## Project acronym: POTENT-X

## Project title: Ports as Energy Transition Hubs

# D4 - Policy Analysis

This document constitutes Deliverable D4 of the POTENT-X project. It establishes an analytical baseline of the regulatory environment governing the deployment of e-fuels in the maritime sector across the North Sea and Baltic Sea regions. The analysis synthesises the principal European Union policy instruments shaping sectoral decarbonisation and assesses the interaction between supply-side infrastructure requirements and demand-side fuel-switching mandates.

The deliverable operationalises the EU regulatory architecture, framed by the REPowerEU Plan (European Commission, 2022), and subsequently codified through a set of EU legislative acts adopted in 2023: the extension of the EU Emissions Trading System to maritime transport (Directive (EU) 2023/959), the Alternative Fuels Infrastructure Regulation (Regulation (EU) 2023/1804), the FuelEU Maritime Regulation (Regulation (EU) 2023/1805), the ReFuelEU Aviation Regulation (Regulation (EU) 2023/2405), and the Renewable Energy Directive recast (Directive (EU) 2023/2413 – RED III). It evaluates policy complementarities, conflicts, and



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implementation gaps affecting the deployment of renewable fuels of non-biological origin in maritime transport across the North Sea and Baltic Sea regions, considering structural factors including renewable fuel availability, electricity pricing, grid carbon intensity, and storage capacity. By mapping regulatory requirements against regional infrastructure readiness and port-level energy resilience constraints, the deliverable provides a common analytical and empirical framework to support coordinated infrastructure planning, business model development, and policy advisory activities across the POTENT Living Lab Networks and associated work packages.

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| List of Abbreviations | |
|---|---|
| **AFIR** | Alternative Fuels Infrastructure Regulation |
| **BNetzA** | Bundesnetzagentur (German Federal Network Agency) |
| **ENTSO-E** | European Network of Transmission System Operators for Electricity |
| **ESPO** | European Sea Ports Organisation |
| **ETS** | Emissions Trading System |
| **ETD** | Energy Taxation Directive |
| **FID** | Final Investment Decision |
| **GHG** | Greenhouse Gas |
| **GT** | Gross Tonnage |
| **GW** | Gigawatt |
| **ICCT** | International Council on Clean Transportation |
| **IEA** | International Energy Agency |
| **LLN** | Living Lab Network |
| **LNG** | Liquefied Natural Gas |
| **MRV** | Monitoring, Reporting and Verification |
| **MW** | Megawatt |
| **NBHC** | Nordic-Baltic Hydrogen Corridor |



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| | |
|---|---|
| **OPS** | Onshore Power Supply |
| **PtX** | Power-to-X |
| **RED III** | Renewable Energy Directive (recast) |
| **RFNBO** | Renewable Fuel of Non-Biological Origin |
| **SAF** | Sustainable Aviation Fuel |
| **TEN-T** | Trans-European Transport Network |



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# Executive Summary

This deliverable [D4] provides a critical analysis of the FuelEU Maritime Regulation (EU, 2023a) and its alignment with the broader European policy architecture for maritime decarbonisation. The report addresses the interplay between FuelEU Maritime and related policy instruments, including the REPowerEU Plan, the extension of the EU Emissions Trading System (ETS) maritime transport, the Alternative Fuels Infrastructure Regulation (AFIR), ReFuelEU Aviation, and the Renewable Energy Directive recast (RED III), to identify policy synergies and frictions affecting the energy transition.

The analysis is part of the POTENT-X (Ports as Energy Transition Hubs) project under the Clean Energy Transition Partnership and coordinated by Chalmers University of Technology. It draws on policy document analysis, comparative assessment across seven countries in the North Sea and Baltic Sea regions, regional data collection, and input from the Living Lab Networks operating across both regions.

Three structural outcomes are outlined in the report:

- EU's maritime decarbonisation framework is structurally coherent: carbon pricing under the EU Emission Trading System (ETS) provides a cost signal; fuel standards under FuelEU Maritime mandate fuel-switching; the Alternative Fuels Infrastructure Regulation (AFIR) establishes port readiness requirements; and Renewable Energy Directive recast (RED III) defines a sustainability criterion for renewable fuels. However, partial harmonisation across these instruments introduces compliance complexity.

- Hydrogen supply gap represents the binding constraint on e-fuel availability for maritime transport. Against the Hydrogen Strategy target of 40 GW of electrolyser capacity by 2030, installed EU capacity was approximately 308 MW by 2024, representing less than 1% of the target. The trajectory makes the REPowerEU electrolyser ambition questionable. Without significant changes in deployment, near-term FuelEU compliance will be carried by biofuels and LNG rather than RFNBOs, despite the regulatory emphasis on e-fuels. Besides, competition with the aviation sector, driven by the ReFuelEU Aviation synthetic fuel sub-mandate, may further constrain available volumes.

- Regional asymmetries result in diverse transition pathways: Denmark and Sweden benefit from low grid carbon intensities and advanced Power-to-X strategies, whereas Poland faces higher electricity prices and substantially higher grid carbon intensity than the Nordic average. Grid capacity at ports represents an additional bottleneck, as simultaneous demand from onshore power supply (OPS) rollout and Power-to-X



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production increases electricity requirements. This asymmetry implies that compliance costs will diverge significantly between operators bunkering in Nordic ports and those in higher-cost regions.

The report provides guidance for EU and national policymakers, port authorities, and the POTENT-X consortium, and outlines how these findings support subsequent work packages on grid impact assessment [T2.3], hydrogen and e-fuel infrastructure planning [T2.4], and business model development [T4.1–T4.5].



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# 1. Part I – Introduction & framing

## 1.1. Introduction

The deliverable [D4] is a policy analysis assessing the alignment of the FuelEU Maritime Regulation with other EU energy and climate policy instruments within  work package 2 (Technology & Supply-Chain Transitions).

The analysis pursues the following objectives:

- To critically assess the alignment of FuelEU Maritime with other EU energy and climate policy instruments and regional conditions affecting the integration of e-fuel policies across the North Sea and Baltic Sea regions.
- To identify infrastructure requirements that enable streamlined development of the e-fuel supply chain from production through storage, bunkering, and distribution.
- To analyse the energy resilience of ports during electrification transitions, with particular attention to the combined electricity demand from shore power supply (OPS) and Power-to-X production.

The report reviews the EU regulatory instruments (up to 2026) with direct bearing on maritime e-fuel deployment. Its geographic scope corresponds to the POTENT Living Lab Networks (LLNs) in the North Sea and Baltic Sea regions. The location-specific analysis addresses renewable fuel availability, electricity price structures, grid carbon intensity, hydrogen storage capacity, and the status of national policy transposition across these regions.

Under POTENT-X (Ports as Energy Transition Hubs under the Clean Energy Transition Partnership), this deliverable conceptualizes ports as critical nodes in the energy transition, investigating how port infrastructure, governance, and business models must evolve to support decarbonized maritime transport and emerging sustainable energy systems. The deliverable directly informs several downstream activities, including Task T2.3 (i.e., assessment of grid impacts from port electrification), Task T2.4. (i.e., hydrogen and e-fuel infrastructure requirements,) and Tasks T4.1–T4.5 (i.e., business model development and policy guidelines for port energy transition). The deliverable also builds upon the CBS publication Ports as Energy Transition Hubs: An Exploratory Study (Sornn-Friese and Dirzka, 2024), which provides the seminal analysis of the role of ports in energy system integration.

