Technology Roadmap

Competitive, resilient and sustainable short sea shipping (SSS)

Contents

1. Description of the Sector

"Short Sea Shipping (SSS) is defined as "the movement of cargo and passengers by sea between ports situated in geographical waters of one or several Member States or between a port situated in waters of Member States and a port situated in waters of an adjacent third country having a coastline on the seas bordering waters of one or several Member States" [1]. On this basis, short sea shipping includes domestic and international maritime transport along European coasts and across regional sea basins[2], including the Baltic Sea, the Nort Sea, the Atlantic, the Mediterranean and the Black Sea, as well as maritime connections with islands, peripheral regions and neighbouring coast countries. For the purposes of this roadmap, the focus is limited to cargo-based short sea shipping. It covers feeder container vessels, general cargo and multipurpose vessels, coastal bulk carriers, coastal tankers and freight-only roll-on/roll-off vessels. Passenger-oriented segments, including ferries, Ro-Pax vessels and cruise vessels, are addressed in separate Waterborne technology roadmap documents.

1.1 Fleet composition, age profile and operating context

The European short sea shipping (SSS) fleet is characterised by a high degree of functional diversity, reflecting the range of cargo types, vessel sizes and operational requirements across intra-European maritime transport. According to a recent study[3] the main cargo-vessel categories considered in this roadmap comprises approximately 6,184 vessels. Most of these vessels operate within the 500-25,000 gross tonnage (GT) range, which accounts for around 74% of the total fleet. This highlights the importance of small and medium-sized vessels adapted to short-distance, regional and high frequency services. Table 1 presents the distribution of the fleet by vessel type and size category.

Type of Vessel	<500 GT	500–25,000 GT	25,000–60,000 GT	>60,000 GT	Total
Bulk carriers	7	180	37	1	225
Container ships	3	540	396	503	1,442
General cargo vessels	30	2,546	239	103	2,918
Tankers	19	1,290	188	102	1,599
Total	59	4,556	860	709	6,184

Source: Adapted from European Commission, *Study on Short-Sea Shipping's Contribution to the European Transport Network and the Means to Support and Revitalize the Sector*

Table 1: Short Sea Shipping Fleet by Vessel Type and Size (Cargo Segments Only)

[1] Regulation (EU) 2024/1679 on Union guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 No 913/2010 and repealing Regulation (EU) No 1315/2013.

[2] European Commission. Eurostat Database. "Short Sea Shipping – Country Level – Gross Weight of Goods Transported to/from Main Ports, by Sea Region of Partner Ports (mar_sg_am_cws)." Last modified March 24, 2026. Accessed March 30, 2026. https://ec.europa.eu/eurostat

[3] European Commission, *Study on Short-Sea Shipping's Contribution to the European Transport Network and the Means to Support and Revitalize the Sector* (data for 2022; based on Eurostat).

As shown in Table 1, general cargo vessels form the largest segment, representing close to half of the quantified fleet[4]. Their importance reflects the versatility of short sea shipping in carrying bulk, semi-bulk, packaged and project cargo across European sea basins. Container vessels also play a significant role, particularly in feeder services and intra-European logistics chains, where standardised cargo handling and integration with global container networks are important. Tankers and bulk carriers, although more specialized, remain essential for the transport of liquid and dry bulk commodities linked to energy supply, industrial production and regional supply chains.

A defining structural characteristic of the SSS fleet is its ageing profile. Nearly half of the vessels are over 15 years old, while only around 17% are newer than five years, indicating relatively slow fleet renewal. This creates important implications for the technology roadmap, as a significant share of the fleet will remain in operation for many years. Modernization will therefore depend not only on newbuilds, but also on retrofitting, modular solutions, fuel flexibility and technologies that can be integrated into existing vessels with limited downtime. The challenge is particularly relevant for bulk carriers and tankers, which typically have longer operating lifetimes, while container vessels tend to be newer and more closely linked to evolving logistics requirements.

The spatial distribution of short sea shipping activity is also uneven. Major European ports such as Rotterdam, Antwerp-Bruges and Hamburg dominate cargo throughput and act as primary gateways for intra-European and global trade flows. At the same time, secondary and regional ports in the Mediterranean, Baltic, Atlantic, North Sea and Black Sea basins play an important role in maintaining regional connectivity, supporting feeder services and linking peripheral and island regions to wider logistics networks. This port structure confirms the corridor-based nature of short sea shipping: large hubs, regional ports and hinterland connections must be considered together when planning clean-energy infrastructure, digital services and fleet deployment.

The composition and age of the fleet also shape its current energy profile. General cargo vessels, tankers and bulk carriers remain largely dependent on conventional marine fuels, while alternative fuels and electrified solutions are still concentrated in newer or more specialised applications. This means that the decarbonization of SSS will be constrained not only by technology availability, but also by vessel size, age, route profile, cargo requirements, port infrastructure and fuel availability. The roadmap therefore needs to combine near-term efficiency and retrofit measures for the existing fleet with longer-term deployment of zero- and near-zero-emission vessels on suitable short sea corridors.

2. Drivers and Constraints

2.1 Drivers

The transformation of short sea shipping is driven by the convergence of legally binding climate, fuel and infrastructure requirements, policy frameworks for investment and industrial competitiveness, multimodal transport policy, digital simplification, safety and security requirements, and market demand for cleaner logistics[5]. Because SSS operates through frequent port calls and corridor-based

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[4] Ibid (*Note: the table covers bulk carriers, container ships, general cargo vessels, and tankers. Freight-only Ro-Ro vessels are included in the scope of this roadmap but are not quantified in this table*)

[5] European Commission, Communication from the Commission, *Sustainable and Smart Mobility Strategy – Putting European Transport on Track for the Future*, COM(2020) 789 final (Brussels, 9 December 2020), 5–6, 15.

services, these drivers need to be addressed as part of an integrated fleet–port–energy–logistics system, rather than through vessel technologies alone. The principal drivers are set out below.

