners attended the meetings each month, including ports and terminal operators, energy companies and researchers from the Baltic Sea Region countries.

In the first stage, all project partners and associated organisations took an active role in providing the necessary information on national plans, projects, and strategies related to hydrogen and electrofuels for their respective countries, or where they had knowledge. This input has been gathered in a dedicated data sheet, which has provided background information for collecting specific details about hydrogen and electrofuel production site projects in the Baltic Sea Region countries. In the second stage, the preliminary findings on mapped projects including the initial observations from the desktop research were presented and validated during the discussions with partners. The last meeting with the project partners in October 2025 was dedicated to receiving feedback on the draft of this report, which was included in the final version.

International workshop and reference group meetings

An international workshop engaging experts among project partners and associated organisations was held on 18th of June 2025. The primarily goal of the workshop was to collect feedback and validate the preliminary insights on H_2-derivatives market development up to 2030 and beyond. The workshop was attended by 32 participants from 18 organisations representing ports, terminals, energy companies and research institutions.

Before the workshop, all participants received login to an online collaboration software called Canva Tool (see canva.com) in which graphs showing results could be seen (see Figure 4). Workshop participants also received guidance on how to enter additional information, data and comments into the tool, before, during and after the workshop. The workshop was conducted as a series of sessions, each focusing on a specific topic. Every session started with a presentation of information given by the workshop coordination team on e.g. results and general information related to the topics that were handled during the session. During and after each presentation, participants could ask questions, add information and comment on the specific topic being discussed. After the presentations, all participants were asked to answer a poll question and time was given to also enter data, information etc into the online tool. The specific questions were also discussed in separate breakout rooms, each with a discussion leader from the workshop coordination team. All verbal and written conversations were recorded, transcribed, and thereafter analysed.

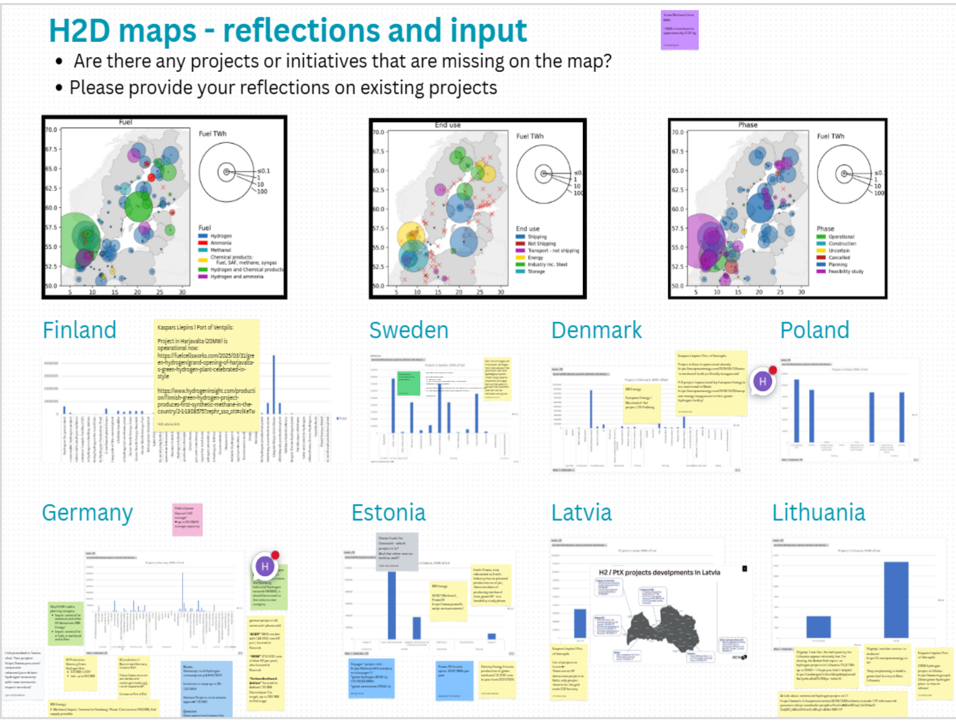

Figure 4. Snapshot from Canva Tool software including comments from participants, used during the workshop.

Workshop with Swedish actors in Luleå

Another workshop was held in the region Norrbotten, in the northern part of Sweden, on the 9th of September 2025. The workshop was arranged by IVL Swedish Environmental Research Institute, Lindholmen Science Park, Port of Luleå and LTU Business. In total, 24 participants attended, representing ports, energy companies, energy infrastructure providers, politicians and the regional authority.

The purpose was to learn more about conditions for H_2-Derivatives fuel production in Sweden. The aim was to create fictional headlines with a narrative about the kind of society we aspire to, including the presence of renewable fuels for the maritime industry in the region by 2035, and to identify key milestones and necessary engagement from all actors to make this future a reality. The three-hour workshops consisted of active participation through group discussions and individual work, mixed with presentations by the workshop organisers to provide background material to be useful for the workshop participants.

3. State of the art and policy context

The market for marine fuels in the Northern European region, including the Baltic Sea Region, is evolving due to environmental regulations, technological advancements, and shifts in demand and supply dynamics. This chapter provides an overview of the current state of knowledge and legislative development for H_2-derivates as fuels for the maritime sector. We highlight key assumptions and data influencing the results of the forecasts, including technological development, production capacity, cost trends, and areas of application highlighted in the literature. Key facts for the market development in the Baltic Sea Region are highlighted and synthesised.

3.1. The landscape for marine electrofuels and renewable marine fuels

A consistent theme across the reviewed literature is the push towards renewable and low-emission marine fuels. In earlier studies this was characterised by a shift to low sulphur fuels, driven by international regulatory pressures such as the IMO's sulphur cap and emission control areas in the Baltic and North Seas. That development represented the first shift in fuel motivated by environmental concerns and can potentially share characteristics with a shift to renewable alternatives. The literature on the current transition on the shipping industry is focused on environmental, technical and cost parameters.

Electrofuels, i.e. fuels created using green hydrogen from electrolysis, have become an increasingly well-researched area with several overall review papers being published in the resent years (Ababneh & Hameed, 2022; Brynolf & Grahn, 2024; Brynolf et al., 2022; Grahn et al., 2022; Gray et al., 2024; Kanchiralla et al. 2024; Odenweller & Ueckerdt, 2025), and key insights are the need for cost competitive feedstocks (in particular electricity), sustainable feedstocks (low-emission energy and materials) and supporting infrastructure. *Renewable marine fuels* most commonly refer to liquefied biogas (LBG), biodiesels and methanol, ammonia and hydrogen produced from renewable energy. Electricity, while not a fuel per se, can also be a renewable means of propulsion if the electricity is green. Figure 5 gives an oversight of the relevant renewable fuels for shipping.

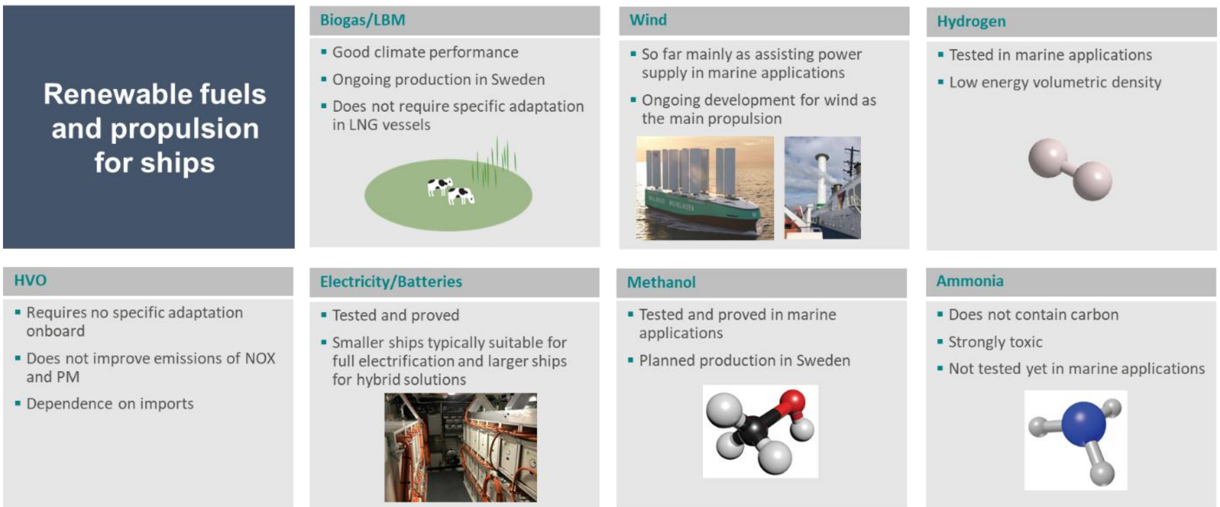

Figure 5. Overview of energy carriers and renewable fuels and some of their specific attributes (Styhre et al., 2024).

Liquefied biogas, known also as Liquefied bio-methane/Biogas (LBM/LBG), and sometimes bio-LNG, is chemically the same as LNG, consisting primarily of methane. It is produced from biomass; it is notable for generally good climate performance and can be used interchangeably with LNG.

There are also biodiesels, which are chemically similar to fossil fuels but uses plant and animal oils as feedstock. The most common is Hydrogenated Vegetable Oil (HVO). HVO can be used as a drop-in fuel without requiring modification on-board or within the fuel storage and bunkering process. However, supply is limited, and it can be seen as a marginal solution compared to future demand of low carbon intensity bunker fuels within the shipping sector.

Methanol can either come in the form of e-methanol, produced by combining hydrogen from electrolysis with captured carbon dioxide, or bio-methanol which is primarily made from biomass. It is seen as one of the most promising renewable fuels due to its ease of handling and relatively good performance. Most methanol engine are dual-fuel engines that can also run on for example Marine Gasoil (MGO).

Hydrogen can also be considered a renewable alternative, but it presents challenges as a marine fuel. Its energy density per unit of volume is low, meaning it must be either heavily compressed or liquefied to store sufficient amounts on board. Even with such processing, its volumetric energy content remains lower than that of most other fuels, creating technical and operational constraints for ship applications. Hydrogen is mostly considered for shorter routes, for example for ferry traffic between Gotland and Swedish mainland, as well as in Port of Klaipėda (Uppsala Universitet, 2025; Offshore Energy, 2025).

Finally, ammonia can be used directly as fuel when combusted. It has the benefit of not containing carbon, meaning that CO_2 is not released during combustion. However, upstream emissions from production still occur, and it is not necessarily better than other renewable fuels in a life-cycle perspective. A main drawback of ammonia is its high toxicity, which demands strict safety measures and careful handling to manage associated risks. At the same time, ammonia is widely expected to become one of the more cost-effective renewable electrofuels to produce, making it an attractive option despite its challenges.

There is no publicly available data on the use of specific alternative marine fuels within the Baltic Sea Region. However, global ship orderbook statistics provide valuable insight into the broader transition toward alternative fuels and the maturity of these as they move toward large-scale deployment. Figure 6 illustrates the development of alternative-fuel-ready vessels in DNV's maritime forecasts from 2021 to 2025. The overall trend shows a growing number of ships equipped for alternative fuels, although most are dual-fuel designs and will not necessarily operate on the alternative fuel in practice.

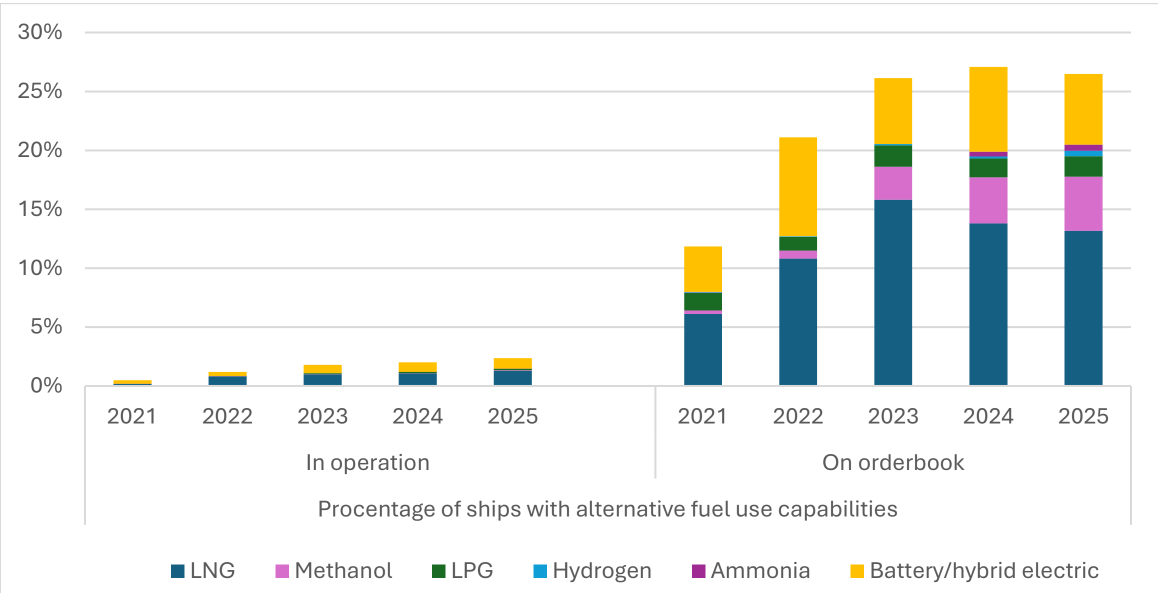

Figure 6. Orderbooks presented in DNVs maritime forecast from 2021 to 2025. Alternative fuel uptake means that the ship is capable of using the fuel but since many have a dual fuel solution it does not mean the fuel will be used during operation.

According to DNV (see Figure 6), the vessel type which currently has the most vessels on order with alternative fuels are container vessels, car carriers and gas tankers/tankers. They are also typically larger vessels within these types. Considering present vessels operating the Baltic Sea Sea as well as information reported in interviews and surveys, we conclude that for the current use of alternative fuels in the Baltic Sea Region larger ferries, RoPax and tankers are significant users.

A global shift towards a more efficient, cleaner and less carbon emitting transport system has been ongoing for many years. However, the shipping sector, being international, has fallen behind the development of land-based operations within Europe (European Maritime Safety Agency, 2021).

Which renewable and low-carbon marine fuels are relevant for commercialisation at different points in time will depend on the technological development and maturity of the considered technologies. Predictions of the technological development of renewables and low-carbon fuels and propulsion technologies are not certain and affected by initiatives, early movers, regulatory development, public perception and more. By 2040, most technologies are expected to have reached maturity if they have had continued financial and regulatory support according to most reviewed market outlooks (e.g. DNV, 2024 or IEA, 2025). Further, continuous innovation in fuel production technologies, such as electrolysis for hydrogen production, can significantly influence future demand patterns.

3.2. Market outlooks

This section outlines general conclusions, insights and relevant information from global and regional market outlooks, energy outlooks and fuel outlooks. Country specific outlooks are presented in Chapter 5 under each specific country section. By compiling and describing the most significant studies, we identify how research and analyses to date have highlighted the potential and challenges for H_2-derivates in relation to other alternative fuels. The chapter does not aim to evaluate the conclusions of these studies, but rather to provide a general starting point for further analysis in subsequent chapters.

The development of H_2-derivates has taken on a prominent role in recent years in the discussion about how shipping can reduce its greenhouse gas emissions. Several international and national actors have published analyses that map the current situation, technological developments and future opportunities for the production and use of such fuels in maritime applications. Through the literature review, interviews and workshops no outlooks have been identified which looks at the market development in the Baltic Sea Region specifically. Several global forecasts have been identified, some European and a few aimed at specific countries within the region (Fraunhofer CLM, 2025). Four different global market outlook reports are reoccurring as primary sources in the reports: IMOs GHG studies (Buhaug, 2009; Faber et al., 2020; Smith et al., 2015), DNVs Maritime Forecasts (DNV, 2022, 2023, 2024, 2025), Llyod's lists annual outlooks (and the associated Global Maritime Trends) and International Energy Agency's (IEA) Global Hydrogen Reviews (IEA, 2023, 2024, 2025).

All identified global outlooks presenting future fuel mixes which include hydrogen-based marine fuel development are either reviews presenting assumed scenarios (IMOs GHG studies, IEA) or results from cost optimisation models (DNV, Lloyd's). The composition in the future fuel mix varies greatly between scenarios and for the past two years all identified global forecasts present several scenarios with different mixes of fuels which include varying amounts of electricity-based fuel production. A summary of the fuel mixes and how much biofuels versus electrofuels they include is shown in Figure 7.

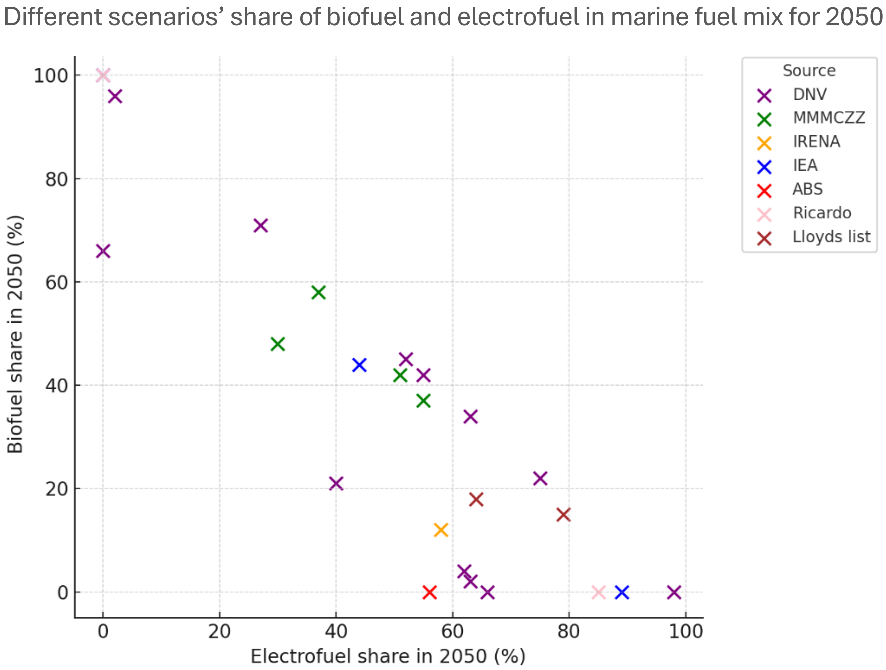

Figure 7. A summary of the fuel mixes and how much biofuels vs electrofuels they include. Please note that most of the outlooks include more than scenario.

Advanced biofuels and electrofuels, particularly e-methanol and hydrogen, are identified as cost-effective alternatives that could dominate the marine fuels market if supported by appropriate carbon pricing and policy measures (Harahap et al., 2023). However, when and to which extent is currently uncertain. The cost optimisation models are picking the marine fuel for the future fuel mix which is assessed to have the lowest future cost, and most studies uses DNVs cost estimates for ammonia as the primary production and sales costs for this fuel. We have not been able to review the underlying data for this cost calculation. It is assumed in all reviewed projections that electroammonia and electromethanol will have the same cost development over time (however, with different initial costs), why it appears that differences in distribution or safety costs are not considered, and instead only feedstock appear to be taken into account. More detailed longitudinal studies on supply chain logistics and fuel distribution models could help validate projected demand curves and supply forecasts (Matejski et al., 2012). At the moment only cost optimisation forecasts have been identified. The demand side of alternative fuel and renewable fuel is generally calculated based on projections of energy use within the sector.

IEAs perspective

An important parameter is investment decisions, and despite the fact that projects aimed at producing hydrogen are constantly being announced on a global scale, investment decisions have actually only been made for a small number of these projects (IEA, 2025).

According to the IEA's latest review from 2025, investment decisions have been made for projects that represent nine percent of the potential total global hydrogen production from all announced projects of the total project pipeline to 2030 (IEA, 2025). Nine percent is an increase of three percentage points from the 2023 review and reflects to some extent the effect of hydrogen promotion policies but is still insufficient in relation to set targets. An important reason for this is that, despite announcements by countries and companies about the importance of hydrogen for climate change mitigation, there is considerable uncertainty about demand and willingness to pay for hydrogen (IEA, 2023). Political initiatives and increased demand are needed to accelerate the market (IEA, 2023).

In general, the hope has been that electrolysers will become cheaper as production reaches greater volumes, but several organisations following this development, including the IEA and Bloomberg New Energy Finance (BNEF), have recently revised their cost estimates for electrolysers upwards due to increased material costs, labour costs and interest rates, which obviously affects the total cost of projects (IEA, 2024). Another important implication is that electrolysis projects rely on the expansion of new renewable electricity generation. When the costs of building new renewable capacity increase, the overall investment calculations for hydrogen production are directly affected, making projects more uncertain or less financially attractive.

DNVs perspective

DNV's outlook implies the Baltic marine fuel market will evolve from a near-term reliance on LNG and biofuel blends (to 2030) into a more diverse, low-carbon mix by 2050 but only if policy, industrial scale-up of renewable hydrogen and coordinated port investments occur. Without those enablers the region risks stranded assets, higher import dependency, and slower decarbonisation than DNV's optimistic pathways assume.

The earlier outlooks do not deem one or suggest that one low greenhouse gas emission fuel is more likely than any else but instead present several different scenarios where different fuels are prolific in the mix (DNV, 2022, 2023, 2024). The general trends are however coherent in the scenarios: By 2030 the Baltic will see growing LNG and biofuel bunkering and a sharp increase in ships capable of using alternative fuels. Volumes of electrofuels (hydrogen, methanol, ammonia) will remain limited and costly. DNV states that they expect the alternative-fuelled fleet capacity to ramp up quickly, but supply of carbon-neutral fuels remains tight and expensive in the near term.

For the Baltic Sea Region this implies:

- LNG growth and dual-fuel uptake: LNG will be an important bridging fuel for many Baltic operators (short-to-medium sea trades, ferries, tankers) thanks to existing bunkering hubs in northern Europe and predictable routes expect LNG bunkering to expand to meet new dual-fuel ships. However, LNG is not carbon-neutral, and its role is transitional.
- Biofuels and blended solutions: Sustainable biofuels (HEFA, advanced waste-based fuels) will be used where available, especially for ferries and passenger services keen on fast decarbonisation. Volumes are limited by feedstock availability and competition with land transport/industry.
- Ports & onshore power: Baltic ports will accelerate shore-power installations for cruise & ferries and increase onshore power supply for RoRo and passenger ships, driven by local air quality and EU rules. Regional cold-climate and ice-class needs will require tailored port equipment.

2030–2040 is a decade of scaling: ports, producers and shipping operators will invest heavily in methanol and ammonia supply chains, electrification (onshore power) for short-sea/coastal traffic, and retrofits/newbuilds. Feedstock and production bottlenecks will determine winners. DNV's mid-century modelling sees a decisive shift in the 2030s as production of electrofuels begins to scale, but supply is limited and include also the following reflections:

- Pilot-to-commercial hydrogen-electrolyser projects in the Nordic/Baltic hinterland and imports of e-methanol/ammonia are expected to grow. Baltic ports that secure early offtake agreements and bunkering infrastructure (tank farms, cryogenic handling, methanol lines) will capture most traffic.
- DNV flags that fleet readiness can outpace supply; the Baltic Sea Region will likely see more dual-fuel and methanol-capable vessels than there is low-carbon fuel available — creating price volatility and investment risk for operators and ports.

- EU instruments (FuelEU Maritime, ETS) and stricter IMO measures will increase demand for low-carbon fuels in the Baltic trading area; this regulatory push will be crucial to stimulate local production and cross-border renewable fuel corridors

By 2050, if DNV's pathways materialise and EU/IMO regulation catches up, the Baltic's bunkering mix will be dominated by carbon-neutral fuels (e-methanol, synthetic LNG/ammonia, advanced biofuels) for deep-sea and ferries/electric/hydrogen-based solutions for short sea. But this outcome is conditional on rapid scale-up of low-carbon fuel production and coordinated port investment.

The Baltic bunkering sector could be largely supplied by carbon-neutral fuels by 2050, provided that large-scale electrolysis, hydrogen derivatives, and sustainable biomass are successfully deployed. In such a scenario, e-methanol and ammonia, along with advanced biofuels for specific segments, would dominate the market, leaving fossil fuel bunkering as only a minor residual. The market is, however, expected to remain diverse and segmented, with different solutions emerging across vessel types and operational profiles. Short-sea and coastal operators, such as ferries and short RoRo services, are likely to adopt batteries, hydrogen, or e-methanol, whereas deep-sea operators will depend more on ammonia, e-methanol, or synthetic LNG, depending on route length and fuel economics. This diversification implies that ports will evolve into specialised bunkering hubs rather than adopting a uniform model. Nevertheless, systemic constraints persist: DNV cautions that challenges related to scaling, cost, and feedstock competition present major uncertainties. Without significant expansion of renewable electricity generation and electrolyser capacity, the Baltic region may be forced to import synthetic fuels at higher costs or face a slower pace of decarbonisation.

In the Baltic Sea Region, several structural and contextual factors influence the transition to alternative fuels and low-emission technologies. The short-sea shipping structure, characterised by short distances, frequent ferry operations, and numerous port calls, creates favourable conditions for the adoption of onshore power supply and battery solutions to reduce local emissions. However, these solutions require significant upfront investment and extensive grid capacity upgrades.

The region's partly cold climate and ice-class requirements further complicate the transition. Ice and winter operations increase both the technical complexity and cost of handling fuels, particularly cryogenic fuels and electrofuels. Consequently, fuel infrastructure design and operation must be adapted to withstand low temperatures and ice conditions.

Another challenge concerns competition for feedstocks and import dependence. The Baltic countries will compete with heavy industry and other transport sectors for access to sustainable biofuels and green hydrogen. Without adequate local production, the region will likely depend on higher-cost imports from Norway, North Africa, or large-scale European initiatives.

Finally, the transition phase is expected to be marked by considerable price volatility and investment uncertainty. Analyses by DNV and regional observers indicate that prices for alternative fuels such as liquefied natural gas (LNG), methanol, and ammonia may fluctuate significantly during the coming years. As a result, ports and shipping companies face the risk of technological or economic lock-in if major infrastructure or fuel-related investments are made prematurely.

Lloyd's perspective

Lloyd's Register (LR) projects a significant transformation in the Baltic Sea's maritime fuel landscape by 2050, driven by stringent decarbonisation regulations, technological advancements, and evolving market dynamics. The transition from conventional fuels to low-carbon alternatives is anticipated to unfold in phases, with varying implications for infrastructure, fleet composition, and regional competitiveness.