The report is structured as follows. Part I introduces the study and describes the methodology. Part II maps the EU policy landscape, presenting FuelEU Maritime and related instruments and



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systematically outlining key synergies and conflicts. Part III analyses regional and country-specific readiness across the North Sea and Baltic Sea LLN regions, including a cross-regional benchmark. Part IV examines infrastructure gaps in the e-fuel supply chain and assesses port energy resilience during the electrification transition. Part V synthesizes the findings and outlines implications to other POTENT-X work packages. Annexes provide supporting data tables, and the reference list.

## 1.2. Methodology

The analysis integrates several methodological approaches:

- **Policy document analysis:** Systematic review of EU legislative texts (regulations, directives, delegated and implementing acts), European Commission communications, impact assessments, and official guidance documents. Primary legal sources were accessed through EUR-Lex and complemented by analysis and commentary from classification societies (DNV, Lloyd's Register, Bureau Veritas) and legal practitioners specialising in maritime regulatory compliance.

- **Benchmark policy assessment:** A structured comparison of six EU policy instruments (the REPowerEU Plan, the EU ETS extension to maritime transport, AFIR, FuelEU Maritime, ReFuelEU Aviation, and RED III) across multiple dimensions, including legal basis, scope, calculation methodologies, fuel definitions, infrastructure requirements, compliance mechanisms, penalty structures, flexibility provisions, exemptions, revenue allocation, timeline alignment, and interaction effects. The benchmark identifies policy complementarities, conflicts, and gaps.

- **Stakeholder consultations:** Informal consultations with the POTENT consortium partners and representatives of the North Sea and Baltic Sea LLNs. Discussions focused on practical implementation challenges, national policy transposition experiences, port-level infrastructure constraints, and regional energy conditions.

- **Regional data collection**: Quantitative data on grid carbon intensity, electricity pricing, electrolyser deployment, OPS capacity, green hydrogen production costs, and port energy demand were compiled from official statistical sources (Eurostat, Ember, ENTSO-E Transparency Platform), EU agencies (European Hydrogen Observatory, European Environment Agency), and industry reports (DNV Maritime Forecast, IEA Global Hydrogen Review, ESPO Environmental Report).

The reports uses categories of EU policy reference: (i) binding legal targets, which are quantitative obligations inside in regulations or directives, (ii) strategic policy ambitions, which are non-binding goals announced in Commission communications and plans, and (iii) modelling-based capacity requirements analytical estimates derived from scenario.

Several shortcomings shall be acknowledged. First, the regulatory framework remains under development. As of Q1, several implementing acts under FuelEU Maritime are still under consultation, including the FuelEU database implementing act (Stahlschmidt, 2026) required for compliance pooling. Similarly, the revision of the Energy Taxation Directive remains under consideration (EU, 2026a). Second, regional data availability varies. While electrolyser deployment data is available at the EU level through the European Hydrogen Observatory, national-level breakdown is less granular. Third, stakeholder consultations were limited to participants in the POTENT-X network. This skews observations toward ports with relatively advanced energy-transition agendas. As a result, the outcomes may understate implementation challenges in less-resourced ports and Member States with weaker administrative capacity. Broader cross-network consultation in subsequent project phases is imperative, and the statements presented here should be understood as a baseline.



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# 2. Part II – Policy landscape

## 2.1. FuelEU Maritime Regulation

The Regulation (EU) 2023/1805 on the use of renewable and low-carbon fuels in maritime transport (FuelEU Maritime) was adopted on 13 September 2023, entered into force on 12 October 2023, and applies from 1 January 2025, with the first reporting period covering calendar year 2025 and verification due by 31 March 2026. The regulation introduces the world's first well-to-wake greenhouse gas (GHG) intensity standard for energy used on board ships (Christodoulou and Cullinane, 2022; Osipova and Carraro, 2023). FuelEU Maritime forms a part of the Fit for 55 package (Vierth et al., 2024) and was adopted under Article 100(2) TFEU (common transport policy). According to Regulation (EU) 2023/1805, the objective is to *'strengthen the consistent use of renewable and low-carbon fuels, while safeguarding maritime traffic and avoiding distortions in the internal market*.'

The regulation applies to ships of 5,000 gross tonnage (GT) and above carrying commercial cargo or passengers, regardless of flag state, with limited exclusions including warships and vessels used for non-commercial government service. While the 5,000 GT threshold is in place, the captured segment accounts for roughly 90% of maritime $CO_2$ emissions reported under the EU Monitoring, Reporting and Verification (MRV) Regulation (EU, 2026b). Voyages between EU/EEA ports are covered for 100% of energy used, while voyages between an EU/EEA port and a third-country port are covered for 50%. To prevent circumvention via nearby non-EU transhipment hubs, the Commission may designate certain ports as 'neighbouring container transhipment ports,' which are excluded from the definition of a port of call under FuelEU Maritime.

FuelEU Maritime progressively tightens GHG intensity targets relative to a 2020 reference value of 91.16 $gCO_2eq/MJ$, derived from emissions data collected under EU MRV Regulation (2015/757). The well-to-wake methodology captures upstream emissions (extraction, production, transport, bunkering) and combustion emissions, covering three greenhouse gases: $CO_2$, $CH_4$, and $N_2O$. This approach captures methane slip from liquefied natural gas (LNG) engines and upstream emissions from hydrogen production, distinguishing FuelEU Maritime from the tank-to-wake scope of the EU ETS (Lu et al., 2025).

**Table 1. FuelEU GHG intensity by 2050**

| Year | FuelEU Target ($gCO_2eq/MJ$) | Reduction vs. Reference | Absolute Reduction |
|---|---|---|---|



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| | | | |
|---|---|---|---|
| 2020 | 91.16 | | |
| 2025 | 89.34 | -2.0% | 1.82 |
| 2030 | 85.69 | -6.0% | 5.47 |
| 2035 | 77.94 | -14.5% | 13.22 |
| 2040 | 62.9 | -31.0% | 28.26 |
| 2045 | 34.64 | -62.0% | 56.52 |
| 2050 | 18.23 | -80.0% | 72.93 |

The first compliance threshold applies from 2025 at 89.34 $gCO_2eq/MJ$, after which the limit tightens in five-year intervals, reaching 18.23 $gCO_2eq/MJ$ in 2050. This corresponds to an 80% reduction relative to the 2020 reference value and broadly aligns with the IMO's revised GHG Strategy and its net-zero ambition for 2050.

FuelEU Maritime follows a goal-based, technology-neutral regulatory design. Rather than prescribing specific fuels or propulsion systems, it sets performance-based limits on the GHG intensity of energy used on board ships, allowing operators to determine the most suitable compliance pathway. The framework is complemented by flexibility mechanisms—including banking, borrowing, and compliance pooling—as well as targeted exemptions reflecting operational and geographic constraints.

The central mechanism in FuelEU Maritime is the Renewable Fuels of Non-Biological Origin (RFNBO) multiplier (Article 5, Annex V), which applies from 1 January 2025 to 31 December 2033. Under this provision, one unit of RFNBO, including e-methanol, e-ammonia, and e-hydrogen, counts double toward GHG intensity compliance. The multiplier therefore reduces the calculated GHG intensity contribution of RFNBO fuels in the compliance balance. The mechanism is intended to incentivise early adoption of e-fuels during the initial phase of FuelEU Maritime implementation.

