WATERBORNE

WATERBORNE TECHNOLOGY LEADERSHIP

Towards a competitive, resilient and sustainable waterborne sector

A Co-programmed Partnership under Framework Programme 10

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CONTENT

The **Waterborne Technology Platform (TP)** has been set up as an industry-oriented Technology Platform to establish a continuous dialogue between all waterborne stakeholders, such as shipowners, shipbuilders, equipment manufacturers, classification societies, infrastructure and service providers, ports, universities or research institutes, and with the EU Institutions and EU Member States. Currently, Waterborne TP represents more than 130 members, originating from 19 EU Member States and four European countries associated with Horizon Europe. As one of our key activities, the Waterborne TP is coordinating the private side of the Co-Programmed Partnership on Zero-Emission Waterborne Transport (ZEWT).

1. PREFACE

The waterborne sector is undergoing a profound **green and digital transformation**. The European Commission is developing a strategy to strengthen the **competitiveness, sustainability and resilience of the EU's maritime manufacturing sector and the related value chains**[1], contributing to a strong **European maritime and inland waterway transport sector**. This strategy will outline measures to boost the twin transition, including actions on **innovation**, investment and the promotion of a global level playing field. In parallel, the EU Ports Strategy[2] aims to address the current and future challenges for European ports by framing a comprehensive approach that defines EU priorities, proposes targeted areas of intervention and provides recommendations and guidance to stakeholders. Areas of focus include **competitiveness, energy transition, security**, including cybersecurity and **military mobility**, external dimensions, **innovation**, social issues, **skills and safety**, as well as investment and financial support. Together these initiatives reflect the growing **strategic importance** of the waterborne sector for **Europe's economic competitiveness, resilience, security and climate objectives**. A coordinated and forward-looking research and innovation approach is therefore essential to enable the sector to deliver on the **twin transition**, strengthen **industrial leadership** and ensure the **effective deployment** of innovative solutions across the waterborne ecosystem.

1 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14745-EU-industrial-maritime-strategy_en
2 https://transport.ec.europa.eu/news-events/news/commission-sets-course-future-eu-ports-and-maritime-industry-2025-07-01_en

2. THE EUROPEAN WATERBORNE SECTOR

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2.1. THE EUROPEAN WATERBORNE ECOSYSTEM

The European waterborne sector is **a dynamic and highly interdependent ecosystem**, featuring a diverse array of public and private stakeholders. These include shipowners (both maritime and inland navigation), shipbuilders, equipment manufacturers, ports, classification societies, infrastructure and service providers (e.g. dredging), blue economy actors as well as universities and research institutes.

The sector plays a significant role in reinforcing the **EU's resilience in terms of trade, safety, security, defence, energy supply, and sustainability**, while enabling the transition towards sustainable energy and more robust **supply chains**[3]. Furthermore, the waterborne sector is fundamental to Europe's **sovereignty and economic and strategic autonomy** and provides the most suitable pathway to achieve the EU's climate ambitions. It is also a major employer, providing 4.2 million direct jobs and contributing approximately € 500 billion annually to the EU's Gross Domestic Product (GDP).

While large enterprises play a key role in research, development, innovation and deployment across the value chain, **small and medium sized enterprises (SMEs) form the largest part** of the EU waterborne sector and play a crucial role both within the sector and in the broader European economy.

The European waterborne sector is a **technology leader**. The **European maritime technology sector**[4] **holds a global leading** position in high-technology shipbuilding, maritime and inland cruise ships, electric ships, offshore support vessels and platforms[5], underwater and unmanned vehicles as well as naval vessels. It also leads in **green and smart port and shipping** technologies, such as battery electric solutions, clean engines, exhaust treatment systems, green equipment, and smart technologies that improve efficiency, operations and automation. European companies supply almost half of the world's maritime equipment and play a leading role in designing and developing most of the global fleet's power systems.

Furthermore, the solutions developed by the European maritime technology sector are key for **dual-use purposes**, significantly contributing to **EU preparedness, security and overall resilience.**

The waterborne sector is **critical for Europe's trade and economy**, handling nearly 90% of international trade. Waterborne transport accounts for 81% of the EU's external trade and 40% of its internal trade.

3 https://www.waterborne.eu/images/240311_EU_Waterborne_Transport_Sector_Joint_Declaration_-_March_2024.pdf
4 https://www.waterborne.eu/images/documents/200527_Zero-Emission_Waterborne_Transport_Proposal_Final_Version_Spread.pdf
5 https://www.waterborne.eu/images/240910_Press_release_Draghi_report_calls_for_a_dedicated_waterborne_partnership.pdf

The European maritime fleet is among the largest in the world, representing 35% of the global shipping fleet[6]. European shipping controls 30% of the world's bulk carriers, 44% of container ships, 35% of tankers and 33% of LNG carriers, making it a leading force in global trade. Furthermore, the European waterborne sector includes approximately 12,000 inland navigation vessels, which are essential for intra-EU trade.
The sector encompasses a wide range of vessel types and services, differentiated by power requirements, operational profiles and autonomy[7]. These include **inland waterway transport vessels, ferries, short sea ships, cruise ships, intercontinental and offshore vessels, as well as blue economy vessels, including those operating in the underwater domain**. Further distinctions exist between **liner and bulk/tramp shipping and their respective business models**, as well as between **retrofitting** existing vessels and **building new ones**.

Ports are gateways for **trade, logistics, energy and military mobility**[8], and serve as strategic hubs for enabling the **energy transition, promoting modal shift**, and advancing the decarbonisation of the waterborne sector. They function as multimodal hubs that facilitate the movement of goods and passengers and support a wide range of economic activities, including shipbuilding, maintenance, logistics, and energy production. European ports are vital gateways linking Europe's transport corridors to the rest of the world, while also supporting the **internal market** and connecting **peripheral and island regions** to the European mainland[9]. Each year, around 400 million passengers embark and disembark in European ports.