Highlights from the Near-Term Outlook (2025–2030):

- Regulatory pressures intensify: The EU's FuelEU Maritime Regulation mandates an 80% reduction in greenhouse gas (GHG) intensity of onboard energy by 2050, with interim targets set for 2030. This regulation is expected to accelerate the adoption of alternative fuels in the Baltic Sea Region.

- LNG as a transitional fuel: liquefied natural gas (LNG) is projected to at least double in demand globally by 2030, owing to its relatively lower emissions compared to traditional marine fuels and the expansion of LNG infrastructure.
- Biofuels and blended solutions: The use of biofuels is expected to grow, particularly in short-sea shipping and ferry operations, as part of the initial steps toward decarbonisation.

Highlights for the Transition Period (2030–2040)

- Scaling of alternative fuels: The adoption of low-carbon fuels such as green methanol, ammonia, and hydrogen is anticipated to accelerate, with demand projected to grow from 0.79 exajoules (EJ) in 2030 to 6.06 EJ in 2050.
- Infrastructure development: Significant investments in bunkering facilities, storage, and distribution networks for alternative fuels will be essential to support the growing demand.
- Fleet modernisation: Shipowners are expected to retrofit existing vessels and order newbuilds capable of operating on alternative fuels, aligning with regulatory requirements and market incentives.

Highlights from the Long-Term Outlook (2040–2050)

- Dominance of carbon-neutral fuels: Electrofuels, including renewable ammonia and methanol, are projected to capture an average of 35% of the global marine fuel mix by 2050.
- Regional disparities: The Baltic Sea Region's competitiveness in this period will depend on early investments in infrastructure, access to renewable energy sources, and the development of efficient supply chains for alternative fuels.
- Policy alignment: Alignment with international regulations, such as the International Maritime Organization's (IMO) targets for GHG emissions reduction, will be crucial for the region's maritime sector to remain competitive.

Other identified relevant assessments

The American Bureau of Shipping (2023) has recently released an updated market outlook for alternative marine fuels. The analysis covers oil and chemical tankers, dry bulk carriers, containerships, liquefied petroleum gas (LPG) carriers, liquefied natural gas (LNG) carriers, car carriers, general cargo vessels, roll-on/roll-off (RoRo) vessels, roll-on/roll-off passenger (RoPax) vessels, and cruise ships. Compared to the previous edition, the projected market shares of methanol and ammonia have both increased. Methanol is expected to enter the market earlier than ammonia, reaching an estimated share of 8% in 2030, while ammonia is projected to account for 2%. By 2040, methanol's share is anticipated to rise to approximately 25%, and ammonia's to about 15%.

MAN Energy Solutions (2022) reports similar trends, indicating an ongoing transition toward greater fuel diversity in the maritime sector. The combined market share of methanol and ammonia is projected to reach approximately 10% in 2030, increasing to around 18% for each fuel by 2040. The forecast includes only minimal use of hydrogen as a marine fuel. By 2050, global shipping is expected to require 300 million tonnes of ammonia, 225 million tonnes of methanol, 80 million tonnes of methane, and 180 million tonnes of single-fuel types, primarily heavy fuel oil (HFO), marine diesel oil (MDO), biofuels, and synthetic fuels. The report further concludes that existing and emerging engine technologies do not constitute a barrier to achieving carbon dioxide emission reductions in the shipping industry.

The Nordic Roadmap project (futurefuelsnordic.com/) includes an assessment of the theoretical maximum potential for alternative fuels in Nordic shipping (Nordic Roadmap, Task 2B). The analysis is based on 2019 ship activity patterns and vessel size data, assuming that hydrogen, ammonia, and methanol are the sole alternative fuels applied across all Nordic domestic and intra-Nordic shipping, as well as half of the traffic between the Nordic countries and adjacent regions. Considering the technical feasibility of each fuel to serve the evaluated traffic, the theoretical maximum demand is estimated at 0.7 million tonnes of hydrogen, or 9.55 million tonnes of ammonia or methanol.

The study further includes a mapping of existing and planned zero-carbon fuel production projects in the Nordic countries up to 2030. The results indicate that the projected hydrogen production capacity could meet the estimated demand if all announced projects reach their target output. In contrast, the combined planned production of methanol and ammonia would cover only about 43% of the estimated technical potential required for shipping. However, considerable uncertainty remains regarding the share of this production that will be allocated to maritime applications, as such information is not specified. For example, Sweden's fossil-free steel industry is expected to consume a substantial portion of the region's future green hydrogen supply.

3.3. EU policy and regulatory landscape

This section focuses on the policy and regulatory context, primarily the EU level directives, communications and regulations on renewable fuels with both direct and indirect potential impact on the electrofuel market formation, including its handling and storage (see Table 1 for an overview of documents included in the analysis). The main question is to what extent the current EU policy and regulatory landscape support electrofuel market formation, development and growth up to 2030 and beyond 2030.

Table 1. The list of EU-level policies, regulations and other instruments with direct and indirect impact on hydrogen fuel market formation including derivatives which have been included in the analysis.

Document Type	Short title	Year
Communication	Ocean Pact	2025
Communication	Clean Industrial Deal	2025
Communication	Affordable Energy Action Plan	2025
Communication	Competitiveness Compass for the EU	2025
Regulation	Net Zero Industry Act	2024
Report	Hydrogen for a Sustainable Europe	2024
Directive	Rules for the internal market for renewable gas, natural gas and hydrogen	2024
Regulation	Regulation on the internal markets for renewable gas, natural gas and hydrogen	2024
Other	Innovation Fund Hydrogen Auctions 2024	2024
Regulation	EU Methane Regulation for the energy sector	2024
Other	Draft Methodology for evaluating the emission saving of low-carbon hydrogen and fuels	2024
Regulation	European Critical Raw Materials Act	2024
Directive	Renewable Energy Directive (RED III)	2023
Communication	European Hydrogen Bank (EHB)	2023
Directive	Energy Efficiency Directive	2023
Directive	ETS Directive	2023
Communication	A Green Deal Industrial Plan for the Net-Zero Age	2023
Regulation	Alternative Fuels Infrastructure Regulation (AFIR)	2023
Regulation	FuelEU Maritime Regulation	2023
Regulation	Carbon Border Adjustment Mechanism	2023
Communication	REPowerEU Plan	2022
Communication	EU Fit for 55	2021
Regulation	European Climate Law	2021
Communication	Proposal for restructuring Energy Taxation Directive	2021
Regulation	EU Taxonomy	2020
Communication	EU Hydrogen Strategy	2020

At the EU level, there are both soft and legally binding measures. The former are often expressed through various policies, strategies and plans (i.e., communication documents) and can be defined as aspirational.

The legally binding measures typically take the form of regulations and directives, both of which are essential for implementing agreed policy objectives and strategies. The key difference between EU regulations and directives is that the former applies automatically as soon as they enter into force, while directives are applicable only after they are transposed into the national law of the EU Member States. This also means that while the targets set in directives are binding, the Member States have freedom to decide how they are to be achieved. These differences are important when considering the potential direct and indirect impact of the EU policy and regulatory landscape on hydrogen electrofuel market.

Between 2020 and 2025, the EU has introduced a suite of initiatives with varying degrees of regulatory pressure and policy guidance on renewable fuel production, infrastructure development, and end-use adoption across multiple sectors, including shipping. The maritime sector, historically excluded from major international and regional climate policy instruments, has come under growing regulatory focus. This shift is reflected in three cornerstone measures, namely, the inclusion of maritime emissions in the EU Emissions Trading System (EU ETS), introduction of GHG intensity standards for shipping fuels in the FuelEU Maritime Regulation and setting infrastructure requirements in ports via the Alternative Fuels Infrastructure Regulation (AFIR).

Despite this broader policy shift, it remains uncertain to what extent the measures introduced specifically support and incentivise the production, storage and uptake of hydrogen and its derivatives in shipping over the short and long term. Accordingly, the below sections present an overview of the potentially direct and indirect policy and regulatory impacts on the electrofuel market in the period up to 2030 and into the following decades.

Policy and regulatory signals up to 2030

Previous studies analysing policy instruments for the introduction of electrofuels in shipping have found that, up until late 2018, EU policies and regulatory frameworks were not specifically promoting the uptake and use of electrofuels in maritime transport (see e.g., Brynolf et al., 2022). However, this has changed with the adoption of the Renewable Energy Directive (RED II) in 2018, which has included electrofuels in the definition of renewable fuels of non-biological origin (RFNBO)[2]. In addition, the revision of RED II which started in 2021 resulted in provisions requiring the EU Member States with maritime ports *"to ensure that from 2030 the share of renewable fuels of non-biological origin in the total amount of energy supplied to the maritime transport sector is at least 1.2 %"* (EU, 2023a). The latter indicative target provides a signal for Member States to introduce corresponding provisions and obligations for fuel producers and fuel suppliers when transposing RED III into national legislation by mid-2025. The first-ever indicative targets for the share of RFNBO in marine fuel mix are part of the broader EU framework under RED III, which requires Member States to collectively ensure that at least 42,5% of the EU's gross final energy consumption comes from renewable sources by 2030, with an aspirational goal of reaching 45%. In addition, RED III set the provisions to increase the use of RFNBO in the final energy and non-energy purposes in industry to at least 42% by 2030.

On a broader scale, the EU Hydrogen Strategy, adopted in 2020, introduced policy direction for renewable hydrogen production and defined three development phases: Phase 1 (2020-2024), Phase 2 (2025-2030), and Phase 3 (2030-2050) (COM/2020/301 final, 2020). The kick-start of renewable hydrogen applications in maritime transport is foreseen to begin in Phase 2 (2025-2030). In Phase 3 (2030-2050), renewable hydrogen and hydrogen-derived synthetic fuels are expected to reach maturity and be deployed at scale across a wide range of applications, including shipping. The strategy also emphasises the importance of stimulating the demand in end-use sectors such as inland waterways, short-sea shipping, and deep-sea shipping. In particular, the production and uptake of synthetic fuels are highlighted as especially relevant for long-distance shipping. Furthermore, recently adopted Clean

[2] RFNBO definition in the Renewable Ehaveeeeegy Directive III (2023) is as follows: "renewable fuels of non-biological origin" means liquid and gaseous fuels the energy content of which is derived from renewable sources other than biomass" (Article 2 (36).

Industrial Deal Communication (COM, 2025) recognises the importance of low-carbon fuels including low carbon hydrogen in the hard-to-abate sectors, including shipping.

The inclusion of maritime emissions to EU ETS system will gradually help narrow the cost gap between conventional and renewable fuels. During the so-called "initial phase-in" period shipping companies are obliged to report emission allowances equivalent to 40% of their verified carbon dioxide emissions as of 2024, which increases to 70% by 2025. The obligation to account for 100% of emissions begins in 2026 and will by then include accountability for methane and nitrous oxide emissions (NO_x) as well. This implies that continuing operations with conventional fuels will become increasingly costly for shipping companies. This trajectory is further strengthened by the Methane Regulation (EU, 2024b), requiring fuel producers and importers to monitor and report methane emissions from 2028 and implement reduction measures from 2030. Together with the EU ETS obligations, this regulation strengthens the overall policy direction to move away from fossil fuels indirectly supporting the market formation of the hydrogen and hydrogen electro fuels.

Revenues from purchased allowances via EU ETS are allocated to the EU budget and some portion goes back to the Member States. Within the EU, ETS revenues are used to finance decarbonisation projects through the Innovation Fund (IF) – one of the world's largest funding programs for demonstrating innovative technologies that reduce GHG emissions. Hydrogen is among the leading thematic areas in the IF portfolio accounting for 43 out of 210 projects as of June 2025. The maritime sector gained a dedicated support within the IF in 2024, when a budget of EUR 200 million was allocated under the second hydrogen auction launched within the framework of the European Hydrogen Bank.

The European Hydrogen Bank is a policy initiative designed to facilitate renewable hydrogen market formation and reduce the cost gap between renewable and conventional hydrogen (COM/2023/156 final, 2023). To advance this goal, hydrogen auctions were introduced in 2023 within the scope of the Innovation Fund, providing fixed subsidies per kilogram of renewable hydrogen produced. Within the scope of hydrogen auctions, a separate basket with dedicated budget for maritime topic was introduced aimed to incentivise the hydrogen producers to supply green hydrogen or its derivatives to maritime transport. The second IF Hydrogen Auction call 2024 resulted in allocation of funding to three bids under maritime topic, amounting to EUR 96,7 million. The third IF Hydrogen Call in 2025 will continue to support the production of RFNBO hydrogen, with targeted focus on off-taker strategies for the maritime sector. It will also provide additional possibilities to obtain subsidies for production of electrolytic low carbon hydrogen.

Complementary to these measures, the Net Zero Industry Act Regulation (2024a) aims to support the scale-up of strategic net-zero technologies including electrolysers, fuel cells and RFNBO. This will be achieved by establishing a supporting framework for producers of maritime fuels, such as simplifying regulatory environment, incorporating resilience and sustainability criteria into public procurement and auction mechanisms. This contributes to accelerating permitting processes and establishing net-zero regulatory sandboxes.

Another core piece in the EU legislation basket with the increasing pressure on the user side to adopt alternative fuels is the FuelEU Maritime regulation which entered into force on 1 January 2025. Starting from 2025 the GHG intensity in marine fuels used onboard ships (above 5,000 GT) calling to EU ports will have to be reduced by a minimum of 2% and 6% starting from 2030; See Figure 8 where the FuelEU Maritime requirements are compared with the not yet adopted IMO Net-zero Framework. Although FuelEU Maritime is generally perceived as a fuel-type neutral, it has specific provisions to encourage the use of RFNBO (in line with the Renewable Energy Directive III):

"When produced from renewable electricity and carbon captured directly from the air, synthetic fuel can achieve up to 100% emissions savings compared to fossil fuels. They also have considerable advantages compared to other types of sustainable fuels with regard to resource efficiency of the production process, in particular as regards water consumption" (EU, 2023).

To support the market uptake of RFNBOs, including synthetic fuels, in shipping, the FuelEU Maritime Regulation introduced the multiplier of "2" criteria, which rewards ships using RFNBOs. In practice, this means that the energy from these fuels counts twice toward compliance, until the end of 2033. This measure, as argued in the regulatory document, was introduced to provide fuel suppliers with greater certainty regarding prospective minimum demand for RFNBO, while also allowing end users flexibility across different market uptake scenarios, given that *"a market for maritime RFNBO is yet to develop"* (EU, 2023b). Additional elements linked to enforcement of RFNBO targets in the FuelEU Maritime are described in the coming sections.

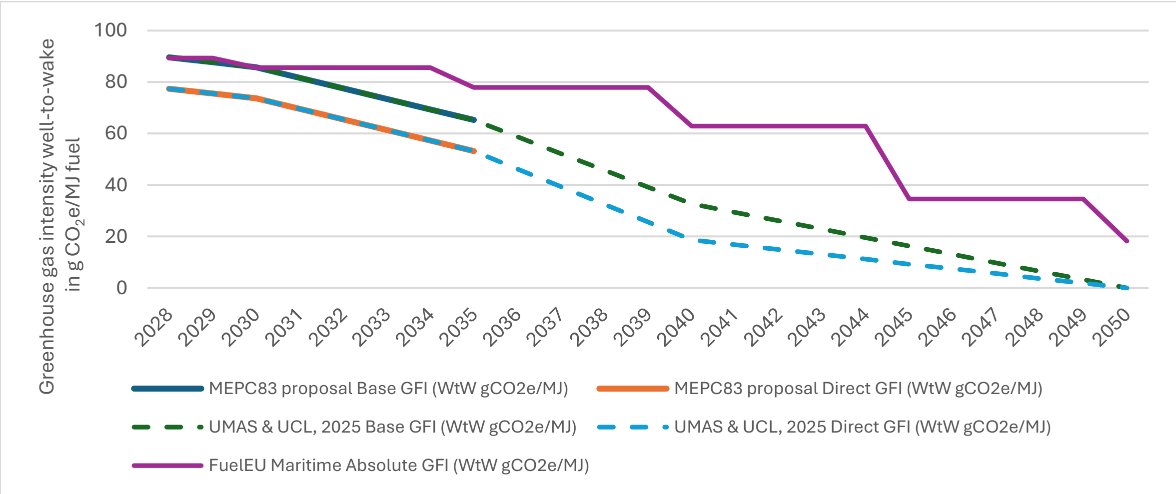

Figure 8. Different greenhouse gas targets and their development over time. MEPC83 refers to the ongoing/postponed IMO negotiations on a Global Net-zero Framework and UMAS & UCL refers to assessments made by UMAS and UCL on behalf of Global Maritime Forum.

A further aspect in the regulatory framework crucial for the market formation of hydrogen and its derivatives is their handling and storage availability. The Alternative Fuel Infrastructure Regulation (EU, 2023c) requires Member States, by the end of 2025, to prepare national policy frameworks that include the current state, future perspectives and planned measures for deploying alternative fuel infrastructure in maritime ports and covering fuels such as hydrogen, ammonia, methanol, and electricity, in addition to onshore power. This requirement is expected to further encourage national authorities and port operators to plan infrastructure development dedicated to hydrogen and its derivatives. Furthermore, the revised Regulation on the internal markets for renewable gas, natural gas and hydrogen (EU, 2024) provides the legal framework for the handling and storage of hydrogen and its derivatives. It also introduces tariff discounts for the injection of renewable and low-carbon hydrogen into the gas grid, complemented by European Hydrogen Bank mechanisms designed to enhance market visibility and facilitate supply–demand matching.

Another strategic communication document – the European Ocean Pact (COM/2025/281 final, 2025) – also highlights the importance of developing alternative fuel infrastructure in ports. Although it does not provide any specific detail on this issue, it refers to the ongoing work of the European Commission to develop a new EU Ports Strategy and an Industrial Maritime Strategy, aimed at strengthening the EU's industrial base and positioning ports as critical hubs in clean energy. In parallel, the ongoing revision of the Energy Taxation Directive, launched in 2021, is expected to remove tax exemptions for conventional marine fuels on intra-EU voyages, and, importantly, to recognise hydrogen as an energy product (EEA-EMSA, 2025).

Taken together, current policy and regulatory measures signal a growing commitment to supporting the market formation of hydrogen and electrofuels. This direction is particularly evident in the RFNBO targets set under RED III, FuelEU Maritime and European Hydrogen Bank mechanisms, among others.

Nevertheless, these measures remain weak and limited in their ability to reduce business uncertainties, introduce effective risk-sharing mechanisms and stimulate realisation of large-scale production volumes for maritime applications in the short- to mid-term. This shortfall is especially significant when considered against the ambitions of the RePowerEU Plan communication (COM(2022) 230 final, 2022), which set out the goal of increasing RFNBO hydrogen production capacity in the EU by 10 Mt and achieve an additional 10 Mt of RFNBO hydrogen imports by 2030.

Policy and regulatory signals beyond 2030

Beyond 2030, the regulatory direction is clearly moving towards stricter decarbonisation targets and continues to be shaped by a technology and fuel neutral approach that largely avoids prescriptive mandates on specific fuels. The FuelEU Maritime regulation is central in this respect. It sets progressively stricter GHG intensity reduction targets for marine fuels: 14,5% by 2035, 31% by 2040, 62% by 2045, and 80% by 2050. Although this regulatory trajectory will gradually exert pressure on both ship operators, fuel producers and suppliers to expand renewable fuel production and distribution capacities, significant uncertainty remains regarding the dedicated measures to support the upscaling of hydrogen and synthetic fuels in the marine fuel mix by 2040 or 2050.

While the FuelEU Maritime regulation introduces a binding 2% RFNBO target from 2034 for companies that do not achieve a 1% uptake by 2031, the requirement is weakened by flexibility conditions that are built in the design of this regulatory provision. For example, the target can be waived if it can be proven that "*… there is evidence of insufficient production capacity and availability of RFNBO to the maritime sector, uneven geographical distribution or a too high price of those fuels"* (FuelEU Maritime, 2023 Article 5.5). Furthermore, there are no additional sub-targets for RFNBO uptake between 2034 and 2050. In this context, advocates for clean transport and energy in the EU have recommended that the anticipated revision of the FuelEU Maritime regulation by the end of 2027 should also include sub-targets for electrofuels (T&E Briefing, 2024). Such provisions could support increased demand for electrofuels from 2030 onwards and provide stronger regulatory incentives to scale up electrofuel production capacity.

In addition, the ETS Directive, which expanded the EU Emissions Trading System to the maritime transport in 2024, will continue to increase the cost of fossil marine fuels beyond 2030. However, modelling results on the combined impact of FuelEU Maritime and the EU ETS over the next 30 years indicate that, for the EU ETS to have a stronger effect stimulating the demand for renewable fuels in shipping, a significant increase in carbon prices would already be required by 2030 (Transport & Environment, 2023). For example, Flodén et al., 2024 study results show that the promotion of large-scale fuel shifts is unlikely without allowance price reaching at least €150-200/tCO_2.

Besides regulatory measures directly oriented towards the maritime sector, there are other policy provisions that may indirectly strengthen the market position of electrofuels in the long term. For example, transport is one of the prioritized sectors in Clean Industrial Deal Communication (COM, 2025), which envisions to develop a number of strategic instruments with potential impact on H_2-derivates beyond 2030. One such initiative is the Sustainable Transport Investment Plan (under preparation as of September 2025), which will propose short- and medium-term measures supporting specific renewable and low-carbon fuels for waterborne transport. The communication also foresees the Hydrogen Mechanism (launched in July 2025) – an online platform aiming to mobilise and connect off-takers and suppliers of renewable and low-carbon hydrogen and its derivatives (including ammonia and methanol). It also foresees support in identifying infrastructure needs such as transport and storage and facilitate access to financial support. The first matching round starts in September 2025.

4. Synthesis of results from workshops, surveys and interviews

This chapter presents empirical findings of the study, based on three complementary sources: two multi-stakeholder *workshops* (one international and one Swedish), two *surveys* distributed to ports and energy companies in the Baltic Sea Region, and the series of semi-structured *interviews* with stakeholders. Together, these activities provide insights into regulatory perspectives, market expectations, and perceived barriers for hydrogen-derived fuels (electrofuels) in shipping. The design and implementation of the surveys, interviews, and workshops are described in detail in Chapter 2, while the following sections summarise the results divided into thematic areas.

4.1. Future marine fuels

Respondents from ports authorities, below referred to as *ports*, were asked in the survey and during interviews about which fuels they see as the most important for ships beyond 2030. The answers reflect the common view that there is no silver bullet and that several fuels will be available for the shipping industry. The necessity to focus on multiple fuels was described by an energy company that participated in the survey: "*We are a customer driven business, and we continuously work to ensure that our commercial offering reflects the needs of our customer base. The future of marine fuels is of a broad spectrum of products, covering conventional fuels with on board carbon capture as well as a multitude of low and zero carbon alternatives. We do not envisage the industry aligning around a single product or compliance pathway in the next three decades*".

The fuels with largest potential, according to the ports, were methanol, ammonia and hydrogen (in that order), but also LNG, LBG and biofuels are important. Regarding which fuels that has the largest potential, one port stated: "*Most probably the renewable fuels (methanol, FAME, ammonia, hydrogen). Anyway, regulation will play a major role, as well as cost competitiveness compared to other fuel types*". Another port stated: "*After 2030, shipping will be dominated by fuels with low environmental impact and zero CO_2 emissions. It is likely that hydrogen, LNG, methanol and ammonia will be key to decarbonization*". Other ports also discussed the relationship between ship type and fuel choice, where electrification could be suitable for smaller ships or shorter distances. Today, only 14% of the surveyed ports charge vessel batteries. However, if the plans to expand charging infrastructure for vessels in port will be realised, this figure will triple by 2030.

Even though ammonia was mentioned by several ports, other recognize the fuel's lack of maturity. One port elaborated on this: "Ammonia, you have kind of a blank page in front of you. I think in terms of uncertainty that feels fairly frightening. The risk assessment states that we can bunker ammonia but then of course we also need the local to go from our Port Authority and this is on a different page".

Of the 28 ports that responded to the survey, 23 currently provide bunkering services, while five do not. The distribution of fuel types handled today by these ports and plans for 2030 and beyond 2030 are shown in Figure 9. As expected, almost all ports offer fossil-based fuels, while very few currently offer methanol, ammonia, hydrogen or bio-methane. The result also shows a clear shift from 2030 from fossil fuels, e.g. marine gasoil (MGO), heavy fuel oil (HFO) and liquefied natural gas (LNG), towards bio- and electrofuels. This noticeable drop is seen already at 2030, especially for MGO. A common sentiment expressed by the ports is that they wish to meet the shipping companies demand, meaning that those who answered that they for example will offer ammonia in 2030 would in reality only do so if there is a demand for it. The low maturity level of ammonia as fuel is evident, being surpassed by hydrogen, a much more expensive fuel, in future bunkering plans.

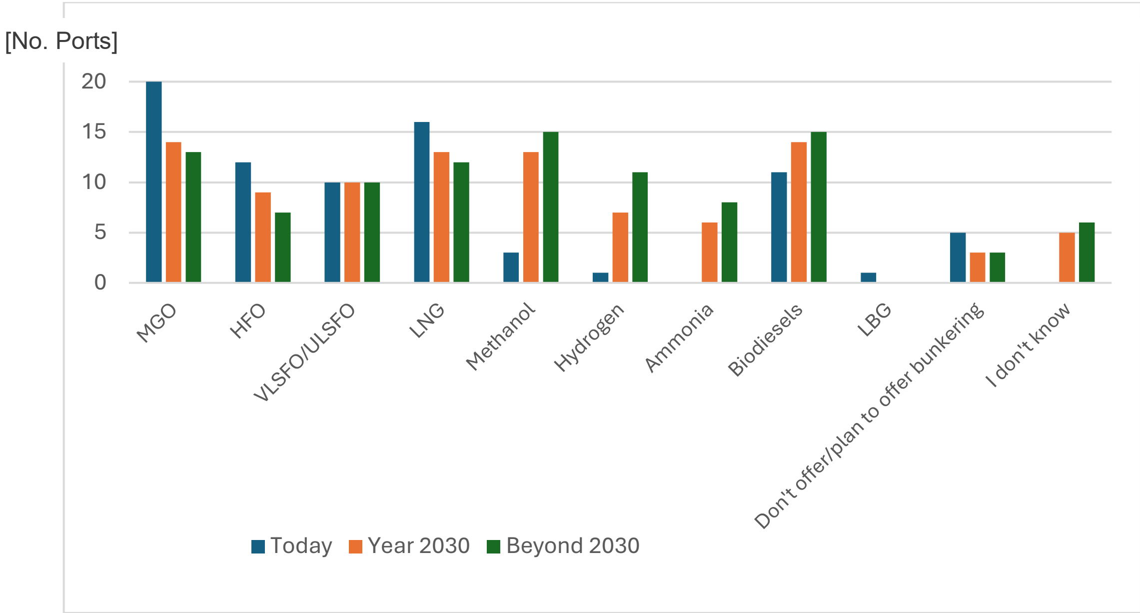

Figure 9. Fuels current supplied by the surveyed ports, along with what fuels they plan to offer by 2030 and beyond 2030.