- **Climate neutrality, carbon pricing and fuel regulation.** The European Climate Law establishes the long-term objective of climate neutrality by 2050, supported by a 2030 target of at least 55% net greenhouse-gas emissions reduction and a 2040 target of 90% net emissions reduction compared with 1990 levels.[6] For shipping, this direction is reinforced by the extension of the EU Emissions Trading System to maritime transport and by FuelEU Maritime, which sets requirements for reducing the greenhouse-gas intensity of energy used on board ships.[7,8] Together, these instruments make emissions performance, fuel choice, operational efficiency and fleet renewal central competitiveness factors for short sea shipping.
- **Alternative-fuel and shore-power infrastructure**. The Alternative Fuels Infrastructure Regulation and FuelEU Maritime create complementary obligations on port infrastructure and vessel energy use[8,9]. AFIR supports the deployment of alternative-fuel infrastructure, including shore-side electricity in maritime ports, while FuelEU Maritime strengthens the demand for renewable and low-carbon fuels and clean energy technologies on board ships. For short sea shipping, this accelerates the need for port electrification, grid reinforcement, standardised shore-power and charging interfaces, alternative-fuel bunkering and closer coordination between vessel investment and port infrastructure. This is particularly relevant for high-frequency services, where infrastructure availability at both ends of a route can determine whether clean propulsion solutions are operationally feasible.
- **Sustainable transport investment**. The Sustainable Transport Investment Plan is a policy and investment framework aimed at scaling up renewable and low-carbon fuels for aviation and waterborne transport and mobilising investment for their production and uptake[10]. For SSS, this is a key driver because the availability, price and certification of sustainable alternative fuels will strongly influence retrofit decisions, newbuilding choices and the business case for zero- and near-zero-emission services.
- **Ports as energy, logistics and security hubs**. The EU Ports Strategy positions ports as strategic nodes for trade, logistics, energy transition, security and the blue economy[11]. For short sea shipping, ports are critical deployment platforms for shore power, charging, alternative-fuel bunkering, digital port-call optimization, safety procedures and multimodal connections. Port readiness, terminal processes, grid capacity and local energy systems must therefore be planned together with vessel modernization.
- **Industrial maritime competitiveness**. The EU Industrial Maritime Strategy links the decarbonization and digitalization of shipping with European industrial competitiveness[12]. It

[6] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality ("European Climate Law"), OJ L 243, 9 July 2021, arts. 2 and 4.
[7] Directive (EU) 2023/959 amending Directive 2003/87/EC as regards, inter alia, the inclusion of maritime transport in the EU Emissions Trading System.
[8] Regulation (EU) 2023/1805 on the use of renewable and low-carbon fuels in maritime transport, commonly referred to as Fuel EU Maritime.
[9] Regulation (EU) 2023/1804 on the deployment of alternative fuels infrastructure, commonly referred to as the Alternative Fuels Infrastructure Regulation.
[10] European Commission, *Sustainable Transport Investment Plan*, COM(2025) 664 final (Brussels, 5 November 2025), 1–2.
[11] European Commission, *EU Ports Strategy*, COM(2026) 112 final (Brussels, 4 March 2026), 3–5.
[12] European Commission, *EU Industrial Maritime Strategy*, COM(2026) 111 final (Brussels, 4 March 2026), 8.

highlights the importance of ship repair, retrofitting, conversion, recycling, advanced manufacturing and maritime technology supply chains. This is directly relevant to short sea shipping, where a large share of the existing fleet will remain in operation for many years and where scalable retrofit packages, modular propulsion systems and cost-effective conversion solutions will be essential.

- **TEN-T and the European Maritime Space**. The revised TEN-T Regulation integrates short sea shipping into the European transport network through maritime links, ports, hinterland connections and the European Maritime Space[13]. This strengthens the role of SSS in connecting regions, islands, peripheral areas and industrial clusters to the Single Market. It also supports the development of green maritime corridors, improved port-hinterland integration and better links between maritime transport, rail, road and inland waterways.
- **Digital simplification and single-market integration**. Short sea shipping is highly sensitive to administrative burdens because high-frequency services may face repeated reporting, customs and border procedures at each port call. The European Maritime Single Window environment provides a framework for interoperable and harmonized reporting for ships arriving at, staying in and departing from EU ports[14]. Wider digital harmonization can reduce duplication, improve data exchange and make SSS more competitive with land-based transport.
- **Industry and market demand**. European industry positions increasingly converge on the need to make short sea shipping more competitive, digitally integrated and easier to use within the Single Market. ECSA calls for measures to reduce administrative and reporting burdens for short sea shipping[15], while the importance of fleet renewal, retrofitting and European industrial capacity is also underlined. Cargo-owner demand for lower-emission logistics can further strengthen the business case for investment in cleaner vessels, port readiness, green transport services and integrated multimodal solutions.
- **Technology readiness and deployment potential**. Several technologies are already available for selected short sea applications, including battery-electric and hybrid propulsion, onshore power, wind assisted propulsion supply, energy-saving devices, hull and propulsor optimization, digital twins, route optimization and condition-based maintenance[16,17]. Methanol-capable engines and vessels are moving towards wider market uptake, while sustainable biofuels and other certified fuels can support transition pathways for parts of the existing fleet. LNG and biomethane may remain transitional options in certain segments, provided that methane slip and lifecycle emissions are properly controlled. Hydrogen, ammonia, fuel cells, onboard carbon capture, advanced autonomy and AI-supported operations require further safety validation, infrastructure development, standards and corridor-based demonstration before broad deployment.

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[13]Regulation (EU) 2024/1679 of the European Parliament and of the Council of 13 June 2024 on Union guidelines for the development of the trans-European transport network, OJ L, 2024/1679.

[14] Regulation (EU) 2019/1239 establishing a European Maritime Single Window environment.

[15] European Community Shipowners' Associations (ECSA), "https://ecsa.eu/wp-content/uploads/2025/04/ESCA-Position-Paper-short-sea-shipping_final.pdf" —

[16] European Commission, Directorate-General for Mobility and Transport, *Study on Short-Sea Shipping's Contribution to the European Transport Network and the Means to Support and Revitalise the Sector: Final Report* (Luxembourg: Publications Office of the European Union, 2025), 91–95, https://doi.org/10.2832/8154948

[17] European Commission, European Alternative Fuels Observatory (EAFO), "Vessels," accessed 6 April 2026, https://alternative-fuels-observatory.ec.europa.eu/transport-mode/maritime-sea/vessels.

2.2 Constraints

The transition of short sea shipping is constrained by fleet, infrastructure, market, regulatory, digital and workforce barriers. These constraints are closely interlinked: investment in clean vessels depends on the availability of port infrastructure and fuels; infrastructure investment depends on predictable vessel demand; and both depend in stable regulation, finance, skills, national and regional differences and operational readiness. The principal constraints are set out below.

