Swedish Environmental Research Institute

Policy Brief and Roadmap Foundations: Conditions for Port of Gothenburg to become a hub for renewable hydrogen-based marine fuels

Julia Hansson, Karl Jivén and Benjamin Storm
IVL Swedish Environmental Research Institute, September 2026

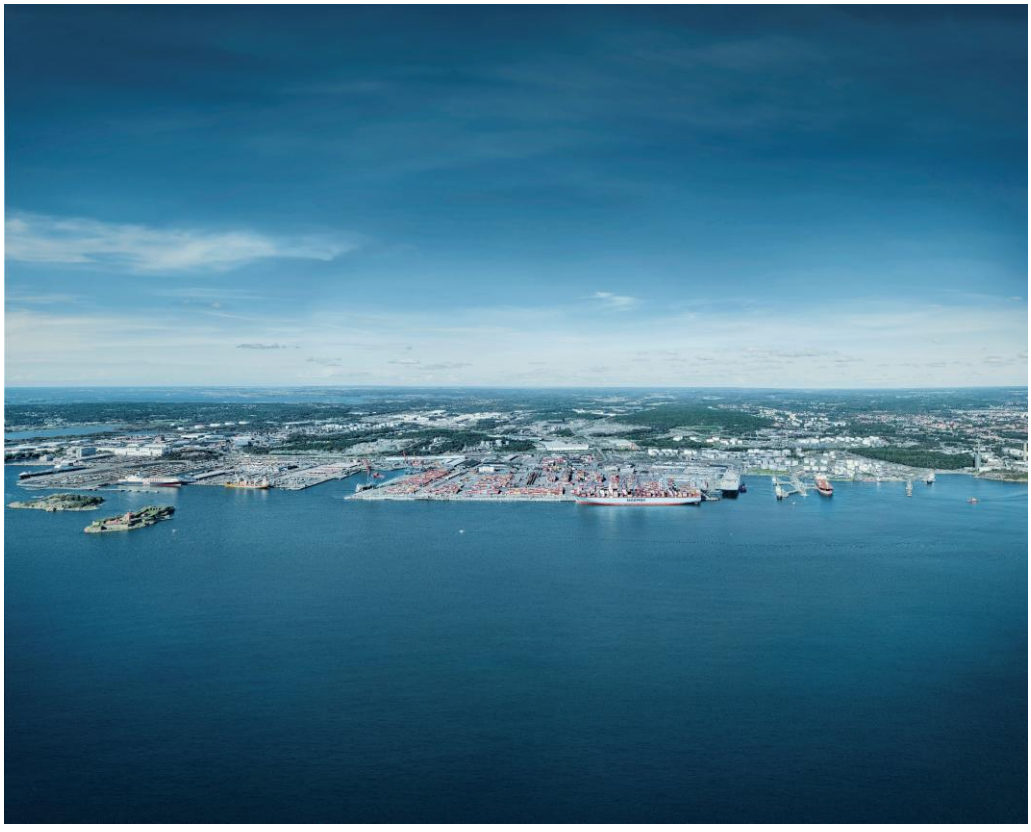


Photo: Port of Gothenburg

Maritime fuel decarbonisation will influence ports

Hydrogen-based energy carriers are widely recognized as central technologies in the transition towards low-carbon energy and transport systems, especially in sectors that are difficult to electrify, such as maritime transport. In this context, ports are strategically positioned to contribute to the deployment of alternative fuels.

Reducing greenhouse gas (GHG) emissions from shipping is necessary to meet the EU climate targets for 2050. For the shipping sector to phase out its GHG emissions by 2050, low-carbon fuels and ships must be scaled up significantly in the coming years. To promote this the EU has introduced policy instruments such as the FuelEU Maritime regulation, which aims to gradually reduce the GHG intensity of maritime fuels until 2050 (Regulation (EU) 2023/1805) and shipping has been included in the EU emissions trading scheme (EU ETS) (Directive 2003/87/EC, 2003).

There are several possible alternative low-carbon maritime fuels e.g., biofuels, renewable hydrogen and other hydrogen-based fuels (the latter produced from electricity, water and carbon dioxide or nitrogen). Ports are expected to become key nodes in the maritime fuel transition, serving not only as centres for fuel handling and storage for the fuels but potentially also for local production and distribution.

This text aims to increase the understanding of the potential for Port of Gothenburg to become a large-scale hub for renewable hydrogen-based maritime fuels, focusing on renewable hydrogen, electro-ammonia, and electro-methanol but also to some extent including biofuels such as liquified biomethane. The possible influence of the FuelEU Maritime regulation on the fuel transition from a Port of Gothenburg perspective will also be addressed.

This text builds mainly on the study "*Local versus regional production of hydrogen-based fuels and port infrastructure with focus on the Port of Gothenburg*"[1] performed within the H2AMN project[2]. In the underlying report there are detailed descriptions of the approach and results including e.g., techno-economic assessments, scenario framework, infrastructure analyses, and fuel production mapping.

POLICY LANDSCAPE

The FuelEU Maritime regulation aims to reduce the GHG emission intensity of energy used on board ships by setting progressively stricter requirements, applicable to vessels over 5 000 gross tonnage[3] (GT). **Figure 1** illustrates the binding reduction trajectory in the FuelEU Maritime, reaching an 80 % reduction in GHG intensity for maritime fuels by 2050 in comparison to the average GHG intensity of the maritime fuel mix in 2020. The FuelEU Maritime applies as so-called Well-to-Wake perspective which means that it covers all

[1] Storm B, Hansson J, Jivén K, Hernández Leal M., 2026. *Local versus regional production of hydrogen-based fuels and port infrastructure with focus on the Port of Gothenburg.* Report C11263. IVL Swedish Environmental Research Institute.

[2] The Hydrogen, ammonia and methanol in hydrogen hubs in the Nordic region (H2AMN) project is funded by Nordic Energy Research, Swedish Energy Agency and Rannis (Iceland) with in-kind contributions from business partners such as the Port of Gothenburg.

[3] Gross tonnage is a measure of a vessel's total internal enclosed volume. It is the internationally standardized way of expressing the overall size of a ship.

emissions from production of the fuel to its final use on board the ship. Combined with the extension of the EU ETS to maritime transport, as well as improvements in ship design, operational efficiency and digitalisation which will reduce total energy demand per unit of transport, this will change the economics, fuel demand, and operational conditions for international shipping.