All bunker technologies are used in ports today, and the most common is tank trucks (91% of the surveyed ports that provide bunker fuels use trucks), followed by ship-to-ship (78%) and shore-to-ship and/or pipe-to-ship bunkering (39%). Choice of bunkering methods becomes more uncertain over time, but the results show that more ports plan to offer shore-to-ship and pipe-to-ship bunkering in the future.

The same question was asked to the energy companies: which fuels are currently offered in the Baltic Sea Region, and future plans. Thirteen companies answered, and their responses are summarized in Figure 10. The results show that there is an expected sharp increase in electrofuel production, and that most of the energy companies are planning to supply methanol beyond 2030. Further, about one third of the surveyed energy companies also commented that they are currently offering, or planning on offering, liquefied biogas (LBG).

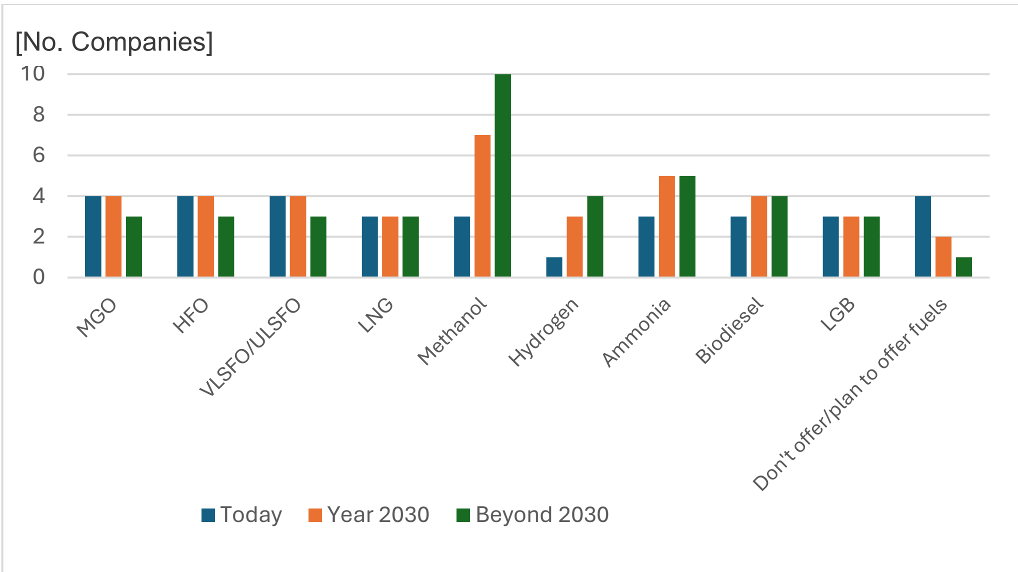

Figure 10. Fuels current supplied by the surveyed energy companies, along with what fuels they plan to offer by 2030 and beyond 2030.

All the surveyed energy companies considered the maritime sector as a potential market, with the following arguments:

- The maritime sector is already a market they supply with fuels, and they intend to maintain this position through the ongoing maritime energy transition.
- The market for renewable fuels in shipping is growing with large potential, especially for methanol.
- National and international (existing and future) regulations from the EU and the IMO are opening new opportunities for renewable fuels.
- The presence of relatively few actors requiring large volumes is beneficial and makes the maritime market attractive for their products.

Overall, the surveyed energy companies are eager to supply the maritime sector with fuels. However, much like the ports, many emphasize the need for an increase in demand before they are willing to commit. Some concern was also raised regarding whether shipping companies would be willing to pay for renewable fuels, and several commented on the importance of policy measures for facilitating renewable fuel uptake. An energy company that commented on this added: *"Our business is built around enabling ammonia as a maritime fuel. We believe the maritime sector is important due to new regulations (existing and future) such as EU ETS, Fuel EU Maritime, IMO NZF and Norwegian emission regulations for offshore sector*".

4.2. Hindrances to market uptake and production capacity

At the international workshop, participants were asked to rank the most significant barriers to developing electrofuels and largely agreed on a set of interlinked hindrances. Before discussions started, a poll among participants showed that costs, followed by investment risks, were ranked as the most pressing hindrances. See Figure 11 for poll results.

The largest hinder for hydrogen derived fuels are	
> 1st	Cost
> 2nd	Investment risks (including selection of fuel type)
> 3rd	Lach of willingness to pay among customers
> 4th	Policy and regulatory uncertainty
> 5th	Lack of production capacity
> 6th	Technology readiness

Figure 11. Poll question results from workshop related to hinder for hydrogen derived fuels.

Costs, investment risks and market uncertainty were consistently ranked as the greatest hindrances to market uptake and increased production capacities. Companies found it difficult to justify capital-intensive infrastructure given the unpredictable policy environment and lack of clear demand. The uncertainty of future prices, regulatory frameworks, and offtake agreements was described as a deterrent to decisive investment.

Lack of subsidies and state support was another central theme. Without state guarantees, subsidies, or long-term contracts, projects were seen as commercially unfeasible in their early stages. Several participants drew parallels to LNG terminal development, where public backing was critical. Proposals included state-guaranteed contracts for a fixed share of production capacity to de-risk investment.

Offtake market challenges and high costs also featured prominently. Many cancelled projects failed because enough buyers could not be secured at viable price points. High production costs combined with technical and engineering complexities added further risk.

Finally, regulatory uncertainty was underscored. While EU frameworks such as the FuelEU Maritime regulation are in place, uncertainties around IMO alignment, national implementation, and shifting deadlines were seen as highly destabilizing — in some cases more pressing than cost factors themselves.

Overall, there was strong consensus that addressing these hindrances is essential for market formation. Without clearer long-term regulatory signals and state-supported risk-sharing mechanisms, the realization of large-scale hydrogen fuel production in the Baltic Sea Region will remain slow and uncertain. A statement from one participant also gave the other perspective: "*Very important to transfer this perspective that the baseline can never be fossil fuels. This perspective should be understood by the users*".

Challenges were also discussed with ports during interviews. One port stated: "the largest challenges to developing alternative fuel bunkering is getting investments. We have developers who have great plans, great ambitious and so on, but problems securing the investment into this project, basically selling the project to the potential investor". Another port summed this up in the following way: "The biggest challenges to developing alternative bunkering in a port? Confusion on the demand side and not clarity". A third port elaborated on the cost issue for shipping companies: "The problem is that the fuel itself is still expensive. We shouldn't fool ourselves, what they are doing is to be as profitable as possible. It's not charity".

Another port's largest hindrance was the reluctance of the local community. "Local community is not ready for this new fuel. We have a very big challenges and we are communicating a lot with the local community regarding it".

One issue related to technology is the lack of electricity or limitations in the electric grid. One port described this: "We need the material to produce the electrofuels. It means that we need a big amount of electricity and capacity of it. At the moment we are struggling with electricity capacity in the port". This was also reflected in the survey where 36 % of the ports indicated that the grid connected to their port today was not sufficient to meet the needs of energy and power transfer capacity, see Figure 12.

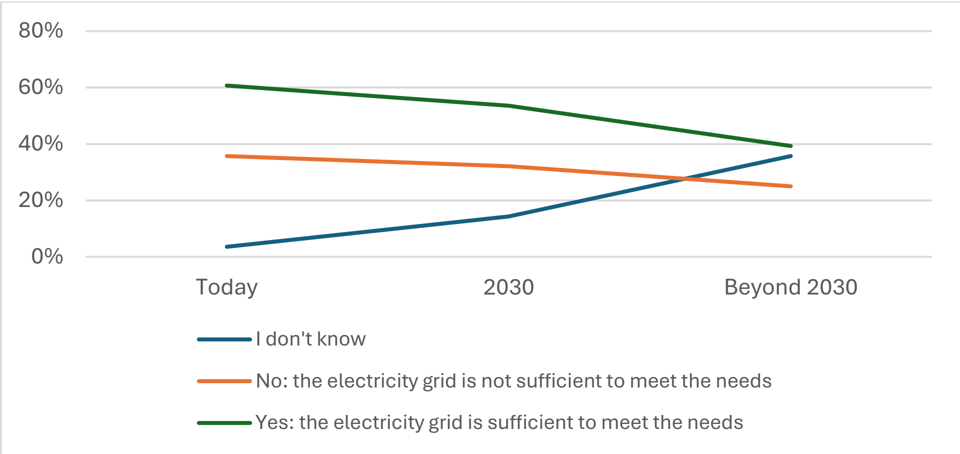

Figure 12. Surveyed ports' indication of electricity grid being sufficient or not to meet their needs of energy and effect over time.

The energy companies had a similar view of electricity supply, with 31% of the companies responding that the electricity grid is not sufficient for their need today, and with increasing uncertainties in 2030 and beyond, see Figure 13.

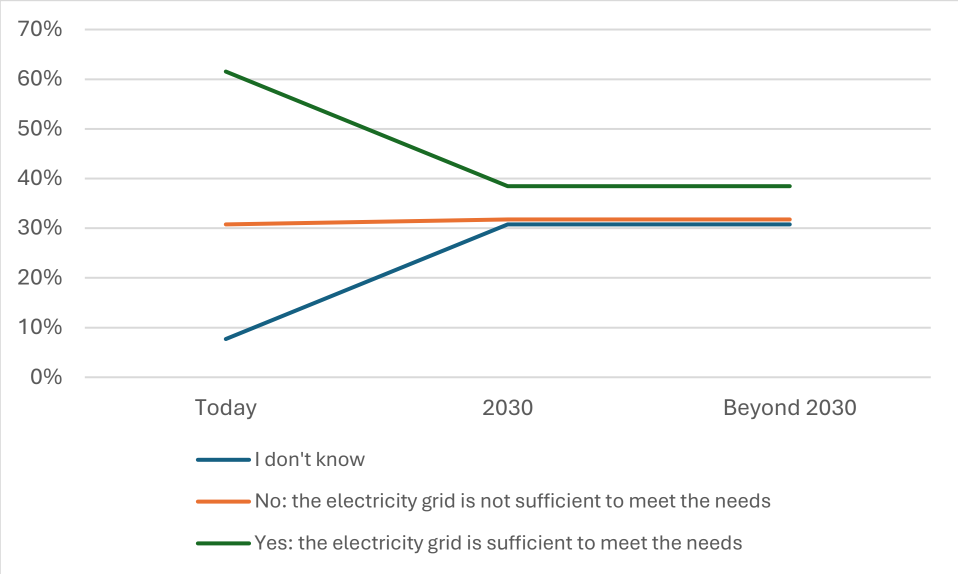

Figure 13. Surveyed energy companies' indication of electricity grid being sufficient or not to meet their needs of energy and effect over time.

4.3. Driving forces to focus on electrofuels

Interviews and surveys showed that the driving forces for working with electrofuels vary among ports and energy companies. The most common aspects mentioned by ports were customer demands, policy and regulations, public pressures, pressures from owners, environmental profiling and business opportunities.

For ports, most common stated driver during interviews and survey responses was customer demand. This is captured in the quote: *"One of our driving forces for looking into renewables are customer demands. In that case, the shipping companies. This is the only reason why we would enter this*". Another port located close to the city centre and with a strong focus on cruise shipping described their two drivers: "*We have the shipping companies that are pushed to have innovation, especially the cruise industry. But we also feel public pressure. The public knows about alternative fuels, and they know that we are not using them*".

Another driving force mentioned by some ports was pressure from their owner, mainly the city or the municipality. One port stated: "*We are owned by the city and the city is aiming to become one of the first climate neutral or emission free city. So of course they are also pushing us*". Another port, owned by the local municipality, commented in the survey that a part of their license to operate is connected to being an early adopter of new technology and working towards sustainability. A third port further elaborated on this reasoning: "*The owner put demand on the development of a carbon neutral program for the port's own activities. When this was analysed we quickly came to the conclusions that is not enough focusing on our own emissions, instead we need to consider all emitters, including trucks and ships in the whole port area. But without the shipping companies' demand, nothing happens. It feels like the energy companies can fix most things, so to speak, as long as they have a customer*".

Several ports also raise the importance of legislation, regulation and policies for an increased interest in renewable fuels, especially among the shipping companies. One port stressed the combination of several driving forces that create synergies, where regulations play an important part: "*The main driving forces are the FuelEU Maritime and AFIR requirements, along with the growing demand from shipowners. Equally important is the industrial sector—clients increasingly require a fully green transportation chain*". This transition towards more sustainable shipping also means business opportunities and to stay relevant in the long term as an energy hub. This sentiment was expressed by some ports, and explicitly by one port as: "*Renewable fuels are a business opportunity and part of the transition we all must go through*". Further, several energy companies point at regulations driving the shift towards renewable fuels: "*National and international regulations are opening new opportunities. The maritime sector is continuously evolving due to environmental concerns, regulatory pressure, shifting global trade dynamics*".

Since ports operations are very diversified due to type of shipping services, customers, geographical locations, etc., local driving forces can drive the transition. One such example was mentioned above: the effect the cruise industry has on the development. Another example is a port with many smaller service vessels operating by tender for a limited time. One port representative explained: "*The driving demand is actually the tenders: you need to do CO_2 reduction or have a very low footprint. The price of the fuel is also, naturally, a driving factor. The reason for them going electrical is partly the tender, but also due to the price of electricity*".

Driving forces expressed by the energy companies slightly differ from ports. Like ports, business opportunities and customer demands are the most important reasons to focus on renewable fuels. Important prerequisites for business opportunities are the availability of green energy and necessary feedstock and inputs, where development is benefiting from a strong expansion of solar energy and wind power in many countries. In addition to business opportunities and customer demands, several energy companies referred to more value-based drivers, expressing their desire to contribute to environmental sustainability, energy transition and security, and fossil fuels independence. One energy company expressed this "*We develop electrofuels to contribute to the transition away from fossil fuels, in line with national and European climate goals*", and another one: "*We are leading developer of electrofuel facilities with a vision to reduce the world's dependency on fossil fuel, particularly in hard-to-abate sectors like shipping and aviation*".

4.4. Timelines and prospects for planned projects becoming operational

A prominent theme at the international workshop concerned the expected time from the initial idea to the actual production of hydrogen derivatives (electrofuels). During the workshop the organiser presented few statements for discussions, based on literature. One of the statements, *"You should expect ten years from idea to production of H_2 derivatives",* triggered a nuanced discussion.

Several participants acknowledged that a ten-year timeline may reflect current conditions but argued that this duration is likely to shorten as technological expertise, permitting routines, and industrial experience improve. Others emphasised that timelines vary considerably by national context and project type, with more business-friendly environments and experienced developers potentially completing projects within four to six years. One participant stated - *"It's possible to do it also perhaps in in six years or even four years later on".*

Nevertheless, long lead times were widely seen as a significant investment risk. Commercial stakeholders underlined that the difference between a five- and a ten-year project fundamentally alters the financial calculus, increasing exposure to market and regulatory uncertainties. Observations from the presenters confirmed that many existing projects already indicate lead times of ten years or more, with postponements being a recurring feature. This raised concerns about whether a substantial share of the 298 identified projects would ever materialise, reinforcing the view that timelines will be central in shaping the market trajectory.

Another statement presented by the organiser and discussed at the workshop *"Maximum 25% of the planned projects will be operational"* invited reflection on the credibility of announced hydrogen initiatives. Many participants viewed this estimate as realistic, or even optimistic, given the number of cancellations in recent years and the large share of projects still in feasibility stages.

Investment challenges and regulatory hurdles were repeatedly cited as reasons why many projects fail to progress to the construction stage at the international workshop. At the same time, some participants highlighted that while the absolute number of projects has declined during the last two years, the quality and seriousness of those remaining may be increasing. This suggests that although fewer projects may proceed, their likelihood of reaching operation could be higher. Nonetheless, the general sentiment leaned toward caution: without stronger market signals and supportive frameworks, only a limited fraction of today's project pipeline is expected to become reality. One participant at the workshop described a confidence for the rate of successful project to increase over time: "*Solutions are following the classical innovation curve. The more stable stage of the cycle is yet to come*".

Investment challenges and regulatory hurdles were repeatedly cited as reasons why many projects fail to progress to construction. At the same time, some participants highlighted that while the absolute number of projects has declined compared to two years ago, the quality and seriousness of those remaining may be increasing. This suggests that although fewer projects may proceed, their likelihood of reaching operation could be higher. Nonetheless, the general sentiment leaned toward caution: without stronger market signals and supportive frameworks, only a limited fraction of today's project pipeline is expected to become reality. One statement showed the confidence for the rate of successful project to increase over time: *"Solutions are following the classical innovation curve. The more stable stage of the cycle is yet to come".*

The reason why many projects for development of hydrogen and H_2-derivatives is slow or paused where also discussed during interviews. Lack of investment money was raised, as were long processes with environmental assessment impacts and application for permits. One port described this further: "*Well, in my opinion or my experience in building things in Germany, it is really, really hard to get sometimes the permission, or the process to get the permission or approval is very long. And it costs a lot, and you have to change plans every time and might be an election in between and you have to change again. I think some international organizations feel like: Ok, we go to Germany, and we'll be fine and they're structured. But we are too structured*". Regarding the cancellation rate of projects, one port described how easy it might be to start a project even without proper anchoring or commitment, and that this can be a reason why many projects are cancelled after some time: "*A politician or someone external, they ask any port director, do you have a strategy on this [making electrofuel available]? Do you have activities on this? And he'll have to say "Yes". You won't find anyone who say no. So everyone say yes and then they realize, oh, I don't know **** about this.*".

4.5. Perspectives on EU Regulatory Frameworks for electrofuels

During the international workshop, participants expressed diverse views regarding the adequacy of current EU policies and regulations in supporting the market formation of hydrogen-derived marine fuels. Approximately two-thirds of the participants agreed that existing EU-level policies are not yet strong enough to effectively stimulate market development and scale-up.

Those participants expressing supporting views on the lack of regulatory stringency observed the need to distinguish between broader energy transition policies—which were generally perceived as well-developed—and mechanisms specifically aimed at incentivizing the production and deployment of renewable fuels. The latter were viewed as underdeveloped, with suggestions that faster permitting processes and more targeted support measures could improve market conditions. Other observations addressed the challenges associated with the regulatory framework's timeline and flexibility. Some participants noted that deadlines can be shifted, creating uncertainty, and underlined that RFNBOs (i.e. electrofuels) may require dedicated regulatory provisions due to their cost-sensitive nature.

In contrast, opinions in favour of the sufficiency of the regulatory environment highlighted that all necessary regulatory incentives are in place, while also noting that there remain gaps in end-use regulations, particularly those targeting shipping. In addition, several other participants considered the EU regulatory framework to be generally sufficient, highlighting regulations such as FuelEU Maritime, which establish progressively increasing targets on GHG intensity reduction, that are expected to drive market uptake of renewable fuels over time. At the same time, some concerns were raised about the ambition of EU targets, especially those relating to green hydrogen production and import volumes by 2030, with some viewing these targets as overly ambitious.

Other observations addressed the scope and future development of regulations. These included whether regulations should specify fuel types or remain technology-neutral, and how EU regulations would align with IMO objectives. Some participants expressed surprise at the perception that current regulations were insufficient, given the volume of policy activity at the EU level.

Finally, while subsidies and state support measures were considered useful instruments for mitigating risk. At the same time, there remained a shared sense of uncertainty about how the regulatory environment would evolve over time and whether EU and IMO frameworks would be harmonized effectively.

One question asked during all interviews was if current EU regulations are strong enough to support the market formation of hydrogen derived fuels. The answers among ports were varied, but with a certain emphasis on the need for stricter regulations and incentives, that those needs to be more precise about what is to be achieved and what the goals are, and that more coordination is needed to realise these strategies. A port that considered that policy instruments were beneficial described the following: "*I think that these laws and regulations that are in place now have had an obvious and clear impact. All the shipping companies that we speak to are currently investigating solutions that will lead them to pay less penalty fees for FuelEU and the emissions trading system. Could more be done? Of course, you can always do more, but spontaneously I think it seems to work*". Another port had another view of the matter: "*There should be regulations, very strict regulations to switch from conventional fuels to alternative.*"

Many ports also stressed the importance of global regulations and referred to expected decisions within the IMO: "I thinker will be difficult with EU alone. It might be for short voyages, for coaster vessels operating within the waters of EU, they might be relevant. But for those involved in the trans-oceanic trade. You need to have IMO for sure. If IMO decides that we need to have this transition to the green solution, then that will be definitely faster and quicker way forward". This standpoint was also shared by one surveyed energy company: "The deployment of e-methanol as a marine fuel is gaining significant momentum, especially with the IMO mandates. We see more and more ships move towards e-methanol to reduce their carbon footprint and to avoid significant penalties for non-compliance".

4.6. Perspectives on national regulations and strategies for electrofuels

In addition to EU regulations, the interviewed ports were asked about their thoughts on national strategies and plans, and if they were satisfied with them for development of energy and hydrogen that exist in their country at the national level. Although design and mission of strategies and plans vary greatly between the Baltic Sea Region countries, there was nevertheless a consensus among most respondents that the ambitions were too low. One critical voice raised from a port in a country without a hydrogen strategy: "*There is no ambitions, and especially if you look at our country, there's no ambitious plan. There are no strategies. We are lacking the hydrogen strategy as such*". Another port stated: "*I feel like there is no real vision how to bring the speed on the ground and it keep changes so much. I think long-term funding and long-term commitment is really lacking right now*". A third port elaborated further: "*We need long term commitments from politicians; this is something that we feel right now is really hard to get because we have a new government which is not as pro new technologies as the prior. And we have a situation that is quite difficult. We have a lot of money that goes into military right now. So maybe on EU level, but on national level, there's no real strategy in terms of like what we fund, how we fund, what are the goals, how to involve industry*".

Policies, processes and strategies for Hydrogen-derivatives on national level were also discussed at the workshop with Swedish actors in Luleå with the conclusions that there is a need for a) a broad political agreement and a strategic direction at the national level to develop a missing Swedish Hydrogen Strategy, b) a new model for risk sharing (companies, municipalities and government) where the state takes greater responsibility, c) clear instruments and economic incentives in order to narrow the cost gap between electrofuels and fossil fuels, and d) more efficient permit processes, for example for wind farms and concessions for the electricity grid.

4.7. Self-sufficiency versus import orientation

Another statement tested during the international workshop was whether the Baltic Sea Region could become self-sufficient in renewable marine fuel production by 2040. Here, participants voiced scepticism, noting that national hydrogen strategies generally aim not only at self-sufficiency but also at export markets. Denmark, for instance, has particularly high ambitions, while countries such as Lithuania face large gaps between current capacity and announced targets. One participant remarked: *"Then we don't need import terminals, we need export terminals".*

The discussion revealed tension between the political narrative of regional self-sufficiency and the economic reality of international trade. Some participants considered self-sufficiency unlikely, pointing to cancelled offshore wind projects or overly ambitious targets. Others suggested that while geopolitical risks might push governments toward prioritising self-reliance, the dominant strategies appear oriented toward renewable fuel export, with implications for the design of infrastructure such as import and export terminals.

4.8. Infrastructure for fuels in ports

Huge investment costs in fuel infrastructure, combined with uncertainties about what fuel will be in demand and when, is creating major headaches for many ports. A port summarizes this difficulty in the following way: "*We handle all oil products: different grades of gasoline, jet fuel, diesel, heating oil, heavy fuel oil, coal tar, kerosene, ethanol, waste oil... The quay is full, more pipes and we must rebuild. The day we build a new quay: what products should we have? Should we have eight or are we up to twelve products and which products can be combined? Building a quay, that's three or four times our annual turnover".* Thus, new port infrastructure is particularly difficult to realize for smaller ports, with fewer customers who can share the investment costs. This was further stressed by another port: "*I think the challenges are that we need to know what the playing field looks like and what choices shipping will make – then we, as a port and energy hub, can start planning. You don't want to get lost in these investments. We are a fairly small port and with customers that we cherish. We want to continue to be cost-effective and sustainable. The fact that the market is still a bit uncertain is why it hasn't happened*". The business risk described above is also raised in the following port: "*But who wants to make the first move? I think we would be happy to make the choice to be good, fourth, fifth, something*". This creates a situation where ports are waiting for others to act first, which risks delaying the introduction of renewable fuels to shipping.

However, one port stated they have another, more forward-leaning and proactive approach, considering fuel infrastructure as any other port infrastructure. "*You can approach it with an infrastructure approach, just like when a port is building a new road. I don't do a business case on that road. I cannot have a port without a road, right? The same approach we go with the electrical grid, onshore power and to some extent into renewable fuels. That's part of our infrastructure. If we want to be a relevant port, we need to have it just like we need a road, just like we need everything else that will be part of the port infrastructure*".

5. The electrofuels landscape in the Baltic Sea Region

This chapter presents a comparative analysis of eight countries, focusing on planned production initiatives, national targets, and the local conditions that underpin the emergence of a future fuel market. Together, these elements provide insights into how regional differences in resources, policy ambitions, and infrastructure may affect the pace and scale of market development.

The initial step in assessing the development of the future fuel market is to examine both existing and planned production capacities in relation to national goals and local enabling conditions. Understanding the market's potential requires consideration of several interrelated factors, including access to renewable energy sources, availability of infrastructure, and the design of regulatory and policy frameworks that shape investment conditions. In addition, the assessment must account for the availability and quality of natural resources, such as renewable electricity, water, and feedstock for hydrogen-based fuel production, which influence both production feasibility and market competitiveness. The development of future fuel demand is inherently difficult to predict, as it is shaped by a wide range of interrelated factors, behaviours, and objectives among multiple stakeholders. At the national level, only broad tendencies can be identified, since local conditions play a decisive role in shaping outcomes, and individual stakeholder initiatives often act as key drivers for scaling demand.

The analysis presented in Chapter 5 is done to understand and describe the present situation and the ongoing f electrofuel market development within the eight countries included in the study. Literature research, surveys, extensive discussions with partners and experts within the specific countries have all been important information and data sources.

5.1. Current and planned national production of renewable electrofuels

This section presents the status of current and planned green electrofuel projects, first for the Baltic Sea Region as a whole, and then on a per country basis. Maps are used throughout this chapter to display the size, type, and location of hydrogen projects. The size of the circles indicates the annual fuel production in TWh, while the colour differs in meaning depending on what is shown. The x- and y-axes around the map are longitude and latitude.