Beyond transport, the waterborne sector plays a strategic role in the broader blue economy. It includes the development and production of offshore platform technologies that are critical, for example, for large-scale **offshore wind parks**. The sector also designs, produces, maintains and operates specialized vessels supporting blue economy activities such as **fishing and aquaculture**[10]. In addition, the European waterborne sector is a technology leader in the underwater domain, including **underwater unmanned vehicles** that are essential for the **security and resilience of submarine cables** and other critical infrastructure. The blue economy further represents a key market for the European maritime technology sector, as it provides diversified demand that helps mitigate the cyclical nature of the **shipbuilding market**[11] and strengthens long-term industrial stability.

6 https://ecsa.eu/european-shipping-key-for-europes-security-with-35-of-global-fleet-studies-find/
7 https://www.waterborne.eu/images/231229_SRIA_Zero_Emission_Waterborne_Transport_2.0_clean.pdf
8 https://transport.ec.europa.eu/news-events/news/commission-sets-course-future-eu-ports-and-maritime-industry-2025-07-01_en
9 https://transport.ec.europa.eu/transport-modes/maritime/ports_en
10 https://maritime-forum.ec.europa.eu/theme/blue-economy-and-fisheries/blue-energy/energy-transition-partnership_en
11 https://www.shipfinex.com/blog/what-is-shipbuilding

2.2. CHALLENGES

The European waterborne sector differs significantly from other industrial sectors due to its scale, unique technologies and fuels, long asset timelines, demanding operating environments and complex regulatory frameworks. These characteristics create specific challenges that require tailored, coordinated policy and research response.

International competition and geopolitical developments[12]

The Draghi report on EU competitiveness highlights the challenges faced by the waterborne sector in relation to international competition and geopolitical developments. In particular, distortive competition on the global market strongly affects the shipbuilding sector, **where Asian competitors can offer prices that are up to 30%-40% lower than those of the European shipyards**. This situation is further complicated by substantial public investments in research, development and innovation in competing regions, for example, **South Korea** recently announced a record investment of **$1.8 billion** to strengthen its leadership in next-gen shipbuilding[13]. While consolidated figures for **China's R&D** investment in shipbuilding are not publicly disclosed the sector is a strategic priority within China's national innovation agenda[14] and benefits from significant, often opaque, **state support**. By comparison, under Horizon Europe, up to € 530 Million has been made available for the transition towards zero-emission waterborne transport through the Co-programmed Partnership on Zero-Emission Waterborne Transport for the period 2021 – 2027. This public funding has been complemented by approximately € 3.3 Billion in private investments and additional support through Horizon Europe but overall remains **well below investment levels** in key competing regions. As a result, Europe's competitive position is increasingly challenged. Beyond commercial shipbuilding, these developments may also affect **naval and defence-related shipbuilding**, given the strong interlinkages between civilian and military maritime technologies.

In parallel, **the EU's ownership share of the global maritime fleet is declining**. Several third non-EU countries, including in Asia, the Middle East and North America, offer highly attractive business environments for shipowners. For example, China provides favourable leasing schemes, while EU commercial banks have reduced their exposure to shipping due to stricter prudential requirements.

The EU also faces growing external pressure regarding the **ownership and management of transport and logistics infrastructure**. In particular, foreign investments in European ports and fleets are increasing, raising concerns related to strategic autonomy, security and resilience.

Research, development, innovation and deployment are therefore critical to **reinforcing Europe's leadership** in the waterborne sector and to enabling **re-entry into markets** currently dominated by global competitors. **Closing the innovation and deployment gap is therefore essential.**

Increased labour shortages combined with growing demand for the waterborne sector

Demographic change presents significant challenges for the European Union and the waterborne sector in particular. Population **ageing and decline** are expected to intensify **labour shortages** across the sector[15] affecting all segments. A clear example is global shortage of seafarers, which has reached critical levels, with projections **indicating a shortfall of around 90,000 seafarers by 2026**[16]. At the same time, global demand for waterborne transport is expected to continue to grow. The world population is projected to reach 8.5 billion by 2030 and 9.7 billion by 2050[17], resulting in **increased global trade volumes and waterborne transport demand**. This trend is reflected in the fourth IMO GHG study[18], which projects that **emissions from maritime transport could increase from about 90% of 2008 levels in 2018 to between 90 and 130% of 2008 levels by 2050** under a range of plausible economic and energy scenarios.

Digitalisation offers a strong potential to mitigate the impacts of labour shortages by improving efficiency, supporting remote and automated operations, and enabling Europe to keep its ships sailing, its maritime technology sector producing and its ports operating.

12 https://commission.europa.eu/topics/competitiveness/draghi-report_en
13 https://koreapro.org/2025/02/south-korea-invests-record-1-8-billion-to-dominate-next-gen-shipbuilding/#:~:text=South%20Korea%20announced%20on%20Tuesday,as%20Trump's%20trade%20war%20deepens
14 https://www.csis.org/analysis/hidden-harbors-chinas-state-backed-shipping-industry#:~:text=The%20most%20direct%20way%20Beijing,a%20total%20of%20$2.1%20billion
15 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/new-push-european-democracy/impact-demographic-change-europe_en
16 https://safety4sea.com/cm-key-trends-in-seafarer-recruitment-and-retention/#:~:text=by%20The%20Editorial%20Team,recruitment%20situation%20compared%20to%202023
17 https://www.un.org/en/global-issues/population#:~:text=The%20world%20population%20is%20projected,and%2010.4%20billion%20by%202100
18 https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20Executive-Summary.pdf

The transition to a zero-emission waterborne sector

The transition to a zero-emission **international maritime sector** will require very substantial investment. Estimated investment needs for decarbonising international maritime transport alone amount to approximately **EUR 39 billion each year between 2031 and 2050**[19]**.** These investments will be required across sustainable alternative energy carriers, onboard and onshore technologies, ports, infrastructure and energy supply systems. The total investment required for the transition of the broader **waterborne ecosystem** will be significantly higher.

While important progress has been made in recent years in the development of energy efficient and zero emission technologies, major investments in research, development, innovation, upscaling and deployment remain necessary to ensure timely implementation. This challenge is compounded by long lifetimes of waterborne assets, with **vessels typically operating for around 30 years.** To meet the **European climate objectives**[20] radically new technologies and assets need to be developed and deployed without delay.