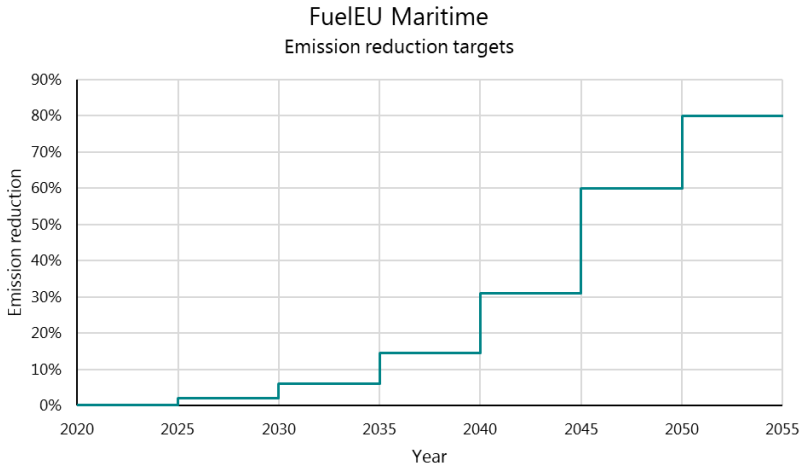


Figure 1. *FuelEU Maritime reduction targets from 2020 to 2050 (Regulation (EU) 2023/1805). The baseline for the emission reduction (corresponding to average GHG intensity of the maritime fuel mix in 2020) is set to 91.16 $gCO_{2equivalents}/MJ$.*

For ports, this transition influences the extent to which different fuels will be used and how the maritime fuels are produced, supplied and distributed. As renewable fuels replace conventional fossil fuels, ports are expected to play an important role in fuel import, storage, bunkering and, in some cases, local fuel production, while strengthening their links to industry, energy systems and international supply chains. Thus, the Port of Gothenburg, already Sweden's primary hub for maritime fuel bunkering, has an opportunity to position itself as a central actor in the maritime fuel transition.

SOME FUEL CHARACTERISTICS

No single alternative fuel is expected to replace today's fossil maritime fuels across all vessel types, routes, and time horizons. Thus, a mix of maritime fuels is expected and likely a broader mix than today. One basic difference between fuel options, that varies substantially, is the energy density. The energy density in terms of volume required per fuel for the same amount of energy in comparison with marine gas oil (MGO) is shown in **Figure 2** for a range of fuel options.

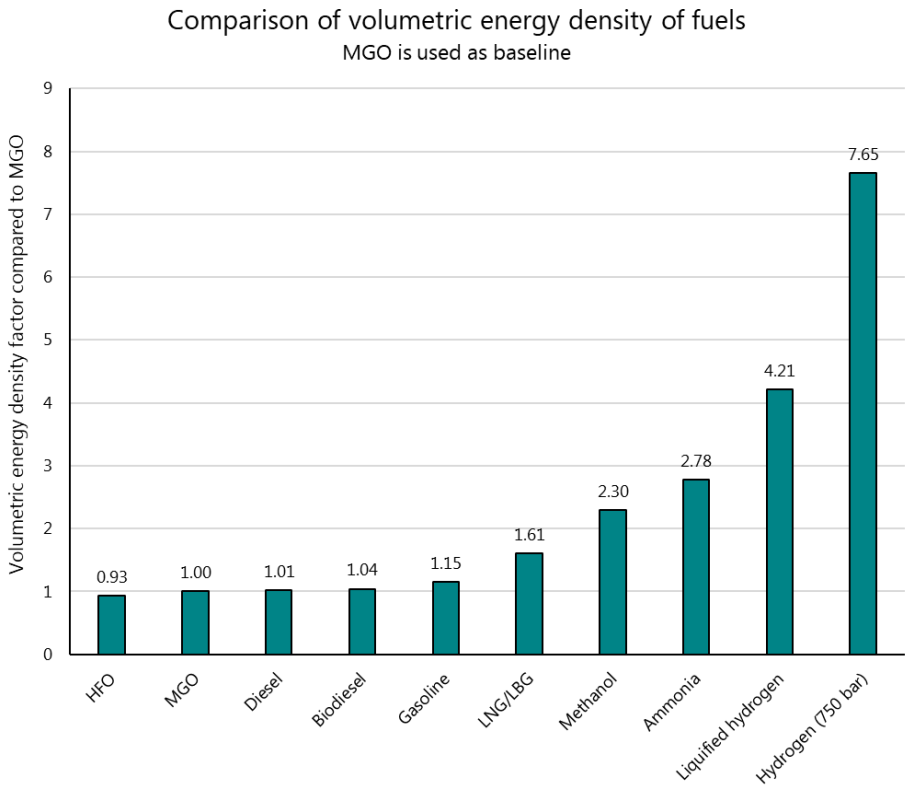


Figure 2. *Volume required per fuel for the same amount of energy, in comparison with marine gas oil (MGO).*

The GHG emissions for different maritime fuels from a Well-to-Wake perspective depend on the production pathway and the propulsion technology used on the ship. Thus, it varies both between different types of fuels and between different production pathways for the same type of fuel.

Although all renewable marine fuels contribute to reducing GHG emissions, they differ considerably in terms of maturity, production pathways, storage and handling requirements, infrastructure needs and operational characteristics. These differences influence both how the fuels may be used in shipping and what they imply for ports. **Table 1** provides a simplified overview of the main characteristics of the renewable fuels assessed in this study from a port perspective.

Table 1. Overview of the main characteristics of the renewable marine fuels assessed in this study from a Port of Gothenburg perspective.

Fuel	Advantages	Operational considerations
Hydrogen	Carbon-free at use, and an important building block for other renewable fuels.	Low volumetric energy density requires large storage volumes and dedicated high-pressure or cryogenic infrastructure. Transport and handling remain relatively costly.
Methanol (bio- and e-methanol)	Mature marine fuel with relatively simple handling and compatibility with much of today's liquid fuel infrastructure. Bio- and e-methanol are chemically identical and can use the same engines, storage and bunkering systems.	Lower energy density than conventional fuels but existing liquid fuel infrastructure can often be adapted with relatively minor modifications. Bio-methanol depends on sustainable biomass resources, while e-methanol requires renewable electricity and renewable CO_2.
Ammonia (renewable)	Carbon-free at use, relatively high energy density compared with hydrogen and well-established global transport and storage for other purposes.	Requires renewable electricity. High toxicity requires dedicated safety measures during storage, handling and bunkering, making widespread adoption in regular port environments unlikely in the short-term. Can largely utilise liquified petroleum gas-type storage and transport infrastructure. Marine engine technology and operational experience are still developing.
Liquefied bio- or e-methane (LBM)	Relatively high energy density and fully compatible with LNG engines and infrastructure.	Requires cryogenic storage and handling but can utilise existing LNG infrastructure. Long-term deployment depends on sustainable feedstock availability and electro-production costs.
Biofuels (HVO/FAME)	High energy density and high compatibility with existing engines and infrastructure, allowing straightforward implementation with limited technical modifications.	Minimal infrastructure changes are required, but long-term deployment is constrained by sustainable biomass availability and competing demand from other sectors.