Key background to the project mapping and IVL H2-derivatives scenario tool

The definition used for projects within this report are presented in Appendix B. Data collection for all countries is as complete as possible, except for Germany where only projects in the north of the country or connected to hydrogen valleys related to projects in the north or by the coast have been assessed.

Fuels are classified in a way that provides the greatest relevance for the maritime sector. Hydrogen, ammonia and methanol are highlighted explicitly, along with any facilities that produce a mixture of these fuels, e.g. a facility producing ammonia from hydrogen which was also produced on-site. The "Other organic**" category includes organic fuels and materials that are not methanol, for example methane, syngas and sustainable aviation fuels (SAF). The projects are not limited to production facilities and includes infrastructure for distribution and similar development projects.

An attempt has been made to identify the potential end use of the fuel produced by each facility/project. The maritime category includes all projects where maritime applications have been mentioned but other end uses such as road transport, energy for non-maritime fuel production or industrial energy, fertilizer production and other chemical products may also be relevant applications. Transport not including maritime mainly refers to road transport but also include aviation and rail applications. The Chemical products category refers to chemicals, steel and fertilizer. Energy refers to energy used for industrial uses, fuel production or domestic use. Infrastructure projects can include bunkering and other storage facilities as well as pipelines. Some projects do not explicitly define their market and may instead name several potential markets e.g., Chemical products and energy, or Transport (non-maritime) and energy, and are labelled accordingly.

The phase of development of each project has been assessed and defined. Projects where explicit information exists, for example if a project is cancelled, is undergoing a feasibility study, has received a financial investment decision, is constructed or is operational have been defined as such. When a project has been announced but further information is missing it is classed as being in planning, which is the most common category. If information about the project is very scarce or if it has not been updated in a long time, then it is classed as uncertain. See Appendix B for a precise definition of each phase.

The Baltic Sea Region

Figure 14 shows a map of current and soon to be realised (i.e. under construction and with a financial investment decision) fuel production in the Baltic Sea Region as of 2025, including fuel type and production capacity. The projects shown are operational, decided or under construction as of 2025. As can be seen, the current production is centred heavily around Denmark and northern Germany. In Lithuania, the red circle in the middle is a plant that will produce green ammonia using hydrogen from electrolysis, planned to start operations in 2026. A total of 38 projects are in operation, with a combined production capacity of 3 TWh, equivalent to 258 000 tonnes of MGO equivalents. Additionally, over 20 projects under construction or with a final investment decision made as of 2025 (approximately 17 TWh).

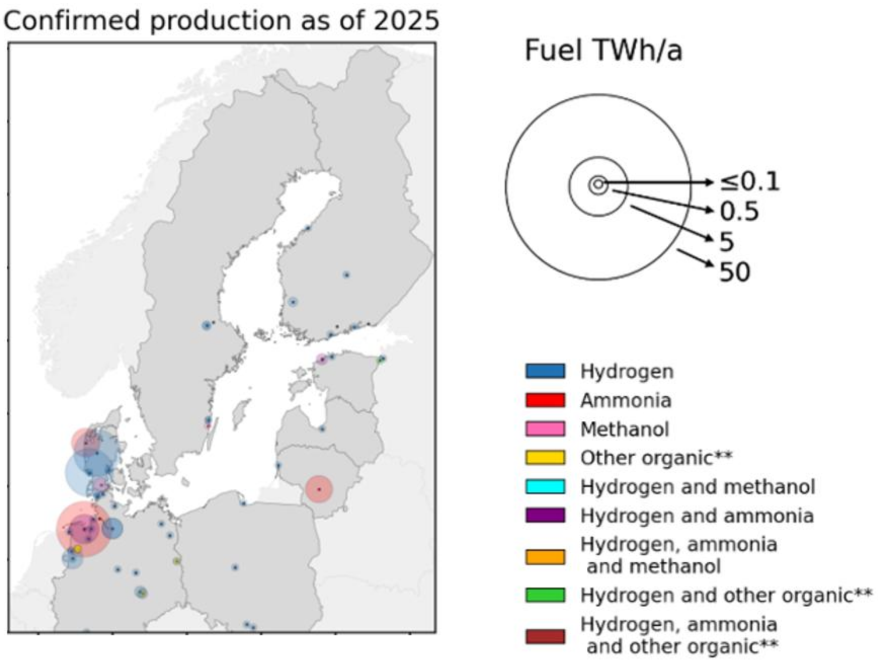

Figure 14. Map showing projects that are in operation, under construction, or decided i.e., where a final investment decision (FID) has been made as of 2025.

Figure 15 shows all projects that have been mapped excluded those which have been cancelled (on hold included). A total of 198 projects from 1992 to 2030 (excluding cancelled projects but including infrastructure), as well as 64 projects where the starting year is beyond 2030 or missing, across all countries with a Baltic coastline excluding Russia have been identified and are included in the dataset. Because only two projects have both an estimated production volume and specified start-up year after 2030 (BrintØ hydrogen island in Denmark and Neptunus in Sweden), it has been decided that these projects along with those without a given start-up year should be included in the maps showing maximum potential production by 2030. This means that the maps show all non-cancelled project that have been mapped for each country, with the assumption that projects without start-up year or start-up year after 2030 are completed before 2030.

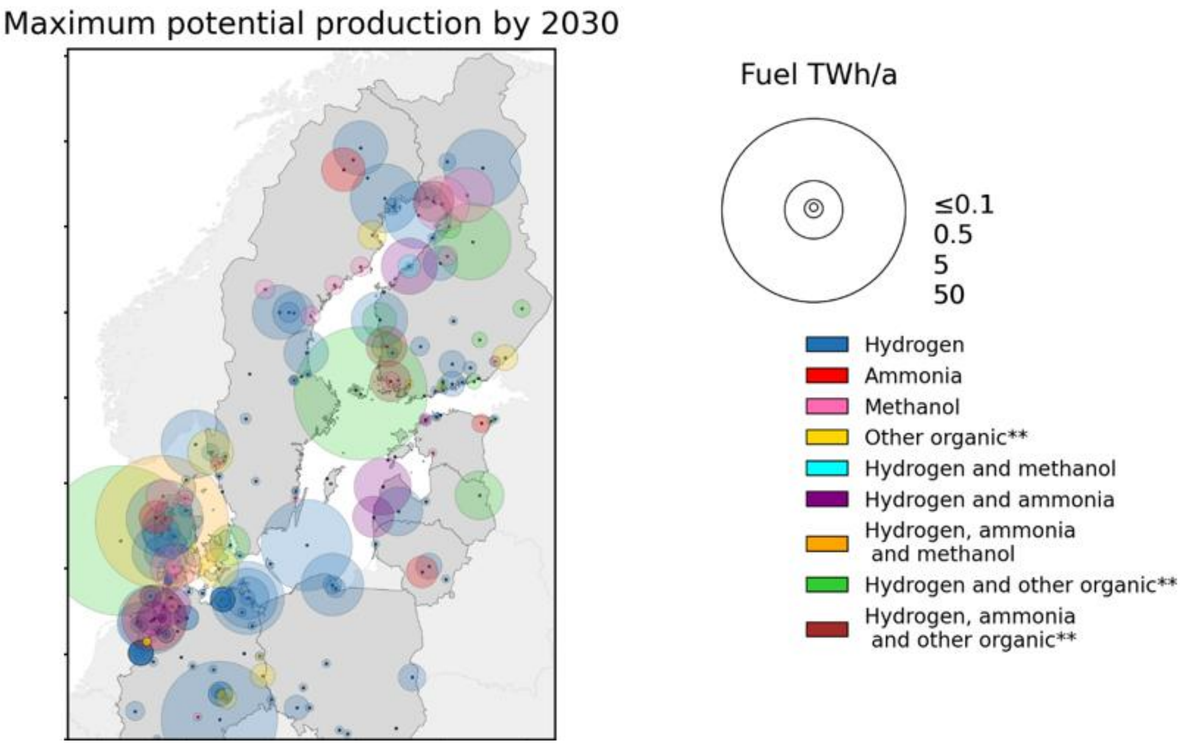

Figure 15. Map showing all non-cancelled projects in the Baltic Sea Region that are currently in operation or could potentially be operational by 2030. Projects without start-up year are included.

Figure 16 shows the total potential fuel production in the Baltic Sea Region, divided by end-use sector and fuel type. Among the planned projects, half of the potential production is pure hydrogen. The reason why the second largest share is *Hydrogen and other organic*** is because many large projects state that the produced hydrogen can be used to produce fuels, but it is not specified which ones. It is therefore included in this category. The distinction between for example *Ammonia* and *Hydrogen and ammonia* is based on whether some of the hydrogen will be used elsewhere or if all of it will go into ammonia production. The *Hydrogen, ammonia and methanol* category consists of a single project; Energy Hub Holstebro in Denmark where the production process is aimed to deliver multiple energy products.

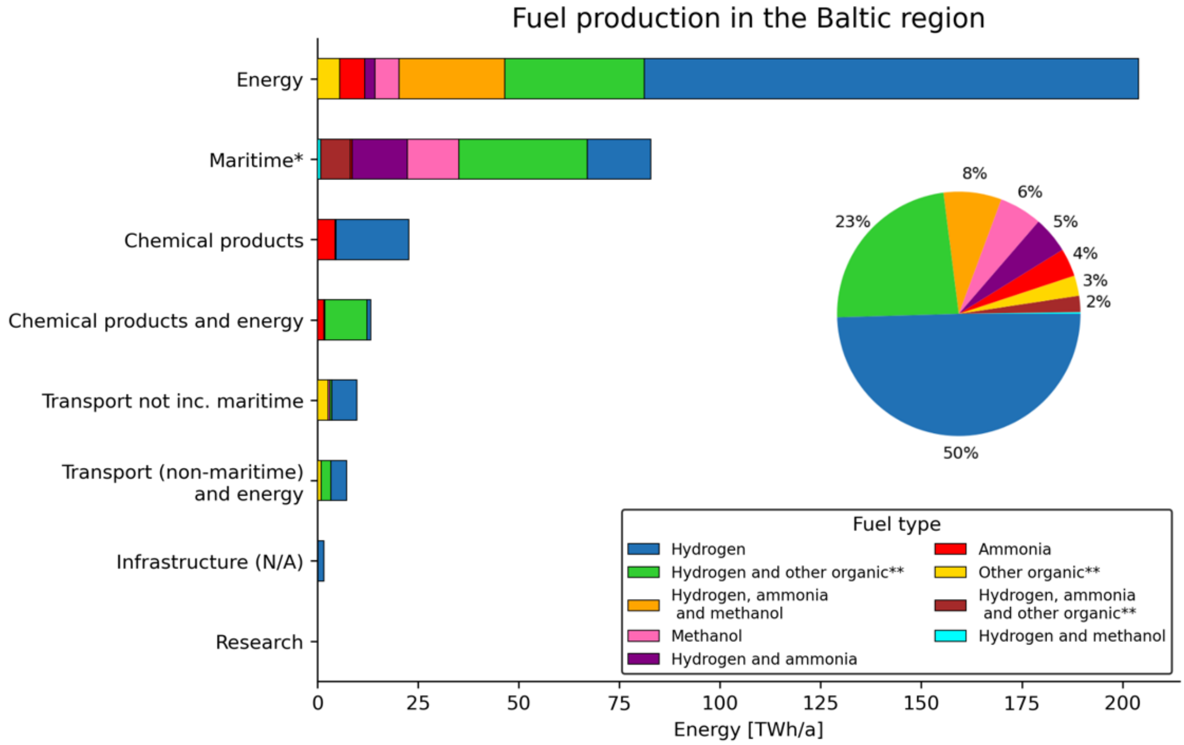

Figure 16. Total potential electrofuel production in the Baltic Sea Region in 2030, divided by end-use sector and fuel type.

Figure 17 shows how the maximum potential electrofuel production is divided between categories of end-use. The total fuel production capacity for all non-cancelled project across all start-up years equals a total yearly production of 338 TWh/year, corresponding to approximately 31 million tonnes of Marine gasoil (MGO). Projects having a start-up year until 2030 equals 150 TWh of annual production. This means that more than half of the planned production is scheduled to happen after 2030.

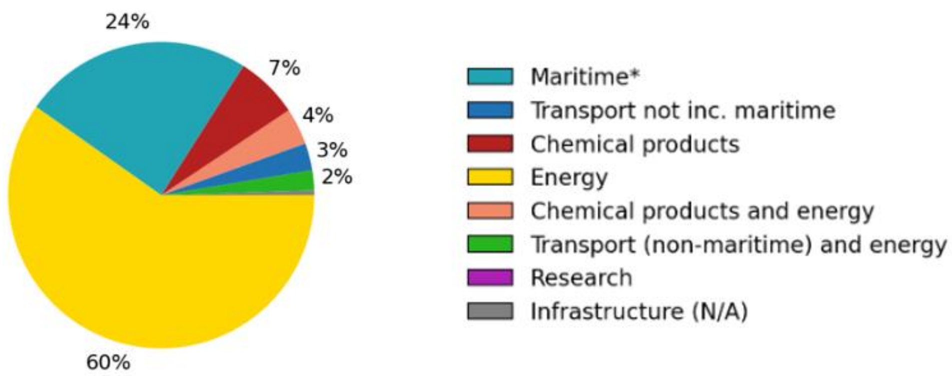

Figure 17. Total potential electrofuel production (energy shares) in the Baltic Sea Region divided by end-use sector.

Figure 18 presents a map of the Baltic Sea region illustrating the potential fuel production capacity by end-use sector. The largest consumer is the energy sector where 60% of the total energy delivery is expected to be made available for industrial and domestic consumption as well as to produce fuels. The upper limit of fuel production capacity available for the maritime sector is approximately a quarter of the total production capacity, or 84 TWh/year, as shown in the figure above. Assuming that all energy that can be used in the maritime sector is made available, then the maritime sector could use 24% of the production capacity. With this assumption, chemical production would be the third largest sector with 11% of total energy use, including steel and ammonia production.

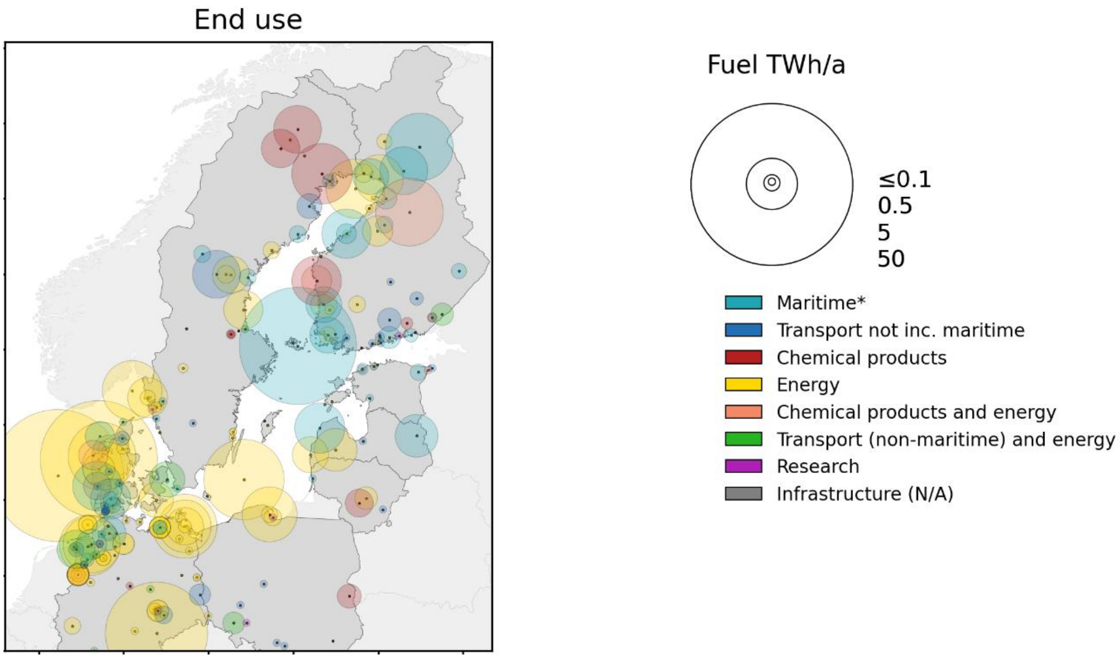

Figure 18. Potential electrofuel production in the Baltic Sea Region divided by end-use sector.

An overwhelming majority of the projects are in the planning stage. Figure 19 shows a map of the Baltic Sea projects and their level of readiness.

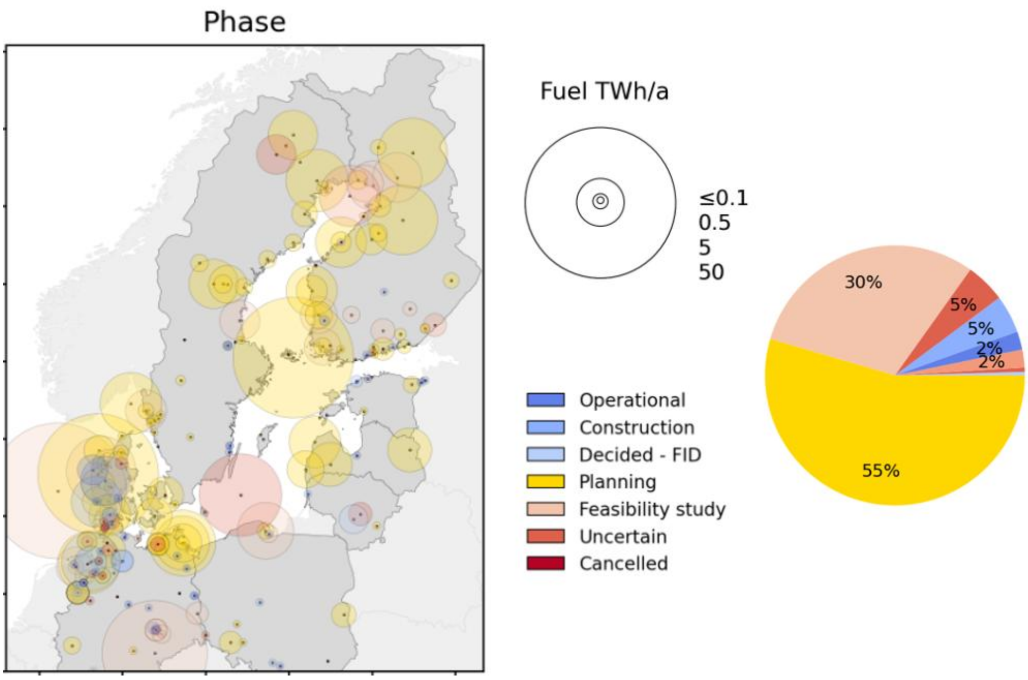

Figure 19. Potential electrofuel production in the Baltic Sea Region divided by project phase, including cancelled projects. The pie chart is divided in energy shares of total potential production.

Only 1.4% of the fuel production capacity is currently available in operating projects, while an additional 4 percentage points corresponds to projects under construction. A small share of project status is uncertain or have a final investment decision, but construction has not yet started. Figure 20 shows the number of projects and expected energy per country. *Other* includes projects that are not cancelled or on hold (planning, feasibility study, operational etc.).

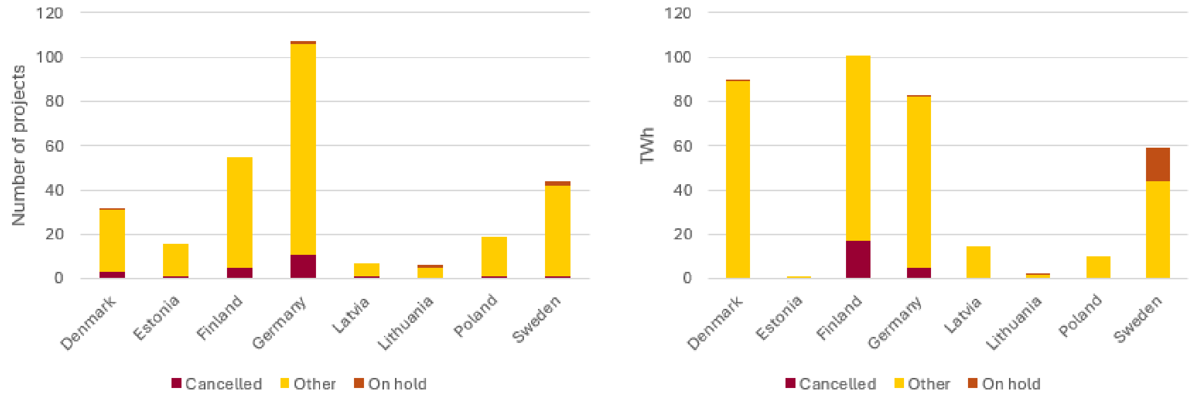

Figure 20. Total number of projects and total potential electrofuel production per country.

The Nordic countries and Germany aim to produce at least three times the amount of fuel as compared to the Baltic States and Poland. Potential fuel supply over time, sector and phase for the Baltic Sea Region is shown in Figure 21.

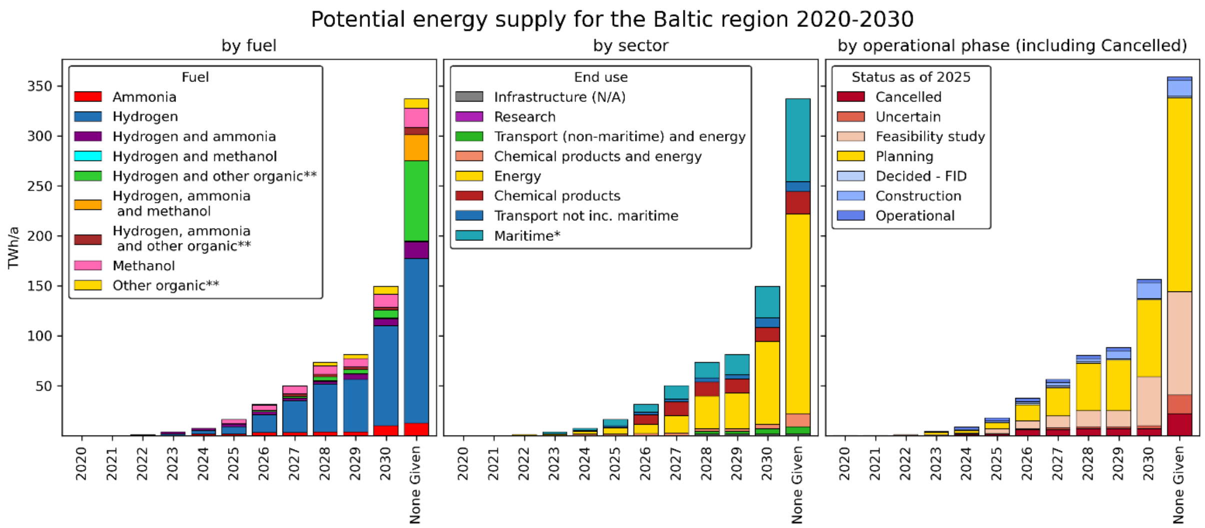

Figure 21. Potential supply over time by fuel, sector and phase for the Baltic Sea Region in energy terms.

A large jump in available fuels is expected between 2029 and 2030, which may be symptomatic of project initiators choosing a well-rounded near-term project completion goal year. Approximately 142 TWh/year of fuel production does not have a set starting date, representing 42% of all expected energy supply. This includes around 67 TWh/year that could potentially go to the maritime sector.

Sweden

As of 2025, Sweden has only a few operational hydrogen production facilities, each smaller than 1 TWh/year, primarily supplying green steel and energy users. Sweden is projected to reach a maximum potential production of 59 TWh/year by 2030 across 43 projects (see Figure 22). Most of this production, around 84%, will be in the form of pure hydrogen. The rest is split fairly evenly between methanol, ammonia and other fuels.

Today, the only methanol production comes from the Södra biomethanol plant in Mönsterås which operates at a small scale. Planned future production is dominated by Liquid Wind, who are planning four different plants that will each produce 100 000 tons of e-methanol per year each. There is currently no green ammonia production in Sweden. However, the Power2Earth project in Jokkmokk/Luleå aims to produce 1,500 tons of ammonia per year for fertilizer production and is Sweden's only green ammonia project.

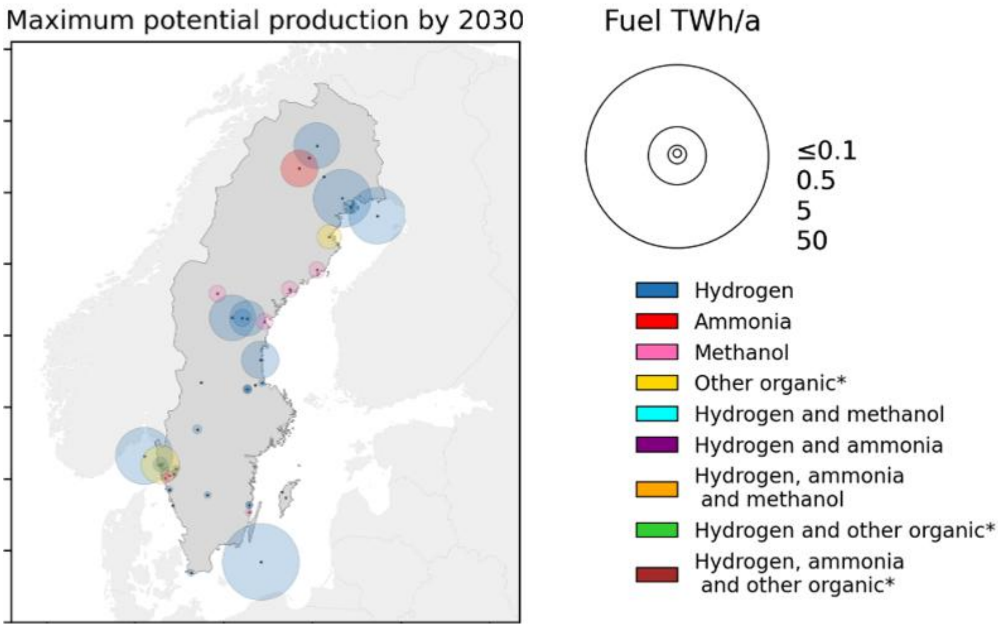

Figure 22. Mapped potential electrofuel production from projects in Sweden by 2030.