Developing and implementing decarbonisation and digitalisation roadmaps by ship type is essential to guide investment, support competitiveness and ensure alignment with EU policy objectives, including the **Competitiveness Compass of the EU**[21].

Modal shift

The Sustainable and Smart Mobility Strategy[22] lays down the objective of shifting a substantial share of freight towards rail, inland waterways and shortsea shipping. The milestones set envisage an increase of transport by **inland waterways and shortsea shipping** of 25% by 2030 and 50% by 2050. **Zero-emission solutions and digitalization** will be key enablers for achieving this modal shift, as they support better integration of waterborne transport into multimodal logistics chains and create new synergies with other transport modes.

Diversified ecosystem

The waterborne sector is characterised by a highly diversified and complex ecosystem, shaped by international, European, national and regional regulatory frameworks and involving a wide range of authorities, including ports, river and waterway administrations and maritime and inland authorities. The sector also comprises a very large number of actors, including approximately 300 shipyards and 22,000 equipment manufacturers across Europe, alongside shipping companies and port operators.

Fragmented developments across this diverse ecosystem are costly and slow. The **twin green and digital transition** of the waterborne sector therefore requires a **holistic, coordinated approach** that brings together public and private stakeholders across the entire value chain.

Urgency of action

To meet multiple policy objectives, remain **internationally competitive**, address **demographic challenges**, achieve the transition to a **zero-emission sector** and strengthen **Europe's resilience**, incremental improvements alone will not be sufficient. Radical changes and the rapid development and deployment of new technologies are required.

Given the long lifetimes **of waterborne** assets, radically new solutions must be deployed as early as possible. Accelerating research, development, innovation, upscaling and deployment is therefore critical to boosting the competitiveness, resilience and sustainability of the European waterborne sector. This aligns directly with the key priorities identified in the **Draghi report on the future of European Competitiveness:** closing the innovation gap, decarbonising the waterborne sector, and reducing strategic dependencies.

19 https://commission.europa.eu/document/download/ec1409c1-d4b4-4882-8bdd-3519f86bbb92_en?filename=The%20future%20of%20European%20competitiveness_%20In-depth%20analysis%20and%20recommendations_0.pdf
20 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2040-climate-target_en
21 https://commission.europa.eu/topics/competitiveness/competitiveness-compass_en
22 https://transport.ec.europa.eu/transport-themes/mobility-strategy_en

2.3. RESEARCH, DEVELOPMENT, INNOVATION AND ITS DEPLOYMENT

Research, development, innovation (RD&I), together with their effective deployment are key to retaining and strengthening the **competitiveness** of the European waterborne sector. However, **Technology Leadership**[23], can only be achieved and sustained when RD&I and deployment are addressed from an ecosystem perspective, encompassing the entire value chain and the close interaction between its different actors. To remain a global frontrunner in the design, production, development and implementation of economically viable innovative technologies and solutions, including on-board and onshore integration, Europe depends on the resilience and performance of an interconnected waterborne ecosystem.

This systemic approach ultimately ensures a competitive advantage over other modes of transport and strengthens the European waterborne sector's position in the global market as Technology Leader.

The development of technological and operational solutions is often closely guided by policy objectives. These objectives aim, among others, to address major societal and environmental challenges, including climate protection, climate change mitigation, economic development, improved quality of life for citizens and the safeguarding of Europe's strategic autonomy.

> **Technology leadership in this context means being a frontrunner in enabling the transformation, by developing and deploying competitive solutions that mitigate climate change, provide the capability to become climate resilient, eliminate all harmful pollutants, improve working conditions or create new jobs, and stimulate economic prosperity, all while ensuring safety and security.**

The waterborne sector is a highly interdependent ecosystem. Figure 1 illustrates the involvement of different segments of the waterborne ecosystem across various ship types, including inland waterway vessels, short sea ships, ferries, cruise ships, offshore vessels, intercontinental vessels and blue economy products. To ensure its leadership position, Europe must ensure that it has the capability and capacity to design, produce, develop and implement economically viable innovative technologies and solutions across all these segments, including their onboard and onshore integration. This requires dedicated research, development, innovation and deployment efforts within the European maritime technology sector. Furthermore, ports and related infrastructure must be equipped to provide the services required by zero-emission and digital vessels. Without such enabling infrastructure, the deployment of innovative vessels and technologies will not be possible. This underlines the need for coordinated action across the entire ecosystem to enable the effective deployment of innovations at scale.

Solutions must also be economically viable across different waterborne transport segments and business models, including liner and bulk/tramp shipping, in order to ensure uptake and deployment. In addition, the transition requires a balanced focus on both the retrofitting of existing vessels and the development of newbuild solutions.

23 https://www.waterborne.eu/images/24_01_15_Annex_5_Waterborne_Long_Term_Strategy.pdf