- **Fleet age, diversity and retrofit complexity**. A large share of the SSS fleet will remain in operation for many years, which limits the pace at which new zero-emission vessels can replace existing assets[18]. The fleet is also highly heterogeneous in terms of vessel type, size, cargo profile, age, route length and operational pattern. This makes it difficult to apply a single decarbonization solution across the sector. Retrofit ability, modularity, fuel flexibility and lifecycle-cost reduction are therefore essential, especially for older vessels, specialized cargo segments and lower-volume or seasonal routes where the business case for newbuilds is weaker. A significant part of the dry-bulk and tanker segments operates on a tramp basis, on unscheduled, spot-market voyages rather than fixed routes. This weakens the investment case: without a predictable rotation, operators cannot align vessel investment with the bunkering or shore-power infrastructure of individual ports, and alternative fuels become viable only once they are available across many ports in sufficient quantity and at competitive prices. For these segments, energy-efficiency measures remain the principal near-term lever, with the applicable solution depending on vessel type, route and business model.[19]
- **Infrastructure and fleet-investment mismatch**. Port electrification, grid capacity, shore-power connections, charging systems, alternative-fuel bunkering and reception facilities remain unevenly deployed across European ports[20]. For high-frequency short sea services, the lack of suitable infrastructure at even one port on a route can prevent the deployment of clean propulsion solutions across the whole corridor.
- **Fuel availability, cost and sustainability uncertainty**. Operators face uncertainty over the availability, price, certification, lifecycle-emission performance and safety requirements of sustainable biofuels, e-fuels, methanol, hydrogen, ammonia and other future energy carriers[21]. Different fuels may be suitable for different vessel types and route profiles, but the timing and scale of fuel availability remain uncertain. This increases the risk of technology lock-in, stranded assets or delayed investment. For some existing vessels, sustainable drop-in fuels may provide a transitional option, but their availability and sustainability credentials will need to be verified.
- **Financing and business-case constraints**. Many SSS operators, including SMEs and companies serving regional, seasonal or lower-volume routes, have limited capacity to finance new vessels, retrofits or digital upgrades[22]. The business case is often weakened by high upfront costs, uncertain

[18]European Commission, Directorate-General for Mobility and Transport, *Study on Short-Sea Shipping's Contribution to the European Transport Network and the Means to Support and Revitalise the Sector: Final Report* (Luxembourg: Publications Office of the European Union, 2025), 91–95, https://doi.org/10.2832/8154948.

[19] Waterborne Technology Platform, Waterborne Technology Leadership: Towards a Competitive, Resilient and Sustainable Waterborne Sector (Brussels: Waterborne Technology Platform, January 2026), https://www.waterborne.eu/images/260115_Waterborne_Technology_Leadership_final.pdf., p. 9

[20]European Commission, Study on Short-Sea Shipping's Contribution, 89–90

[21]Ibid, 91–95.

[22]Ibid., 81–83, 95–97.

fuel-price differentials, charter arrangements, limited ability to pass costs to customers, uncertain residual values and fragmented demand for green transport services. Smaller ports may also lack the organizational capacity and financial resources to modernize infrastructure or access EU support mechanisms. Without de-risking instruments and predictable demand, first movers may face disproportionate costs.

- **Administrative and single-market barriers**. Short sea shipping can face repeated reporting, customs and border procedures at each port call, even where cargo is moving within the Union[23]. These burdens are particularly problematic for high-frequency services and can make SSS less competitive than road transport. Administrative complexity also limits the attractiveness of SSS for shippers and logistics providers. Further harmonisation, digital reporting and simplification are therefore needed to reduce duplication and strengthen the role of SSS within the Single Market.
- **Safety, certification and regulatory readiness**. Alternative fuels, onboard batteries, high-power charging, carbon capture, automation, remote operations and cyber-physical systems introduce new safety and operational risks. Certification pathways, emergency procedures, crew training, port preparedness and class and flag-state approval processes are not yet mature for all technologies and use cases[24]. This can delay deployment even where technologies are available. The challenge is particularly acute in short sea shipping because new fuel handling, charging, bunkering, cargo operations and port turnaround often occur within constrained port environments and tight schedules.
- **Digital fragmentation and cybersecurity exposure**. Digital systems used by ports, terminals, operators, authorities and logistics actors are not yet sufficiently interoperable. This limits real-time data exchange, port-call optimisation, just-in-time arrival, emissions reporting and integrated corridor management[25]. At the same time, greater digital connectivity increases exposure to cyber risks. Cybersecurity must therefore be treated as an operational safety and resilience issue, not only as an IT function, particularly where vessels depend on continuous interaction with ports, terminals, traffic systems and shore-support services.
- **Skills and workforce transition**. The safe deployment of new fuels, electrification, digital systems, automation and remote operations depends on the availability of suitably trained crews, shore operators, port personnel, emergency responders, inspectors and maintenance teams[26]. Skills gaps may slow deployment or increase operational risk. Training systems, competence standards and certification requirements will need to evolve in parallel with fleet and infrastructure renewal, while human-centered design will be necessary to ensure that digital and automated systems support rather than overburden crews and shore-based operators.

3. Target Capabilities

Drawing on the Waterborne Technology Leadership document, this section sets out the operational capabilities that SSS should develop by 2035, 2040 and 2050.

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[23]ECSA, *ECSA Position Paper on a Single Market for Short Sea Shipping*, 2.

[24]European Commission, *Study on Short-Sea Shipping's Contribution*, 91–95.

[25]Regulation (EU) 2019/1239 establishing a European Maritime Single Window environment.

[26] European Commission, *Study on Short-Sea Shipping's Contribution*, 95–97.

3.1. 2035: Early Deployment Phase

By 2035, short sea shipping should be capable of deploying low- and zero-emission solutions on the routes and vessel segments where operational conditions are favorable. Battery-electric and hybrid propulsion should be used increasingly on short-distance, high-frequency and predictable services, supported by onshore power supply, standardized charging interfaces and improved port energy management. Sustainable alternative fuels, including certified biofuels and methanol where available, should contribute to emission reductions in parts of the existing fleet, while energy-efficiency measures, hull and propulsor optimization, energy-saving devices and operational optimization should deliver near-term reductions across a broader range of vessels.

Operational integration between vessels, ports and logistics actors should also improve significantly by 2035. Short sea services should be supported by better data exchange, digital reporting, route optimisation, just-in-time arrival, berth coordination, shore-power availability information and condition-based maintenance. Digital tools should support crews and operators in improving reliability, port-call efficiency and energy management, while operations should remain largely human-controlled.

By this stage, the sector should also have developed the basic safety, regulatory and workforce capabilities needed for early deployment. This includes safety procedures for batteries, shore power, charging and alternative fuels; initial cybersecurity measures; updated emergency-response arrangements; and training programs for crews, port and terminal personnel, shore operators and maintenance teams. However, transformation by 2035 may still be limited by fleet age, infrastructure gaps, fuel availability, financing constraints and the uneven readiness of ports and corridors.

3.2. 2040: Scale-Up and System Integration Phase

By 2040, short sea shipping should be capable of scaling zero- and near-zero-emission solutions across a wider range of routes, vessel types and sea basins. Clean propulsion options should be commercially available for the main cargo-based SSS segments, supported by more mature shore-power, charging and alternative-fuel bunkering infrastructure in major ports and selected short sea corridors. Sustainable fuels, electrification, hybridization and fuel-flexible systems should be integrated with vessel design, retrofit strategies and operational profiles.

Digitalisation should move from individual tools to integrated corridor management. Vessels, ports, terminals, energy suppliers, authorities and hinterland operators should be able to exchange operational data securely and in near real time. This should support port-call optimisation, automated compliance reporting, emissions monitoring, predictive maintenance, energy planning and multimodal coordination. Remote support and partial automation should become feasible in controlled environments, particularly for machinery monitoring, port approaches, maintenance support and selected corridor operations.