Most of the projects identified so far plan, according to publicly available information, to produce hydrogen in close proximity to where it will be used. This approach, often referred to as *on-site production*, is currently the dominant model in Sweden. However, there are also projects under development that aim to produce hydrogen for further distribution and commercial sale. Only around 4% of the planned fuel production mentions maritime use. Chemical products is the dominant end use sector, see Figure 23.

Geographically, production is dominated by the northern part of Sweden consisting of three major projects: green steel production in Boden (Stegra, formerly known as H2 Green Steel) and Gällivare (the HYBRIT project), along with the aforementioned ammonia plant in Jokkmokk/Luleå. Methanol production is focused on the west and east coasts, except for Liquid Wind's plant in Östersund. Almost all projects are in the planning phase, as shown in the right diagram of Figure 23. The large uncertain amount comes from the wind park Neptunus which was halted by the government in 2024 due to safety concerns (Regeringen, 2024).

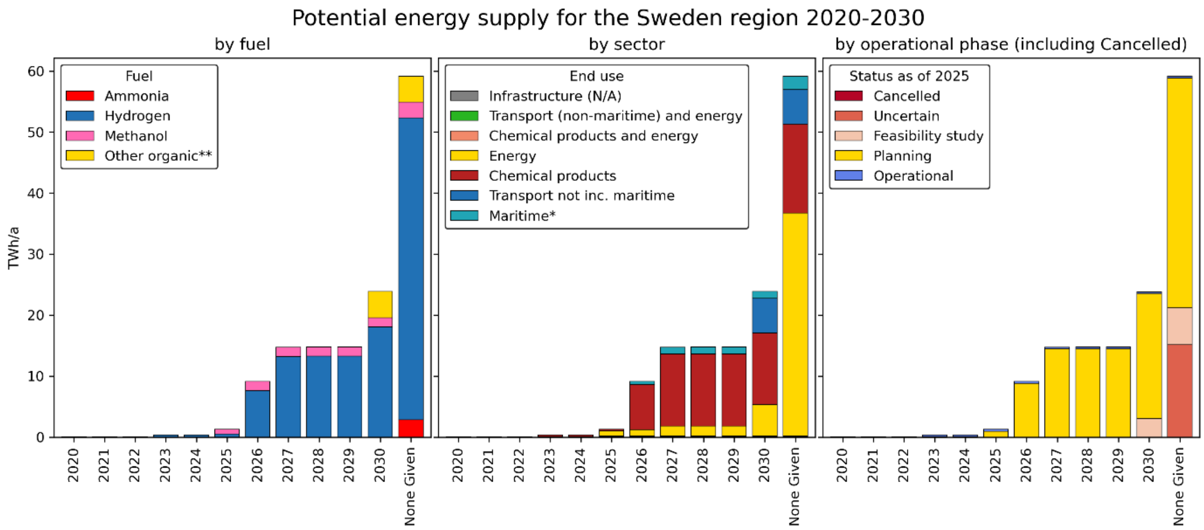

Figure 23. Potential electrofuel supply over time by fuel, sector and phase for Sweden.

Denmark

Denmark is positioning itself as one of the most important hubs for hydrogen and electrofuel production in Northern Europe, with several large-scale projects planned that together are expected to deliver around 94 TWh per year of electrofuels, see Figure 24. Roughly 14% of this output is projected to be available for the maritime sector, particularly in the form of methanol and ammonia. The Danish project landscape is heavily concentrated with nearly two-thirds of the total projected energy delivery from just two facilities. The largest, BrintØ (Hydrogen Island), is due to begin in 2039 and will produce about 33 TWh/year of hydrogen, making it the single largest project in the entire Baltic Sea Region. The second-largest facility is the Idomlund power plant (26 TWh/year), planned to produce renewable hydrogen and later methanol and ammonia. While no starting year is given, if Idomlund's fuels move into Power-to-X (PtX) production, they would significantly expand maritime availability.

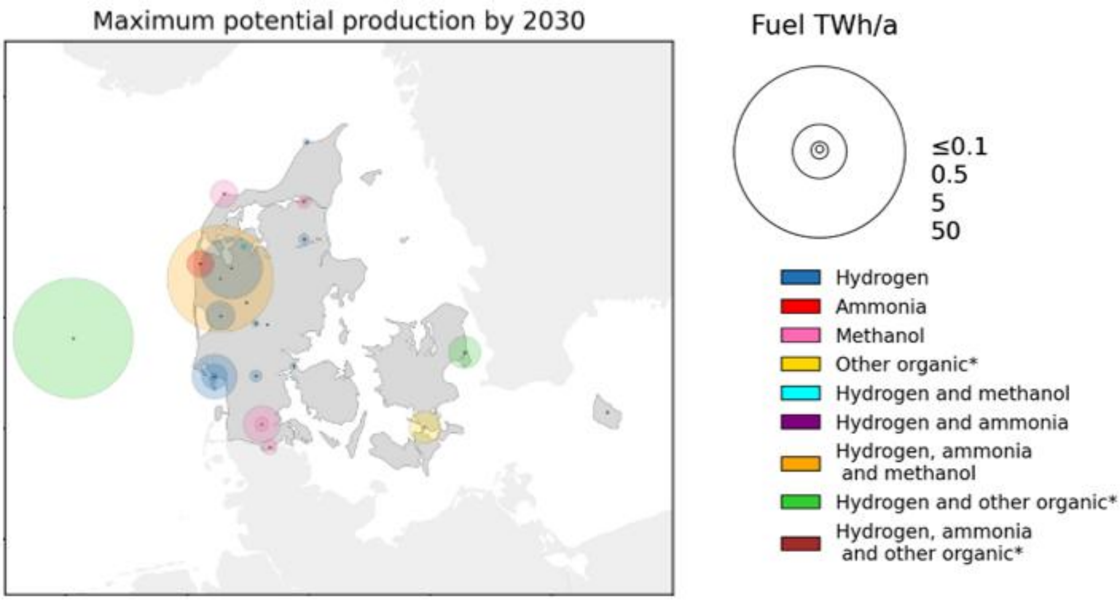

Figure 24. Mapped potential electrofuel production from projects in Denmark. Also projects expected to start production after 2030 has been included (BrintØ Hydrogen Island included).

Excluding these two mega-projects, Denmark still offers a diverse portfolio of facilities, particularly along the west coast of Jutland. At Ramme, a green ammonia plant is already operational at small scale, using both wind and solar power. For methanol, The Kassø e-methanol plant at the Port of Aabenraa is also operational and is currently the only Danish site offering direct maritime fuel supply, highlighting how early e-methanol is being adopted in Denmark. As of 2025, Denmark delivers around 2 TWh/year of fuel, made up almost entirely of ammonia and e-methanol represented by the aforementioned Ramme and Kassø plans. This is despite the fact that the planned future production is dominated by pure hydrogen. Another notable project is a solid oxide electrolysis cell (SOEC) factory in Herning, the largest of its kind in Europe, set to start production in 2025. Planned potential electrofuel supply in Denmark is shown in Figure 25.

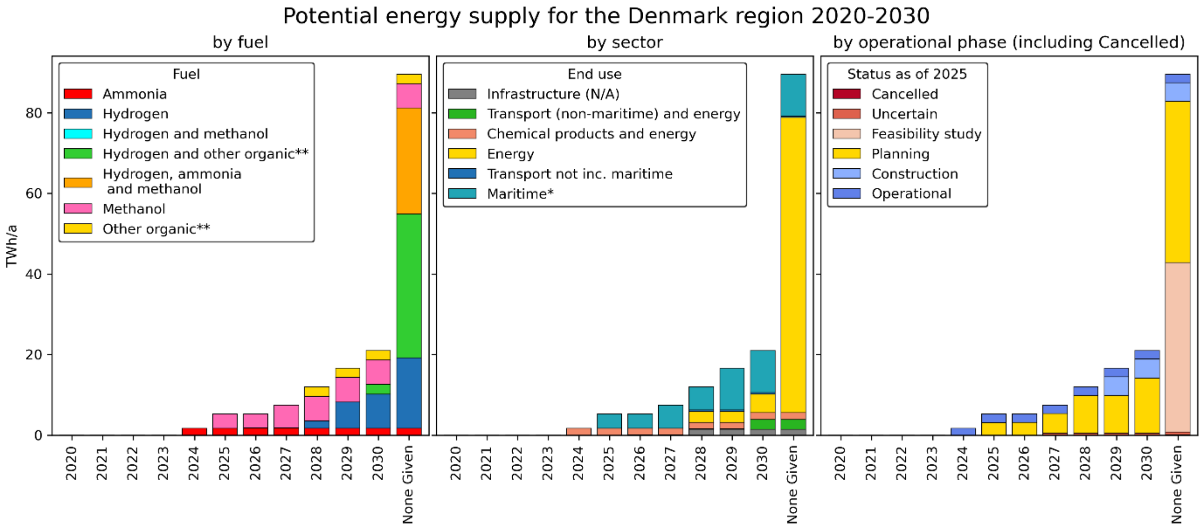

Figure 25. Potential electrofuel supply over time by fuel, sector and phase for Denmark.

Infrastructure development is designed to support large-scale integration into European markets. Two cross-border pipelines connecting Denmark with Germany are planned; *H2 Interconnector* which connects Bornholm with Lubmin, and *HyperLink 3* which extends from an underground hydrogen storage facility in Lille Torup to Heidenau and the other *HyperLink* pipelines in Germany. Furthermore, a concept has been developed for a pipeline connecting the Lille Torup facility to northern Norway and west Sweden. These efforts position Denmark not only as a domestic hub but also as a potential key exporter of renewable hydrogen to the wider European energy system.

Germany

The German projects surveyed will potentially produce a maximum of 82 TWh/year of fuel energy, most of which will be in the form of pure hydrogen (around 83 %). Pure ammonia production and co-production of hydrogen and ammonia make up around 13%. Most of all fuel produced is expected to serve the energy sector, with hydrogen feeding into national and cross-border networks. For maritime use, the largest contributions will come from dual production projects, specifically hydrogen–ammonia projects. An overview of the mapped fuel production projects in Germany is shown in Figure 26.

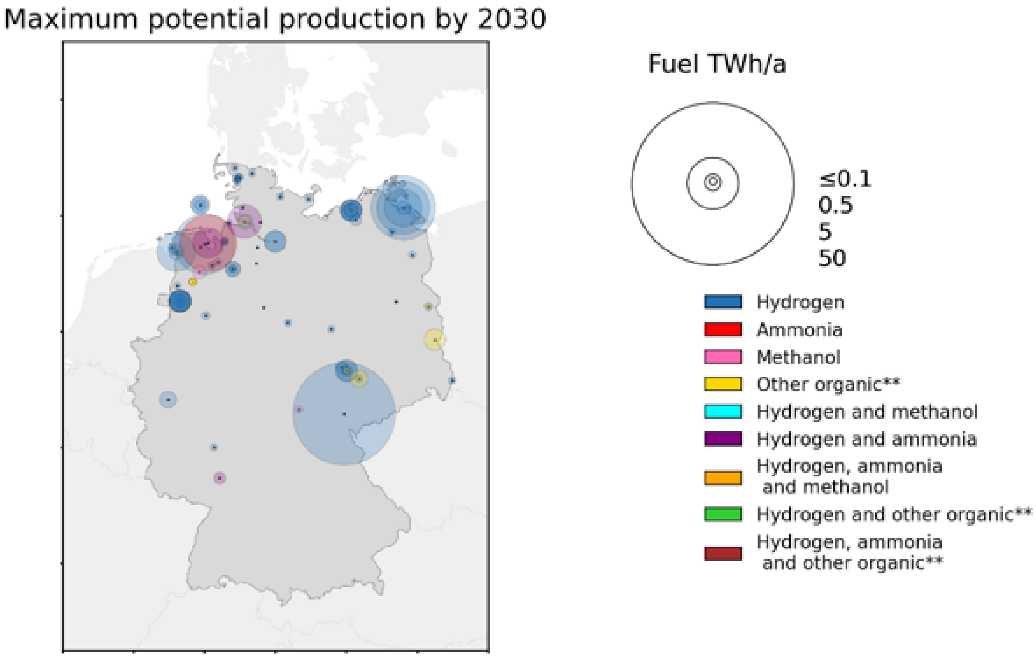

Figure 26. Mapped potential electrofuel production from projects in Germany. Also includes projects without a defined start-up year.

Germany's production is geographically concentrated in two coastal hubs: Wilhelmshaven in the northwest and Lubmin in the northeast. Wilhelmshaven, close to Bremerhaven, is being developed as a central energy hub with projects led by Uniper, including the Green Wilhelmshaven Terminal where ammonia is planned to be imported and cracked into hydrogen, along with the construction of a 1 GW electrolyser. This hydrogen will connect to the European Hydrogen Backbone, supporting inland industrial clusters. These facilities are either under construction or have reached a final investment decision.

Hamburg is also positioning itself as a pioneering case of port decarbonisation. The Hamburg Green Hydrogen Hub is one of the first global projects aiming to decarbonise an entire port economy. A 60-kilometre hydrogen pipeline, constructed by Gasnetz Hamburg, will supply green hydrogen to industrial users south of the Elbe and to port operations, making Hamburg a model for integrated maritime use. Brunsbüttel is emerging as another coastal node, where hydrogen will be converted into synthetic methane. Brunsbüttel also hosts an ammonia import terminal under planning, together forming most of the country's anticipated maritime supply. On the northeast coast in Lubmin, up to 1.6 GW of electrolysis is planned to be constructed long term by the company H2APEX. Lubmin will also connect to Denmark via the *H2 Interconnector* pipeline. Planned potential electrofuel supply in Germany by fuel, sector and phase is shown in Figure 27.

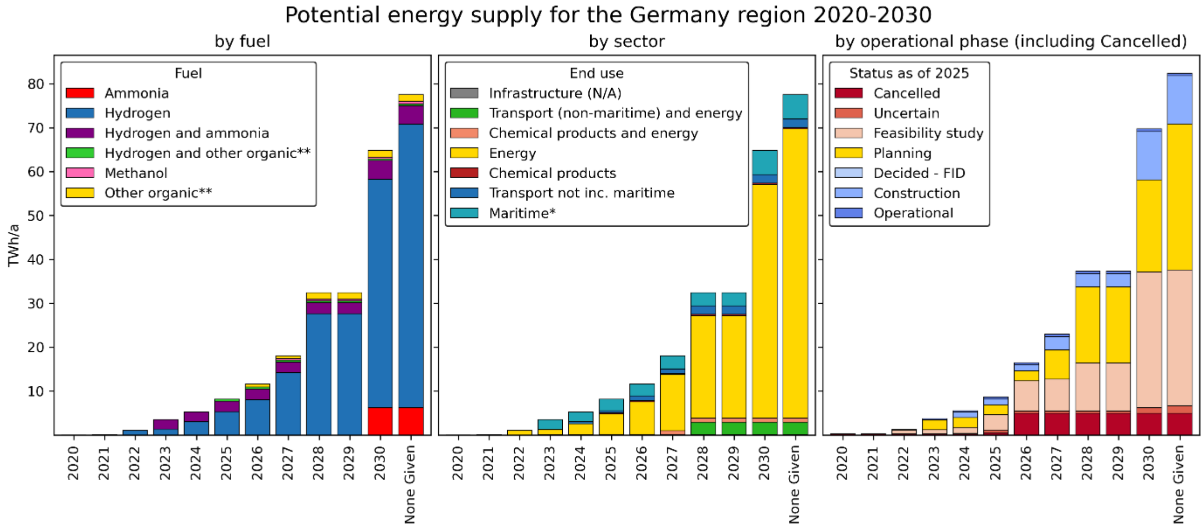

Figure 27. Potential electrofuel supply over time by fuel, sector and phase for Germany.

While these sites are near the sea, the current understanding is that production will be directed primarily to the general energy system rather than directly to shipping. Germany's hydrogen availability will grow steadily between 2025 and 2028, before jumping sharply in 2030 as large-scale facilities in Wilhelmshaven, Lubmin, and Brunsbüttel come online. While most 2030 energy volumes are still in feasibility or planning stages, the share of projects with a final investment decision is already increasing rapidly. This trajectory places Germany on track to become one of Europe's largest producers and importers of hydrogen and ammonia.

Poland

Poland is the third largest hydrogen producer in the EU, supplying the chemical, petrochemical, steel, and food industries with around 1.3 million tonnes per year. Almost all energy is entirely grey hydrogen, generated via steam methane reforming although there is some production of renewable hydrogen from municipal waste (Smolén and Żelisko, 2023). Several Polish companies, including state-owned enterprises, have already initiated cooperative projects at the European level (Smolén and Żelisko, 2023). Energy for industrial and chemical uses are the largest end users taking >90% of the maximum potential energy production capacity. Much of this hydrogen is intended for use in refining and replacing fossil-derived feedstocks.

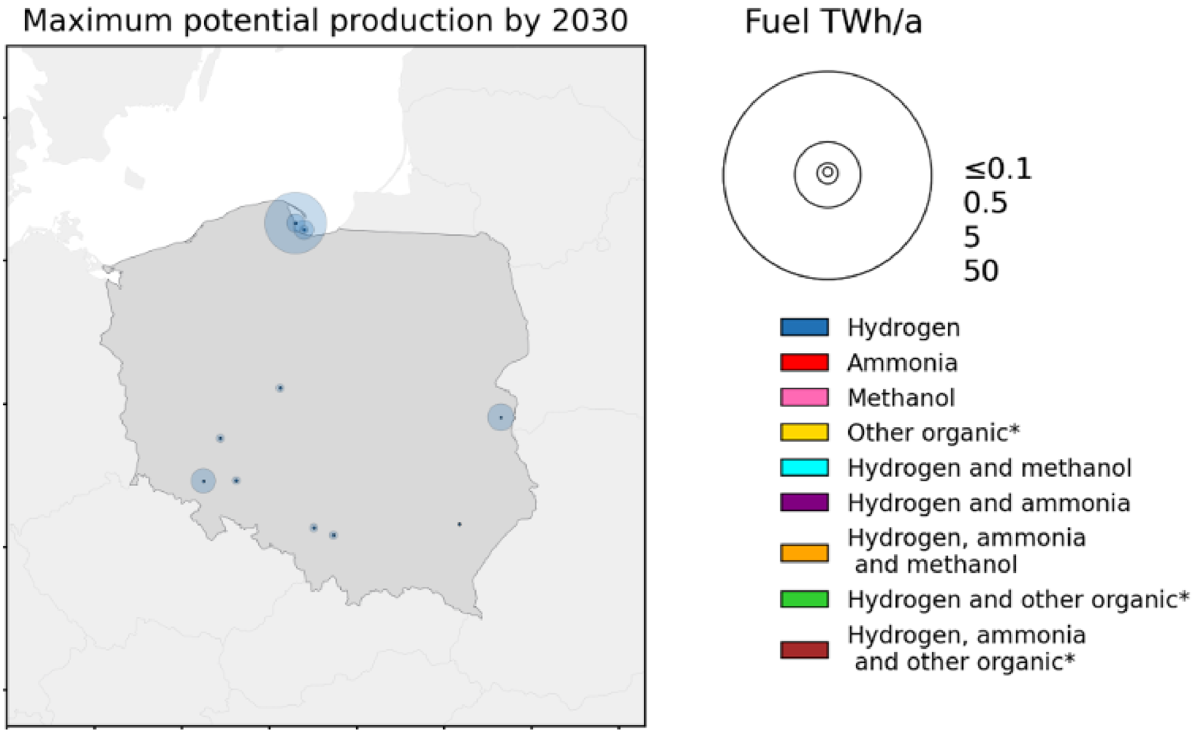

Figure 28. Mapped potential electrofuel production from projects in Poland. Also includes projects without a defined start-up year.

Despite its current position as major producer of fossil hydrogen, the maximum potential renewable fuel production capacity available in 2030 based on the identified projects in this report is only projected to reach 10 TWh/year (see Figure 28), which is significantly lower than for the neighbouring countries Sweden and Germany. The country could however reach the target set in the Polish hydrogen strategy of 2 GW electrolysis capacity by 2030 (Ministerstwo Klimatu i Środowisk, 2021) assuming that key projects are finished until then.

The Polish hydrogen strategy also aims for at least five hydrogen valleys. Several regional hydrogen valleys have been announced, including in Pomerania, West Pomerania, Greater Poland, Masovia (including the HySPARK project), Lower Silesia, Silesia, and Subcarpathia. These initiatives are designed to connect industry, research institutions, and local governments to pilot hydrogen solutions and support local acceptance of renewable energy technologies. The focus is primarily on production and use in industry.

All the initiatives in Poland focus on hydrogen production, with none of the mapped projects planned to produce any other electrofuels. No projects either have been identified with the maritime sector specifically identified as the end user. However, in the port city Gdynia 0.5 TWh/year electrolysis is planned, as well as the NeptHyne (Nexus consultants) offshore windfarm, currently undergoing a feasibility study with planned start-up year of 2030. Around a third of the maximum potential energy delivery is announced in projects without a stated start-up year.

Central infrastructure projects for the markets development in Poland are for example the Nordic-Baltic Hydrogen corridor, ultimately connecting Finland and the Baltic States to Germany will travel through Poland, integrating its emerging hydrogen economy into the larger region.

Estonia

There is no market for hydrogen production and consumption in Estonia today (Estonian Hydrogen Roadmap, 2023). However, the mapped projects amount to 1.0 TWh/year of production of which approximately 82% could potentially be available to the maritime sector. Nine out of a total of fifteen identified projects have estimates of produced fuel volume. These are broadly distributed across Estonia's coasts and at port locations including Tallinn, Narva, Paldiski, Sillamäe, Saaremaa and Muuga, see Figure 29. An overwhelming majority of the volume will consist of ammonia from the Derivaat NH3 projects, Voyager 1 in Paldiski and Voyager 2 in Ida-Virumaa. These aim to produce 0.25 TWh/year and 0.5 TWh/year of ammonia respectively for both fertilizer and maritime applications. Voyager 1 is under construction and due to be operational in 2026, and voyager 2 is still in the planning stages due to come online in 2028.

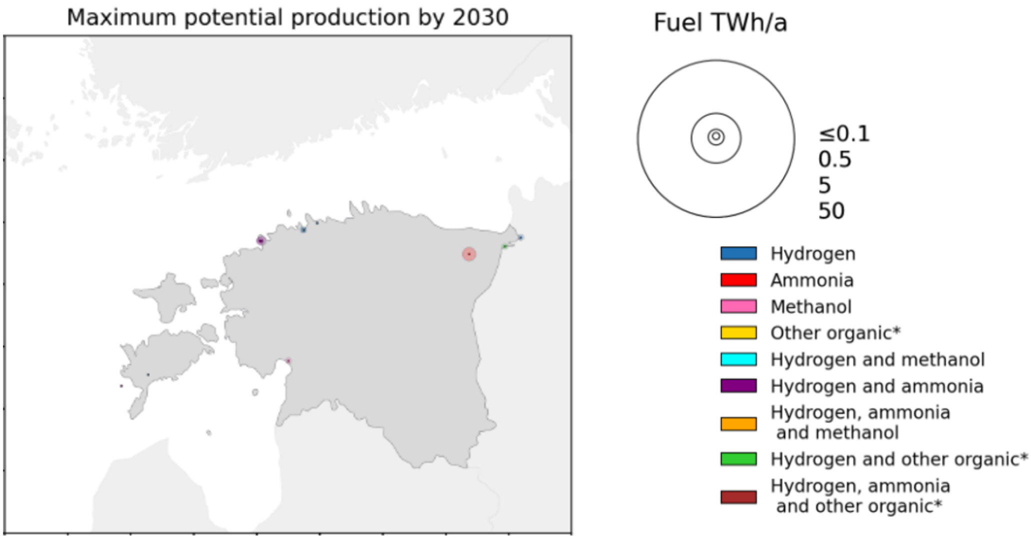

Figure 29. Mapped potential electrofuel production from projects in Estonia. Also includes projects without a defined start-up year.

Other maritime related projects such as the Estonian Islands Energy Agency's production of hydrogen and ammonia in Saaremaa, HYEELIWTS in Muuga and EHYTRANSP in Tallinn all aim to produce hydrogen and or ammonia for the maritime sector. However, these projects are still in early development and currently lack confirmed start-up years as well as estimated fuel production.

As for methanol, a large 2.8 TWh/year methanol production facility in Pärnu was also planned but was cancelled in 2025. If realised, it would have made up most of the country's electrofuel production in terms of energy. Another methanol plant is now planned in Pärnu instead, but it is only planned to produce 0.06 TWh/year.

Also, one of the largest planned projects is an 820 MW wind farm off the coast, which is planned to start operation in 2032. This project includes hydrogen and ammonia production, but the volumes are uncertain and therefore not included in the country total.

Latvia

Despite there only being six hydrogen production projects in Latvia, their total planned output amount to 14.6 TWh/year, see Figure 30. Around half of this is in the form of pure hydrogen. Of the rest, a quarter is co-production of hydrogen and ammonia. The other quarter is co-production of hydrogen, methanol and SAF. Out of the total production capacity 57% could potentially be available for maritime use.

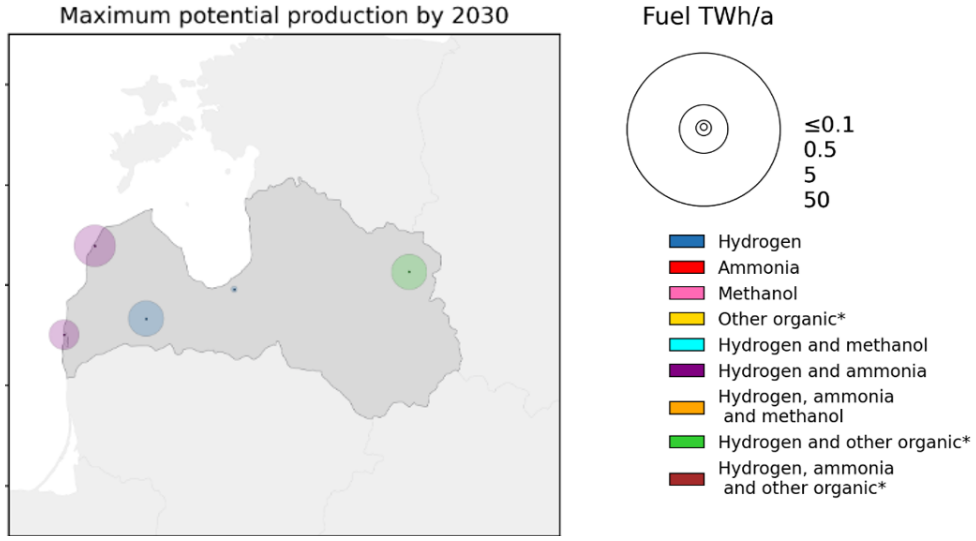

Figure 30. Mapped potential fuel production from projects in Latvia. Also includes projects without a defined start-up year.