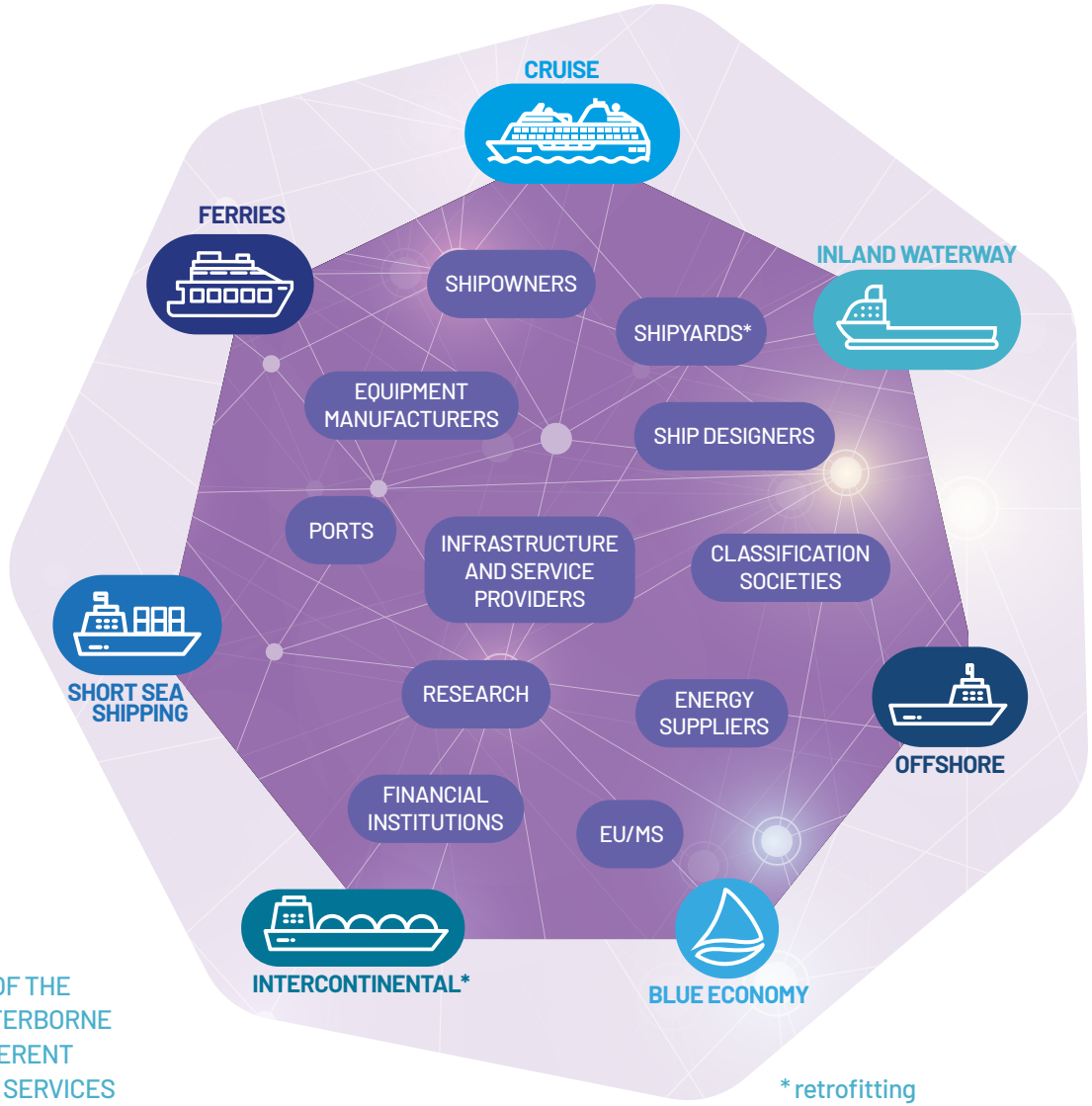

FIGURE 1

INVOLVEMENT OF THE EUROPEAN WATERBORNE SECTOR IN DIFFERENT PRODUCTS AND SERVICES

Implementation pathways

Research, development, innovation and deployment will be centred around four interconnected pillars:

- A resilient, competitive and sustainable maritime technology sector
- The transformation of waterborne transport
- Port ecosystems
- Unlocking the potential of the blue economy.

Under Horizon Europe 2021 – 2027, investments have been made in developing and demonstrating energy-efficiency and zero-emission solutions for parts of the waterborne fleet. For certain ship types, mainly those with lower power requirements and shorter operational autonomy, solutions **are approaching technical readiness.** For other ship types, particularly those with high power requirements and long operational autonomy, key technologies still require further development to reach **technological maturity.**
The proposed Partnership will address the full innovation chain, from **fundamental research through to deployment.** Particular emphasis will be placed on **upscaling solutions** and bridging the "valley of death" by supporting technologies in becoming **commercially viable** and deployable at scale. Integrated areas of attention across future RD&I activities will include sustainability solutions, including circularity, as well as digital solutions.

To stimulate deployment, dedicated technology roadmaps will be developed for different product and system categories, including the **maritime technology sector, port ecosystems, inland waterway transport, short sea shipping, ferries, cruise ships, intercontinental shipping, offshore vessels and the blue economy.** Where relevant, a further distinction will be made between liner and bulk/tramp shipping and their respective business models, as well as between retrofitting existing vessels and constructing newbuilds. These roadmaps will also address implications for jobs and skills, as well as the impact on rules, regulations and standards required to enable deployment.

> As technologies continue to evolve, it is vital that innovation in the waterborne sector remains human-centred, supporting reskilling, inclusivity, and collaboration across industry, academia, and policymakers. This alignment is essential to match technological progress with workforce needs and broader societal value. Furthermore, the development of technologies must progress in coordination with regulatory developments, to enable the effective deployment of innovations.

Stimulating the **systematic** deployment of economically viable innovations will provide the European waterborne sector with a **frontrunners position** and accelerate **the transition towards a resilient, competitive and sustainable** European maritime technology sector. At the same time, this presents opportunities to **export European solutions and products to global markets.** However, achieving this requires an ecosystem-approach. A competitive value chain also heavily depends on a **resilient supply chain** that can source the entire product from raw materials to finished high-tech parts. **Reliable delivery** equally requires a well-connected and innovative trans-European network. An example of the interdependency of the ecosystem is available in the textbox below.

(Complex) vessels are typically one-off orders built in very short series, meaning that a significant amount of engineering work must be performed for each new project. To ensure the frontrunners role of the European waterborne sector, and the stimulation of demand at the European maritime technology sector, a systematic approach towards deployment of innovations is required. This could be further analysed per product type as in figure 1.
This requires that all key players team up, including shipowners (both maritime and inland navigation), shipbuilders, equipment manufacturers, ports, classification societies, infrastructure and service providers (e.g. dredging), energy suppliers, as well as universities and research institutes. In addition, financial institutions, and in case of electrification, utility companies, should be involved. As regards digitalization, there is for example a need to ensure adequate 5G coverage, and relevant organisations should be involved. On a case-by-case basis, additional stakeholders need to be identified. The systematic approach would solve the "chicken and egg" dilemma as regards sustainable alternative energy carriers. In addition, green corridors (for liner traffic or traffic in certain regions, could be established). This will have a spin-off effect for other segments of the waterborne sector (e.g. in ports) or for other modes of transport or industries (e.g. in the hinterland).