SCENARIO FRAMEWORK

Four alternative maritime fuel scenarios for reaching the FuelEU Maritime emission reduction targets by 2030 and 2050 (i.e., having different fuel mixes) are developed in the underlying report. These are applied to two different potential future maritime fuel demand cases relevant from a Port of Gothenburg perspective. These illustrative scenarios are intended to assess how different fuel pathways may affect the demand for different fuels, infrastructure needs, production requirements, costs and supply.

The two future maritime fuel demand perspectives include:

- **Ship fuel consumption linked to the Port of Gothenburg** case that refers to the estimated annual fuel consumption of ships calling at the port. This is based on fuel used during port operations and an allocation of 50% of the fuel consumption from voyages to and from Gothenburg.
- **Bunkering volumes in the Gothenburg area** case that represent the estimated total annual fuel volumes supplied to ships in and around the wider Gothenburg area. These volumes are substantially larger than the fuel consumption directly associated with ships calling at the Port of Gothenburg (currently roughly a factor ten larger). Due to the presence of major refineries, fuel terminals and bunkering infrastructure, approximately 80% of all marine fuels bunkered in Sweden are currently bunkered in the Gothenburg area.

The following four alternative maritime fuel mix scenarios are evaluated:

- **Biobased scenario** with higher shares of biofuels such as biomethanol and biodiesel.
- **RFNBO scenario** with higher shares of so-called renewable fuels of non-biological origin (RFNBOs), here including hydrogen, electro-methanol and electro-ammonia.
- **Gas scenario** with a fuel mix dominated by liquefied bio-methane and liquefied natural gas (LNG). Electro-methane is also one possibility but is not included in this study.
- **Mixed scenario** with a combination of the fuel scenarios including a mix of alternative fuels.

Besides the transition to alternative fuels, the demand for maritime fuels will also depend on the development of the shipping demand, which is influenced by for example transport work, ship size development, fuel efficiency improvements and cargo utilization. To consider this, each fuel mix scenario is analysed under a low-growth and a high-growth demand development, resulting in a range of possible futures for 2030 and 2050. In this text the focus is on the so-called low-growth shipping demand case[4] corresponding to a total decrease in maritime fuel demand in energy terms, of approximately 20% between 2025 and 2050. This is illustrated for different shipping segments in the EU in **Figure 3**, however the same approximate expected decrease is valid also for the two Gothenburg related fuel demand cases assessed here. In fuel demand terms, the ship traffic by roll-on/roll-off (RoRo) vessels, product tankers, roll-on/roll-off with passengers (RoPax), oil tankers and container ships represent the larger shares for the Port of Gothenburg. For illustrative purposes, **Figure 3** also shows the high-growth shipping demand scenario, which is used in the underlying report but not in this policy brief.

[4] In the low growth case, a 40% increase in transport work by 2050 compared to 2020 is assumed. The size of certain ship types (bulk ships, container ships and gas tankers) is assumed to increase. In addition, fuel efficiency improvements according to the Energy Efficiency Design Index (EEDI) regulation is assumed and cargo utilization for container ships improves somewhat.

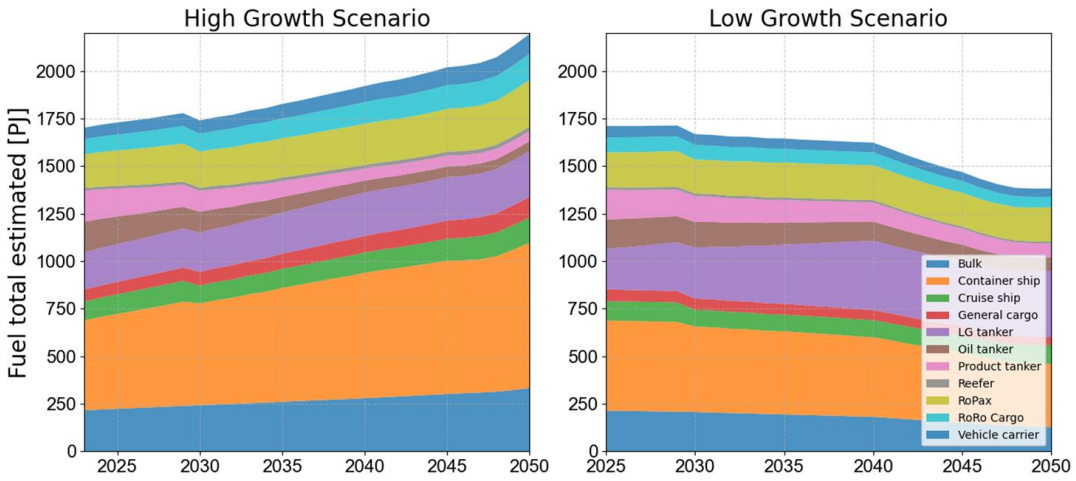


Figure 3. *Estimated total maritime fuel demand in the EU[5] in a high and low-growth shipping demand scenario considering transport work and efficiency changes.*

[5] The EU here represents the European Economic Area (EEA) which is the EU27 plus Norway, Iceland and Liechtenstein.

The Port of Gothenburg's future role in the maritime fuel system

Approximately 80 % of all marine fuels bunkered in Sweden are today handled in and around the Port of Gothenburg area. This situation, combined with the presence of refineries, energy terminals, industrial users, and strong hinterland connections, gives the Port of Gothenburg a key role in any future low-carbon fuel system.

The estimated development of maritime fuel demand linked to the Port of Gothenburg, for the Gothenburg area bunkering volume case, and the alternative future fuel mix scenarios is shown in **Figure 4**. The fuel consumption volumes presented in the figure reflect Gothenburg's role as a regional fuel supply and bunkering hub and not only the fuel demand generated by ships calling at the port. Due to the concentration of refineries and fuel infrastructure in the area, a large share of fuel is supplied to vessels operating elsewhere. As mentioned, total bunkering volumes are currently estimated to be roughly about ten times larger than the fuel consumption associated with port calls in Gothenburg, i.e., representing the other future maritime fuel demand perspective included. The corresponding figure for the latter case looks similar but with approximately a factor of 10 lower estimated fuel demand per year.