The outcome largely depends on the success of three projects by the company PurpleGreen, whose projects amount to a total fuel production of 12 TWh/year. None of PurpleGreen's projects have a stated start-up year however, and in Latvia as a whole no projects are currently in construction or have received a FID. The only currently operational project started in 2019, when Riga inaugurated hydrogen powered trolleybuses that use 3.3 TWh/year of fuel.

One of the largest projects in Latvia, CIS Liepāja, is being developed by Power-to-X Liepāja and aims to build a port terminal with a 2.5 TWh/year hydrogen plant using wind energy. They intend to export hydrogen to other EU countries for use in the transport and energy sectors with an estimated start year of 2029. According to the project description, a doubling of the electrolyser capacity from 500 MW to 1 GW as well as 400 000 t/a ammonia production is considered optional and is not included in the mapping made here.

Latvia is a part of the Nordic-Baltic Hydrogen Corridor and is planned to have a pipeline running through it from Estonia to Lithuania.

Lithuania

Lithuania's current hydrogen project landscape is comparatively narrow in scope, with five identified active projects providing 1.5 TWh/year from 2026, shown in Figure 31. The largest is Achema's fertilizer plant in Kaunas which has secured EU finding and is building a 171 MW electrolyser to replace the use of natural gas with hydrogen. Achema is also responsible for what would be the second largest project in the country, the Jonava green hydrogen facility, which currently is put on hold. If realised it could provide up to 1 TWh/year, bringing the total fuel energy production for the country to 2.5 TWh/ year.

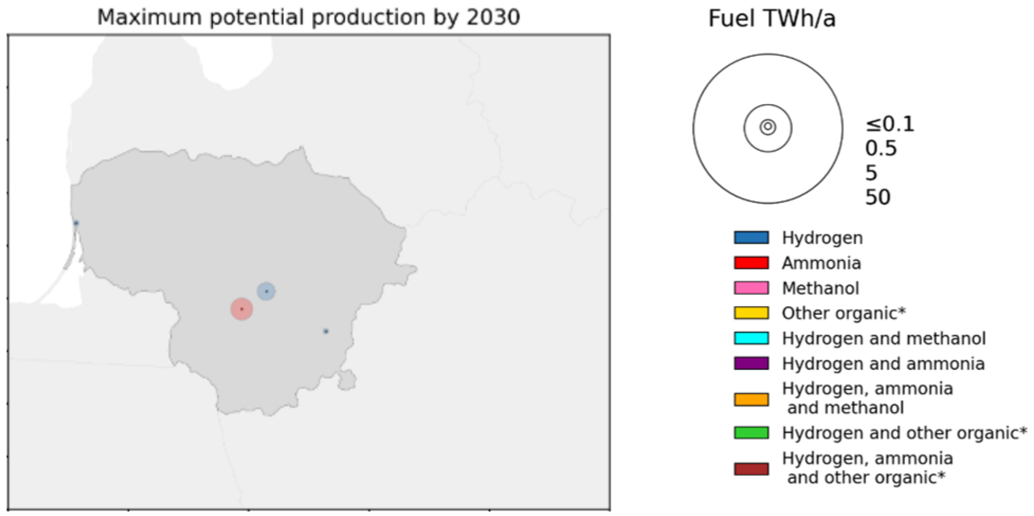

Figure 31. Mapped potential electrofuel production from projects in Lithuania. Also includes projects without a defined start-up year.

In 2015–2021, fossil-based hydrogen demand in Lithuania's industry was about 260,000–320,000 tonnes annually (Baringa, 2022). Most was used for ammonia production and petroleum refining. Both industries are mentioned as potential off-takers of renewable and low-carbon hydrogen in the future. Strategic efforts such as the Baltic Hydrogen Corridor and the gas grid injection project show intent to embed hydrogen into wider energy networks, yet only the latter has reached demonstration stage.

Beyond these industrial sites, most projects are small in scale (only a few thousand MWh/year). A notable one that is close to completion is hydrogen production at Port of Klaipėda, planned to produce 127 tonnes of hydrogen per year. Part of this will be used to power Lithuania's first hydrogen-driven vessel (Offshore Energy, 2025). On the map, the Kaunas and Jonava projects are clearly shown as the two big circles in the middle. Two of the six projects are pipelines which is why they are not shown on the map.

Finland

Finland has high ambition, indicated in Figure 32, with the mapped projects showing 84 TWh/ year fuel production by 2030 across 50 projects. Two thirds of this energy is potentially available for the maritime sector, which makes the planned maritime capacity in Finland the highest among the surveyed countries. Infrastructure initiatives, including the Baltic Sea Hydrogen Collector and Nordic hydrogen corridors, are undergoing feasibility studies and expected to become operational by 2030.

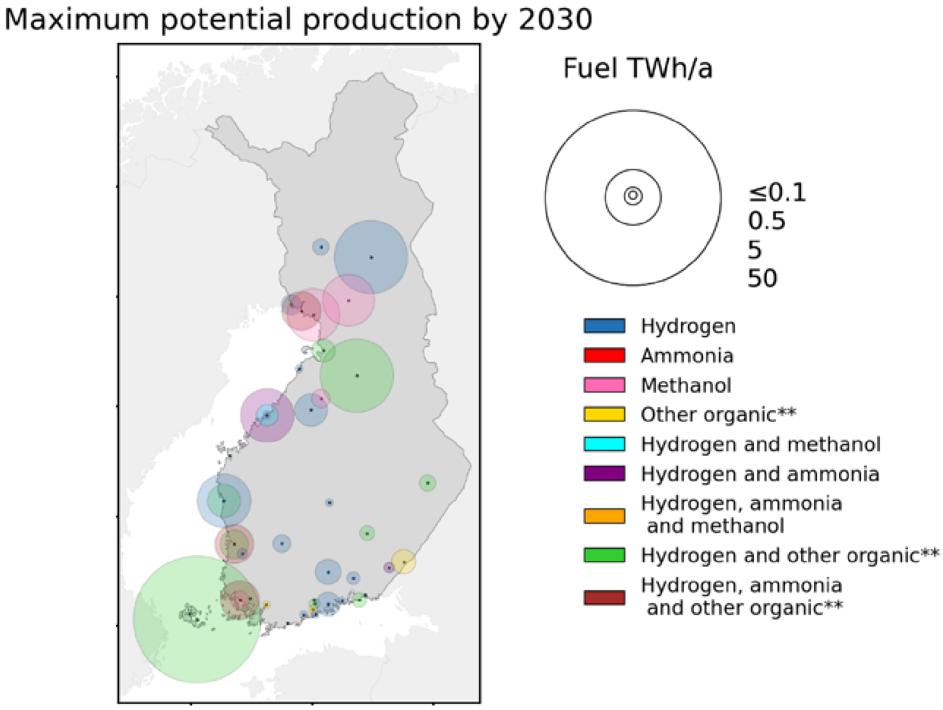

Figure 32. Mapped fuel production from projects in Finland.

The largest project in Finland is *Långnäs Mega Grön Hamn* on Åland, an island located between Sweden and Finland. This project includes a 3 GW electrolyser which would be used to create electrofuels for the maritime industry. Another key hub is in Kokkola on Finland's west coast, where large facilities aiming to produce hydrogen, ammonia and methane for the maritime sector are planned. Kristiinankaupunki is also important, with two upcoming hydrogen production facilities; Kristinestad PtX by Koppö Energia Oy and PlugPower's Green hydrogen production for steel manufacturing, although these facilities are primarily aimed at supplying energy for industrial applications.

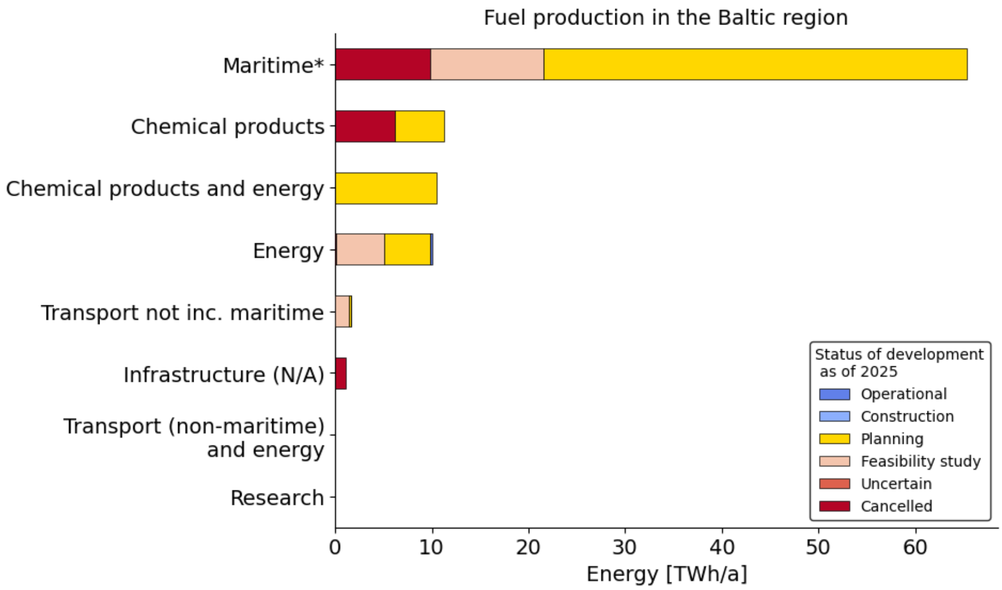

Figure 33. Potential electrofuel supply over time by fuel, sector and phase in Finland.

Approximately 1% of the maximum potential electrofuel is currently available in 2025. Almost all projects are in the planning or feasibility study stages, see Figure 33 and the right diagram in Figure 34. Five hydrogen projects have been cancelled so far:

- The Neste 10 TWh/year electrolyser at Porvoo due to come online in 2024
- Hydrogen for green steel project at Raahe
- H-FLEX-E project at Vaasa producing hydrogen and electrofuels, due 2026.
- Flexens offshore wind project at Åland
- Flexens green ammonia plant in Kokkola, due 2025

Together, these facilities would have been able to produce around 17 TWh/year of fuel energy. The reasons behind these cancellations include challenging market conditions and company financial performance.

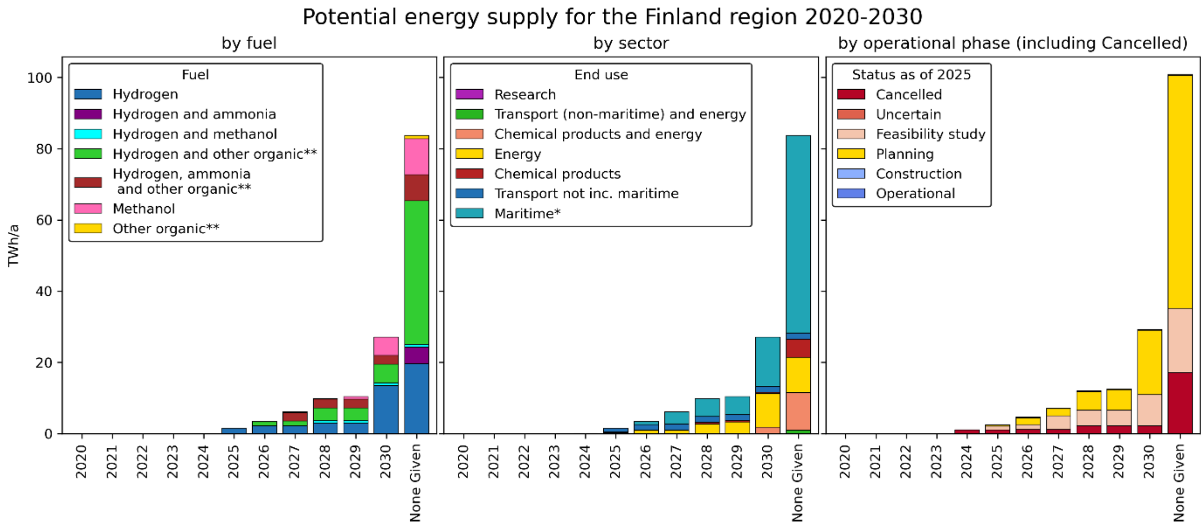

Figure 34. Planned potential electrofuel supply over time in Finland.

5.2. National overview of future renewable electrofuel use and production

This chapter summaries the analysis of how the market might develop for electrofuels in the region and analysed countries. First, central movements on the European market are presented followed by each nation. Focus is on specific developments in each nation, their plans and how they differ from or align with the Baltic Sea Region at large.

Two reoccurring key concepts for the strategic work on electrofuels in the regions are hydrogen strategies and hydrogen valleys. Hydrogen strategies refer to national and European strategies/plans outlining how renewable hydrogen and other electrofuels will be produced, transported, stored, and used to support the transition to a climate-neutral economy. They typically include goals, regulatory measures, investments, and technological pathways to integrate hydrogen into the energy system. In 2017, Japan was the first country in the world to adopt a hydrogen strategy, and since then, more countries have followed.

Hydrogen valleys are a term used for a geographically concentrated ecosystem that integrates the entire hydrogen value chain, from production, storage, and distribution to multiple end-uses, within a single region or locality. They serve as demonstration and scaling environments for a local or regional hydrogen economy, showcasing how hydrogen can support sector integration, decarbonization, and economic development. These initiatives typically bring together multiple stakeholders to develop value chains that demonstrate the technical, economic, and regulatory feasibility of hydrogen deployment. It is a common concept used in the Baltic Sea Region and most countries have one or more hydrogen valley projects ongoing or getting started.

In the context of the evolving fuel market, hydrogen valleys may play an important role by functioning as test environments for the expansion of hydrogen production and use. They enable the optimization of infrastructure, assessment of cost structures, and development of supply–demand relationships within defined settings prior to broader market implementation. Furthermore, hydrogen valleys can contribute to aligning national objectives with regional capacities, ensuring coherence between production potential, resource availability, and end-use applications in support of sustainable growth and the diffusion of hydrogen-based fuels. These initiatives may thus facilitate market development by reducing uncertainty, promoting collaboration, and generating empirical knowledge that informs policy, investment, and regulatory processes across the hydrogen economy.

In the countries included in this report many hydrogen valleys are in very early development stages which still has not met the maturity level where they are defined with clear aims, however they have a key role in the future development. In their hydrogen strategies, countries highlight their comparative advantages for producing hydrogen. Important factors in this context are usually the countries' natural resources (e.g., natural gas), geographical conditions (e.g., for the expansion of renewable electricity production), and industrial capacity (e.g., experience in handling hydrogen in refineries and the chemical industry). In short, countries highlight their comparative advantages in their strategies, which in this respect can also be seen as a showcase for international investors to invest in hydrogen projects in the country, a purpose that is often stated in the strategies or the official communication surrounding them.

Table 2. Summary of results from market outlook at national levels. The table presents national targets, estimated productions based on analysis in 5.1 and key strategies.

Country	Has a specific hydrogen strategy?	Covers electrofuels broadly?	Name of strategy	Year published	Goal for renewable electrofuel production 2030	Long term goal for renewable H2D production 2050	Estimated production 2030[3]	Expected imports by 2030
Latvia	No	No	Latvian Energy Strategy 2050	N/A	N/A	N/A	100-600 GWh/year	n/a
Estonia	Yes	Yes	Estonian Hydrogen Roadmap	2023	No quantitative goal	No quantitative goal	10-320 GWh/year	n/a
Finland	Yes	Yes	Valtioneuvoston periaatepäätös TEM/2023/14	2023	10% of the EUs hydrogen need	None	1 900-6 700 GWh/year	n/a
Lithuania	Yes	Yes, primarily as ammonia feedstock	Vandenilio strategija	2022	30 000 tonnes of hydrogen, or 300-350 MW electrolysers	No goal set, but projected to reach 12 TWh	175-630 GWh/year	n/a
Sweden[4]	No	No	N/A	N/A	N/A	N/A	4 000-14 000[5] GWh/year	n/a
Germany	Yes	No, but does include reflections on hydrogen as a feedstock for power-to-x	National Hydrogen Strategy - Update	2023	10 GW electrolysers	2030 considered long-term	4 500-16 000 GWh/year	45-90 TWh, expected imports via pipelines and shipping
Poland	Yes, with a focus on 2030 and a broad outline for 2040	No, only hydrogen focus	Polish hydrogen strategy until 2030 with an outlook until 2040	2021	Installed production capacity of 2 GW	None	1 800-6 500[6] GWh/year	n/a
Denmark	Yes	Yes	The Governments strategy for power-to-x	2021	4-6 GW	None	1 500-5 500 GWh/year	n/a
Europe	Yes	Yes	A hydrogen strategy for a climate-neutral Europe	2020, updated 2024	40 GW, 10 Mt RFNBO production	Matured and rolled out production and use	N/A	40 GW by 2030

[3] If 7-25% of planned production is realised by 2030
[4] However, there is a proposal for a national strategy for fossil-free hydrogen developed by the Swedish Energy Agency in 2021 (www.energimyndigheten.se/nyhetsarkiv/2021/forslag-till-nationell-strategi-for-fossilfri-vatgas/)
[5] Several large projects in very early development
[6] Only hydrogen and very low amount planned for maritime

The European Union as a whole

The EU has set very ambitious targets in the field of hydrogen. The EU launched its hydrogen strategy in 2020, focusing on how hydrogen can contribute to a climate-neutral Europe, and the strategy set a target of producing ten million tons of renewable hydrogen within the Union by 2030. Following Russia's full-scale invasion of Ukraine, the EU's energy policy has increasingly focused on energy security, which has also had an impact on the hydrogen strategy. The target for production within the Union has now been supplemented by an equally large import target, which aims to contribute to the diversification of energy supplies to Europe. In recent years, the EU has pursued policies to achieve its hydrogen targets, and the report provides an overview of these policies. In addition, it also looks at a few individual European countries, including Germany, which can be said to have a particularly strong focus on hydrogen in its energy and foreign policy, not least from an energy security perspective.

Since 2013, the European Commission has been compiling biennial lists of projects considered to be of common interest (Projects of Common Interest, PCI) to contribute to the Union's energy and climate goals. Stress is also put on cross-border hydrogen infrastructure, known as ‘corridors’, with the aim of enabling a coherent European market. PCI projects of relevance for the electrofuel development are highlighted under each nation. Two PIC projects are of direct special interest for the development of the electrofuel market in the Baltic Sea region: Nordic-Baltic hydrogen corridor, which if realised will connect Finland, Estonia, Latvia, Lithuania, Poland and northern Germany, and the Baltic Sea hydrogen Collector, which if realised will connect Sweden, Finland and northern Germany.

Sweden

Sweden does currently not have a hydrogen strategy nor any other clear production, use or import targets for electrofuels (see Table 2). However, the Swedish Energy Agency developed a proposal for a national strategy for fossil-free hydrogen in 2021[7], a task initiated by the Swedish government, but the strategy has not been officially adopted. Despite this the identified projects in planning are significant if realised, as they could amount to as much as almost 59 TWh of electrofuels. Sweden has a significant supply of biogenic CO_2 (estimates at 40 million tonnes a year by Hansson et al. (2018)) and large land areal which could be used for renewable electricity production, making this scale of production feasible in relation to feedstocks. However, it has been noted in workshops and interviews that the current legislative landscape is lacking in support and clarity. Several hydrogen-related projects in Sweden have experienced delays due to lengthy and complex permitting processes. This is exemplified by the planned Hybrit demonstration-scale plant in Gällivare. Looking ahead, additional challenges are emerging in relation to securing sufficient power capacity, as many projects are affected by limited access to grid connections and transmission capacity. The Swedish electricity grid has direct power capacity issues today and expansion of renewable energy production is therefore challenging.

It could also be noticed that many of the identified projects in Sweden for production of hydrogen-based fuels (in Nygård Basso et al., 2022; Stenersen and Lundström, 2023) are in the vicinity of ports or the sea, which imply that they, if realised, potentially could be relevant for ports and the shipping sector in the future. Interconnector projects such as the Nordic Hydrogen Route (Sweden–Finland) and the Baltic Sea Hydrogen Collector (Sweden–Finland–Germany) could ease regional balancing and supply if realised, but they are long-lead and will not by themselves guarantee sufficient energy for large domestic electrofuel volumes by 2030. This also means that transport of fuels through ports might be required.

To project a demand of marine fuel on the Swedish market is difficult. Some 30 TWh of fossil marine fuels are sold annually in Sweden to domestic and international ships (Swedish Energy Agency, 2022), with substantial variations in recent years, but with a steady rise since the 90s. In addition, terminals and ports also consume large quantities of diesel fuels (Winnes & Styhre, 2017). However, official statistics for international shipping are unreliable and the use of electricity in ports is missing (Vierth, 2023).

[7] Available in Swedish at www.energimyndigheten.se/nyhetsarkiv/2021/forslag-till-nationell-strategi-for-fossilfri-vatgas/

Currently, the chemical and refinery industries account for most of the hydrogen production in Sweden. Annual production is estimated at approximately 192,000 tonnes of hydrogen, corresponding to around 6.4 TWh per year. Steam reforming of natural gas remains the dominant production pathway, representing roughly two-thirds of total output. The remaining share originates from industrial by-product streams and, to a limited extent, from electrolysis, which is estimated to contribute slightly less than three percent of the total.

Denmark

The Denmark's work on electrofuels is focused heavy on creating production at a scale where export is possible. It's the nation besides Finland with the highest production goals and it is already a net exporter of renewable electricity through the electricity grid. In 2020, Denmark's net export of electricity to Germany amounted to 3 TWh. The Danish hydrogen strategy sets (see Table 2) out the goal of establishing between 4 and 6 GW of electrolysis capacity by 2030, supported by DKK 1.25 billion in public funding. These efforts are closely linked to Denmark's broader energy and climate objectives, including the establishment of 3 GW of additional renewable energy capacity and a national commitment to reduce CO_2 emissions by 70 per cent by 2030. The development of electrofuel technologies is considered essential to achieving these targets, as they enable the conversion of surplus renewable electricity into carbon-neutral fuels that can replace fossil-based energy carriers in hard-to-abate sectors such as shipping and aviation.

The maritime sector plays a central role in Denmark's strategy. The Government has declared its intention to achieve a climate-neutral shipping sector by 2050 at the latest, aligning with the Danish shipping industry's own voluntary target and international efforts initiated at COP26. Many of the already identified projects are directly tied to the maritime sector as an end user, and the total planned production is the highest in the Baltic Sea Region. Ports close to planned projects are therefore likely to handle e-methanol or other electrofuels in the future, and for example port of Bornholm are closely linked to large production projects.

The Danish market is today signalling a move towards electromethanol over hydrogen or ammonia. A crucial component is therefore the utilisation of biogenic CO_2 as a feedstock from biobased industry and through carbon capture and utilisation (CCU) processes. The Danish Climate Act explicitly allows negative emissions from technological solutions such as CCS to contribute to meeting the country's climate reduction targets. There are estimates that biogenic CO_2 from Danish point sources will amount to between 1 million and 5 millions of tonnes of CO_2 in 2040, enabling this transition (Danish Energy Agency, 2024).

We have not been able to identify any direct assessments on if the Danish electricity grid will be able to provide the electricity required, but local electricity production is planned for most electrofuel production projects announced. However, in the interviews as well as in project reports it has been noted that the Danish energy grid and economy is closely tied to the Norwegian, Swedish and German development. Its role as a future electrofuel producer and exporter might therefore be tied closely to the development in these countries.

Germany

Germany has maintained a strong strategic focus on hydrogen as a key component in achieving its energy and climate objectives. The country's first National Hydrogen Strategy was adopted by the federal government in 2020, and an updated version was released in 2023. This revision was developed in the context of Russia's full-scale invasion of Ukraine, which placed greater emphasis on energy security through diversification of energy supply. According to the updated strategy, both domestic hydrogen production and hydrogen imports are considered central to national energy security.

The German hydrogen strategy aims for at least 10 GW domestic electrolyser capacity by 2030, which amounts to 87.6 TWh/year assuming 24-hour operation (BMWK, 2023). An "atlas" called H2 PoWerD has been developed by Fraunhofer Institute along will several other actors and researchers, aiming to show what locations in Germany are most suitable for hydrogen production (Behrens et al., 2025).

According to the import strategy, the federal government currently maintains bilateral hydrogen partnerships with around 50 countries, complemented by additional agreements at the regional and state levels. Imports from other countries are also planned to cover a large part of the demand (see Table 2). Pure hydrogen is believed to be imported mainly via pipeline, while electrofuels such as methanol will be imported via ships. Estimates suggest that between 50 and 70 per cent of Germany's expected hydrogen demand in 2030 (equivalent to 95–130 TWh) will need to be met through imports.

Beyond 2030, imports are forecasted to remain essential, as total hydrogen demand is projected to reach 360–500 TWh by 2045, alongside an additional 200 TWh of electrofuels such as methanol, ammonia, and other electrofuels. In response to this considerable import requirement, Germany adopted a dedicated Hydrogen Import Strategy in 2024, with a clear emphasis on achieving a diversified supply base.

In addition to the hydrogen auctions held within EU Innovation Fund, the auctioning process is provided as a service on a voluntary basis (Auction-as-a-Service) to countries in the European Economic Area (EEA), but then with national funds. The purpose of the service is to enable member states to avoid establishing their own national auction procedures and to support projects on their own territory. Germany was the first member state to take advantage of this opportunity when it made €350 million from its national budget available to hydrogen producers in the country for the first EU auction, which was approved by the Commission in April 2024.

A further cornerstone of Germany's hydrogen strategy concerns the development of an integrated national hydrogen infrastructure, formally designated as the Hydrogen Core Network. This initiative represents a coordinated effort among gas transmission system operators to conceptualise and design what effectively constitutes a nationwide hydrogen transmission grid. The proposal, endorsed by the Federal Network Agency (Bundesnetzagentur) in October 2024, marks a critical institutional milestone in the materialisation of Germany's hydrogen economy. The Hydrogen Core Network is envisaged to serve as the structural backbone of this emerging system, facilitating the interconnection of domestic production sites, industrial demand centres, underground storage capacities, and international import corridors. Through this configuration, the network is intended to enhance both the spatial and functional integration of hydrogen flows across Germany and, by extension, within the broader European energy system.