A '*sunrise clause*' introduces a mandatory 2% RFNBO sub-target from 1 January 2034 if monitoring indicates that the RFNBO share of total shipboard energy remains below 1% in 2031. If the share exceeds 2% before January 2033, the sub-target will not apply. The European Commission may also waive the sub-target if RFNBO production capacity proves insufficient or prices remain prohibitively high. This conditional design reflects both the policy ambition to stimulate early deployment and the recognised immaturity of the e-fuel supply chain.

Starting 1 January 2030, container ships and passenger ships of 5,000 GT and above must connect to OPS or deploy a qualifying zero-emission technology while at berth in TEN-T ports where OPS has been installed under AFIR. The obligation applies when the ship's stay at berth exceeds two hours. Qualifying zero-emission alternatives listed in Annex III include onboard battery storage, fuel cells, and wind-assisted propulsion. The implementing acts defining the



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acceptance criteria for these technologies remain under discussion as of 2026. From 1 January 2035, the requirement extends to all EU ports where OPS is available. Additional exemptions apply where OPS is unavailable, technically incompatible with the vessel, or where connection would threaten grid stability, as well as in cases of unscheduled safety port calls or force majeure.

The regulation specifies a penalty for non-compliance with OPS requirements of €1.50 per kW of total installed electrical power demand, multiplied by hours of non-compliance while at berth. This results in a significant financial incentive for compliance. For example, *a container ships with an electric demand of 8 MW spending 24 hours at berth without OPS would face a penalty of approximately €288,000*.

The first reporting period commenced on 1 January 2025, with verification due by 31 March 2026 and penalty assessment by 30 June 2026. Several implementing and delegated acts have been adopted, including provisions on verification activities (EU, 2024a), monitoring plan templates (EU, 2024b), verifier accreditation (EU, 2024c), and neighbouring transhipment port lists (EU, 2025). However, the FuelEU database implementing act remains under discussion as of 2026, creating uncertainty regarding compliance pooling and reporting. The database operates on EMSA's THETIS-MRV platform, which was updated in June 2025 to support partial reporting.

While the regulatory architecture is wide-ranging, there are underlying design constraints: First, the RFNBO 2× multiplier provides a strong theoretical first-mover incentive, but its practical effect is bounded by RFNBO availability, i.e., multiplier that cannot multiply volumes that are not supplied at scale (see Table 2). Second, the sunrise clause for the 2% RFNBO sub-target is conditional on a 2031 monitoring observation. Under current deployment trajectories, this condition may be activated, yet the Commission's discretionary waiver based on production capacity or price provides a release valve that may dilute the regulation's purpose. The joint effect is a regulation whose stringency in the late 2020s depends substantially on supply-side developments that are outside the Commission's control.

## 2.2. Related EU Policy Instruments

**EU ETS Maritime Extension (Directive 2023/959)**: The extension of the ETS to maritime transport was established by Directive (EU) 2023/959 and applies from 1 January 2024. Under the scheme, shipping companies must surrender emission allowances for GHG emissions from ships above 5,000 GT calling at EU ports, with a phased compliance schedule covering 40% for 2024 emissions, 70% for 2025, and 100% from 2026 onward. The geographic scope mirrors FuelEU Maritime, covering 100% of emissions from intra-EU voyages and 50% from



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voyages between EU and third-country ports. Unlike FuelEU Maritime's well-to-wake approach, the EU ETS initially regulates only tank-to-wake $CO_2$ emissions, with methane ($CH_4$) and nitrous oxide ($N_2O$) included from January 2026. Maritime shipping reported 89.8 million tonnes of verified $CO_2$ emissions in 2024. With EU carbon allowances trading between €50 and €90 during 2024–2025, industry estimates suggest that compliance costs for container carriers alone exceeded USD 1.4 billion in 2025. Together with FuelEU Maritime, ETS forms part of a dual policy architecture in which carbon pricing provides an economic signal while fuel standards mandate reductions in lifecycle GHG intensity (Bucak et al., 2025). However, the different calculation methodologies—tank-to-wake versus well-to-wake—can lead to complexity for compliance planning and may produce inconsistent incentive signals, particularly for LNG, which performs more favourably under tank-to-wake accounting than under a well-to-wake assessment that captures methane slip (Cariou et al., 2021).

**Alternative Fuels Infrastructure Regulation (AFIR, Regulation (EU) 2023/1804):** The regulation, applicable from 13 April 2024, establishes binding requirements for the deployment of alternative fuel infrastructure across TEN-T. Member States were required to adopt National Policy Frameworks by 31 December 2024, outlining strategies for the deployment of alternative fuel infrastructure, including hydrogen-based and synthetic fuel bunkering at ports. AFIR further requires the availability of LNG bunkering infrastructure along the TEN-T core maritime ports by 1 January 2025. For port electrification, TEN-T core maritime networks must provide OPS for container and passenger vessels by 1 January 2030, with installations sufficient to meet at least 90% of average annual electricity demand at berth (Osipova and Carraro, 2023; Uzun et al., 2024). AFIR therefore establishes the infrastructure backbone enabling compliance with operational decarbonisation measures introduced under FuelEU Maritime.

**Renewable Energy Directive (RED III, Directive (EU) 2023/2413):** The directive raises the EU renewable energy target to at least 42.5% by 2030 and introduces a sub-target for RFNBOs of at least 1% of transport energy (EU, 2023b). The RFNBO delegated acts (Commission Delegated Regulations (EU) 2023/1184 and (EU) 2023/1185), originally adopted under Article 27(3) of RED II and continuing to apply under RED III, specify the conditions under which hydrogen qualifies as renewable and therefore whether e-fuels can be counted as RFNBOs under FuelEU Maritime. Three criteria apply. Additionality requires renewable electricity used for hydrogen production to originate from installations commissioned within 36 months of the electrolyser and without public operating support. Temporal correlation requires monthly matching of renewable electricity generation and hydrogen production until 31 December 2029, followed by hourly matching from 1 January 2030, which may constrain electrolyser utilisation without storage or additional renewable capacity. Geographic correlation requires the electrolyser and renewable generation source to be located in the same bidding zone, or in directly interconnected zones with equal or higher electricity prices.



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RFNBOs must also achieve at least 70% lifecycle GHG emissions savings relative to a fossil comparator of 94 g$CO_2$eq/MJ.

**REPowerEU and the Hydrogen Supply Gap:** The REPowerEU Plan places renewable hydrogen at the centre of the EU's strategy to reduce dependence on Russian fossil fuels and accelerate decarbonisation in hard-to-abate sectors. The Plan targets 20 Mt of renewable hydrogen consumption in the EU by 2030, comprising 10 Mt of domestic renewable hydrogen production and 10 Mt of imports. Commission modelling associated with REPowerEU indicates that achieving this objective would require approximately 65 GW of installed electrolyser capacity by 2030, compared with 44 GW under the Fit for 55 baseline scenario. Deployment, however, remains limited. By 2024 the EU had installed approximately 308 MW of electrolyser capacity, with approximately 1.8 GW under construction by October 2025, indicating a substantial gap between policy ambition and current deployment trajectories. This gap represents a structural constraint on the near-term availability of RFNBOs, including e-fuels required under FuelEU Maritime.