The waterborne sector actively invests in research, development and innovation, education, training and skills development as well as deployment across the **full value and supply chain, including SMEs, start-ups and regional actors.** This is essential **to remain a frontrunner** in the global **green and digital transformation.** However, investments by the sector alone are far from sufficient to ensure Europe remains a Technology Leader in the waterborne sector. A joint and coordinated approach regarding research, development, innovation and deployment is therefore essential. In this context, a **Co-Programmed Partnership** ensuring waterborne technology leadership, starting in 2028, is not only timely but critical for the transition towards a resilient, competitive and sustainable European waterborne sector.

3. RESEARCH AND INNOVATION STRATEGY

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RD&I and deployment in an interconnected waterborne ecosystem

Technology Roadmaps

Targeted pathways to enable deployment:

- Maritime technology sector
- Port ecosystems
- Inland waterway transport
- Short sea shipping
- Ferries
- Cruise
- Intercontinental shipping
- Offshore
- Blue economy

01 POLICY OBJECTIVES

define strategic goals for competitiveness, resilience, sustainability, safety and security, and EU autonomy, guiding the direction and ambition of RD&I.

02 RD&I

translates policy objectives into validated innovations across the entire value chain.

03 Deployment & Scale-Up

move innovations from development to market through large-scale demonstration, first-of-a-kind deployment and upscaling.

04 Ecosystem Readiness

ensures enabling conditions and coordinated action across the waterborne ecosystem to support effective deployment.

05 Impact & Feedback

deliver economic, environmental and social benefits and feed lessons back into policy, regulation and future RD&I priorities.

FIGURE 2

RD&I AND DEPLOYMENT IN AN INTERCONNECTED WATERBORNE ECOSYSTEM

The European waterborne sector has developed a set of ambitious missions and visions to be achieved by 2040 and 2050[24]. The achievement of these ambitions and missions require a comprehensive, mission-driven Research and Innovation (R&I) strategy. This strategy ensures ***rapid technological progress, accelerated demonstration and deployment, strengthened industrial competitiveness, and seamless integration of innovations across vessels, ports, infrastructure and the expanding blue economy.*** The waterborne sector's transformation is uniquely complex: waterborne assets have long lifespans, vessels operate globally, require specialized fuels and equipment, and depend on interoperable port logistics systems. These characteristics make coordinated, large-scale R&I investment indispensable, for achieving climate neutrality, digital excellence, resilience, safety and security, and technology leadership.

The R&I strategy builds on the visions and mission of the waterborne sector and translates them into a coherent set of technological and innovation pathways. Each pillar corresponds to a critical technological challenge area where research, development, innovation and its deployment must deliver impact towards 2035, 2040, and 2050. The strategy integrates TRL pathways across product categories, technology themes and infrastructure, ensuring a realistic but ambitious progression of innovations toward operational maturity.

The R&I strategy focuses on four mutually reinforcing objectives:

1. Ensure the transition to a competitive, resilient and sustainable maritime technology sector
2. Accelerate the transformation of waterborne transport through zero-emission energy systems, safety and security innovations, next-generation connectivity and automation.
3. To transform European ports into next-generation hubs for energy, logistics, digital services and industrial activity, equipped to handle the demands of zero-emission vessels, smart and robust logistics chains, offshore energy systems and resilient coastal infrastructure
4. Strengthen Europe's technology leadership in the blue economy, enabling the growth of offshore renewable energy, a future-proof blue economy fleet and excellence in the underwater domain.

Across these objectives, cross-cutting priorities include digitalization, sustainability (including circularity), supply chain resilience, standardization, regulatory innovation and workforce transformation. These cross-cutting priorities apply to all four pillars and are therefore not repeated in full detail under each thematic area.

24 https://www.waterborne.eu/images/250708_Strategic_Research_Agenda_Final.pdf

3.1. RESILIENT, COMPETITIVE AND SUSTAINABLE MARITIME TECHNOLOGY SECTOR

3.1.1. VISION

The European maritime technology sector, including shipyards and the full manufacturing value chain, will be technology leader in sustainable, digital and competitive manufacturing and deployment by 2050. The maritime technology sector will operate with resilient supply chains, world-class manufacturing capability, high-skilled talent and advanced industrial ecosystems that support zero-emission vessels, smart ports, offshore infrastructure, underwater systems and digital waterborne services. Europe will set global standards for innovation, safety and environmental performance, and maintain sovereignty over critical technologies essential to its economic, environmental and security objectives.

3.1.2. MISSION AND STRATEGIC OBJECTIVES

This requires a powerful, innovation-driven industrial base capable of designing, manufacturing, retrofitting and maintaining advanced vessels, equipment, systems, components and infrastructures, including technologies with civil, security and defence relevance, contributing to Europe's preparedness, resilience and strategic autonomy. Strategic objectives include:

- Securing industrial resilience and strategic autonomy by reinforcing European supply chains for critical components, materials, fuels, digital technologies and cybersecurity systems
- Scaling industrial capacity to produce zero-emission vessels, alternative fuel systems, digital infrastructures, autonomous platforms and offshore technologies at a pace aligned with climate and competitiveness goals
- Advancing world-class manufacturing and shipyard transformation, including automation, robotics, modular construction, digital shipyards and circular production models
- Driving leadership in high-value innovation, from green propulsion and smart materials to AI-enabled systems, underwater technologies and integrated digital twins
- Building a future-ready workforce with advanced skills in automation, software, energy systems, cyber-resilience and sustainable engineering
- Promoting regulatory leadership and standardization to secure Europe's influence in global waterborne markets and ensure timely adoption of emerging technologies
- Supporting SMEs and cross-sector collaboration to accelerate innovation diffusion and strengthen Europe's waterborne industrial ecosystem

3.1.3. R&I PRIORITIES

Next-generation green maritime technologies and integrated propulsion systems

Develop and scale propulsion and energy systems tailored for zero-emission vessels across all segments, including e.g. ammonia, hydrogen, methanol, advanced batteries, hybrid solutions and renewable assisted propulsion. Research will focus on manufacturability, safety, energy efficiency, lifecycle cost performance, scalability and global deployability. Europe must own the intellectual property and industrial capability for these systems.