Several major infrastructure projects are currently under development to strengthen Germany's role as a central hub in the emerging European hydrogen economy. The internal hydrogen infrastructure initiative, known as H2ercules West, aims to establish a large-scale pipeline network connecting industrial centres in western and southern Germany with import terminals and storage facilities in the north. Complementing this inland network are several planned ammonia reception terminals, including the facilities in Brunsbüttel and Wilhelmshaven, developed respectively by multiple consortiums and major energy companies such as BP and Uniper. These terminals are designed to enable the large-scale import, handling, and conversion of ammonia—used as a hydrogen carrier—into low-emission fuels and feedstocks for industrial use. Furthermore, the planned offshore hydrogen pipeline between Norway and Germany, currently referred to as the CHE Pipeline, is set to provide a direct and secure supply route for low-carbon hydrogen produced from renewable energy sources in Norway. Collectively, these projects are expected to constitute critical components of Germany's hydrogen import and distribution infrastructure, reinforcing its long-term energy security and decarbonization objectives.

Poland

As can be seen in Chapter 5.1, all ongoing projects identified in Poland are directly aimed at hydrogen production. The Polish Hydrogen Strategy until 2030 (with an outlook to 2040) reflects this and focuses only on domestic hydrogen production and infrastructure (see Table 2). Poland's focus on hydrogen development is likely linked to its current position as one of Europe's largest producers and consumers of hydrogen, primarily used in refineries and chemical industries. Today, nearly all hydrogen is produced from fossil fuels, mainly natural gas. Rather than aiming to become a large-scale exporter or transit hub for hydrogen, Poland's hydrogen strategy focuses on transforming its domestic production towards low-emission and renewable sources. The Strategy largely treats hydrogen as a domestic matter, focusing on internal value chains and omitting detailed plans for international hydrogen trade. This aligns with the national aim of reducing dependence on imported fossil fuels and strengthening energy security.

The strategy largely omits the global hydrogen market and international trade, indicating that Poland is expected to be a pragmatic participant rather than a frontrunner (Smolén and Żelisko, 2023). Numerical targets are defined only for hydrogen buses, while other transport modes and end users are not specified. In this sense, Poland's hydrogen development is less about creating a new export sector and more about ensuring that its existing hydrogen-dependent industries remain viable in a decarbonising Europe. Hydrogen is not yet a mainstream topic in Poland, but the Strategy has sparked discussion among stakeholders, including oil and gas companies, renewable energy promoters, and local governments (Smolén and Żelisko, 2023).

The Strategy's annex, produced by the Institute of Power Engineering, the University of Warsaw, and the Institute for Ecology of Industrial Areas, provides a 516-page analysis of hydrogen technology potential in Poland until 2030, with an outlook to 2040. Hydrogen is described as a clean energy storage medium and a viable solution for industrial applications where direct electrification is not feasible, while also highlighting potential economic benefits of emerging hydrogen value chains (Smolén and Żelisko, 2023). The Poland's hydrogen strategy emphasises the development of "low-emission hydrogen" rather than strictly renewable hydrogen, allowing support for hydrogen produced from fossil fuels combined with carbon capture and storage (CCS) or carbon capture and utilisation (CCU).

For market development, proponents of the Polish hydrogen economy, including industry stakeholders and policymakers, list several domestic advantages (Kupecki et al., 2021, p. 455-456), such as the scale of the pre-existing hydrogen economy, steady demand from numerous industries, or developed automotive and rolling stock industries which can participate in the hydrogen value chains. However, Poland's capacity to produce low-carbon hydrogen is constrained also over time. Challenges include limited clean electricity availability, reliance on natural gas imports, and minimal experience with CCS (Smolén and Żelisko, 2023). The country still relies heavily on coal and natural gas, and renewable electricity accounts for only about 32 per cent of total power generation (Strojny et al., 2024). High electricity demand for hydrogen production covered by Poland's largely carbon-intensive grid (912 kg CO_2/MWh) risks increasing emissions without mitigation. Renewable energy supply is therefore crucial and is discussed by several stakeholders as a key barrier to overcome for electrofuels to become a mainstream product in the nation. Onshore wind expansion has been severely limited by restrictive zoning laws since 2016, and nuclear power will not become available until at least the mid-2030s. This limits the availability of clean electricity for large-scale electrolysis. The potential to store carbon in CCS systems are also limited within the country, and as such other production pathways are needed to replace the fossil hydrogen produced today.

One of the most important measures for implementing the Polish Hydrogen Strategy is establishing a stable regulatory environment for the hydrogen sector, including projects within hydrogen valleys. Polish hydrogen valleys include the Pomeranian Hydrogen Valley, West Pomeranian Hydrogen Valley, Greater Poland Hydrogen Valley, Masovian Hydrogen Valley (including HySPARK), Central Hydrogen Cluster, Lower Silesia Hydrogen Valley, Silesian and Lesser Poland Hydrogen Valley, Subcarpathian Hydrogen Valley, and the Amber Hydrogen Valley (Smolén and Żelisko, 2023). These valleys can serve as platforms for debate and demonstration of breakthrough technologies, fostering positive public perception of renewable energy (Spasowska, 2025).

Planned actions and support programs will be financed through the National Fund for Environmental Protection and Water Management for infrastructure such as fuelling stations and fuel cell buses, and the National Centre for Research and Development for R&D and innovation. The estimated cost of achieving key indicators is around EUR 2.3 billion, with the first round of support programs valued at least EUR 450 million (Polish Ministry of Climate and Environment, 2021a). Poland has also engaged in international cooperation, including hydrogen partnerships with Iceland and Japan to develop low-carbon hydrogen and sustainable value chains (Polish Ministry of Climate and Environment, 2022e; 2023a; Smolén and Żelisko, 2023).

However, the pace of development is slowed by regulatory and investment barriers. Until December 2024, hydrogen was regulated only as “another type of combustible gas” under the Energy Law, with no dedicated legal framework for production, transport, or storage. This created uncertainty for investors and hindered project implementation. Current government work is concentrated on creating a “hydrogen constitution,” with a draft hydrogen law presented in mid-2024, intended to establish a more stable regulatory environment.

“In light of Poland's modest hydrogen production capacity deployment plans in comparison with the European frontrunners like Germany or France, it will be difficult for Poland to maintain its current position in the hydrogen economy”. (Strojny et al., 2024)

It is therefore unlikely that more hydrogen will be handled in the port due to higher domestic production of renewable hydrogen as today’s production of hydrogen is high and mainly relies on pipeline transport. The main key drive for increase handling in polish ports are if it is used as a fuel and bunkered in port, or if the domestic fossil hydrogen is replaced with imported hydrogen handled in for example port of Gdansk or Gdynia.

Estonia

As part of the green transition planned under the EU 2021-27 funding, Estonia has developed a hydrogen roadmap to accelerate the introduction of renewable-based hydrogen as an energy carrier in the market, including for consumption. Estonia's hydrogen strategy, as outlined in the Estonian Hydrogen Roadmap 2023, focuses on developing a comprehensive hydrogen ecosystem by 2030. The strategy aims to utilize renewable energy sources, such as wind and solar, to produce green hydrogen through electrolysis.

The Estonian work on electrofuels is tied to three stages of development. The current phase is the pilot phase which will last until 2030, and which final step will include an evaluation phase of the pilot projects and current state of hydrogen on the Estonian market. This is in line with the few identified projects in Chapter 5.2, where all can be described as smaller pilot projects. There are no clear production goals set yet, instead the Estonian ministry has chosen an approach focus on development of legislation, specific pilot projects and co-operation and knowledge sharing. A national support scheme for hydrogen value chain pilot projects has been announced,

For the maritime sector it is especially interesting to note that the hydrogen road map includes the activity “Analysis for possible procurement of fuel cell ferries“ tied to assessing the feasibility of hydrogen solutions in the Estonian energy system.

After 2030, the country is set to enter a scaling phase according to the roadmap focused on expanding and refining the value chain established during the piloting stage. Continued research and development will be essential, not only to enhance existing technologies but also to strengthen the economic model and seize emerging opportunities. To ensure that supply and demand evolve in balance, regional collaboration among market actors will be key, alongside the advancement of solutions for production, distribution, storage, and end-use applications. Competence development will remain a priority, with ongoing training of specialists and experts. At the same time, the roadmap sets out a road where applied research capacity continues to grow, addressing market barriers and adapting to changes in renewable energy access, technology progress, and insights from earlier pilot projects. In value chain segments where domestic production meets demand, for example in transport, energy storage, or chemical production. The technologies deployed should be capable of achieving net-zero emissions across their life cycles. Moreover, within five years, these technologies should demonstrate a path toward financial independence, even without major increases in renewable energy availability. New pilot initiatives may also emerge, for instance in the production of synthetic green fuels, further reinforcing Estonia's hydrogen ecosystem.

The final stage presented goes on from 2036 to 2050, when the Estonian hydrogen sector will enter an expansion phase that builds on the progress and lessons of earlier stages. This phase represents a shift toward full integration of hydrogen across the economy, leveraging earlier investments and technological maturity to strengthen Estonia's energy resilience and sustainability. Growth in wind power capacity and decreasing electrolysers costs could make domestically produced hydrogen increasingly competitive with other energy carriers and technologies. In the transport sector, broader hydrogen deployment will depend on key enabling factors, for example the affordability of new hydrogen vehicles, the feasibility of retrofitting existing fleets for hydrogen use, and the global price of green hydrogen remaining comparable to that of natural gas. Should a consistent surplus of renewable hydrogen emerge, opportunities for its use in additional sectors could be explored. From the standpoint of the roadmap you cannot say with any certainty at the current stage of such a production will occur.

Latvia

Latvia currently lacks a strategy on electrofuel, but the energy system is currently undergoing rapid changes. In February 2025, Latvia, along with Estonia and Lithuania, successfully disconnected from the Soviet-era BRELL power grid, marking a significant step towards energy independence from Russia. This decoupling was followed by synchronization with the European electricity grid. Latvia's energy system is currently characterized by a significant reliance on imported fuels, with limited domestic production capabilities. The country does not operate any oil refineries and imports all its refined petroleum products. In 2023, Latvia imported approximately 2.3 million tonnes of oil products, primarily from Lithuania (50%), followed by Russia (20%) and Finland (17%). The country has a significant production of renewable electricity. In 2024, Latvia generated a total of 6 322 GWh of electricity, with 4 643 GWh (approximately 73%) coming from renewable sources. Hydropower contributes with around 51% of the total electricity generation. Other renewable sources include wind power, solar energy, and biomass. Natural gas accounts for approximately 28% of electricity generation, while the remainder is supplemented by imports, mainly from neighbouring countries. Latvia has committed to reducing greenhouse gas emissions by 65% from 1990 levels by 2030 and aims to achieve net-zero emissions by 2050. This ambitious goal is supported by the European Union's Green Deal and is reflected in the country's National Energy and Climate Plan.

Latvia's market for electrofuels is still in its early stages, but the country is actively developing its alternative fuel infrastructure as part of broader energy and transport strategies. Despite the lack of a hydrogen strategy, the country has an Energy Strategy 2050 (Table 2) which was approved during 2025. The strategy has developed several scenarios for Latvia's energy future by 2050, ranging from optimistic to pessimistic. The Draft Law on Alternative Fuel Infrastructure and the Transport Energy Law establish regulatory conditions for alternative fuel deployment and define targets for energy diversification in transport (Ministry of Transport, 2025a; Saeima, 2025). The Transport Development Guidelines 2021–2027 and the National Climate and Energy Plan 2021–2030 emphasize the decarbonization of the transport sector and the gradual integration of synthetic and renewable fuels, including hydrogen-based fuels (Ministry of Transport, 2021; Ministry of Economics, 2021). Latvia's Long-Term Energy Strategy (2025) further outlines the need to support low-carbon technologies, highlighting both production and distribution infrastructure for electrofuels (Ministry of Economics, 2025). Earlier plans, such as the Alternative Fuel Development Plan 2017–2020, provided the initial framework, which has since been updated to incorporate advanced biofuels and synthetic fuels (Par alternatīvo degvielu attīstības plānu, 2017).

Currently, the electrofuel market in Latvia is nascent, with infrastructure for large-scale production and distribution limited and most efforts remaining at the planning or pilot stage. The projects announced today amount to a maximum of 2.5 TWh of electrofuel where most is not meant for used in the transport sector (see Table 2). Hydrogen and electrofuels are prioritized in sectors that are difficult to electrify, particularly heavy-duty transport and maritime shipping, and Latvia is exploring partnerships and investments to establish local production capacity (Netherlands Enterprise Agency [RVO], 2023).

Regarding electrofuels there are some activities are ongoing in the country. Notable for the maritime sector is that Latvia is pioneering the development of a hydrogen-powered vessels. Construction has commenced on the country's first hydrogen-electric coastal fishing vessel at the AtoZ shipyard, in collaboration with Riga Technical University. This project aims to create a sustainable technological solution for the fishing industry. While fossil fuel storage infrastructure is well-established, recent analyses recommend a gradual transition toward agency-managed models to maintain energy security while enabling the integration of alternative fuels (Deloitte, 2023).

Economic and strategic drivers for electrofuel adoption include EU decarbonization targets such as RED II and Fit-for-55, which encourage alignment with EU incentives and cross-border collaboration, particularly within the Baltic Sea Region. Market growth is currently constrained by high production costs, limited economies of scale, and regulatory uncertainties. However, national and EU-level strategic investments in hydrogen and renewable electricity supply are expected to improve competitiveness in the medium term. Challenges include the high cost of production, limited distribution networks, insufficient domestic renewable electricity capacity, and the need for regulatory clarity. Opportunities exist through integration with Latvia's hydrogen economy plans, potential import/export within the Baltic Sea Region, alignment with EU green transition funding, and niche applications in shipping and heavy transport where electrification is not feasible. Overall, while the electrofuel market in Latvia remains at an early stage, ongoing policy support, strategic planning, and EU alignment indicate a cautiously positive trajectory for its development.

Lithuania

The number of identified plans in 5.1 for Lithuania are small in scale and few compared to for example Sweden, Finland and Demark. The total identified production is 2.5 TWh of fuel in all projects, however, Lithuania has set clear development targets in its startegic work (see Table 2). In 2024, Lithuania adopted a hydrogen strategy focused on

> "Lietuva, įvertinusi ES tikslus ir savo galimybes vystyti žaliojo vandenilio ekosistemą, taip pat numato išskirti pagrindinius žaliojo vandenilio plėtros etapus, aktyviai investuoti į vandenilio gamybą ir panaudojimą, siekdama savo įsipareigojimų mažinti įtaką klimato kaitai ir didinti energetinę nepriklausomybę" – The Lithuanian hydrogen strategy (LIETUVOS RESPUBLIKOS , 2024)

> "Lithuania, having assessed the EU's goals and its own capabilities to develop a green hydrogen ecosystem, also plans to identify the main stages of green hydrogen development, actively invest in hydrogen production and use, in order to meet its obligations to reduce the impact on climate change and increase energy independence". – The Lithuanian hydrogen strategy (LIETUVOS RESPUBLIKOS ENERGETIKOS MINISTRAS, 2024), translated in the project

Lithuania has developed an ambitious strategy to establish a domestic market for green hydrogen and hydrogen-based fuels, as part of the country's overall goal of achieving climate neutrality and reducing its dependence on fossil fuel imports (LIETUVOS RESPUBLIKOS ENERGETIKOS MINISTRAS, 2024). The strategy aims to enable a rapid scale-up of production, distribution, and use of green hydrogen, primarily produced using electrolysis based on renewable energy sources such as wind and solar power.

The strategy envisages a two-phase market development: an initial phase to 2030 followed by an expansion phase to 2050. During the first phase, the focus is on establishing the necessary infrastructure, implementing pilot projects, and creating a predictable regulatory framework. Subsequently, large-scale commercialization is planned with integration into industrial processes, the transport sector, and the energy system.

The first phase has several clear goals relevant for the market outlook:

- install no less than 1.3 GW of electrolysis equipment capacity
- produce no less than 129,000 tons of renewable hydrogen per year

- launch a pilot electromethane production project
- install no less than 10 hydrogen refuelling stations, with at least one designated for the maritime sector
- implement a pilot project for the use of green hydrogen and/or its derivative products in ships

Scenario ranges in the strategy and related studies (e.g., Baringa, 2022; national modelling) indicate potential production trajectories that could support limited domestic substitution of marine fuels during the 2030s. Larger-scale electrofuel manufacture would require both additional electrolyser capacity (beyond 1.3 GW) and reliable low-carbon electricity dedicated to these processes. The planned single maritime hydrogen refuelling station and ambitions to use hydrogen-based fuels in shipping signal policy intent, but the projected 2030 volumes are insufficient to decarbonise most of the bunker demand. Translation of green hydrogen production into marine electrofuels will depend on local electrofuel conversion capacity near ports and on offtake agreements with shipowners or operators.

Domestic demand projections are modest to 2030 but rise towards 2050 (see Table 2). The following expansion phase will follow an identified major demand from fertilise and chemistry industries as well as synthetic fuel production. National guidelines project green hydrogen demand for transport, maritime and aviation at around 0.257 TWh by 2030 and 1.683 TWh by 2050. Industry constitutes the largest share of projected hydrogen demand, with total hydrogen consumption rising to approximately 24.2 TWh by 2050. The government has set a specific export target of roughly 33,000 tonnes of hydrogen by 2030, signalling an early interest in cross-border trade within the Baltic energy market. Lithuania finale energetic and non-energetic energy demand is expected to reach 75 TWh per year in 2050, with almost half being covered by electricity (DNV, 2023) Currently, Lithuania relies heavily on net imports of natural gas, oil and electricity for its supply (DNV, 2023). Potential green hydrogen production and consumption centres in Lithuania is shown in Figure 35.

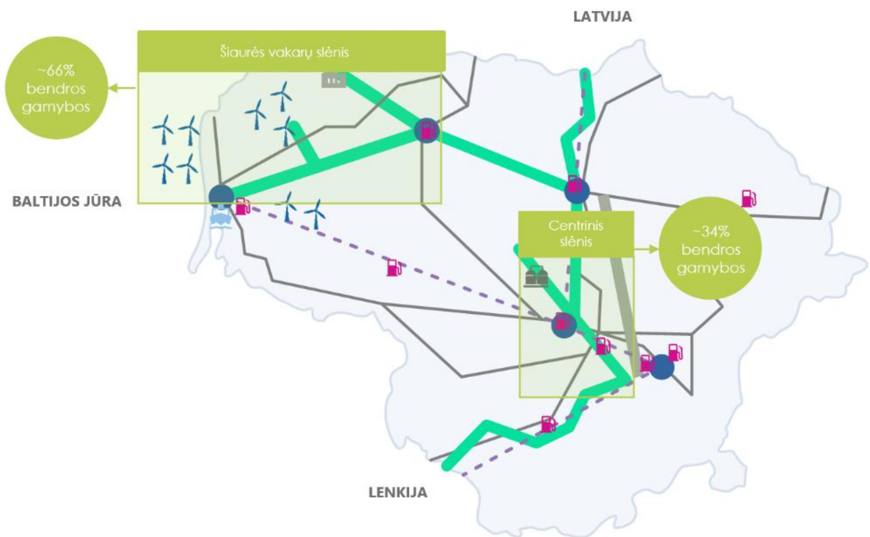

Figure 35. Potential green hydrogen production and consumption centres in Lithuania as identified in the hydrogen strategy.

The Lithuanian hydrogen strategy suggests the export of hydrogen and hydrogen-based fuels to nearby EU markets as a possible future niche, given the country's geographical location and connection to the Baltic energy market. The goal is to have at least 33 000 t of H_2 ready for exports in 2030 (see Table 3). A central part of the strategy is to establish standards and certification systems for green hydrogen, in line with the EU's regulatory framework for renewable fuels of non-biological origin (RFNBO).

Table 3. Projected Green Hydrogen Demand in Lithuania during the period 2023-2050. Source: Guidelines for Hydrogen development in Lithuania 2024-2050 (2024-04-26 Nr. 2024-07749)

Green H_2 demand	2023 (thousand tonnes)	2030 (thousand tonnes)	2040 (thousand tonnes)	2050 (thousand tonnes)
Export	0	33	51	43
Transmission losses	0	1	4	7
Electricity production	0	0	0	17
Transport	0	8	32	51
Industry – fertiliser production	0	83	240	472
Industry – oil refinery, synthetic fuels	0	5	92	141
Total	0	129	419	732

At the same time, there are several challenges and uncertainties that may affect the development of the market. Among other things, high conversion losses, technical uncertainty around storage and distribution, and the risk that the market will initially be dominated by imported hydrogen from fossil sources are highlighted in the strategy (LIETUVOS RESPUBLIKOS ENERGETIKOS MINISTRAS, 2024). Another risk is that Lithuanian industrial companies may lose competitiveness if the cost of domestically produced green hydrogen cannot be reduced in line with international alternatives.

Finland

Finland has established goals to be a clear leader on the electrofuel market, with a significant market share of the European market in 2030 (see Table 2). Finland is actively developing its electrofuel market as part of a broader energy policy focused on reducing emissions in transport and industry. This development is guided by national strategies, EU regulations, and investments in hydrogen and synthetic fuel production. EU regulations, including RED II and Fit-for-55, guide Finland's policy toward more sustainable energy solutions. Finland leverages these regulations through national support schemes and targeted investments, particularly in electrofuel production (Government of Finland, 2025a). In Finland, the Act on the Distribution Infrastructure for Alternative Fuels in Transport (Act 475/2024) implements the EU Alternative Fuels Infrastructure Regulation (AFIR) at the national level. This law requires the establishment of a comprehensive and compatible distribution network to support the use of electricity, hydrogen, and synthetic fuels in transport (Finlex, 2024; European Commission, 2023).

Finland is currently advancing its position in the emerging market for electrofuels, particularly through investments in green hydrogen infrastructure. The recent commissioning of the country's first industrial-scale green hydrogen plant in Harjavalta represents a significant milestone in the Finnish energy transition. Operated by P2X Solutions, the facility utilizes pressurized alkaline electrolysers with a capacity of twenty megawatts, producing hydrogen from renewable electricity that meets EU criteria for non-biological renewable fuels (Bjorkman, 2025). This production marks an important step towards replacing grey hydrogen, traditionally derived from fossil fuels, with green alternatives, which are expected to significantly reduce industrial carbon emissions.

Despite these advancements, market development has faced challenges. Green hydrogen remains considerably more expensive than conventional fossil-based hydrogen, creating hesitancy among potential industrial users to commit to long-term supply contracts. This economic barrier has slowed broader adoption and financing opportunities, posing a risk to Finland's ability to meet the EU's target of 42% renewable industrial hydrogen by 2030 (Bjorkman, 2025; Gasgrid

Finland, 2025). Additionally, policy uncertainty and the lag in incorporating EU goals into national legislation contribute to the cautious approach by industry actors (H2Finland, 2025).

The Finnish electrofuel value chain is gaining structure through initiatives that foster collaboration between hydrogen producers, industrial consumers, and research clusters. Organizations such as H2Finland and the Hydrogen Cluster Finland provide networks that support innovation, market intelligence, and investment opportunities, facilitating the scaling of hydrogen-based fuels (H2Finland, 2025; Hydrogen Cluster Finland, 2025). Concurrently, Finland aims to leverage its strategic position in Europe to shape regional hydrogen markets, positioning domestic production capabilities as part of a broader European hydrogen economy (Business Finland, 2024).

Looking ahead, electrofuels, particularly synthetic methane and other hydrogen-derived fuels, are poised to play a crucial role in Finland's low-carbon transition. However, the pace of market uptake will likely depend on continued technological development, cost reductions, and supportive policy measures that incentivize early adoption and long-term industrial partnerships. The access to biogenic carbon is estimated to be as high as Sweden, with estimate at 44 million tonnes per year at point sources in 2040. Information from interviews and national reports also indicates that the electricity grid in Finland is fit to handle large expansions of renewable electricity production without having power grid issues. How large quantities of electrofuel which will be managed in the ports in the future will depend on the implementation of the hydrogen pipeline and how much will be shipped by sea vs through fixed infrastructure. Market growth is currently constrained by high production costs, infrastructure limitations, and regulatory uncertainties. However, strategic investments and EU green transition funding are expected to improve competitiveness in the medium term.

5.3. Future supply and demand for the region

Maritime fuel demand and market development

The market for electrofuels in the Baltic Sea region in 2030 will be shaped by a mix of global production constraints, regional infrastructure rollout and the pace of maritime fuel demand transition. According to EMSA's 2024 estimates, the projected global electrolyser capacity by 2030 could supply hydrogen fuels for 13 to 19 percent of the global fleet if sufficient renewable electricity and capacity increases are achieved. Green ammonia production needs a three- to fourfold increase to support the foreseen demand in their forecasts. However, large-scale ammonia propulsion is unlikely to occur before 2035 since the technology is far from large scale implementation (Styhre et al., 2024). These global constraints will directly affect the Baltic Sea Region, where competition for electrolyser capacity, renewable power and feedstock materials will remain high.

There are potential direct limitations at the global scale for the potential production of electrofuels, however, the projects and projections brought forward in this report have reached a level of maturity where raw material potential is taken into consideration. How much will be available for the maritime sector of these fuels, their financial feasibility and how much will be managed in the ports remains uncertain. Many large-scale projects are being planned, but not all will be realised. The IEA (2024) estimates that if all global planned projects were realised, up to 49 million tonnes of hydrogen with low associated greenhouse gas emissions could be produced annually by 2030. However, the hydrogen demand expected as a result of existing policy commitments is only around 11 million tonnes per year. This gap illustrates the uncertainty surrounding the future market and shows that even ambitious production efforts may outpace demand unless supported by targeted policies and stronger market incentives. This mismatch has been highlighted in the interviews in the project as well as in the workshops.

This reports analysis of the announced production capacity in the Baltic Sea Region shows that even though total planned volumes are impressive, delays, cancellations and regulatory challenges will significantly reduce actual output. For this reason, regional assessments should translate these plans into more realistic scenarios that account for the risk of cancellations. In Table 2, we have summarised the results for the different Baltic Sea Region countries if 7-25% of the planned production until 2030 is realized. The total production could amount to over 50 TWh per year beyond 2030 if 25% of the planned production is realised in the region (plants in operational stages and additional projects), with a lower estimate of 14 TWh if 7% are realised. The realisation rate of 7-25% is in line with the discussions in the workshop (see Chapter 4.4.) as well as the assessments by Odenweller and Ueckerdt (2025) on the share of electrofuel projects realized globally.