Safety, security and resilience capabilities should also mature by 2040. Predictive risk management, cyber-resilient systems, harmonized safety procedures and improved emergency preparedness should support the wider use of alternative fuels, electrification, digital systems and automated functions. The sector will also be capable of operating more reliably under disruption, including extreme weather, port congestion, energy-supply constraints and cyber incidents. Industrial capacity for repair, retrofitting, conversion and modular technology integration should be sufficiently developed to support deployment beyond pilot projects.

3.3. 2050: Full Transformation Phase

By 2050, short sea shipping operates as a climate-neutral, digitally integrated and resilient component of the European transport system. The cargo-based SSS fleet is capable of using zero- and near-zero-emission energy solutions at scale, supported by a mature port and energy ecosystem. Greenhouse-gas emissions and harmful air pollutants are reduced to levels consistent with climate-neutral transport, while noise, waste and other environmental impacts are systematically addressed through vessel design, operational optimisation and port integration.

Operations will be highly connected and increasingly automated, with vessels, ports, terminals, energy systems and hinterland logistics functioning as part of integrated short sea corridors. Digital systems support continuous optimisation of routes, energy use, cargo flows, emissions performance, maintenance and port-call planning. Remote and automated functions are used to improve safety, efficiency and resilience, while maintaining clear human oversight and robust regulatory control.

By 2050, short sea shipping is fully integrated into multimodal logistics chains and regional transport systems. It supports modal shift from road to sea where viable, strengthens island and peripheral connectivity, reduces congestion, improves supply-chain resilience and contributes to circular-economy flows. The sector combines clean vessels, smart ports, skilled workers, safe operations and competitive services, supporting Europe's wider objectives for sustainable transport, industrial leadership and a resilient waterborne economy.

4. Technology Pathways (Task theme leader(s))

The Waterborne Technology Leadership priorities are translated into technology pathways for cargo-based short sea shipping. The focus is on the vessel categories and operations covered by this roadmap, while the pathways reflect the operational characteristics of short sea shipping, as these are described above.

4.1 Future propulsion and energy systems enabling a climate-neutral short sea fleet

The transition of short sea shipping requires scalable, safe and efficient propulsion and energy systems that are suited to the diversity of short sea vessels, route lengths, cargo profiles and port-call patterns. Technology development should remain fuel- and technology-neutral, while prioritising energy efficiency, retrofitability, operational reliability, cost competitiveness and integration with port and energy infrastructure.

4.1.1 Operational objectives

Enable climate-neutral short-sea propulsion through scalable engine-hybrid electrification, OPS/charging, fuel flexibility, high-efficiency energy systems, renewable energy-harvesting technologies, and energy-saving devices. These solutions should reduce propulsion power demand and harmful emissions, including underwater noise, without sacrificing cargo capacity, turnaround time, route reliability or safe operation, including in winter and high-latitude conditions.

4.1.2 Target capabilities for 2035, 2040 and 2050

By 2035:

- Battery-electric and hybrid propulsion are mainstream on suitable routes, supported by standardised charging and OPS deployment. Modular and swappable energy systems are available. TRL 6-9
- Sustainable fuel capable engines and retrofit solutions, including but not limited to methanol, ethanol, ammonia, hydrogen and biofuels, expand across vessel classes where fuel supply and safety frameworks emerge. TRL 7-9
- LNG and biomethane may remain transitional options for certain segments, provided that methane-slip reduction and lifecycle emission control are properly addressed. TRL 7-9
- Energy Saving Devices (ESDs), including friction-reduction systems, propulsor, rudder, and hull improvements, become “standard options” where they deliver verified operational and economic benefits TRL 5-9
- On-board renewable energy harvesting technologies, including wind, solar and wave-assisted systems, achieve wider adoption where there are compatible with short sea vessel design and operations TRL 5-9.
- Smart waste heat recovery systems developed to increase energy efficiency TRL 5-8
- Fuel cells adopted selectively for auxiliary power and extended zero-emission port operations in corridor contexts. TRL 4-7
- Exhaust aftertreatment solutions developed and piloted for on-board capture and port-wise handling of harmful emissions, e.g. carbon capture, methane slip, ammonia slip, nitrous oxide etc. TRL 3-8
- Development of propulsion systems reducing underwater noise pollution. TRL 5-8.

By 2040:

- Selective new ammonia deployments on longer/higher-energy corridors with robust safety/ aftertreatment integration. TRL 5-9
- Deeper hybridisation: larger storage, improved controls, more zero-emission near-port operation and reduced engine running hours. TRL 5-9
- Tailored integrated, modular and software driven energy systems for vessel propulsion. TRL 5-9
- Short Sea vessels operating in Arctic/high-latitude regions implement winterisation and operational limitations (low temperature, icing, remoteness), extended to new fuels and electrified systems. TRL 5-9

- Fully modular "fuel-agnostic hulls," with interchangeable battery rooms, sustainable fuel modules, hydrogen packages, or future synthetic-fuel reformer units installed during major overhauls rather than committing one hull to one lifetime fuel.

By 2050:

Climate-neutral fleet with modular engine-hybrid-electric architectures on sustainable fuels plus selective fuel-cell modules, integrated into climate-neutral port ecosystems.

Increased range for fully electric propulsion.

Onboard wind, solar and wave energy technologies to contribute to on-board energy supply.

4.1.3 Required enablers

- Port electrification and grid capacity sized for frequent calls and fast turnarounds.
- Fuel availability (methanol now; ammonia scaling later) in coastal hubs plus standardised bunkering procedures.
- ESD verification standards for financing and operational decision-making.
- Verification standards for energy contribution from onboard power generation by wind, solar and wave, and how they are accounted for in average GHG intensity of energy used on board a ship.

4.1.4 Key research gaps (linked to achieving the objectives, building on the current state-of-play).

- Fast turnaround charging / battery logistics without cargo or schedule penalties.
- Fuel flexibility integration for mid-size vessels with minimal retrofit downtime.
- ESD savings validation under real coastal conditions and integration into routing/EMS.
- Validation of contribution of energy harvesting technologies (wind, solar and wave) under real short sea shipping conditions.
- Arctic/low-temperature operation for new fuels & electrification: cold impacts on fuel systems, batteries, sensors and materials.

4.2 Intelligent safety, security and resilience as foundational enablers

As short sea vessels and operations become more digital, energy-intensive and interconnected, safety, security and resilience become defining conditions for competitiveness. Short sea shipping operates in dense coastal waters, busy port approaches, constrained terminals and weather-exposed environments. The safe deployment of alternative fuels, electrification, automation and connected systems therefore requires predictive safety tools, cyber-resilient ship-shore systems, emergency preparedness and harmonised operational procedures.