**Table 2. Hydrogen supply gap**

| Status Category | Capacity (MW) | % of 2030 Target | Notes |
|---|---|---|---|
| Installed (2024) | 308 | 0.8% | (European Hydrogen Observatory, 2024) |
| Under Construction (Oct 2025) | 1,800 | 4.5% | (EY, 2025) |
| FID Reached (global, committed) | 4,200 | 10.5% | (IEA, 2025) |
| 2030 Target (EU Hydrogen Strategy) | 40,000 | 100.0% | Modelled requirement (REPowerEU) |
| | 65,000 | 100.0% | (EU, 2022) |

**ReFuelEU Aviation (Regulation 2023/2405):** The regulation establishes minimum shares of Sustainable Aviation Fuel supplied at EU airports, increasing from 2% in 2025 to 70% by 2050, including a dedicated synthetic fuel sub-target rising from 1.2% in 2030 to 35% by 2050. The 1.2% synthetic fuel requirement alone may necessitate approximately 0.8 Mt of e-kerosene by 2030, equivalent to roughly 0.13 Mt of green hydrogen at conversion ratios. By contrast, the FuelEU Maritime's −6% GHG-intensity target in 2030. In case the target is partially supported by via RFNBOs, this implies a green-hydrogen call on the same supply pool of similar order of magnitude. Aviation and maritime are therefore not just drawing from a shared base in principle, but by 2030 these sectors may compete for materially overlapping volumes of green hydrogen and renewable electricity.

**Energy Taxation Directive (proposed recast)**: The proposed recast of the Energy Taxation Directive (Council Directive 2003/96/EC; COM(2021) 563 final) would revise the EU framework for taxing energy products and electricity by linking minimum tax rates more closely to energy



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content and environmental performance. In maritime transport, the proposal would phase out the current mandatory tax exemptions for fossil maritime fuels on intra-EU voyages, thereby strengthening the relative position of RFNBOs and other low-carbon fuels. As long as the proposal remains under negotiation, however, this fiscal layer remains absent from the EU maritime decarbonisation framework, leaving carbon pricing under the ETS and fuel standards under FuelEU Maritime to carry most of the regulatory burden.

**Table 3. EU implementation pathway (in 2026)**

| Year | Instrument | Milestone / Requirement |
|---|---|---|
| 2024 | EU ETS | 40% phase-in of allowance surrender (Sep 2025) |
| | AFIR | Entry into force (April 2024) |
| | | National Policy Frameworks due (Dec 2024) |
| 2025 | FuelEU Maritime | −2% GHG intensity target applies; RFNBO 2× multiplier starts |
| | EU ETS | 70% phase-in of first surrender (Sep 2026) |
| | AFIR | LNG refueling availability required along the TEN-T core network (Jan) |
| | RED III | Transposition deadline (May 2025) |
| | ReFuelEU Aviation | 2% SAF blending obligation starts |
| 2026 | EU ETS | 100% allowance surrender + $CH_4$ and $N_2O$ coverage (Sep 2027) |
| 2030 | FuelEU Maritime | −6% GHG intensity; OPS mandate at TEN-T ports (>2hr stays) |
| | AFIR | OPS installed at TEN-T core maritime ports (90% demand) |
| | RED III and + Delegated Reg. (EU) 2023/1184 | 42.5% RE target; 1% RFNBO transport (RED III); hourly matching |
| | RED III | 42% RFNBO use in industry (interim industrial sub-target) |
| | ReFuelEU Aviation | 6% SAF + 1.2% synthetic fuel sub-mandate |
| 2033 | FuelEU Maritime | RFNBO 2× multiplier expires (31 Dec 2033) |
| 2034 | | 2% RFNBO sub-target (conditional sunrise clause) |
| 2035 | | −14.5% GHG intensity; OPS extended to all EU ports |
| | RED III | 60% industry RFNBO target |
| | ReFuelEU Aviation | 20% SAF + 5% synthetic |
| 2040 | FuelEU Maritime | −31% GHG intensity (62.90 $gCO_2eq/MJ$ ceiling) |
| 2045 | | −62% GHG intensity (34.64 $gCO_2eq/MJ$ ceiling) |
| 2050 | | −80% GHG intensity (18.23 $gCO_2eq/MJ$); net-zero aligned |
| | ReFuelEU Aviation | 70% SAF + 35% synthetic |

## 2.3. Policy Alignment and Conflicts

The EU's maritime decarbonisation framework combines carbon pricing, fuel standards, infrastructure regulation, and renewable energy certification into a layered regulatory



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architecture. The ETS  increases the cost of fossil fuels use through carbon pricing, while FuelEU Maritime imposes progressively tighter lifecycle GHG-intensity limits on energy used on board ships. AFIR complements these measures by mandating the deployment of alternative fuel and electricity infrastructure at ports. RED III, in turn,  establishes the sustainability criteria governing renewable fuels, including RFNBOs, thereby determining which fuels qualify under FuelEU Maritime compliance rules. The temporary RFNBO multiplier further incentivises early deployment of the e-fuel value chain. A comparable policy alignment emerges in port electrification: the FuelEU Maritime requires demand-side OPS mandate, while AFIR obliges ports to install the corresponding infrastructure. Together, these instruments link carbon pricing, operational standards, infrastructure deployment, and renewable fuel certification within a single regulatory framework.

**Methodological divergence**: The point of contention is linked to GHG accounting boundaries. The ETS applies a tank-to-wake $CO_2$ (expanding to include $CH_4$ and $N_2O$ from 2026) approach, while FuelEU Maritime uses a well-to-wake lifecycle methodology . As a result, certain fuels may perform differently across the two regimes. For example, LNG gains a relative advantage under ETS but is penalised under FuelEU Maritime for upstream methane emissions and methane slip. Ship operators must therefore manage compliance under two distinct metrics, potentially receiving conflicting signals about fuel choice.

In practice, this divergence results in a two-metric optimisation problem for ship operators. An operator selecting between LNG, bio-LNG, and methanol may face one ranking under tank-to-wake ETS accounting (where LNG performs relatively well on direct $CO_2$) and another ranking under well-to-wake FuelEU accounting (where methane slip and upstream emissions penalise LNG).  In particular, operators with diverse fleets and routes may rationally optimise for the binding constraint in respective segments, resulting in fragmented fuel-procurement strategies and higher hedging costs against allowance prices. The methodological gap therefore raises compliance complexity, as well as the risk of mis-timed capital decisions.

**OPS threshold misalignment**: OPS provisions under AFIR and FuelEU Maritime follow different regulatory logics. AFIR requires TEN-T core ports to install OPS capacity sufficient to meet at least 90% of average electricity demand at berth, whereas FuelEU Maritime requires certain vessels to use OPS only when port stays exceed two hours. These distinct thresholds mean that infrastructure obligations and operational requirements do not always coincide. An assessment of 489 EU ports by the ICCT therefore concludes that the two instruments  remain ‘only partially harmonised,’ particularly with respect to port-call thresholds, demand coverage and regional exemptions (Osipova and Carraro, 2023).

**Cross-sectoral RFNBO competition**: The FuelEU Maritime and ReFuelEU Aviation both rely on RFNBOs derived from the same pool. Given the currently limited scale of green hydrogen



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production in the EU relative to projected demand, the two sectors are in direct competition for scarce fuels.

**Tax exemption persistence**: As long as the proposed revision of the Energy Taxation Directive remains unresolved, fossil maritime fuels used on intra-EU voyages remain exempt from minimum energy taxation. This undermines the carbon price signal provided by the ETS and the fuel-switching incentive of FuelEU Maritime by preserving a fiscal advantage for conventional fuels. The absence of taxation also implies shore-side electricity is possibly a cost disadvantage in some Member States.