The future need for fuel production via planned facilities must be balanced against behavioural and policy drivers as well as demand analysis. As put by UCLs analysis of the proposed IMO legislation:

> *"Conventional marine fuels producers are given a clear initial signal of continued demand for their product and may believe the large existing fleet of conventional ships that will continue to need 'oil' will sustain demand out to 2040. Under current RU pricing, the relative competitiveness of pay to pollute for this fleet, would lead expectations of significant demand for oil at least out to the mid-2030's".* (Smith, 2025)

As UCL's analysis of the proposed IMO legislation points out, conventional marine fuel producers are given a clear signal of continued demand for their product. The large existing fleet of conventional ships that will continue to need oil will likely sustain significant demand until at least the mid-2030s.

The development of future fuel demand is inherently difficult to predict, as it is shaped by a wide range of interrelated factors, behaviours, and objectives among multiple stakeholders. At the national level, only broad tendencies can be identified, since local conditions play a decisive role in shaping outcomes, and individual stakeholder initiatives often act as key drivers for scaling demand. On the demand side, DNV's 2025 forecast suggests that total demand for maritime transport measured in tonne-miles will grow by around ten percent by 2030 before levelling off and eventually returning to today's levels by mid-century (Figure 36). This projection is based on the assumption that future maritime transport will become increasingly decoupled from economic growth as economies rely more on services rather than goods, and that countries and regions will become more self-sufficient. As a result, the Baltic Sea Region can expect moderate growth in transport activity up to 2030 and a more uncertain trajectory thereafter, which limits the rate at which overall fuel demand will increase.

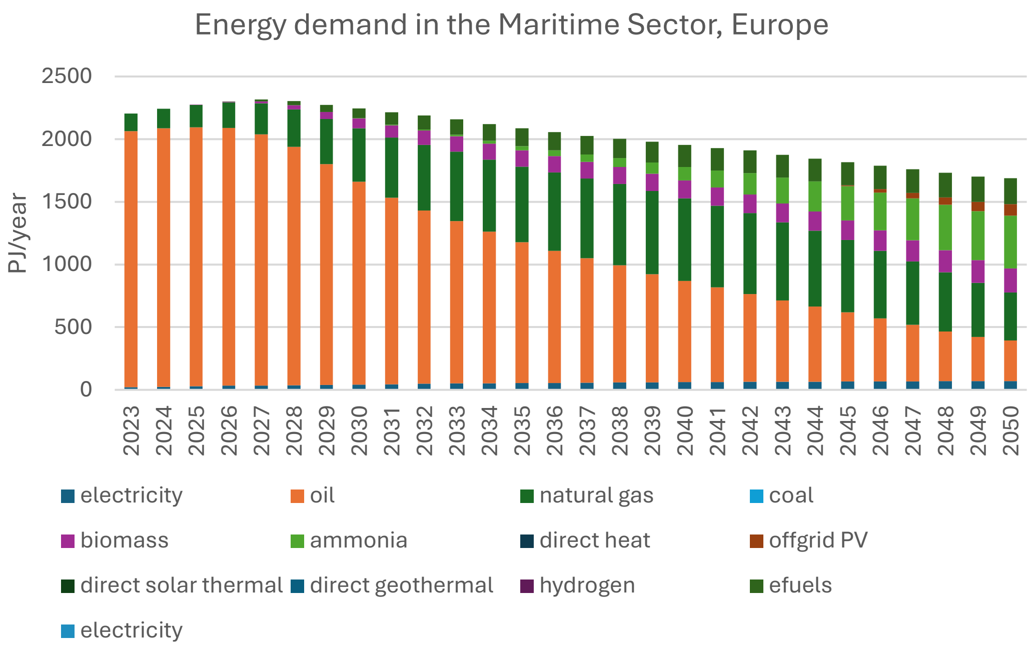

Figure 36. Projected demand based on primary energy source in the scenario suggested by DNV 2025.

For the Baltic Sea Region, the near-term outlook found in this report suggests that supply will consist mainly of small-scale and pilot projects for electrolysis and electrofuel production, complemented by a few commercial facilities. Demand for renewable fuels will likely grow slowly, with early adoption taking place in ferry services and among operators participating in incentive schemes (especially FuelEU maritime pooling). However, these demands are likely to be met by biofuels rather than electrofuels unless singular largescale projects are released and directly aimed at the maritime market, for example the Danish projects on Bornholm.

To reduce these risks and support a more stable market for electrofuels in the Baltic Sea Region, coordinated measures will be required. These include demand guarantees or offtake agreements, phased investment in bunkering infrastructure linked to credible projections of ship-level fuel uptake, stronger carbon pricing to improve the competitiveness of electrofuels, and regional collaboration on expanding renewable electricity generation. Scenario-based planning that converts announced projects into realistic supply projections will help policymakers, shipowners and port authorities design strategies that limit the risk of both supply shortages and stranded investments.

Demand for renewable fuels driven by FuelEU Maritime

As the market is still in an early stage, it remains uncertain which development pathway is most likely. To provide an indication of how future energy demand for electrofuels may evolve, two scenarios for renewable fuel use in the European Union was utilized (Fridell et al., 2022). These scenarios combine projections of maritime transport demand with the carbon-intensity reduction targets outlined in FuelEU Maritime.

The analysis is based on two transport seaborn trade demand trajectories from DNV (2020): a **High scenario** with 200% growth by 2050 and a **Low scenario** with 40% growth in transport demand. The future ship energy requirements are then estimated based on assumptions about transport work, ship size changes, improved vessel capacity utilization, and expected energy efficiency gains, based on EEDI requirements (Fridell et al., 2022). Fuel consumption is calculated by applying these parameters to MRV data through an equation that accounts for changes in transport work, vessel efficiency, size, and utilisation between 2024 and 2050 (Fridell et al., 2022). Figure 37 shows the two scenarios used to estimate energy needs per ship type until 2050 for the European shipping fleet. Container ships represent the largest share of energy needs today, followed by RoPax ships.

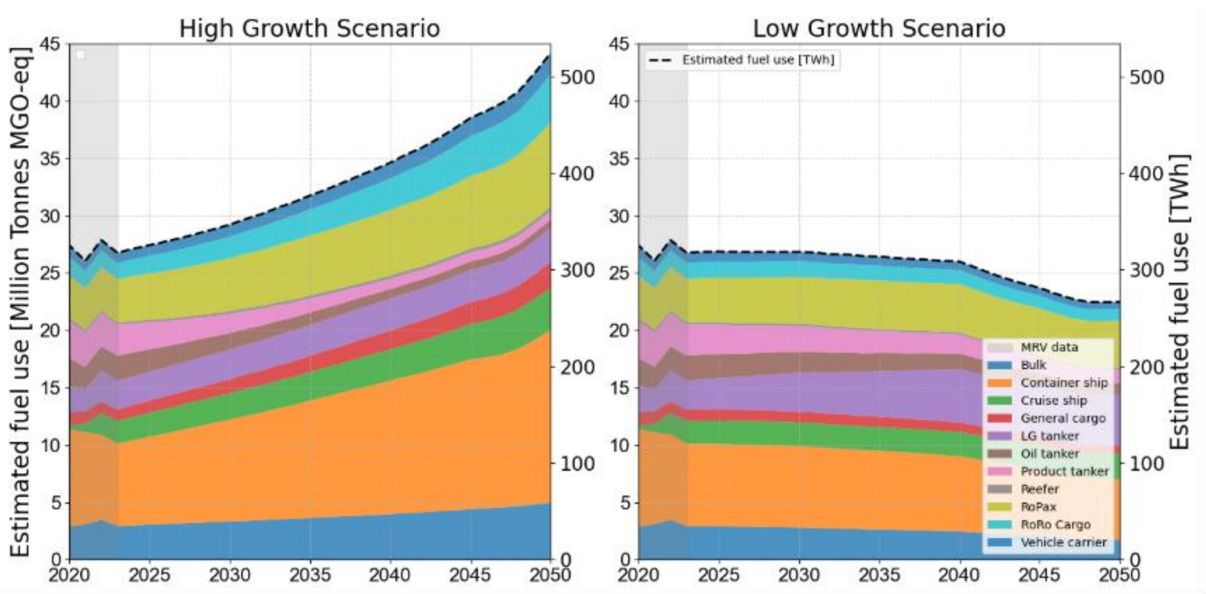

Figure 37. Calculated energy scenarios for the European shipping fleet. The grey area indicates where the calculation is based on real data as reported to MRV for 2020-2023 and estimated data from 2024 onwards.

The potential demand for renewable bunker per year was estimated using the demand set each five-year period by FuelEU Maritime and the scenarios presented in Figure 37. An average greenhouse gas emission factor for renewable fuel alternatives was assumed for the calculations based on Brynolf et al. (2023) and vary between 10.2 g CO_2 eq./year (2025) and 5.9 (2050). The results are shown in Figure 38. Since the baseline fleet scenario is dominated by ICE engines, and the average emission factor for green fuels also accounts for different types of drivetrains (e.g., battery-electric engines), these results should be interpreted with caution, as these drivetrains have different overall efficiencies.

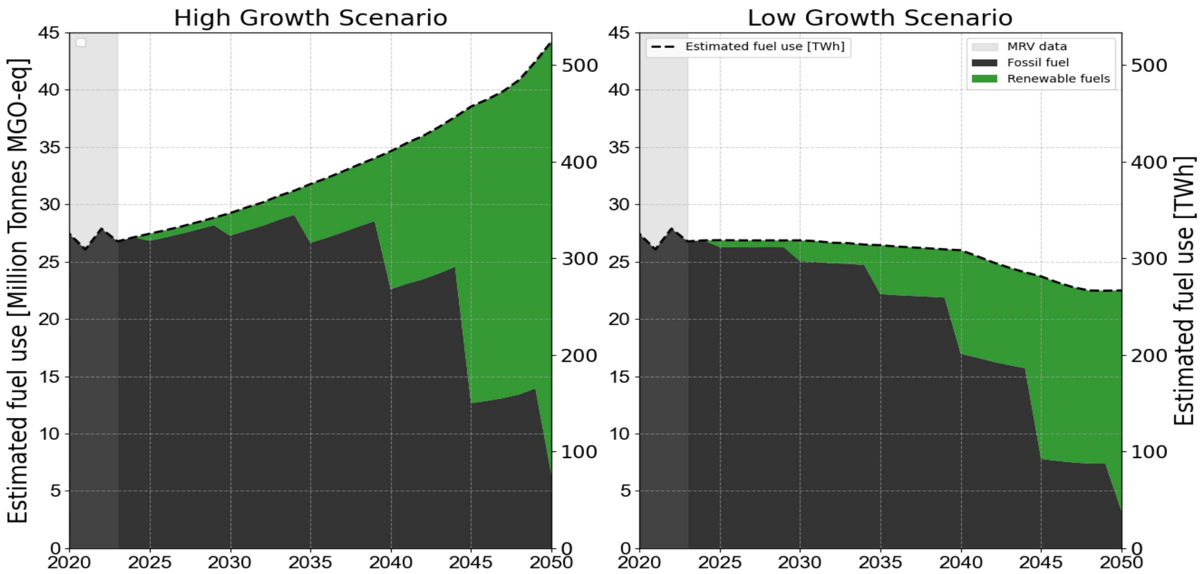

Figure 38. Potential demand of renewable fuel alternatives in the European Shipping fleet to meet the FuelEU Maritime targets.

The demand grows each year from the introduction of the requirements in 2025 in both scenarios. The increase is significant in terms of total volume beyond 2035. The high growth scenario reaches levels of 38 million tonnes of renewable fuel requirements in 2050, and the low growth scenario 19 million tonnes. This could be filled by electrofuels, but also direct use of electricity and biofuels. The share which will be met by electrofuels is yet unknown.

Major bunkering ports

From the mapping of infrastructure projects in the region we have noted that most projects are planned and operational in or adjacent to the major bunkering ports of today. These are Port of Rotterdam, Port of Antwerp, Port of Gothenburg, and Port of Skagen. In the survey a total of seven ports stated that they have vessels bunkering every day in the port, indicating that they could have a significant future role regardless of if there will be local production of electrofuels. Since there is already established infrastructure and a long-standing tradition of bunkering in these ports, it is likely that they will continue to play a central role as hubs for fuel supply in the future. They possess existing facilities, logistical flows, customer-base, and expertise that make them well positioned to adapt to future fuels and new bunkering solutions. This provides both practical and economic advantages, reinforcing their role as key bunkering hubs within a more sustainable maritime system.

Considering the fuel and infrastructure projects that are planned and already in the pipeline, at least the following ports appear particularly interesting for the future distribution of electrofuels in the Baltic region:

- Port of Rostock
- Port of Hamburg
- Port of Aalborg

- Port of Tallinn
- Port of Rønne
- Port Esbjerg
- The Port of Klaipėda
- Ports of Stockholm (i.e. Kapellskär, Stockholm, Stockholm Norvik och Nynäshamn)
- Port of Gdynia
- Port of Skagen
- Port of Gothenburg
- Port of Helsinki
- Port of Kiel
- Port of Ventspils

It is unlikely that all these ports will take on a leading role, but a few are likely to establish themselves as central bunkering ports as new fuels are introduced and demand increases. A central finding of this report is the critical need for coordinated infrastructure planning across the Baltic Sea basin. Several ports are already positioning themselves as future electrofuel hubs, yet their plans remain largely national in scope.

Alongside the established ship-bunkering hubs, new opportunities are emerging for additional ports to position themselves as bunkering nodes. This is particularly the case when electrofuel production is planned in close proximity to the port. Local production enables local bunkering, reducing the need for fuel transport and thereby lowering overall costs. As a result, these ports are expected to assume a new and increasingly important role in the future bunkering landscape of the Baltic Sea Region.

There are bunker on offer today in most of the interviewed and surveyed ports, if requested by a shipping company. Bunkering from shore-to-ship is primarily taking place in a few ports with major energy ports, but bunkering from ship-to-ship has occurred in almost all ports and is the most common bunkering method reported. Ship-to-ship bunkering offers a large degree of flexibility on where a bunkering activity takes place and means that bunkering of renewable fuels is not tied to bunker being stored in adjacent ports to a shipping activity, line or vessel route. It is therefore likely that if a port will handle electrofuels it is more dependent on that it has available import infrastructure or production in the region where the fuel is then stored in the port area. This was brought up as a primary aspect by both port authorities and terminal companies in the interviews and has been highlighted by for example UNTAD (2025) which stated regarding hydrogen specifically that “Countries that aspire to harness ports to develop a green hydrogen economy need to invest in import and export terminals, port equipment such as refuelling stations and bunkering infrastructure and pipelines to transport hydrogen.”

5.4. Feasibility of export/import

Globally, hydrogen trade is one of the key drivers for hydrogen project announcements and development. According to the IEA, export-oriented low-carbon hydrogen production from announced projects are expected to account for about 45% of total production volumes by 2030 (IEA, 2025). However, large uncertainties around their realisation by 2030 exists since only about 5% of the announced projects have reached the investment stage. Most of the announced projects are in countries with limited capital and export infrastructure. This underlines gaps in distribution networks whereby lack of hydrogen export terminals, plants and port handling capacity in some global regions can hinder market scale-up. Furthermore, approximately 40% of the announced export-oriented projects are at a very early stage and around 55% are undergoing feasibility studies. Most of the announced hydrogen projects target exports to North Europe primarily to Germany and Netherlands (IEA, 2025 p. 127). Most of the projects are located in the Middle East, North Africa, as well as Central and South America. China and the United States are considered the most likely to make the announced electrolysis projects operational by 2030.

Hydrogen imports to the EU

RePowerEU Plan (2022) envisages that up to 50 percent of the EU hydrogen will be covered by imports. A special report by the European Court of Auditors (ECA, 2024) evaluating the EU's industrial policy on renewable hydrogen, and particularly the import targets set for 2030 highlighted several uncertainties. The report notes:

> *"For imports, the REPowerEU plan refers to 10 Mt of imported hydrogen. However, one Commission document indicates that imports are composed of 6 Mt of renewable hydrogen and approximately 4 Mt of ammonia, a hydrogen derivative <...> It is not clear whether this figure refers to 4 Mt of hydrogen that should be imported (equivalent to around 25 Mt of ammonia) or 4 Mt of ammonia (equivalent to 0.6 Mt of hydrogen)". (ECA, 2024 p. 22)*

Considering these inconsistencies, the projected renewable hydrogen import volumes to the EU by 2030 should be viewed as largely aspirational. Current assessments suggest that total hydrogen imports are likely to remain modest until around 2040 - below 10 Mt in total (ECA, 2024, p. 24).

In this context, the three major hydrogen import corridors are considered to play a central role in supplying Europe, including the Baltic Sea Region countries, with green hydrogen namely the Mediterranean route, the North Sea route and Ukraine (when the conditions allow). Each corridor presents different cost structures for imported green hydrogen and its derivatives depending on transport distance and mode (pipelines versus shipping).

Soler et al., (2022) estimated electrofuel costs when produced and imported to Europe from other regions and found that very long transport distances do not result in significant differences of liquid electrofuel costs if compared to similar electrofuels produced locally in the South of Europe. However, long transport distance has considerable influence on the imported green hydrogen costs in Europe. A study by Galimova et al., 2025 compared the cost of importing green e-methanol from solar-rich regions such as Chile and Morocco with local production costs in Germany, Finland and Spain. The results indicate that imports to Germany could reduce costs by up to 15% from 2040 onwards. In countries with higher local production costs, such as Finland, imports appear economically viable both in the short- and long-term, offering cost reductions from 6% to 37%, depending on the exporter and the year imports take place. The study also highlights that pipeline transport is more cost-effective option for distances up to 420-475 km, whereas shipping becomes more competitive beyond that range (Galimova et al., 2025).

Looking at the policy landscape enabling future imports of hydrogen and H_2-derivates to Europe, the EU signed Memorandums of Understandings and Green Hydrogen Partnerships on green hydrogen with several countries such as Egypt, Japan, Morocco, Kazakhstan, Ukraine and Namibia. In addition, ongoing negations on free trade agreements with India and Australia as well as EU-Chile Association agreement has provisions on green hydrogen cooperation. However, as noted by Lenivova (2022), large-scale imports of renewable hydrogen from outside Europe and as envisioned in the EU-level targets, are unlikely to materialise by 2030. Instead, the first international trade flows are expected to remain within Europe, primarily between countries such as Norway, Germany, and the Netherlands, before more distant suppliers become viable.

Hydrogen import and export landscape in the Baltic Sea Region

In the Baltic Sea Region, several countries have announced plans for the export of hydrogen and electrofuels to other EU countries. These ambitions are particularly explicit in those countries that have adopted national hydrogen strategies. For example, Lithuania sees the export of hydrogen and hydrogen-based fuels to nearby EU markets as a potential future niche, given the country's geographical location and its integration within the Baltic energy market. The goal is to have at least 33 000 tonnes of hydrogen available for exports by 2030. The scale of export-oriented hydrogen production remains largely unclear across other Baltic Sea Region countries, as specific volumes dedicated to exports by 2030 have not yet been clearly defined or are subject to successful realisation of large-scale projects.

Regarding renewable electrofuels imports in the Baltic Sea Region countries, Germany has the clearest and most advanced strategy. In 2024, the Federal Ministry for Economic Affairs and Energy adopted Germany's import strategy for hydrogen and H_2-derivates, under which the Federal Government expects to import around 50-70% of its hydrogen and derivative fuel demand by 2030. This corresponds to approximately 45-90 TWh of hydrogen. The country's total hydrogen demand is estimated to reach 95-130 TWh by 2030 (BMWK, 2024), However, the demand for hydrogen and H_2-derivates is expected to develop in other industrial sectors first, while demand for maritime transport purposes is expected to develop in the medium to long term:

> *"Due to long investment cycles required to replace vessels' propulsion systems, a large demand for various hydrogen derivatives is not to be expected before the medium or long term". (BMWK, 2024 p. 11).*

As shown in Table 2, apart from Germany, most Baltic Sea Region countries do not yet have fully developed hydrogen and H_2-derivates import strategies at the national level. In general, the production volumes outlined in national hydrogen strategies are oriented towards domestic consumption and export of hydrogen-based goods rather than large-scale fuel imports.

6. Concluding remarks

The Baltic Sea Region is emerging as a strategic hub for the development and deployment of hydrogen and its derivatives (methanol, hydrogen and ammonia), driven by the region's strong renewable energy potential, particularly offshore wind, and its position as a key transport and industrial corridor in Northern Europe. Sweden, Finland, Estonia, Latvia, Lithuania, Poland, Denmark, and Germany's Baltic Sea coastline are all advancing hydrogen roadmaps and pilot projects, though with differing levels of maturity and focus.

While several national strategies highlight hydrogen as a cornerstone of decarbonisation, the pace of implementation varies. Northern countries, particularly Finland and Sweden, are leading in research, industrial integration, and cross-sectoral hydrogen use, while Baltic States focus more on enabling frameworks and attracting foreign investment. This uneven progress poses challenges for regional integration but also creates opportunities for complementary specialisation, such as hydrogen production in renewable energy-rich areas and derivative processing or consumption in industrial and port clusters.

The hydrogen initiatives in the region form a diverse landscape with various drivers and end goals. The countries in the region demonstrate noticeable drivers and strategic focuses for hydrogen and hydrogen-derivative development, reflecting their respective energy systems, industrial structures, and national priorities. Most of the countries share a commitment to expanding hydrogen capacity in terms of producing, storing, transporting and bunkering of fuels, but their motivations vary, from export ambitions and industrial competitiveness to energy independence and ensuring a balanced energy system. Denmark, for example, benefits from a surplus of renewable electricity and therefore prioritises large-scale hydrogen and electrofuel production for export and for decarbonising international transport. In contrast, Poland's strategy is more domestically oriented, driven by the need to decarbonise heavy industry and reduce dependence on fossil-based hydrogen. Sweden and Finland emphasise integrating hydrogen into industrial transformation processes, particularly in the steel and chemical sectors, while Germany combines industrial decarbonisation with strong policy support for import corridors and international partnerships. The Baltic States (Estonia, Latvia, and Lithuania) are in earlier stages of development but increasingly consider hydrogen to strengthen energy security and regional integration.

Against this diverse national backdrop, the pace and direction of hydrogen market development depend on the strength and coherence of policy and regulatory frameworks at both EU and national levels. While countries pursue different strategic priorities, the alignment of rules, incentives, and infrastructure planning across the region is emerging as a key prerequisite for large-scale deployment. While current policy and regulatory measures are sufficient to initiate the uptake of hydrogen and its derivatives, they remain inadequate to support their large-scale deployment and market integration. Stronger and more coherent frameworks and market mechanisms are needed to accelerate the scale-up of renewable hydrogen and H_2-derivates in the short, medium and long-term. The European Court of Auditors (2024) evaluating the EU's industrial policy on renewable hydrogen has likewise concluded that the effects of the current EU rules on renewable hydrogen market ramp-up, as well as the cost competitiveness of renewable hydrogen, remain uncertain. Furthermore, the work on standardisation and certification is yet to be done.

Future outlook

The future of hydrogen and hydrogen derivatives in the Baltic Sea Region will depend largely on two interconnected dimensions: the ability to scale efficient renewable hydrogen production and the establishment of reliable offtake markets. Furthermore, the feasibility of large-scale hydrogen derivative trade within, to and from the Baltic Sea Region will depend on the timely realisation of announced projects and supporting infrastructure as well as the development in the rest of the world. Despite export-oriented ambitions, especially in Denmark and Finland, the region's overall production capacity and port readiness remain at an early stage.

Electrofuels, including e-methanol, e-ammonia, remain a longer-term option, likely to be driven by aviation and heavy transport decarbonisation policies rather than near-term cost competitiveness. Ammonia stands out for its potential as both fertilizer feedstock and a zero-carbon maritime fuel but also with severe safety and security risks. Methanol, already handled safely in several Baltic Sea ports, offers near-term potential due to its liquid state and compatibility with existing logistics and engine technologies.

For the shipping sector, one of the key economic activities in the Baltic Sea, the adoption of hydrogen derivatives could play a decisive role in realising regional Green Shipping Corridors i.e., emission free routes connecting two or more ports. Following the Clydebank Declaration, several Baltic Sea Region countries have committed at the national level to accelerate the deployment of renewable fuels in maritime transport, with an increasing number of port authorities taking leadership roles. However, the absence of harmonised fuel standards, limited bunkering infrastructure, and a lack of long-term supply contracts continue to undermine investment certainty and slow the transition

To achieve hydrogen and hydrogen derivative production at scale within the region, there is a need for additional regulatory measures and market mechanisms that provide stronger incentives in the short to medium term. Current instruments seem insufficient to deliver the scale and certainty required for maritime large-scale deployment within the near future, a conclusion also supported by previous studies such as Odenweller and Ueckerdt (2024) and Pomaska and Acciaro (2022). Previous research findings indicate that large governmental subsidies will be needed to close the implementation gap between announced hydrogen projects and their actual realisation by 2030. To this end, Odenweller and Ueckerdt (2024) proposed a need of balanced policy mix approach in addressing the upscaling needs of green hydrogen projects. This would require combination of measures such as replacing the current short-term policy push with stable and long-term policy on supply-side subsidies (e.g., fixed-premium auctions for green hydrogen) and combining them with demand-side policies (e.g., clear and more ambitious sub-targets for electrofuels in marine fuel mix). According to Odenweller and Ueckerdt (2024), a gradual shift from subsidies to market-based mechanisms such as ambitious carbon pricing or carbon contracts for difference will be essential to ensure the practical upscaling needs of hydrogen and hydrogen-based synthetic fuels.

Finally, global competition poses an additional challenge. There is a clear risk that countries, such as China, through strategic allocation of substantial resources to develop production capacity and expertise in the manufacture of electrofuels, will establish a significant competitive advantage that the European industry may subsequently find very difficult to overcome. This development could mirror previous patterns observed in the fields of solar photovoltaics and battery technologies. The coming decade will be decisive; choices made now about policy instruments, regulations, collaboration, infrastructure, and governance will determine whether the Baltic Sea Region becomes a central player in the hydrogen derivative economy or remains a follower in a globally competitive field.

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Appendix A List of reviewed material

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Appendix B Definitions of project phases

A project was included in the dataset if it has an assigned location and can be tied to a company, either through published material (such as a press release) or through interviews and survey.

The following phases were used to classify projects in the dataset.

- **Cancelled:** Project has been cancelled with no clear signs of it coming back
- **On hold:** Project has been put on hold for an unknown amount of time
- **Decided – FID:** A final investment decision (FID) has been taken, and the project is set to begin construction
- **Feasibility study:** A feasibility study is currently being performed or has been performed.
- **Planning:** Before construction. Clear plans have been put forward, but there is no FID or ongoing feasibility study that is known of.
- **Construction:** Project is currently under construction
- **Operational:** The site is currently in operation
- **Uncertain:** Information about the project is very scarce, or it has been a long time since there were any updates.