4.2.1 Operational objectives

- Enable safe and resilient short sea corridor operations by deploying safety frameworks for alternative fuels and electrification, cyber-resilient ship-shore systems, predictive risk management and emergency preparedness suited to dense coastal traffic, frequent port calls, and winter/ice conditions relevant to Nordic and Arctic-adjacent routes.

4.2.2 Target capabilities for 2035, 2040 and 2050

By 2035:

- Harmonised safety protocols for batteries, charging, electrification and future fuel related operations in busy coastal ports; improved emergency coordination and drills.
- Cyber resilience baselines scaled for SMEs/operators, plus safe lifecycle integration as systems become more complex.
- Operational resilience increasingly includes port disruption, weather volatility, and energy availability (including dual use related disruptions).

By 2040:

- Predictive safety and dynamic risk modelling integrated into corridor operations and port interfaces.
- Predictive maintenance and condition-based monitoring becoming standard features.
- Winterisation/extreme weather safety integrated into design and operational limitations.
- Cyber risk management is increasingly treated as operational safety, not only IT hygiene, because short sea vessels depend heavily on frequent digital exchange with ports, terminals, agents, traffic systems, and shore support, all of which expand the cyber attack surface.
- Safety systems become more integrated across ship and shore, with common data models for arrival windows, power availability, bunkering readiness, berth status, and emergency planning.
- Certified "guardian AI" that continuously combines machinery signals, weather, port readiness, cargo stability, battery health, and cyber anomalies into a single live risk picture for master and shore control.

By 2050:

- Zero-accident/zero-pollution corridor operations supported by continuously assured safety and cyber security.
- Robotic onboard response teams handle battery-room inspection, toxic leak detection, confined-space checks, and first-fire intervention before human crews enter hazardous spaces.
- Introducing a "safe-harbor autonomous mode" that automatically reconfigures speed, power, ventilation, and communications when severe weather, cyber incidents, or grid-side failures compromise the voyage plan.

4.2.3 Required enablers

- Harmonized safety cases and class/flag approval pathways for alternative fuels, batteries, and OPS/charging.
- Joint emergency preparedness at corridor scale (ports, responders, operators).

4.2.4 Key research gaps (linked to achieving the objectives, building on the current state-of-play).

Safe operations at the interface of electrification + fuel bunkering + cargo handling in constrained ports.

Assurance/certification for safety-critical AI systems and cyber-physical resilience.

Extreme weather safety of batteries and fuel systems (icing, ventilation, leak detection, emergency response).

4.3 Fully connected, automated and data-driven coastal systems

The future short sea system will rely on secure and interoperable data exchange between vessels, ports, terminals, energy providers, authorities and hinterland logistics nodes. Digitalization, automation and AI-supported decision-making can improve reliability, reduce emissions, optimize port calls and support new service models, provided that systems are interoperable, cyber-secure and designed for real short sea operating conditions.

4.3.1 Operational objective(s)

Enable data-driven, automated corridor operations through secure connectivity, smart waterways, digital twins, and expanded autonomy in machinery condition monitoring and maintenance, improving reliability and reducing operating cost and emissions across high-frequency services.

4.3.2 Target capability 2035, 2040 and 2050

By 2035:

- Digital twins and smart maintenance become standard: condition-based maintenance, AI diagnostics & optimization, energy efficiency optimization, remote support. TRL 4-8
- Smart waterways services improve safety and predictability in dense traffic; secure standard communication and decision making solutions underpin corridor operations and allows for remote piloting/operation. TRL 4-8
- Just-in-time arrival, just-in-time connection to port infra, and just-in-time offloading and loading deployed at major logistic hubs. TRL 4-8
- Emission & Pollutant (airborne and underwater) detection enhanced to support active control of energy and propulsion systems. TRL5-9
- Automated berth approaches, smart mooring, and semi-automated maneuvering introduced.

By 2040:

- Partial autonomy expands from navigation into machinery system autonomy (automated reconfiguration, safe fallback), validated in cross-border corridors. TRL 5-8Just-in-time arrival, just-in-time connection to port infra, and just-in-time offloading and loading becomes standard practice. TRL 7-9
- Fleet-level orchestration becomes more sophisticated, with operators balancing ETAs, berth windows, energy prices, charging slots, carbon costs, and intermodal connections across entire route networks.

- Compliance will become digital by default, with FuelEU, ETS, MRV-style reporting, fuel certification, and real-time emissions accounting integrated directly into ship and fleet software.

By 2050:

- Fully integrated digital corridor ecosystems (ship–port–tugs-waterway–energy), with continuous assurance through continuous exchange of machine-readable planning data. AI used to help optimize the whole corridor rather than just one vessel.
- “Self-negotiating” port calls emerge, where vessels automatically bid for arrival slots, shore power windows, and loading priorities based on energy state, cargo urgency, emissions cost, and downstream connections.
- Semi-autonomous feeder and coastal vessel convoys become viable on selected routes, using geofenced autonomy and shore supervision to reduce crew workload while preserving safety and regulatory control.

4.3.3 Required enablers

- Interoperable digital architectures and secure data spaces across stakeholders.
- Corridor-scale testbeds for autonomy in mixed traffic and harsh winter conditions.

4.3.4 Key research gaps (linked to achieving the objectives, building on the current state-of-play).

- Certifiable AI diagnostics and autonomous maintenance decisioning (continuous assurance).
- Resilient positioning and communications for safe operations under interference/degraded connectivity.

4.4 Human-centered design and a future-ready workforce

The transition of short sea shipping depends on people as much as on technology. Alternative fuels, electrification, digital tools, remote support and automation will change tasks, responsibilities and competence requirements both on board and ashore. Human-centred design, intuitive decision-support systems, training and social sustainability must therefore be embedded in technology development and deployment.

4.4.1 Operational objective(s)

Enable a human-centred workforce transition by reducing cognitive load via better HMIs and alarm strategies, building competencies for new fuels/electrification and digital tools, and supporting sea-to-shore operational models that sustain safety and reliability under labour shortages. The attractiveness of short sea careers will depend increasingly on decent work, connectivity, training, and skills portability, because the sector will compete for digitally literate and technically adaptable talent.

4.4.2 Target capability 2035, 2040 and 2050

By 2035:

- Training ecosystems for alternative fuels, battery safety, charging, and automated systems; improved HMIs and alarm handling, boosting the development of efficient emergency response solutions for vessels and ports.

- Routine remote diagnostics and shore support integrated into operations

By 2040:

- Fully skilled workforce operating advanced systems safely and efficiently.
- Human-AI resilience procedures established.
- Unmanned engine room concept deployed, with introduction of robotic maintenance capabilities. Machinery, cybersecurity, and cargo specialists joining through secure remote systems.
- Mixed-reality maintenance and emergency training embedded into daily work, allowing crews to rehearse charging faults, fuel leaks, cyber incidents, and port-approach failures.