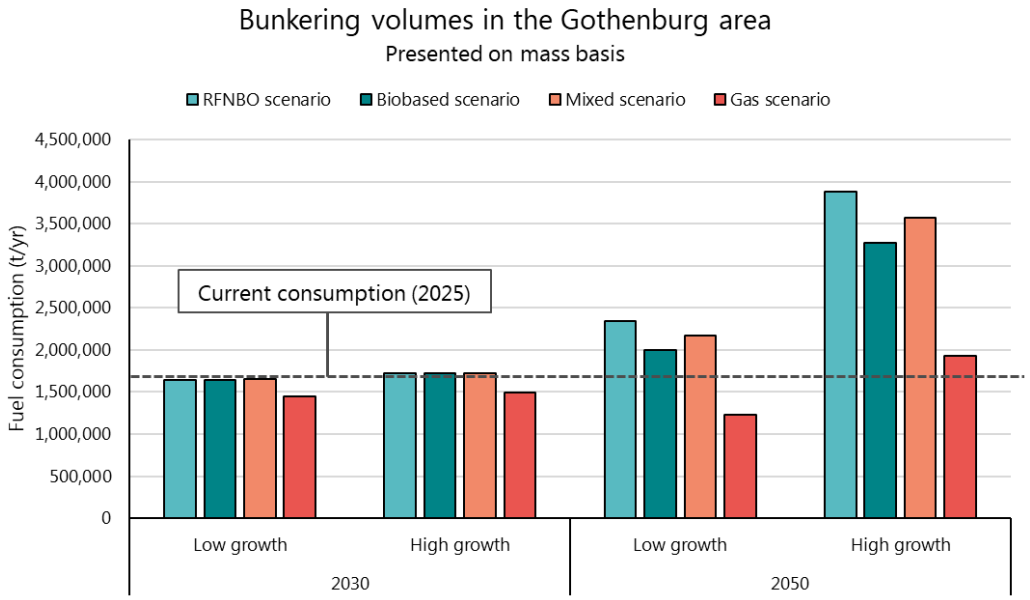


Figure 4. *Estimated bunkering volumes (in ton fuel per year) in the Gothenburg area for four different fuel mix scenarios (for descriptions see the text), presented for a high and low maritime fuel demand growth case in the year 2030 and 2050. The black dashed line indicates the assumed current (2025) bunkered volumes.*

FUEL SCENARIOS IN LINE WITH FUELEU MARITIME

Several different fuel pathways i.e., fuel mixes can meet the FuelEU Maritime requirements in 2030 and 2050 The estimated demand for various fuels in the different fuel scenarios for the Gothenburg area bunkering volumes case (and for the low growth scenario) can be seen in **Figure 5 5** and the corresponding findings for the ship fuel consumption linked to the Port of Gothenburg case in **Figure 6**. The corresponding approximate share of the various

fuels for the fuel mix scenarios (for the low growth case) are illustrated in **Table 2**. All the developed fuel mix scenarios can technically meet the FuelEU Maritime requirements by 2030 with relatively limited changes. By 2050, however, differences become pronounced.

One key conclusion, for the Port of Gothenburg is that the **demand for renewable and low carbon fuels will increase sharply**, particularly after 2035. A mixed fuel strategy, combining biofuels, electrofuels (RFNBO) and electricity, seems to offer the most realistic pathway to comply with regulation while maintaining operational and economic robustness.

The results assume that the ships representing the fuel demand for the two maritime fuel demand perspectives relevant for the Port of Gothenburg jointly reaches the FuelEU Maritime regulation. This means that they can meet the requirements individually or by pooling[6] with other ships included in this specific demand case. As the pooling mechanism within the regulation allows ships to combine their compliance levels and be assessed together instead of individually, the vessels could also pool with ships outside these demand cases. The impact of this depends on which ships are responsible for the reduction. If individual ships calling at Port of Gothenburg use a large share of renewable fuels and pool with other ships the demand for renewable fuel could be higher.

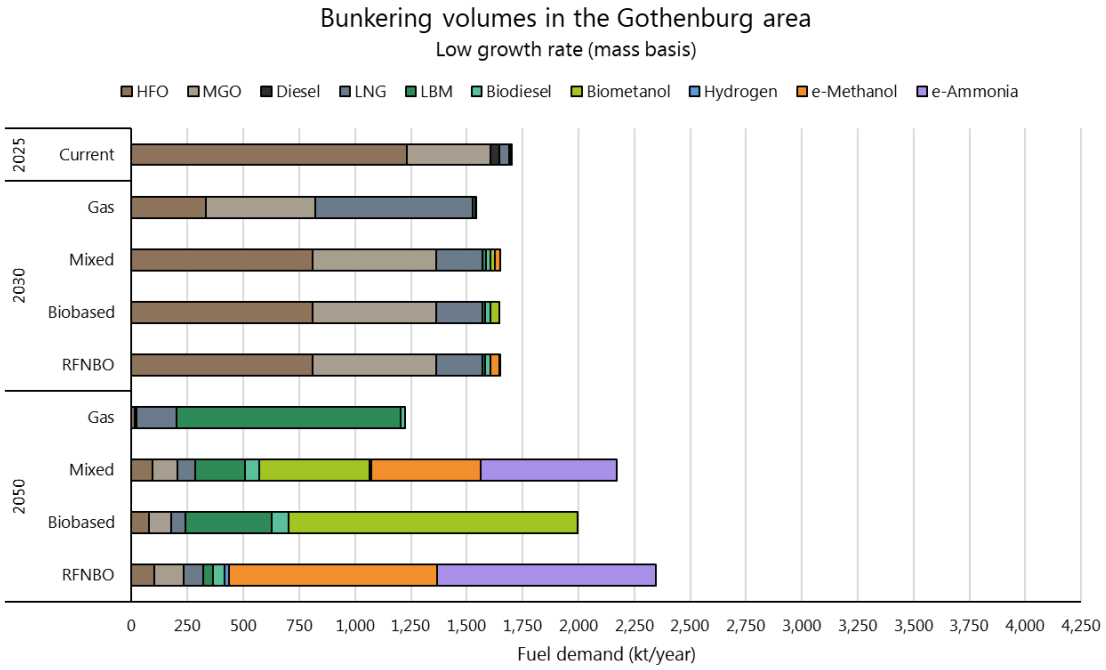


Figure 5. *Estimated fuel demand (in kton per year) in the different fuel mix scenarios for the Gothenburg area bunkering volumes case and the low growth demand case in 2025, 2030 and 2050.*

[6] The pooling mechanism in FuelEU Maritime allows several ships to be treated as a group for compliance purposes. Ships that use fuels with a lower greenhouse-gas intensity than required can compensate for ships in the same pool that exceed the target. If the pool, as a whole, meets the required GHG intensity level, all participating vessels are considered compliant. This gives shipowners flexibility to deploy renewable and low-carbon fuels on the vessels where it is most practical or cost-effective.