Digital shipyards, advanced manufacturing and robotics

Transform European shipyards and production clusters into highly automated, digitally integrated industrial ecosystems. Priorities include robotics for welding and assembly, additive manufacturing, standardisation and modular construction, designs that enable industrial production, digital twins of production lines, automated quality assurance and AI-enabled planning tools. These developments will **reduce production time, costs and environmental impact** while increasing precision and capacity.

Materials innovation, circularity and lifecycle optimization

Research lightweight, recyclable and corrosion-resistant materials, advanced coatings, smart materials with embedded sensing, and circular production processes. Develop lifecycle intelligence platforms enabling circular design, predictive maintenance, remanufacturing and end-of-life recovery. The waterborne sector must shift toward full circularity to reduce resource dependency and increase sustainability.

Digital, cyber-secure and interoperable waterborne systems and supply chains

Strengthen European R&I capacity in digital system integration, ship software interoperability and cyber-secure architectures across the full ship lifecycle. RD&I should address interoperable software frameworks, secure data exchange, lifecycle system compatibility and cyber-resilience of onboard and onshore systems. These capabilities are essential enablers for resilient, muti-tier supply chains, with improved transparency, risk assessment, and compliance with EU critical infrastructure and cybersecurity requirements, while reducing systemic dependencies in critical waterborne technologies.

High performance systems for autonomy, sensing and digital integration

Develop integrated solutions that combine advanced sensing, situational awareness, secure data exchange, edge computing and AI-assisted decision systems. These technologies are essential not only for autonomous vessels but also for smart ports, offshore infrastructure and underwater systems

Workforce transformation, skills development and human-centred design

Research human-machine interface design, digital training platforms, XR-based competence development, and new job profiles for autonomous operations, digital engineering, energy systems and cybersecurity. New safety culture where incidents are treated as a learning opportunity. The maritime technology sector must attract and retain talent while ensuring workers adapt comfortably to new industrial processes.

Standards, certification and regulatory pathways enabling global leadership

Develop future-oriented certification schemes, testing protocols and standardization frameworks for alternative fuels, digital systems, autonomous technologies, underwater infrastructure and circular materials. Europe's regulatory leadership will influence global markets and expand export opportunities for European maritime technologies.

3.1.4. DEVELOPMENT TRAJECTORIES

By 2035 – Industrial Upgrade and Innovation Acceleration

- Deployment of the digitalization of core shipyard processes, early robotics adoption and first modular construction lines across leading European yards
- Deployment of advanced materials and circular design principles in new vessel classes
- Testing of autonomous and smart system integration into vessel designs
- To test modelling of ship software interoperability to identify waterborne cyber risks
- Deployment of first European-wide industrial partnerships emerging from RD&I programmes, focused on critical waterborne technologies
- Execution of training focused on digital manufacturing and sustainable engineering
- Deployment of energy efficiency improving and emission abatement technologies on existing vessels.

By 2040 – Scaled Manufacturing and System Integration

- Deployment of large-scale production of zero-emission vessels and propulsion systems supported by automated shipyards and modular assembly
- Demonstration of integration of digital twins across design, production and maintenance for mainstream vessel classes
- Deployment of widespread adoption of advanced robotics, predictive automation and real-time quality control in shipbuilding
- Resilient component manufacturing clusters operational in key European regions.
- Workforce transformation well advanced, with digital and automation skills embedded in waterborne education and on the job training.

By 2050 – Globally Competitive, Fully Sustainable and Autonomous Industrial Ecosystem

- European maritime technology sector recognized as global leader in clean propulsion, automation, materials science and offshore technologies
- Fully digital, highly automated shipyards capable of high-volume, cost-effective production of zero-emission and autonomous waterborne assets
- Fully circular material flows in vessel construction, operation and end-of-life management
- Operationalisation of secure, sovereign and cyber-resilient supply chain architectures enabled by RD&I in digital integration, interoperability and cybersecurity
- Complete integration of AI-enabled design, production, maintenance and recycling
- A thriving innovation ecosystem of SMEs, research institutions and industrial partners driving continuous advancement

3.1.5. EXPECTED IMPACTS

- Strengthened competitiveness and global market share of European maritime technology sector in current markets, as well in some markets currently dominated by Europe's competitors
- Increased industrial capacity to produce and deploy zero-emission, digital and autonomous waterborne solutions at scale
- Reduced dependency on external suppliers for critical waterborne technologies, enabled by RD&I driven development, validation, and deployment of European technological alternatives, interoperable system architectures and cyber-secure digital solutions
- Improved environmental performance across waterborne assets lifecycles through advanced materials and circular manufacturing
- Higher resilience of Europe's waterborne industrial base to geographical, economic and climate disruptions

3.2. THE TRANSFORMATION OF WATERBORNE TRANSPORT

3.2.1. VISION

By 2050, European waterborne transport will be a force of European competitiveness as a safe, secure, and resilient mode of transport, interconnected with European yards, ports and equipment manufacturers, delivering zero harmful emissions, zero pollution and zero fatalities. Operations include a high level of automation and digital intelligence, moving personnel from sea to shore leveraging advancements in remote operations and dual-use vessel technology. Smart integration of vessels, ports and waterways will enable seamless integration into logistics and transport chains, through secure data flows, delivering efficient, predictable and low-impact logistics. The sector will create a market for European value chains delivering energy systems, digital technologies, automation and safe operational practices, backed by regulatory frameworks and standardisation that strengthen Europe's technological sovereignty, enhance societal well-being and support strategic resilience.

3.2.2. MISSION AND STRATEGIC OBJECTIVES

This transformation requires coordinated progress across environmental, technological, industrial, regulatory and social dimensions.

The aim is to eliminate all harmful emissions to air and water, while embedding a strong safety culture that delivers zero fatalities and zero pollution across waterborne operations. The sector will fully exploit digitalization, automation, and secure data exchange to enhance efficiency, reliability and integration across ports, logistics chains, waterways and energy systems, enabling seamless multimodal mobility and resilient supply chains. Europe needs to maintain its world leading position as a developer of advanced and competitive waterborne systems and equipment.

A human-centred transition is equally vital. As demographic pressures and technological advances reshape the workforce, investment in skills, training and improved working conditions will ensure that crews, operators, engineers and port personnel can safely and confidently operate emerging technologies. Social sustainability and inclusion will be integral to a just and effective transition.