By 2050:

Mature human-automation teaming practices across navigation and machinery operations. Every officer and engineer work with an onboard AI copilot that explains alarms, recommends responses, checks procedures, translates technical information, and tailors guidance to the vessel's route and energy system.

4.4.3 Required enablers

- Competence standards aligned with new fuel hazards and automation roles.
- Change management and organisational models for sea-to-shore processes.

4.4.4 Key research gaps (linked to achieving the objectives, building on the current state-of-play).

- Human factors and trust in AI for maintenance/autonomous functions.
- Demonstrating training effectiveness for rare-but-critical events.

4.5 Forward looking regulation, standardization and system-level integration

Regulation, standardization and certification will shape the speed and scale of deployment in short sea shipping. New fuels, electrification, automation, data governance, cyber resilience and system-level integration require harmonized frameworks that provide safety, investment certainty and cross-border acceptance. Regulatory development should advance alongside technology development, while supporting deployment through goal-based rules, technical standards and regulatory sandboxes.

4.5.1 Operational objective(s)

Enable rapid corridor-scale deployment by creating harmonised standards and certification pathways for electrification, methanol/ammonia/hydrogen/new fuels bunkering, autonomy beyond navigation, and cyber resilience—ensuring system-level integration of vessels, ports, waterways, and energy networks.

4.5.2 Target capability 2035, 2040 and 2050

By 2035:

- Standardized OPS/charging interfaces, battery safety, fuel certification, and reporting/compliance processes support wide uptake.
- Adopting lifecycle, well-to-wake, GHG accounting.

By 2040:

- Mature safety standards for alternative fuels, carbon capture and handling, autonomous operations, and corridor data exchange, enabling multi-country operations.
- Regulation itself becomes machine-readable, with vessels consuming live digital rulebooks, fuel passports, charging rights, and verifier interfaces through APIs so that compliance becomes continuous rather than retrospective.

By 2050:

- Fully harmonised system-of-systems regulation and standards across the EU waterborne ecosystem.
- Future coastal regulation shift from ship-by-ship rules to corridor-level carbon budgets, where ports, operators, cargo owners, and energy providers jointly optimize total emissions for a whole regional logistics chain.

4.5.3 Required enablers

- AFIR/Fuel EU-aligned implementation support and consistent technical standards.
- Regulatory sandboxes for new fuels, new energy sources, and autonomy (including machinery autonomy).

4.5.4 Key research gaps (linked to achieving the objectives, building on the current state-of-play).

- Standardised verification for alternative energy sources such as solar and wind, ESD performance and inclusion in compliance/finance.
- Certification frameworks for adaptive AI and continuously updated software systems.
- Carbon capture and handling related standards.
- Safety related development of standards in all areas.
- AI-systems safety and risk analysis.
- Cybersecurity standards and regulations development.

5. Enablers and Deployment

The pathway-specific enabling conditions noted above identify what is needed for each technology area. This section highlights the enabling conditions required to move from research, pilots and first-of-a-kind applications towards wider deployment across short sea corridors, fleets, ports and logistics chains.

5.1. Corridor-based deployment and system integration

Deployment should be organised around short sea corridors and port networks rather than around individual vessels alone. The Baltic, North Sea, Atlantic, Mediterranean and Black Sea basins differ in terms of cargo flows, route length, weather exposure, vessel size, port density, energy availability and hinterland connections. For this reason, clean and digital short sea corridors and hubs for bulk/ tramp shipping will be used as practical deployment environments where shipowners, ports, terminal operators, energy suppliers, shipyards, equipment manufacturers, classification societies, authorities, logistics providers and cargo owners develop scalable solutions together.

Early deployment should prioritise routes with high traffic density, predictable operations and repeated port calls, including feeder container services, freight-only Ro-Ro services, general cargo routes, coastal tanker movements, bulk flows and island supply routes. These corridors should validate shore-side electricity, fast charging, alternative-fuel bunkering, fuel certification, battery and modular energy systems, just-in-time arrival, port-call optimisation, cargo handling, emissions reporting, safety procedures and commercial arrangements.

The objective should be to move from isolated demonstrations to replicable corridor packages. These packages should combine vessels, port infrastructure, energy supply, digital services, safety procedures, financing models and operational rules. Once validated on high-potential routes, they can be adapted to lower-volume, seasonal, remote or more operationally complex services.

5.2. Clean-energy supply, refuelling and charging infrastructure

Clean-energy availability is a central condition for decarbonising short sea shipping. Battery-electric and hybrid propulsion are relevant for short-distance, predictable and high-frequency services, but their deployment depends on port charging capacity, shore-side electricity, grid readiness and sufficient turnaround time. Sustainable fuels, including certified biofuels, renewable methanol and other low- and zero-carbon fuels, can support emission reductions in parts of the existing fleet and in newbuilds where fuel supply, safety frameworks and lifecycle-emission performance are assured.

Ports and terminals should therefore develop as multi-energy nodes for SSS. Shore-side electricity should be deployed and standardised in line with regulatory requirements and should be planned together with grid reinforcement, port energy management, charging infrastructure and vessel investment. For suitable routes, shore-side electricity should gradually evolve from hotel-load supply towards high-capacity charging for propulsion batteries.

Alternative-fuel bunkering infrastructure should first be developed in strategic coastal hubs and green corridors where vessel demand, fuel supply, safety procedures and port capacity can be aligned. Methanol may be deployed earlier in some segments, while ammonia, hydrogen and other future fuels require further safety validation, infrastructure development and operational experience before broader deployment. LNG and biomethane may remain transitional options in selected cases, provided that methane slip and lifecycle emissions are properly controlled. Infrastructure planning should therefore be fuel-flexible and corridor-based, avoiding premature lock-in while supporting technologies that are ready for deployment.

5.3. Fleet renewal, retrofitting and industrial readiness

The SSS fleet is heterogeneous and ageing, and a large share of existing vessels will remain in operation for many years. Deployment must therefore combine newbuilds with retrofitting and conversion of existing vessels. Retrofitability, modularity, fuel flexibility and lifecycle-cost reduction are essential, especially for small and medium-sized operators, specialised cargo segments and lower-volume routes where the business case for newbuilds is weaker.

Standardised and repeatable retrofit packages should be developed for different vessel categories, including feeder container vessels, general cargo and multipurpose vessels, coastal tankers, bulk carriers and freight-only Ro-Ro vessels. These packages may combine hybridisation, batteries, methanol-ready or fuel-flexible engines, after-treatment systems, energy-saving devices, wind-assisted propulsion, hull and propulsor optimisation, waste heat recovery, digital energy-management systems and onboard monitoring.

Shipyards, repair yards, equipment manufacturers and classification bodies should prepare for repeated conversion programmes rather than one-off prototypes. This requires modular designs, pre-certified components, standardised interfaces, yard capacity, skilled workers and predictable demand. Strengthening European ship repair, retrofitting, conversion and equipment supply capacity will be a key condition for turning the roadmap into industrial deployment.