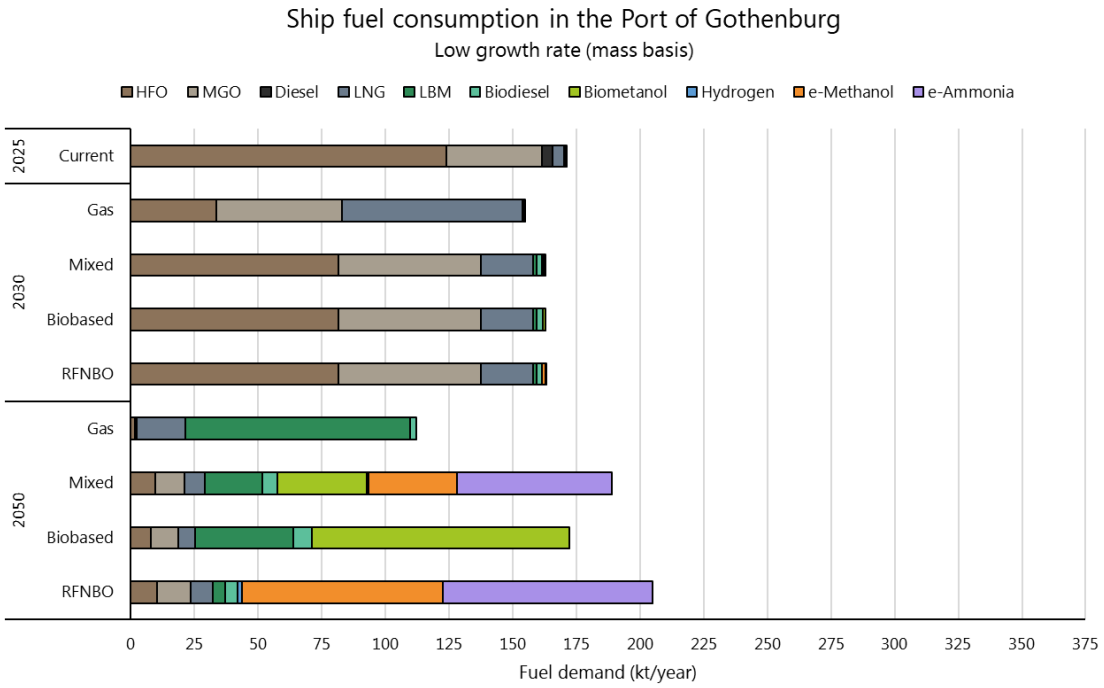


Figure 6. *Estimated fuel demand (in kton per year) in the different fuel mix scenarios for the ship fuel consumption linked to the Port of Gothenburg case and the low growth case in 2025, 2030 and 2050.*

Table 2. *Estimated share of each fuel in the different scenarios in 2030 and 2050 for the low growth case, in energy terms.*

Fuel: Low growth case	Assumed current (2025)	RFNBO (2030)	RFNBO (2050)	Biobased (2030)	Biobased (2050)	Gas (2030)	Gas (2050)	Mixed (2030)	Mixed (2050)
LNG	3%	14%	7%	14%	6%	50%	16%	14%	7%
MGO	22%	34%	10%	34%	8%	30%	1%	34%	8%
HFO	72%	48%	7%	48%	6%	20%	1%	48%	7%
Diesel	2.5%	0%	0.0%	0%	0%	0%	0%	0%	0%
Gasoline	0%	0%	0.0%	0%	0%	0%	0%	0%	0%
Biomethane	0.3%	0.9%	3.8%	0.9%	30.7%	0.36%	70.6%	0.9%	17.9%
Biodiesel	0.4%	1.4%	3.8%	1.4%	5.7%	0.12%	1.6%	1.3%	4.7%
Electricity	0%	0.9%	11.4%	0.9%	10.5%	0.32%	9.9%	0.9%	10.9%
Hydrogen	0%	0%	3.8%	0%	0%	0%	0%	0%	1.6%
e-Methanol	0%	0.3%	26.5%	0%	0%	0%	0%	0.2%	11.7%
Biometanol	0%	0%	0%	0.3%	34%	0%	0%	0.2%	11.7%
e-Ammonia	0%	0%	26.5%	0%	0%	0%	0%	0%	19.5%
Fossil	99.3%	96.5%	24.3%	96.5%	19.2%	99.2%	18%	96.5%	22%
Renewables	0.7%	3.5%	75.7%	3.5%	80.8%	0.8%	82%	3.5%	78%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

NEED FOR ADDITIONAL MARITIME FUEL PRODUCTION TO MEET FUTURE DEMAND

The estimated approximate number of renewable fuel production plants required by 2050 to meet the projected maritime fuel demand in the two future maritime fuel demand perspectives cases is shown in **Table 3**.

Table 3. Example that shows the estimated number of plants of different types required to meet the 2050 fuel demand of electro- and biomethanol as well as electro-ammonia in the Gothenburg area bunkering volume case based on reference plant capacities (representing size of planned plants). The low and high range represents the two shipping demand cases included i.e., ship fuel consumption linked to the Port of Gothenburg and bunkering volumes in the Gothenburg area.

	Number of fuel production plants		Reference plant capacity (t/yr)
	Mixed scenario	RFNBO or Biobased scenario	
Electro-methanol[7]	0.35- 5	0.8-9.5	100 000
Biomethanol[8]	0.35-5	1-13	100 000
Electro-ammonia[9]	0.1-1	0.15-2	550 000

For the Gothenburg area bunkering volume case and in terms of hydrogen there is only an estimated minor hydrogen demand in 2030 in the RNFBO. To meet the demand in the RFNBO case an electrolyser of up to 2.5 MW would be required. By 2050 the estimated hydrogen demand in the RFNBO and mixed scenario corresponds to an electrolyser capacity of 115 – 205 MW and 50 – 85 MW, respectively, corresponding to the size of one mid-to-large sized commercial hydrogen production plant. For the ship fuel consumption linked to the Port of Gothenburg case a factor ten lower hydrogen production would be needed. In terms of biomethane, by 2030 it is estimated that about 10-40 % of the estimated supply potential in Sweden need to be realised to meet the biomethane demand with Swedish production for the Gothenburg area bunkering volume case (and a few procent in the ship fuel consumption linked to the Port of Gothenburg case. By 2050 about 1-120 % of the Swedish biomethane potential is needed with about 3-25 % in the mixed scenario for the ship fuel consumption linked to the Port of Gothenburg case and Gothenburg bunkering case, respectively.

A comparison of the estimated fuel demand corresponding to the future bunker demand of these fuel types in the Gothenburg area by 2050 and planned biofuel and electro-fuel projects in Sweden, thus indicates that the corresponding domestic production of hydrogen-based fuels will not be sufficient to meet the estimated fuel demand. In particular, demand for biomethanol, electro-methanol and electro-ammonia seem to exceed planned supply. Thus, there is a need for additional fuel production investments in Sweden, and/or expanded import flows from other countries. The size of the fuel demand in the ship fuel consumption linked to the Port of Gothenburg case is, however, easier to accommodate with only parts of the planned production capacity in Sweden.

INFRASTRUCTURE IMPLICATIONS

The transition to alternative maritime fuels has important implications for port infrastructure. This is due to both the lower volumetric energy density of renewable fuels compared to conventional ones and to the differing physical and chemical properties of the new fuels. Some fuels, such as methanol, can, with minor modifications, use large parts of

[7] Örnsköldsvik eFuel project — Liquid Wind, https://www.liquidwind.com/ornskoldsvik
[8] Methanol Institute and GENA Solutions. Renewable methanol, https://www.methanol.org/renewable/
[9] Bioenergy International, Fertiberia. Power2Earth Project, https://bioenergyinternational.com/power2earth-consortium-to-develop-swedens-first-fossil-free-mineral-fertilizer-facility/

today's liquid fossil fuel systems. Others, such as hydrogen, ammonia, and liquefied methane, require new storage concepts, safety systems and handling procedures.