**Table 4. Policy instrument synergy vs. conflict assessment**

| Instrument Pair | Synergy | Conflict | Opportunity | Key Interaction |
|---|---|---|---|---|
| ETS ↔ FuelEU | High | Mid | Mid | Carbon price reinforces fuel-switch incentive; methodological divergence (TTW vs WTW) |
| AFIR ↔ FuelEU | High | Low | Mid | OPS supply (AFIR) matches OPS demand mandate (FuelEU); threshold misalignment |
| RED III ↔ FuelEU | Mid | Low | Mid | RFNBO quality assurance; additionality, temporal, geographic criteria for fuel eligibility |
| RePowerEU ↔ FuelEU | Mid | Mid | Low | $H_2$ production targets support RFNBO supply, but gap (0.3 GW vs 40 GW Hydrogen Strategy target / 65 GW REPowerEU modelling) is critical |
| ReFuelEU Aviation ↔ FuelEU | Low | Mid | Low | Cross-sector RFNBO competition; aviation synthetic mandate absorbs scarce green $H_2$ |
| ETD (proposed) ↔ FuelEU | Mid | Low | Low | Tax removal would strengthen signals; continued exemptions undermine carbon price |



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# 3. Part III – Regional & Country-Specific Analysis

This section assesses maritime e-fuel deployment readiness across the two POTENT-X Living Lab Networks. The North Sea LLN region groups Sweden (west coast) and Germany. The Baltic Sea LLN region groups Denmark, Sweden (east coast), Poland, Estonia, Latvia, and Lithuania. Sweden appears in both regions, reflecting the country's dual coastline. Each country is assessed across three analytical dimensions directly relevant to maritime e-fuel deployment: (i) electricity system characteristics, (ii) hydrogen strategy and project development, and (iii) port and maritime infrastructure. The cross-regional benchmark in Section 3.3 provides the synthesis.

## 3.1. North Sea LLN region

**Sweden** (North Sea) has a principal advantage that is tied to electricity costs and carbon intensity, i.e., approximately 45% hydropower, 29% nuclear, and 17% wind and the average carbon intensity at roughly 20–40 $gCO_2eq/kWh$. Maritime decarbonisation is linked to green corridor development. The Trelleborg–Lübeck/Travemünde Green Shipping Corridor[1], formalised through an MoU signed 13 March 2024, targets fossil-fuel-free operations by 2040. Port of Trelleborg received EU AFIF co-financing for OPS at ferry berths. A separate Gothenburg–Rotterdam Green Corridor[2] MoU links Sweden to the broader European Green Corridors Network.

**Germany** doubled its electrolyser target to 10 GW by 2030, but in autumn 2025 the economy ministry effectively abandoned the rigid target, shifting to a more flexible approach after only 1.3 GW reached final investment decision. With wholesale electricity prices and grid carbon intensity among the highest in Western Europe, Germany has pivoted toward importing hydrogen and derivatives rather than large-scale domestic production. Green hydrogen costs in Germany run approximately €7.50–8.50/kg in 2025, versus projections of €2–3.50/kg in Denmark and Sweden. Port infrastructure mirror this import orientation. Hamburg is developing a 100 MW electrolyser[3] at the former Moorburg coal site, a 40 km hydrogen pipeline network, and Germany's first green ammonia import terminal. The planned 9,700 km hydrogen

[1] https://www.trelleborgshamn.se/en/green-shipping-corridor-between-port-of-lubeck-and-port-of-trelleborg/
[2]https://www.portofrotterdam.com/en/news-and-press-releases/port-of-rotterdam-and-port-of-gothenburg-kick-off-green-corridor-initiative
[3] https://www.ramboll.com/projects/energy/hamburg-green-hydrogen-hub-100-mw-green-hydrogen-plant-powered-by-wind-and-solar


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core network, approved by BNetzA in October 2024, will largely convert existing natural gas pipelines, with an initial 1,800 km start-up grid by 2027–2028.

## 3.2. Baltic Sea LLN region

**Denmark** is advanced, bridging ambitious PtX targets with concrete operational facilities. The national Power-to-X strategy targets 4–6 GW of electrolyser capacity by 2030[4]. A first PtX tender (DKK 1.25 billion) in 2023 awarded six projects totalling over 280 MW. The government approved construction of a 133 km hydrogen pipeline from Esbjerg to the German border in September 2025, with 3 GW export capacity targeting 2030 operations.

The most significant operational milestone is the Kassø Power-to-X plant in Aabenraa– the world's first large-scale commercial e-methanol facility, with 42,000 tonnes/year capacity. First e-methanol was produced on 12th of March 2025, with deliveries to Maersk's methanol-fuelled container vessel Laura Mærsk. Denmark's grid carbon intensity of approximately 139 $gCO_2eq/kWh$ and target of 100% green electricity by 2027 provide a strong support for RFNBO compliance.

The Bornholm Energy Island[5]–a 3 GW offshore wind hub with 2 GW connection to Germany– secured a historic bilateral agreement at the Hamburg North Sea Summit with CEF funding. The North Sea Energy Island[6], by contrast, has been postponed indefinitely due to costs exceeding DKK 200 billion.

**Sweden** (Baltic) is characterised by the Trelleborg–Lübeck Green Shipping Corridor and OPS deployment at Gothenburg. The country's near-zero grid carbon intensity makes it a potential RFNBO production hub for Baltic demand, though limited pipeline infrastructure constrains distribution. The HYBRIT (fossil-free steel) and H2 Green Steel (800 MW electrolyser in Boden) exploit northern Sweden's cheap hydropower, but these industrial projects primarily serve the steel sector rather than maritime.

**Poland** is a high carbon-intensive economy, with coal supplying 56% of electricity in 2024 and grid carbon intensity of approximately 666 $gCO_2eq/kWh$. Average day-ahead electricity prices of €100/MWh in 2024 (versus €39 in Norway) make domestic green hydrogen production economically challenging. Poland's offshore wind ambitions are substantial[7]–5.9 GW by 2030,

[4] https://investindk.com/insights/denmark-announces-new-power-to-x-strategy
[5] https://bornholmenergyisland.eu/en/
[6] https://northseaenergyisland.dk/en
[7] https://windeurope.org/news/poland-powers-ahead-first-offshore-wind-auction-delivers-strong-results/



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8–11 GW by 2040– with Baltic Power under construction and Baltica 2 (1,498 MW) expected online by 2027. These offshore wind resources could eventually support hydrogen production.

**Baltic Sea region** is highly diverse. Estonia's economy was historically based on fossil fuels, is undergoing rapid decarbonisation toward a 100% renewable electricity target by 2030. The country set as a national target of 1 GW green hydrogen production capacity by 2030. The OPS deployment at major ports (Tallinn, Sillamäe) is in the initial stages. ELWIND offshore wind (joint with Latvia) has CEF funding and targets auctions in 2026 with completion by 2030, providing future renewable input for hydrogen. Lativa's electricity system is dominated by hydropower and biomass, with significant cross-border interconnection, i.e., Baltic synchronisation with the European grid in 2025. The country's hydrogen strategy is less advanced than its neighbors. The country's role is shaped primarily as a transit and storage node within the Nordic-Baltic Hydrogen Corridor (NBHC[8]). Lithuania is grid synchronised with Continental Europe in 2025 and a rapid renewable expansion underway, with a 100% renewable electricity target for 2030. The country formulated a hydrogen-production strategy, i.e., 1.3 GW target by 2030, scaling to 8.5 GW by 2050. The 2025 grid synchronisation with the European system minimised a critical geopolitical risk and supported more integrated renewable energy markets.