In parallel, regulatory innovation, harmonization and standardization must advance alongside technological progress. New rules, certification pathways and technical standards will enable safe use of alternative fuels, deployment of autonomous functions and integration of digital technologies. Europe's leadership in regulatory shaping will support timely, coherent adoption across the complex waterborne governance landscape and safeguard competitiveness.

Digital solutions are the fastest and most scalable way to optimize emissions across the global sailing fleet, especially since most vessels will always be older than the latest technology. By providing real-time information and enabling continuous improvement, digital platforms help ships operate more sustainably and support the industry's shift toward shared, software-based fleet management solutions.
Together, these objectives, including decarbonization, safety and security, digitalization and automation, industrial resilience, human capital development, regulatory innovation, and ecosystem integration, form a comprehensive, coherent and future-oriented framework for the successful transformation of European waterborne transport.

3.2.3. R&I PRIORITIES

The transformation of the waterborne sector depends on an ambitious, forward-looking research and innovation agenda that positions Europe as the global leader in zero-emission, digital, safe and resilient waterborne solutions. The following integrated priorities reflect the technologies and capabilities that will shape the competitiveness of the sector over the next decades and determine its ability to meet climate, economic and security challenges.

Future propulsion and energy systems enabling a climate-neutral fleet

Develop scalable, safe and efficient zero-emission propulsion technologies, including but not limited to hydrogen-, ammonia- and methanol-based systems, advanced batteries, fuel cells, hybrid architectures and renewable-assisted propulsion. Emphasis will be placed on energy efficiency, cost competitiveness, system integration and global market readiness. Advanced energy intelligence, predictive optimization and vessel-level digital twins will underpin Europe's long-term technological advantage.

Intelligent safety, security and resilience as foundational enablers

As vessels and operations become more digital and complex, safety and security will become defining features of competitiveness. Research will drive the development of predictive safety ecosystems, autonomous incident response, enhanced sensing, cyber-resilient infrastructures and new methods for safe fuel handling and emergency management. These innovations will be essential for unlocking autonomous navigation, enabling alternative fuels and protecting Europe's strategic waterborne assets.

Fully connected, automated and data-driven waterborne systems

The future waterborne system will function as a continuously connected network where vessels, ports, waterways and logistics nodes share data and optimize operations in real time. Priorities include interoperable digital architectures, remote and autonomous vessel functions, advanced sensing and communication systems, and AI-driven traffic and logistics coordination. These developments will increase efficiency, lower emissions and open the door to new business models built around service provision and lifecycle optimization. Smarter operation of ships and fleets, supported by AI, can help optimize fleet operations and improve collaboration between shore and vessel. This increases efficiency and reduces emissions, while robotic operation and maintenance can be used in hazardous or uncrewed areas to improve safety and reliability.

Human-centred design and a future-ready workforce

The sector's future success depends on people as much as on technology. R&I will advance human-machine teaming, intuitive decision-support systems, ergonomic design and workload optimization. Next-generation training ecosystems, including XR and digital simulation, will prepare the workforce to operate increasingly automated, data-rich and alternative fuel-based systems. Social sustainability and safe working conditions will remain essential pillars. AI and human–machine interaction: clear rules are needed for ethical use, transparency, liability, and responsible monitoring of crew workload and performance using AI and XR.

Forward looking regulation, standardization and system-level integration

Regulation will shape markets and determine the global relevance of European innovation. R&I will support the development of standards, certification schemes and regulatory sandboxes for new fuels, autonomy, data governance and cyber resilience. System-level planning tools will guide investments in ports, waterways, energy networks and logistics hubs to ensure that physical and digital infrastructures evolve in parallel with technological advances. This integrated approach is essential for deployment at scale. Standardizing user interfaces can improve safety and make systems easier to use and integrate.

3.2.4. DEVELOPMENT TRAJECTORIES

By 2035 –Early Deployment Across the Sector

- Deployment of standardised charging infrastructure, backed by competitive European Manufacturing (TRL 9)
- Deployment of wind assisted propulsion and further development of smart management of wind propulsion as a hybrid power source.
- Increased adoption of autonomous and remote navigation in designated corridors, supporting the roll-out of a universal regulatory framework.
- Roll-out of cyber-secure digital infrastructures in leading ports and shipyards
- Early deployment of workforce training ecosystems focused on cyber security, safety and alternative-fuel competencies

By 2040 – System Integration and Regulatory Maturity

- Large-scale adoption of zero-emission energy systems across mainstream fleet/vessel categories, supported by well-established infrastructure (port energy networks)
- Safe, regulated use of autonomous operations and functions in mixed-traffic environments, enabled by harmonized European standards
- Integration of vessel, port and waterway digital systems enabling real-time coordination and predictive traffic management (standardization of data exchange)
- Deployment of mature safety and emergency systems and culture enabled by AI-based situational awareness and dynamic risk modelling (within a human centred design perspective)
- Testing of comprehensive monitoring of ship software interoperability and cyber risks
- Deployment of strong workforce transition with digital and automation skills mainstreamed across maritime education

By 2050 – Full Transformation and Operational Maturity

- Universal deployment of zero-emission propulsion across all vessel categories, including long-distance maritime transport
- Safely functioning large-scale autonomous operations across maritime and inland corridors
- Fully circular vessel lifecycle models implemented at scale
- Complete digital integration between vessels, ports, hinterland logistics and energy networks
- A fully skilled workforce operating advanced systems in safe and attractive working environments
- Deployment of next-generation, highly resilient navigation and sensing capabilities, including quantum-enabled technologies, enhancing accuracy, autonomy and protection against interference.