5.4. Digital infrastructure, data governance and smart corridor management

Digitalisation is a prerequisite for efficient, reliable and low-emission SSS operations. Current tools such as port community systems, maritime single window reporting, digital twins, route optimisation, condition-based maintenance and emissions monitoring provide an important basis, but they need to be connected into interoperable corridor services.

Priority should be given to secure data exchange between vessels, ports, terminals, authorities, energy providers, logistics operators and cargo owners. This should include real-time port-call information, berth and terminal readiness, shore-power availability, charging slots, bunkering readiness, cargo status, weather conditions, emissions data and hinterland connections. Interoperability is essential: digital systems should reduce administrative complexity rather than create new fragmentation.

By 2035, digital corridor services support major short sea hubs and high-frequency services through improved reporting, port-call optimisation, just-in-time arrival and condition-based maintenance. By 2040, these systems enable predictive maintenance, automated compliance reporting, fleet-level optimisation, energy planning and remote support. By 2050, SSS corridors function as integrated digital ecosystems in which vessels, ports, terminals, energy systems and logistics chains exchange machine-readable planning and operational data continuously.

5.5. Safety, security and climate resilience

Safety, security and resilience must be treated as deployment conditions from the beginning. Short sea vessels operate in dense coastal traffic, busy port approaches, constrained terminals, exposed sea areas and, in some regions, winter, ice and low-temperature conditions. New fuels, electrification, high-power charging, batteries, carbon capture, automation and remote operations introduce new risks that must be addressed through harmonised safety cases, emergency procedures, crew training and port-level preparedness.

Alternative-fuel bunkering, battery charging, cargo handling and port operations should be assessed together because these activities may occur in constrained port environments and within short turnaround windows. Corridor-level emergency preparedness should involve ports, terminal operators, shipowners, fuel suppliers, emergency responders, authorities and classification societies.

Cybersecurity must also become part of operational safety. As vessels depend increasingly on digital exchange with ports, terminals, agents, traffic systems and shore-support centres, cyber incidents may affect safety, reliability and supply-chain continuity. Climate resilience should be integrated into vessel design, route planning, port infrastructure, cargo handling and emergency response, particularly for services exposed to extreme weather, icing, port disruption and energy-supply constraints.

5.6. Regulation, standards and certification

A stable, goal-based and technology-neutral regulatory framework is essential for investment certainty. SSS will need harmonised standards and certification pathways for shore-side electricity and charging, batteries, methanol, hydrogen, ammonia, fuel-flexible engines, onboard carbon capture, energy-saving devices, wind-assisted propulsion, digital reporting, automation, remote operations and cyber resilience.

Regulatory sandboxes should be used to test new operational concepts in controlled corridor environments and should feed into permanent certification pathways as technologies mature. This is particularly important for alternative fuels, machinery autonomy, remote support, digital compliance and ship-shore data exchange. Cross-border acceptance is also essential, because short sea shipping often operates between Member States and across regional sea basins.

Common standards are needed for lifecycle and well-to-wake greenhouse-gas accounting, verification of energy-saving devices, verification of wind, solar and other renewable-assisted technologies, fuel certification, fuel passports, digital reporting and cybersecurity. Consistent interpretation of EU requirements will reduce fragmentation, support investment and help operators deploy solutions across multiple routes and jurisdictions.

5.7. Finance, business models and market uptake

The main deployment barrier is often not technological readiness alone, but the lack of a positive business case. Zero-emission vessels, renewable fuels, shore-power connections, charging systems, retrofits, digital integration and safety upgrades require significant investment, while many SSS operators face uncertain payback periods, charter constraints, fuel-price volatility and limited ability to pass additional costs to customers.

Deployment will require a combination of EU, national, regional and private financing. Grants, guarantees, low-interest loans, de-risking instruments, green corridor funding, port infrastructure support and revenue recycling from market-based instruments should be considered. Support should be designed to address the needs of SMEs, regional services, seasonal operations, island supply routes and smaller ports, where investment capacity is more limited.

Market demand should also be strengthened through green transport contracts, public procurement, cargo-owner commitments, pooling mechanisms, long-term fuel offtake agreements and cooperative infrastructure models. Business models such as energy-as-a-service, battery-as-a-service, shared charging infrastructure and corridor-level fuel procurement can reduce first-mover risk and support wider uptake. Deployment should therefore link technology investment with predictable demand and shared benefits across the logistics chain.

5.8. Skills, workforce transition and social acceptance

The deployment of clean and digital SSS depends on a workforce able to operate, maintain and supervise new systems safely. Crews, shore-based operators, port workers, terminal personnel, emergency responders, inspectors, shipyard workers and authorities will need competences in alternative fuels, electrification, high-voltage systems, battery safety, methanol, hydrogen and ammonia handling, digital reporting, cybersecurity, remote support, automated systems and emergency response.

Training and certification should evolve in parallel with technology deployment. Simulation, XR tools, digital training platforms and corridor-level emergency drills can support preparation for rare but critical events, such as fuel leaks, charging failures, battery incidents, cyber disruptions, severe weather and port-approach failures. Competence standards should be aligned across onboard, port and shore-based roles, particularly where operations become more integrated.

Human-centred design should guide the introduction of automation and AI-supported decision-making. New systems should reduce workload, improve situational awareness and support safe collaboration between crews, remote support centres and port actors. Social dialogue, clear career pathways, decent working conditions and skills portability will be needed to ensure that the transition improves the attractiveness of short sea shipping careers.

5.9. Deployment milestones

By 2035, selected clean and digital short sea corridors are operational. Battery-electric and hybrid systems are deployed on suitable short-distance and high-frequency routes, shore-side electricity and standardised charging available at key ports, and sustainable alternative fuel-capable engines and retrofits expand where fuel supply and safety frameworks are available. Energy-saving devices, route optimisation, digital reporting, condition-based maintenance and early remote-support applications deliver near-term operational and environmental benefits.

By 2040, deployment moves from pilots to scale. Zero- and near-zero-emission propulsion solutions are commercially available for the main cargo-based SSS segments, supported by interoperable charging and alternative-fuel bunkering infrastructure in core coastal hubs and selected corridors. Predictive safety, cyber-secure data exchange, automated reporting, integrated corridor management, remote support and partial automation are standard features of advanced SSS corridors. Industrial capacity for retrofitting, conversion and modular technology integration supports deployment beyond first movers.

By 2050, short sea shipping operates as a climate-neutral, digitally integrated and resilient component of Europe's transport system. Vessels, ports, terminals, energy systems and hinterland connections function as an integrated network supporting zero-emission logistics, modal shift, island and peripheral connectivity, circular-economy flows, secure supply chains and European industrial competitiveness.