The relatively low energy density of hydrogen results in the need for large storage volumes. Also, ammonia, methanol and methane have lower energy density than MGO but does not require similar storage volumes as hydrogen. Hydrogen requires storage capable of withstanding high pressures and resistant to hydrogen embrittlement. Ammonia can be stored in pressure vessels like what is used to store liquid petroleum gas (LPG). For ammonia toxicity is also a key challenge to handle. Liquefied biomethane and LNG are chemically identical, enabling them to share infrastructure and storage systems. However, they cannot use existing liquid hydrocarbon systems and instead require dedicated cryogenic storage and handling facilities.

Estimated potential change in storage and handling volumes for the Port of Gothenburg is illustrated in **Figure 7** for the Gothenburg area bunkering volumes case and for the ship fuel consumption linked to the Port of Gothenburg case in **Figure 8**. Currently there is no significant storage of LNG in the Port of Gothenburg and thus lack of existing storage facilities to be used for liquified biomethane.

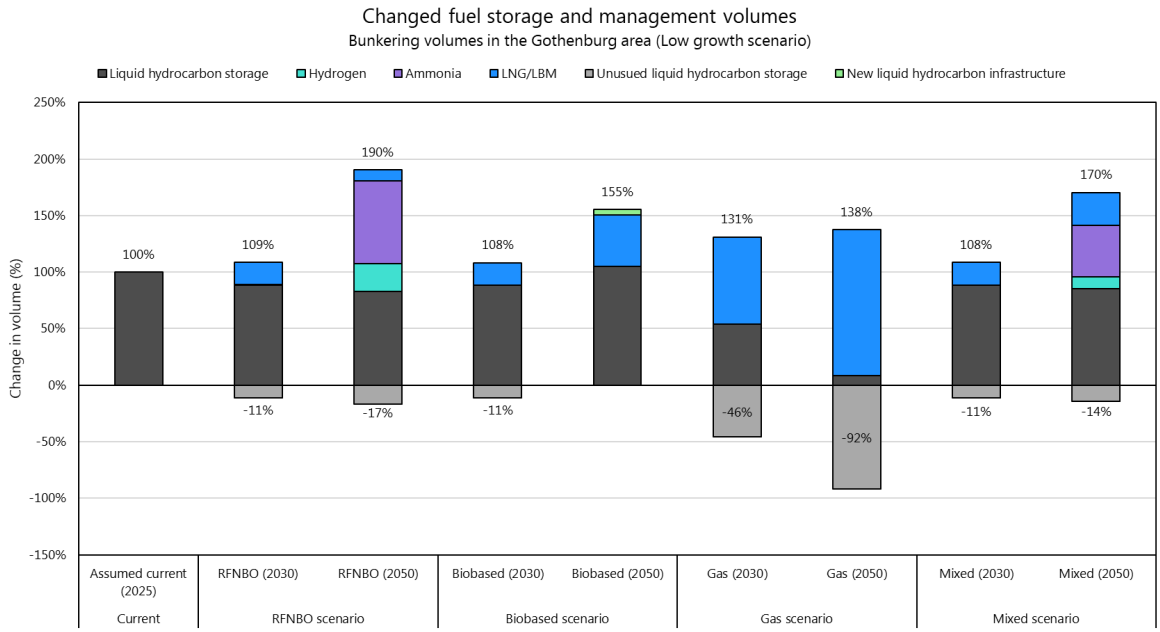


Figure 7. *Changes in fuel handling and required storage capacity, in percentage, compared to current volumes (2025) for Gothenburg area bunkering case. The results are presented for 2030 and 2050 (low growth rate) for each fuel mix scenario. Positive values indicate total increase in storage capacity compared to assumed current level and while negative values indicate the share of the assumed existing infrastructure that is no longer required.*

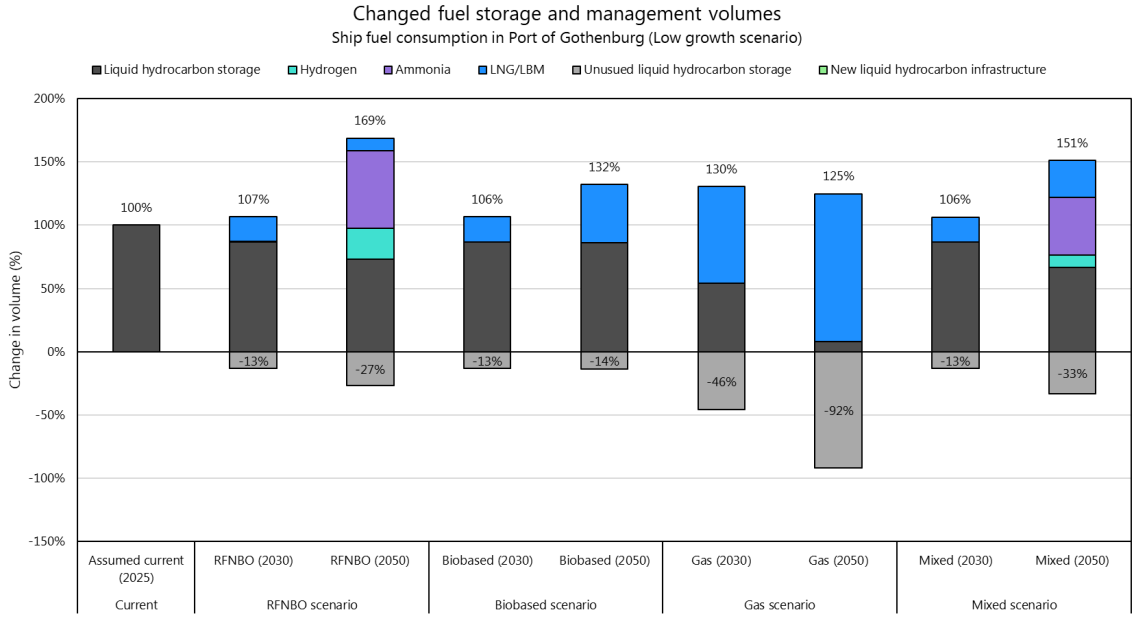


Figure 8. *Changes in fuel handling and required storage capacity, in percentage, compared to current volumes (2025) for the ship fuel consumption in the Port of Gothenburg case. The results are presented for 2030 and 2050 (low growth rate) for each fuel mix scenario. Positive values indicate total increase in storage capacity compared to assumed current level and while negative values indicate the share of the assumed existing infrastructure that is no longer required.*

The analysis highlights that a fuel approach with a mix of fuel types allows incremental infrastructure development, re-use of existing assets and step-by-step investment needs. Strategies dominated by only There is a risk for creating stranded assets or limiting future adaptability (in terms of infrastructure built for specific fuels not possible to adopt for other fuels) if the transition is dominated by specific types of alternative fuels, particularly in case of substantial handling of LNG and biomethane. However, in terms of storage volume the additional need is largest for the electrofuels (RFNBO) scenario in the long-term (2050) followed by the mixed scenario while by 2030 the additional storage volume is the largest in the gas scenario. The biobased scenario causes the least change to infrastructure, followed by the mixed scenario.