## 3.3. Cross-regional benchmark

The study-area countries highlight structural asymmetries that shape e-fuel implementation prospects: Denmark and Sweden possess advantages in respect to low grid carbon intensities (enabling easier RFNBO certification), lower electricity costs (reducing green hydrogen production costs), and more advanced national PtX strategies. Germany occupies a middle position with strong import infrastructure plans but high domestic production costs. Poland's combination of high grid carbon intensity, expensive electricity, and coal dependency signals some challenges. The Baltic States are in transition, with the NBHC representing some upside for regional hydrogen supply.

Three patterns can be highlighted: First, the Nordic countries (Denmark, Sweden) bridge low-carbon grids with cost-competitive electricity and the most concrete project pipelines. This positions these countries as net e-fuel exporters within the region. Second, Germany faces a productive-cost disadvantage that has shifted national strategy toward imports and pipeline infrastructure rather than domestic synthesis. Third, Poland and the Baltic States are at different points along the same trajectory. Poland is constrained by carbon intensity and

[8] https://www.nordicbalticbydrogencorridor.com



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electricity pricing, the Baltic Sea region constrained by scale but with strong political alignment and offshore-wind opportunities. A plausible implication is that cost-of-compliance will diverge.

These asymmetries have direct implications for FuelEU Maritime compliance costs. Ships bunkering e-fuels produced in Denmark or Sweden will possibly face lower fuel costs than those relying on German-produced hydrogen derivatives, leading to competitive distortions. The pooling mechanism under FuelEU provide partial mitigation, allowing ships calling at Nordic ports to share compliance surpluses with those in less advantaged regions.

**Table 5. Cross-regional benchmark of structural conditions for maritime e-fuel**

| Country | Grid $CO_2$ ($gCO_2$/kWh) | Avg. electricity price 2024 (€/MWh) | Electrolyser installed/planned by 2030 | OPS status at major ports |
|---|---|---|---|---|
| **Denmark** | ~139 | ~50 | 4–6 GW (target) | Advanced (Aabenraa, Esbjerg) |
| **Sweden** | 20–40 | ~40 | 800 MW industrial (H2 Green Steel) | Advanced (Gothenburg, Trelleborg) |
| **Germany** | High | High | 10 GW target (effectively softened) | Mid (Hamburg developing) |
| **Poland** | ~666 | ~100 | Offshore wind 5.9 GW by 2030 | Lagging |
| **Estonia** | Mid | Mid | 1 GW target | Early |
| **Latvia** | Mid | Mid | NBHC transit role | Early |
| **Lithuania** | Mid | Mid | 1.3 GW (8.5 GW by 2050) | Early |


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# 4. Part IV – Infrastructure & Resilience

## 4.1. Fuel supply chain infrastructure requirements

**Hydrogen production**: The gap between hydrogen policy ambition and actual deployment represents a significant risk to the availability of maritime e-fuels (Pomaska and Acciaro, 2022). The REPowerEU Plan indicates that achieving its hydrogen objective would require approximately 65 GW of installed EU electrolyser capacity by 2030, up from 44 GW under the Fit-for-55 baseline. The installed EU capacity, however, reached only approximately 308 MW by 2024. While electrolyser manufacturing capacity has expanded rapidly— reaching around 10.4 GW per year by late 2024 with a pathway to 21 GW per year by 2025—the majority of announced projects remain at early development stages. Approximately 98% of the 142 GW project pipeline is still at concept or feasibility stage (EY, 2025). As a result, only a fraction of low-emissions hydrogen has reached final investment decision, with committed production projected at roughly 4.2 Mt per year by 2030, significantly below the EU's 10 Mt domestic target.

**E-fuel synthesis**: In 2026, the Kassø plant[9] in Denmark is the only large-scale proof-of-concept for maritime e-methanol production. Projects, such as the FlagshipONE project in Sweden, were cancelled[10]—citing a only slowly developing liquid e-fuel market.

The cancellation signals that current market signals are insufficient to underwrite investment decisions: Developers cite the absence of long-term offtake contracts and the cost gap with fossil bunker fuels as binding. Industry statements indicate that the required investment in EU e-methanol and e-ammonia synthesis is at approximately €30–60 billion by 2030. This is against the backdrop of a currently committed pipeline that is significantly smaller. Green ammonia is even less advanced with Yara's demonstration plant at Herøya[11] in Norway inaugurated in June 2024 but no commercial-scale maritime ammonia bunkering infrastructure operational. $CO_2$ sourcing represents an additional bottleneck. Europe's total Direct Air Capture (DAC) capacity stands at approximately 47 kt$CO_2$/year, dominated by Climeworks' Mammoth plant[12] in Iceland at 36,000 t$CO_2$/year.

[9] https://europeanenergy.com/kasso/
[10] https://www.spglobal.com/energy/en/news-research/latest-news/energy-transition/081524-orsted-scraps-swedish-flagshipone-e-methanol-project-under-development
[11] https://www.yara.com/corporate-releases/yara-opens-renewable-hydrogen-plant-a-major-milestone/
[12] https://www.ramboll.com/lets-close-the-gap/world-s-largest-direct-air-capture-project



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**Storage and distribution**: Salt cavern hydrogen storage shows promise, with Europe having a technical potential of 84.8 PWh and pilot projects underway at Gasunie Zuidwending[13] in the Netherlands or H2CAST Etzel[14] in Germany. The transition from pilot to commercial-scale storage will require significant investment in geological characterisation, connection infrastructure, and regulatory frameworks.

**Bunkering infrastructure**: Methanol bunkering is more advanced than ammonia bunkering, which is partly because methanol can be used in some conventional engines and does not pose the same toxicity challenges as ammonia. Several ports (see Singapore[15]) provide ship-to-ship or truck-to-ship methanol bunkering. Nonetheless, e-methanol bunkering capacity is in 2026 minimal. Ammonia bunkering requires specialised handling due to toxicity concerns, and no major commercial-scale maritime ammonia bunkering terminal operates in Europe. The AFIR's National Policy Frameworks require plans for alternative fuel bunkering infrastructure but impose no hard mandates for hydrogen, ammonia, or methanol–a gap given FuelEU's demand-side fuel requirements.

## 4.2. Energy resilience of ports during transitions

In a port-energy context, resilience includes three operational dimensions: Redundancy (alternative supply pathways when the primary grid is constrained), flexibility (the ability to shift loads in time and across uses), and prioritisation (rules for allocating scarce capacity among competing demands). These dimensions set forth different infrastructure and governance choices, and the appropriate strategies vary by port size, grid topology, and the relative weight of OPS versus PtX.

**Grid dependency risks**: The OPS mandates and PtX ambitions set forward electricity grid capacity at ports. A single large container ship draws 6–10 MW at berth; a cruise ship 10–16 MW (Uzun et al., 2024). In larger ports with several ships at berth, connecting simultaneously these ships can be above 50–100 MW. Adding PtX production can multiply port electricity demand.