6. Expected Impacts

The implementation of this roadmap is expected to support the transformation of cargo-based short sea shipping into a zero-emission, competitive, digitally connected and resilient component of the European transport system. Its impacts will depend on the coordinated deployment of fleet technologies, port infrastructure, clean-energy supply, digital services, safety frameworks, financing instruments and workforce capabilities across short sea corridors.

6.1. Impacts on short sea competitiveness and modal shift

A central expected impact of the roadmap is to strengthen the competitiveness of short sea shipping within European logistics chains. Cleaner vessels, improved port-call efficiency, reliable digital reporting, better cargo visibility and closer integration with hinterland transport can make SSS more attractive to shippers and logistics providers. This is particularly important for feeder container services, general cargo, coastal bulk flows, coastal tankers, freight-only Ro-Ro operations and island supply chains. By improving reliability, transparency and environmental performance, the roadmap supports modal shift from road to sea where short sea services are operationally and commercially viable. This reduces land-side congestion, improves the resilience of European freight transport and strengthens the role of SSS as a core element of multimodal logistics.

6.2. Environmental and climate impacts

The roadmap eliminates greenhouse-gas emissions and air pollutants from short sea shipping through a combination of energy efficiency, electrification, hybridisation, sustainable alternative fuels, renewable-assisted propulsion, shore-side electricity and operational optimisation. In the near term, the main benefits are expected from measures that can be applied to the existing fleet, including energy-saving devices, hull and propulsor optimisation, route optimisation, shore-side electricity and sustainable alternative fuels where available. In the longer term, deeper emission reductions will depend on the deployment of zero- and near-zero-emission propulsion solutions on suitable routes and vessel segments. The roadmap aims to reduce environmental pressures in ports and coastal areas, including emissions at berth, underwater noise and other local impacts. Its environmental impact will therefore depend not only on vessel technologies, but also on port readiness, fuel availability, electricity supply and corridor-level deployment.

6.3. Port, corridor and clean-energy impacts

Short sea shipping has frequent interaction with ports, terminals and hinterland logistics systems. One of the main expected impacts of the roadmap is therefore the development of ports as deployment platforms for clean and digital SSS. Ports will increasingly need to provide shore-side electricity, charging capacity, alternative-fuel bunkering, energy management, safety coordination, digital port-call services and efficient links to rail, road and inland waterways. The roadmap improves alignment between vessel investment and port-energy planning. Coordinated corridor deployment reduces the risk that vessels are built or retrofitted without the necessary infrastructure, or that ports invest in infrastructure without sufficient vessel demand. This will be particularly important for smaller and regional ports, where the capacity to finance and implement clean-energy infrastructure may be more limited.

6.4. Impacts on regional connectivity and supply-chain resilience

Short sea shipping plays a strategic role in connecting islands, peripheral regions, industrial clusters and regional markets to the Single Market. The roadmap strengthens this role by improving the reliability, efficiency and environmental performance of short sea services. This is important not only for major hubs, but also for secondary ports and regional corridors that support territorial cohesion and essential supply chains. A more resilient SSS system provides additional capacity and redundancy when road, rail or port systems are disrupted. Better digital coordination, port-call management, predictive maintenance and climate-resilient operations can help maintain services under conditions of congestion, extreme weather, energy-supply constraints or other disruptions.

6.5. Fleet renewal, retrofitting and industrial impacts

The roadmap will stimulate fleet renewal and retrofitting in the European short sea sector. Because much of the fleet will remain in operation for many years, a significant impact will come from scalable retrofit solutions, modular propulsion systems, fuel-flexible engines, batteries, energy-saving devices, after-treatment systems, digital monitoring and onboard energy-management systems. This creates opportunities for European shipyards, repair yards, equipment manufacturers, technology suppliers, classification societies and digital-service providers. The development of standardized retrofit packages, pre-certified components and repeatable conversion models reduces costs, shortens yard time and improves the bankability of clean SSS investments. In this way, the roadmap supports both maritime decarbonisation and European industrial competitiveness.

6.6. Digitalisation and administrative-efficiency impacts

The roadmap accelerates the development of digitally connected short sea corridors. Improved data exchange between vessels, ports, terminals, authorities, energy suppliers and logistics operators can support just-in-time arrival, berth coordination, shore-power planning, charging slots, bunkering readiness, emissions reporting, cargo visibility and hinterland integration. Digitalisation reduces administrative burdens. More interoperable reporting systems and better use of the European Maritime Single Window environment reduces duplication and makes SSS easier to use within the Single Market. Over time, digital corridor management, automated compliance reporting, condition-based maintenance and fleet-level optimisation improve reliability, reduce waiting times, lower fuel consumption and support better use of port and vessel capacity.

6.7. Safety, security and operational-resilience impacts

The roadmap improves safety and operational resilience through harmonised safety procedures, predictive maintenance, digital risk management, cyber-secure systems, improved emergency preparedness and better coordination between vessels, ports and authorities. These impacts are particularly important because SSS operates in dense coastal waters, constrained port environments and weather-exposed sea basins. At the same time, the deployment of batteries, high-power charging, methanol, hydrogen, ammonia, onboard carbon capture, automation and remote support introduces new risks. The roadmap therefore supports safer deployment by linking technology uptake with certification, crew training, port preparedness, emergency drills and cyber-resilience requirements. This will increase confidence among operators, regulators, crews, port communities, cargo owners and the public.

6.8. Workforce and social impacts

The transition of short sea shipping creates new skills requirements both on board and ashore. Crews, shore operators, port personnel, emergency responders, inspectors, maintenance teams and shipyard workers will need competences in alternative fuels, electrification, digital systems, cybersecurity, automation, remote support and environmental compliance. If properly managed, the roadmap contributes to safer, cleaner and more attractive jobs in the SSS sector. Human-centred design, simulation-based training, social dialogue and skills portability will be important to ensure that new technologies support workers rather than increasing complexity or workload. The transition also creates new high-skilled roles in shore support, digital operations, clean-energy services, retrofit engineering and safety management.

6.9. Impact monitoring and deployment feedback

The impacts of the roadmap should be monitored through a limited set of indicators that link technology deployment to operational, environmental and market outcomes. Relevant indicators include greenhouse-gas emissions, air pollutant emissions, share of vessels using renewable or zero-emission energy solutions, number of retrofitted or newly built clean vessels, availability of shore-side electricity and charging, alternative-fuel bunkering availability, port-call efficiency, corridor reliability, modal shift from road to sea, digital reporting coverage, accident and incident rates, cybersecurity readiness, workforce training and the number of pilot solutions reaching commercial deployment. Monitoring should also support feedback into the roadmap. Lessons from clean corridors, retrofit programmes, port infrastructure projects, digitalisation initiatives and regulatory sandboxes should be used to adjust deployment priorities over time. This will help ensure that the roadmap remains responsive to technology maturity, market uptake, infrastructure readiness and the practical needs of short sea operators, ports and logistics users.