Maintaining parallel fuel systems increases complexity, but also significantly enhances resilience against market and technology uncertainty. This comparison gives an overview on potential changes in storage needs due to potential fuel changes linked to FuelEU Maritime. In practice, however, also other factors will influence the actual need for increased storage.

Business opportunities and strategic implications for the port

The Port of Gothenburg plays an important role in enabling shipping companies to comply with FuelEU Maritime and EU ETS requirements. The fuel transition is not only a cost driver. It also influences the port's commercial landscape.

OVERALL STRATEGIC ROLES

Port of Gothenburg can function as a hydrogen-based fuel hub by supplying hydrogen-based fuels to domestic, Nordic and international shipping corridors, strengthening its role far beyond the Swedish market. Three potential strategic roles for the port can be distinguished:

Import hub for renewable marine fuels: The Port of Gothenburg can serve as a key entry point for renewable and hydrogen-based fuels produced elsewhere in Sweden, the Nordic region, or internationally. As renewable fuel demand increasingly exceeds present and today planned domestic production capacity—especially towards 2050—import capability might be essential to ensure fuel availability for ships calling at Gothenburg and for broader bunkering operations in the region.

Production hub for selected fuels: Local and near-port production can strengthen security of supply and create opportunities for industrial integration. The analysis indicates that local hydrogen production is economically attractive assuming current electricity market conditions remain, primarily because hydrogen is relatively costly to transport. For hydrogen-derived fuels such as electro-methanol and electro-ammonia, production in regions with lower electricity prices may offer lower costs than local production (as exemplified by the fuel production cost analysis in the next section). As electricity market conditions evolve, however, the conditions for local production may improve.

Combined import and production hub: A combination of local production and imported renewable fuels i.e., a hub where local production, imports, storage and bunkering are integrated might be a more realistic long-term role. This approach maximises flexibility, reduces dependence on individual fuel supply pathways, and allows the port to adapt incrementally as technologies, regulations and markets evolve.

For the port new or somewhat changed opportunities emerge for all these roles in terms of:

- Fuel storage, blending and bunkering services,
- Energy system integration (waste heat, oxygen (co-products in case of local production), grid balancing),
- New partnerships with additional fuel producers, shipping companies and energy providers.

By proactively positioning itself as a facilitator of renewable fuel flows, the Port of Gothenburg can strengthen its attractiveness as a logistics, energy and industrial hub.

ESTIMATED FUEL COSTS

Fuels having a relatively low fuel production cost (and thus potentially a lower price) in relation to the GHG emission reduction, i.e., a low carbon abatement cost will be demanded first by the shipping sector. Biofuels generally have a lower carbon abatement cost than electro-fuels. However, also for example future availability, sustainable supply potential and suitability for different ship types will influence the attractiveness for different fuels. Biofuel pathways might for instance over time become constrained by the limited biomass supply potential. However, the current supply of biomass based maritime fuels is larger than for hydrogen-based maritime fuels.

The cost of producing electrofuels is uncertain and depend largely on the electricity price. Estimated fuel production costs per Swedish electricity bidding zone for hydrogen-based fuels including cost for transport from Northern Sweden (SE1-2) to Gothenburg (SE3) are shown in **Figure 9**. This is included as an example of potential region to "import" from, in reality, renewable maritime fuels could be imported from other regions. The sourcing of e-methanol, e-ammonia and liquefied hydrogen from Northern Sweden to Gothenburg seems more economically advantageous compared to local production in Gothenburg. On the other hand, for compressed hydrogen local production in Gothenburg seems like a more economically viable option due to high transport and handling costs. In this case the estimated production cost for e-methanol and e-ammonia is similar. However, there are studies indicating that ammonia might become a more cost-effective future fuel option[10] (.

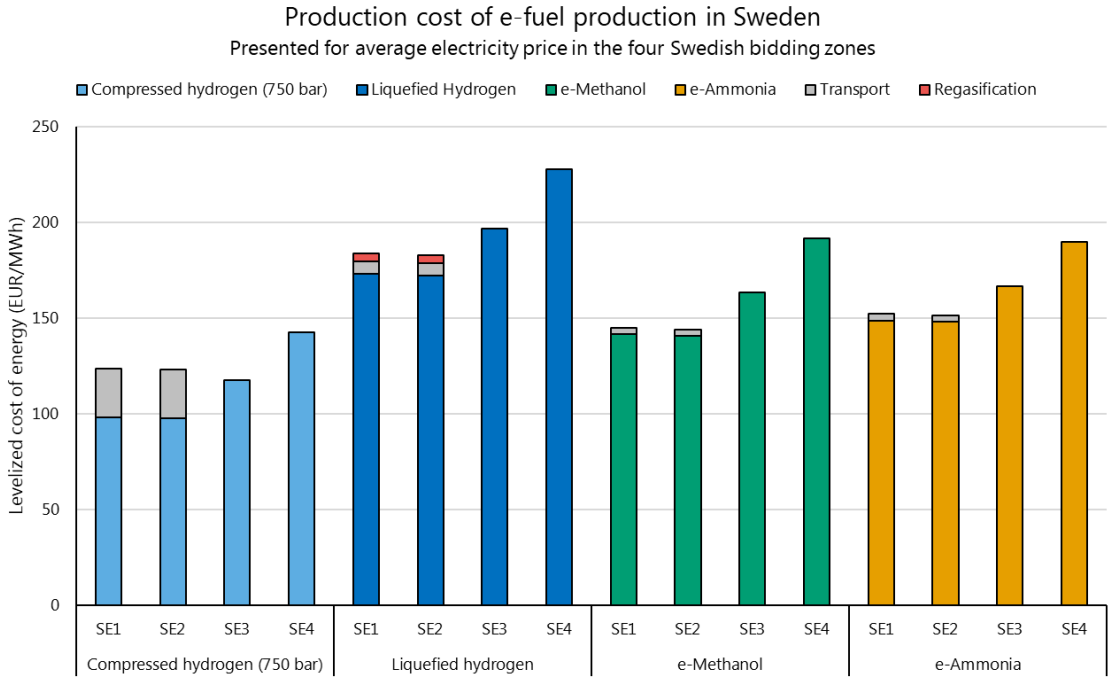


Figure 9. *Levelized cost of energy for hydrogen, e-methanol, and e-ammonia for all four Swedish electricity bidding zones, including an added general transport costs for shipping the fuels from northern Sweden (e.g., Umeå) to the Port of Gothenburg.*

[10] For example: Kanchiralla, F.M., Brynolf, S., Hansson, J., Grahn, M., 2026. Aligning global shipping climate policies with life cycle perspective. Policy brief. Nature Energy. https://doi.org/10.1038/s41560-026-02080-z.