The European Commission's Grid Action Plan estimates €584 billion in grid upgrades needed by 2030, which should upgrade the distribution grids in the EU that are in some cases over 40 years (around 40%). The upgrade can take 3–10 years to build.

**OPS deployment status**: Based on the ESPO Environmental Report 2024 (ESPO, 2024),, 58% of the surveyed European ports provide OPS at one or more berths, of which 56% provide high-

[13] https://www.gasunie.nl/en/projects/hystock-hydrogen-storage
[14] https://h2cast.com/frs/
[15] https://www.mpa.gov.sg/media-centre/details/singapore-to-award-licences-for-methanol-bunkering



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voltage options. As the survey covers a self-selected subset of ESPO members the number should be interpreted as indicative. Nonetheless, only approximately 21% of the OPS capacity required for AFIR compliance is installed or contracted. An ICCT study (Osipova and Carraro, 2023) identified 51 ports across 15 EU coastal states equipped with 309 MW of shore power, while an DNV study (DNV, 2026) in 2025 indicated that only 20% of required OPS connections installed or contracted across 31 major ports, with only 11% of container vessel connections in place. Current capacity would need to triple or quadruple by 2030 to comply with AFIR requirements.

**Prioritisation under grid constraints**: During grid-constrained periods, ports can face allocation problems. OPS demand is largely inflexible, i.e., ships arrive on schedule and require connection within a berth window, while PtX production is, in principle, more flexible. A simple prioritisation rule therefore supports OPS during peak calls and PtX during off-peak hours. In practice this implies that PtX facilities at ports should be designed for variable operation rather than baseload, with implications for project economics and offtake contracts. To lessen the implications, ports may install on-site battery storage to bridge OPS peaks, demand-response contracts, microgrid configurations enabling islanded operation, and modular container-based OPS solutions. Only some ports outlined such prioritisation frameworks formally.

**Backup and flexibility options**: Mitigation strategies include smart grid controls at the port level, on-site battery storage, demand-side management coordination between OPS scheduling and PtX production, and modular container-based OPS solutions (see Warnemünde[16]). The standardisation gaps persist with ships typically operate at 60 Hz while European grids run at 50 Hz, requiring frequency converters. The interaction between OPS and PtX demand is particularly critical ports that seek to become energy transition hubs must serve ships at berth while simultaneously powering electrolysers– through the same grid connections. This dual demand can result in scheduling and capacity management challenges, which only some ports have yet addressed systematically.

[16]https://interreg-baltic.eu/wp-content/uploads/2024/08/D1.1-Role-of-Port-Authorities-in-green-port-operation-activities.pdf



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# 5. Part V — Synthesis & Recommendations

## 5.1. Summary and policy implications

The analysis identifies three structural 'stressors' that shape the challenge for e-fuel implementation in the North Sea and Baltic Sea regions:

- The hydrogen supply gap is the binding constraint. Installed EU electrolyser capacity in 2024 (~308 MW) is less than 1% of the 40 GW EU Hydrogen Strategy target for 2030, and roughly 0.5% of the 65 GW deployment level implied by REPowerEU modelling. Besides, 98% of projects are at the concept stage, and e-fuel availability for maritime is lagging the regulatory timeline. The RFNBO multiplier under FuelEU Maritime provides incentives, but there is barely any RFNBO to multiply. Competition with aviation's synthetic fuel mandates will intensify as ReFuelEU mandates scale. A plausible implication is that FuelEU compliance through 2030 may imply the usage of biofuels, bio-LNG, and operational measures rather than RFNBOs (despite regulatory architecture's emphasis on e-fuels). This can lead to risks: First, compliance investments lock in fuels with restricted 2040–2050 viability under tightening intensity caps. Second, the RFNBO multiplier expires in 2033 prior to sufficient e-fuel volumes are available to be multiplied, i.e., may lessen the first-mover incentives.

- Regional asymmetry may result in diverse development trajectories. Only some countries possess structural advantages: Denmark (operational e-methanol production, high renewable electricity share, pipeline to Germany) and Sweden (near-zero grid carbon intensity, cost-efficient electricity). The Nordic-Baltic Hydrogen Corridor is a suitable initiative to link production in the north with demand in the source, but with commercial operations coming possibly too late. A plausible implication is that policy responses should be regionally differentiated: Nordic countries need export and corridor infrastructure (pipelines, storage, bunkering coordination). Germany and the Low Countries need import-terminal certification and offtake-aggregation mechanisms. Poland and the Baltic States need targeted EU co-financing tied to grid decarbonisation milestones rather than uniform RFNBO mandates.



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- Grid infrastructure is a significant bottleneck. Ports which strive to be energy hubs are under dual pressure to invest in OPS and PtX infrastructure. At €584 billion (EU, 2022) in needed grid investment and 5-to-15-year build timelines for substations, the physical infrastructure may ultimately shape the pace transition and not any regulation. This suggests that grid permitting and substation lead times can set the binding pace of port decarbonisation, and policy instruments not yet deployed may influence whether the 2030 AFIR targets can be achieved.

The cross-cutting ‘stressors’ is the *partial harmonization of the regulatory architecture*. While the instruments are complementary in intent, the different GHG accounting boundaries (tank-to-wake vs. well-to-wake), misaligned OPS thresholds (AFIR vs. FuelEU), and absent taxation layer may contribute to compliance complexity that raises transaction costs and may produce suboptimal fuel choices.

## 5.2. Policy and port authority recommendations

**EU policymakers**: First, improve methodological consistency (ETS and FuelEU Maritime). The Commission should provide, prior to the 2028 ETS review, a technical study on extending ETS allowance accounting to a well-to-wake basis aligned with FuelEU Maritime and propose (1) a methodological convergence in the 2028 review or (2) a unified compliance-reporting layer through THETIS-MRV that translates emissions across metrics for operators. Second, accelerate RFNBO supply. The Innovation Fund's earmarked maritime allowances should be deployed through a dedicated maritime-RFNBO call by 2027, prioritising projects with binding offtake agreements with bunker suppliers. Similarly, the European Hydrogen Bank's auction design should add a maritime-offtake bonus to address the offtake-uncertainty barrier identified in the FlagshipONE cancellation. Third, address the bunkering infrastructure gap. The 2027 AFIR review should introduce binding hydrogen, ammonia, and methanol bunkering targets at TEN-T core maritime ports, with an interim mandate for at least one alternative-fuel bunkering point per Member State by 2030, financed through the AFIF and CEF Transport instruments. Fourth, resolve the Energy Taxation Directive uncertainty. The present-day support for fossil maritime fuels weakens the overall policy architecture by offsetting the carbon-price signal of the ETS. The Council should conclude negotiations under qualified-majority rerouting via Article 192(2) TFEU in case a unanimity is blocked, with a transposition deadline aligned to the 2030 FuelEU and AFIR milestones.



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**National policymakers**: First, prioritise grid investment at ports. Member States should designate TEN-T core maritime ports as 'projects of overriding public interest' under the RED III emergency-permitting provisions. This would support the grid-connection timelines, and include a fixed share (e.g., 10–15%) of national ETS revenues to port grid reinforcement, in line with the FuelEU revenue-recycling provisions. National grid development plans (i.e., see the plan by Statnett[17]) should explicitly incorporate the projected electricity demand associated with OPS and PtX production. Second, support the development of regional hydrogen corridors. The Danish hydrogen export corridor illustrates a workable mechanism for addressing regional supply asymmetries between low-cost production zones and major demand centres. Governments along candidate corridors (notably the Nordic–Baltic Hydrogen Corridor and the Esbjerg–Hamburg pipeline) should align infrastructure planning, regulatory frameworks, and permitting through joint inter-governmental working groups, with binding milestones.

**Port authorities**: First, publish, by 2028, a long-term port energy plan with a binding OPS/PtX prioritisation framework. The plan should set allocation rules for grid-constrained periods (favouring inflexible OPS demand over time-shiftable PtX), specify on-site battery and microgrid capacity, and include staged grid-connection milestones. Second, position the port as an active intermediary in FuelEU compliance pooling. Ports can institute a ship registry with surplus or deficit compliance balances calling at the port and broker pooling arrangements, particularly where OPS or alternative-fuel bunkering is available. This registry would shift the port from passive infrastructure provider to operational intermediary within the FuelEU compliance system, i.e., may provide new revenue streams via brokerage fees or pooled-compliance services.

**Living Lab Networks**: By 2027, the LLNs should commit to publishing standardised compliance-cost and operational-constraint data. The data should be structured to support the 2028 ETS review and the 2027 AFIR review. The LLNs are uniquely placed to provide insights into how FuelEU Maritime, ETS, and AFIR requirements materialise at the port level. Channelling these insights into formal Commission consultations would raise the policy return.

## 5.3. Inputs to Other Work Packages

[17]https://www.statnett.no/en/about-statnett/our-strategy-electrification-for-a-new-era/construct-the-grid-and-power-system-faster-and-more-efficiently/



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The deliverable [D4] provides a critical analysis of the policy architecture for maritime decarbonisation, which introduces inputs to several downstream POTENT activities:

- Task [2.3]. The analysis of grid dependency risks and dual OPS/PtX demand in this deliverable provides the framing for the quantitative assessment of port electrification impacts on local and regional electricity networks.

- Task [2.4]. The infrastructure gap analysis in this deliverable maps the e-fuel supply chain from production through bunkering, identifying where policy instruments create requirements versus where gaps. Based on the outcome, the task should prioritise detailed techno-economic assessment of the missing links–e-fuel synthesis capacity, $CO_2$ sourcing, and bunkering infrastructure.

- Task [4.1-5]. The policy synergies and conflicts analysis in this deliverable provides the regulatory context for business model development. The FuelEU pooling mechanism, ETS revenue recycling, and hydrogen auction structures represent specific commercial opportunities that can underpin the task, while the guidance for port authorities support directly T4.3 and T4.5.



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# 7. Annex

The table maps the six instruments across twelve regulatory dimensions. Three dimensions are particularly diagnostic of policy interaction: (i) GHG accounting methodology, where ETS (tank-to-wake) and FuelEU Maritime / RED III (well-to-wake) divergence results in the operator-level compliance complexity discussed in Section 2.3; (ii) penalty structures, where the FuelEU VLSFO-equivalent and the current ETS allowance price set the marginal abatement cost faced by operators; and (iii) timeline alignment, where the 2030 cluster (FuelEU −6%, AFIR OPS, RED III hourly matching, ReFuelEU 6% SAF) constitutes the binding integration test.

| Dimension | FuelEU Maritime | EU ETS Maritime | AFIR | RED III | ReFuelEU Aviation | ETD (proposed) |
|---|---|---|---|---|---|---|
| **Legal Basis** | Reg. (EU) 2023/1805; Art. 100(2) TFEU | Dir. 2023/959; Art. 192(1) TFEU | Reg. (EU) 2023/1804; Art. 91(1) TFEU | Dir. (EU) 2023/2413; Art. 194(2) TFEU | Reg. (EU) 2023/2405; Art. 100(2) TFEU | Proposed revision of Dir. 2003/96/EC; Art. 113 TFEU |
| **Scope (Maritime)** | Ships >5,000 GT; 100% intra-EU, 50% extra-EU | Ships >5,000 GT; phase-in: 40% (2024), 70% (2025), 100% (2026+) | TEN-T core & comprehensive ports; OPS + LNG | All transport fuels incl. maritime; ≥1% RFNBO by 2030 | EU airports >800k pax; competes for RFNBO molecules | Intra-EU voyages (if adopted) |
| **GHG Methodology** | Well-to-wake ($CO_2$, $CH_4$, $N_2O$); ref: 91.16 $gCO_2eq/MJ$ | Tank-to-wake $CO_2$ (+ $CH_4/N_2O$ from 2026) | N/A | Lifecycle GHG via RED II delegated acts | Lifecycle per RED methodology; ≥70% GHG reduction | Energy-content based (€/GJ) |
| **Fuel Definitions** | RFNBOs, biofuels, biogas, low-carbon fuels | Covers emissions from any combusted fuel | LNG (core ports); shore-side electricity (OPS) | RFNBOs: $H_2$ from electrolysis + criteria | SAF: biofuels, recycled carbon, synthetic (e-kerosene) | Differentiated by energy content (€/GJ) |
| **Infrastructure Requirements** | Demand-side: ships must use OPS at TEN-T ports (2030+) | N/A | Supply-side: OPS at TEN-T core by 2030; LNG by 2025 | N/A | SAF supply at EU airports | N/A |
| **Compliance Mechanisms** | Annual balance via EMSA THETIS-MRV | EU MRV monitoring; national registries | Member State reporting on National Policy Frameworks | National certification; voluntary schemes (ISCC EU) | Fuel supplier + airline reporting | National tax codes; MS discretion |
| **Penalty Structure** | €2,400/t VLSFO eq. deficit; OPS: €1.50/kW×hr | €100/$tCO_2$ excess emissions | N/A | N/A | €2× (SAF−conventional) × volume shortfall | Standard tax evasion penalties |
| **Flexibility Provisions** | Banking, borrowing (2%, 10% surcharge), pooling (Art. 21) | Full allowance trading; banking across periods | MS temporary exemptions; 90% | Monthly→hourly correlation (2030); | Book-and-claim; system-wide within MS | MS rates above minimums; transitional periods |



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| | | | demand threshold | additionality transition | | |
| **Exemptions** | <5,000 GT; non-commercial; MS temporary (Art. 2(3)–(6)) | <5,000 GT; offshore (until review); ice-class partial | Non-TEN-T; outermost regions; <1 MW demand | Low-carbon grids (<18 $gCO_2eq/MJ$) ; pre-2028 installations | <800k pax; outermost regions; humanitarian/military | Extra-EU voyages only (proposed) |
| **Revenue Allocation** | Penalties to administering MS; reinvest in RE fuels/OPS | Innovation Fund (20M allowances earmarked maritime) | National + EU co-financing (CEF, AFIF, Cohesion Fund) | Indirect: RFNBO certification costs to producers | Penalties to MS; SAF premium passed through | National budgets; no ring-fencing (proposed) |
| **Timelines** | 2025: −2%, RFNBO 2×. 2030: −6%, OPS. 2033: 2× expires. 2050: −80% | 2024: 40%. 2025: 70%. 2026: 100% + $CH_4/N_2O$. Review 2028 | Apr 2024: in force. Jan 2025: LNG. Jan 2030: OPS | Nov 2023: in force. 2030: 42.5% RE, 1% RFNBO, hourly | 2025: 2%. 2030: 6%+1.2% synth. 2035: 20%+5%. 2050: 70%+35% | Under negotiation (2026) |



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