The estimated total fuel cost for the fuel mix used in the different scenarios (for the low growth shipping demand scenario) including an assumed cost for emission allowances in the EU ETS for the remaining use of fossil fuels is presented in **Figure 10**. With an assumed increase in the EU ETS price (up to about 150 Euro in 2035), the EU ETS cost may constitute approximately half of the fuel cost by 2030. The RFNBO scenario has the highest total fuel costs, due to the larger use of the costlier electrofuels. The gas scenario has the lowest costs, followed by the biobased scenario, however the cost difference is limited in the 2030 perspective.

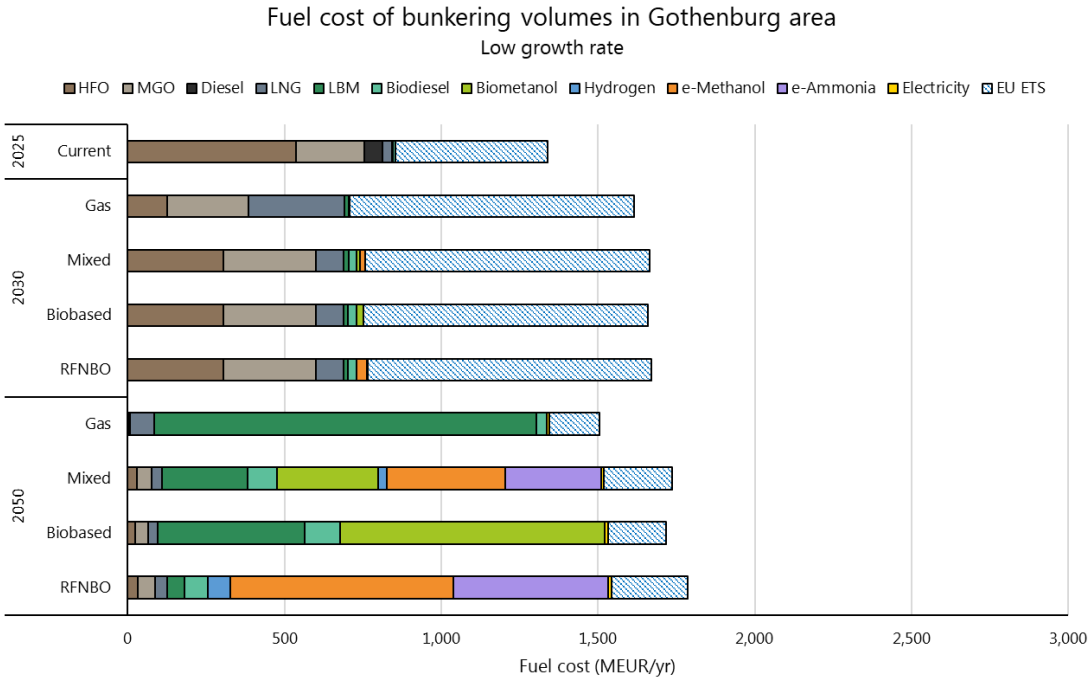


Figure 10. *Estimated fuel cost of the bunkering volumes in the Gothenburg area for each fuel mix scenario in the low growth case for 2025, 2030 and 2050. The assumed emission allowance cost is 149 EUR by 2030 and 194 EUR by 2050.*

Key messages and future work

The maritime fuel transition is characterised by considerable uncertainty regarding future fuel availability, costs, technology development and regulatory frameworks. Flexibility and adaptability will become increasingly important for both shipping and ports. Key messages from the analysis include:

- **No single renewable fuel is expected to dominate future shipping.** Several fuel pathways can contribute to meeting the FuelEU Maritime requirements, and different fuels are likely to serve different vessel segments and operational needs.
- **A diversified fuel portfolio appears to be the most robust strategy.** Combining biofuels, hydrogen-based fuels and electricity reduces dependence on individual technologies and increases resilience towards future market and regulatory developments.
- **The Port of Gothenburg has favourable conditions to become a renewable marine fuel hub.** The Port is well positioned to combine local fuel production, fuel imports, storage and bunkering services while strengthening its role within Nordic and international fuel supply chains.
- **Infrastructure should be developed in a phased and flexible manner.** Future investments should prioritise infrastructure that can accommodate multiple fuel pathways and adapt as technologies and markets evolve. By 2030, a transition primarily towards gaseous fuels is projected to require the largest increase in new storage capacity, whereas by 2050 a transition dominated by electrofuels is expected to result in the greatest additional storage demand. In a mixed-fuel scenario towards 2050, the storage need is somewhat larger for electrofuels than gas-based fuels. Thus, an increase in demand for storage capacity for renewable fuels can be expected given that the fuels are to be handled in the port.
- **Large-scale fuel production and distribution in major ports may create economies of scale**, enabling more efficient utilisation of infrastructure and strengthening the Port's long-term competitiveness.

Strategic choices made during the coming decade are therefore likely to influence not only the future competitiveness of the Port of Gothenburg, but also Sweden's and the Nordic region's ability to support the transition towards climate-neutral maritime transport.

Looking ahead

The analysis highlights several areas where additional work would strengthen strategic planning and support future investment decisions. Further studies are recommended on:

- Financing models and business cases for future port infrastructure.
- Electricity availability, grid capacity and conditions for large-scale local hydrogen production.
- Balance between local production, imports and exports of renewable marine fuels.

- Infrastructure planning for storage, bunkering and distribution of multiple fuel types.
- Integrated energy systems and opportunities to utilise co-products such as waste heat and oxygen.
- Continued monitoring of fuel production costs, technology development, market evolution and regulatory frameworks.

The development of a renewable marine fuel hub will require continued collaboration between ports, fuel producers, energy companies, shipping companies, industrial actors, infrastructure owners and public authorities. As technologies, markets and regulatory frameworks continue to evolve, maintaining flexibility in both infrastructure planning and fuel strategies will remain essential.

Future fuel strategies are also likely to be increasingly influenced by considerations related to resilience and security of supply. Recent geopolitical developments have highlighted the importance of reducing dependencies on vulnerable global supply chains for critical technologies and energy-related products. This is crucial also for renewable maritime fuel pathways and ca be expected to influence future investments, infrastructure planning and policy development for renewable marine fuels. Consequently, future decisions may need to balance not only GHG reductions, costs and technology maturity, but also factors such as domestic production capability, diversity of supply chains, availability of critical feedstocks, resilience of energy systems and long-term security of supply.

For ports, this further strengthens the importance of maintaining flexibility across multiple fuel pathways and developing infrastructure that can accommodate different fuels and supply routes as markets, technologies and geopolitical conditions evolve.