3.2.5. EXPECTED IMPACTS

- Zero-emission waterborne transport fully in line with EU Climate targets
- Elimination of air, water and noise pollution from vessels and port operations
- Zero-accidents and incidents through predictive safety and real-time navigation systems
- Strengthened cybersecurity and protection of critical waterborne and underwater infrastructure
- Improved operational reliability, ensuring continuity during weather, geopolitical or technical disruptions
- Increased competitiveness through efficiency and predictability of logistics flows, reducing voyage and turnaround times
- Enhanced competitiveness of waterborne transport, supporting modal shift toward more sustainable mobility
- Stronger European leadership in secure, digital, green and autonomous maritime technologies
- Lower lifecycle and operational costs enabled by modularity, digitalization and circularity
- Creation of high-skilled jobs in digital technologies, automation, alternative fuels and advanced maritime technology sector
- Safer and more attractive working environments for maritime and port personnel
- A future-ready workforce equipped to operate zero-emission, automated and digital systems
- Increased EU strategic autonomy through resilient supply chains and reduced technological dependency
- More harmonized regulatory frameworks that accelerate deployment and innovation
- Stronger integration of waterborne transport into Europe's energy, logistics, industrial and security systems

3.3. PORT ECOSYSTEMS

3.3.1. VISION

By 2050, European ports will be fully integrated, zero-emission, digitally enabled and climate-resilient ecosystems at the heart of global supply chains and Europe's energy transition. They will function as smart, autonomous and interconnected nodes where vessels, energy systems, logistics, hinterland transport, **defence operations** and port-city interfaces operate in harmony, driving competitiveness and sustainability for Europe's waterborne sector and its economy.

3.3.2. MISSION AND STRATEGIC OBJECTIVES

This transformation requires ports to evolve from infrastructure providers into a network of active system orchestrators, operating sophisticated digital platforms, enabling alternative fuels, managing real-time logistics flows, and providing secure, climate-resilient services. As critical nodes in global supply chains and energy networks, ports must be able to withstand extreme weather, cyber threats and geopolitical shocks, while enabling efficient, seamless, low-impact operations for both **civil and military purposes.**

Strategic objectives include:

- Becoming a network of zero-emission and climate-neutral nodes, with electrified operations, clean energy systems, circular material flows and green port services
- Ensuring climate resilience and continuity of operations through adaptable infrastructure, nature-positive design and integrated resilience planning
- Deploying smart, interconnected logistics systems that use real-time data, automation and AI to optimize flows between vessels, terminals, hinterland transport and energy networks
- Integrate safe and efficient operations of autonomous vessels, ensuring interoperability with port digital systems, automated traffic protocols, and real-time management platforms.
- Becoming major energy hubs for hydrogen, ammonia, electricity, and renewable energy integration, enabling the decarbonization of waterborne and wider industrial systems
- Enhancing port security and cyber resilience to protect critical waterborne and energy infrastructures
- Scaling workforce competence and digital readiness, equipping port personnel with the skills needed for automation, data management, alternative fuels and advanced safety operations
- Strengthening Europe's competitiveness by supporting innovative business models, attracting investment and building resilient supply chains

3.3.3. R&I PRIORITIES

Zero-emission port operations and clean energy integration

Develop solutions enabling climate-neutral port operations, including full electrification of equipment, shore-side power and integration with energy sector for charging of electric ships, on-site renewable energy generation, advanced storage systems, and integration with smart grids. Focus on scalable infrastructure for hydrogen, ammonia, methanol, CO_2 handling, offshore energy import/export and multimodal energy exchange.

Smart, automated and data-driven logistics ecosystems

Advance digital platforms enabling real-time coordination of vessels, terminals, cargo flows and hinterland transport inside and between ports. R&I will concentrate on harmonised data exchange, automation, robotics, sensor development, AI-enabled scheduling, predictive capacity management, digital twins of port operations, and seamless digital integration with customs, authorities, and logistics actors.

Resilient and adaptive infrastructure

Develop adaptive port and hinterland infrastructure and nature-based coastal protection capable of withstanding climate change impacts (sea-level rise, extreme weather) as well as other developments (geopolitical, cargo flows, etc). R&I will support advanced materials, modular construction, structural health monitoring and integrated resilience planning **linking ports, waterways and coastal zones.**

Ports as energy hubs and circular economy engines

Support the development of networks of ports as major nodes for alternative fuels, renewable energy, CCS/CCUS logistics and circular value chains. Research will advance multi-energy terminals, circular waste and recycling solutions, and digitally managed resource flows linking waterborne, industrial and urban sectors.

Enhanced security and (cyber-)resilience for critical port infrastructure

Strengthen (cyber)security, situational awareness and protection of port-critical infrastructure and networks, including energy systems, digital platforms and underwater assets. R&I will focus on identifying key risks to port operations and activities, secure-by-design architecture, intelligent detection and response systems, and integrated cyber-physical resilience strategies.

Human-centered port innovation and workforce transformation

Develop new operational concepts, ergonomic systems and training models for automation, alternative fuels, digital control rooms and resilience management. Furthermore, innovations are needed in organisational aspects, such as creation of new business models and collaboration methods. R&I will promote advanced simulation, XR-enabled training, competence frameworks and safe human-machine cooperation across port operations.

Forward-looking regulation, standardization and multimodal integration

Support regulatory innovation, data governance models and harmonized standards enabling cross-border, port-port, port-vessel and port-hinterland interoperability. Develop tools for energy system integration, alternative fuel certification and coordinated multimodal planning.

3.3.4. DEVELOPMENT TRAJECTORIES

By 2035 – Smart and Clean Foundations Established

- Widespread deployment of shore power, electric ship charging, electrified equipment and energy-efficient terminal operations, considering port-wide electricity demands
- Established widespread operational procedures for hydrogen, ammonia and methanol bunkering, alongside CO_2 handling systems and early procedures to cope with nuclear powered vessels
- Harmonized data procedures for data exchange between European port stakeholders
- Initial deployment of port digital twins and AI-enabled traffic coordination across terminal clusters
- Deployment of autonomous vessel traffic coordination systems integrated with port digital platforms.
- Roll-out of integrated cybersecurity platforms and monitoring systems
- Demonstration of adaptive (and nature-based) port infrastructure that is able to meet future challenges
- Demonstration of new business models to speed up implementation of new technologies throughout European port ecosystems.
- Introduction of digital and alternative fuel training programs for port operators

By 2040 – System Integration and Large-Scale Automation

- Near complete electrification and decarbonization of core port operations
- Consolidated multi-energy hubs supplying alternative fuels, green electricity and hydrogen-based products
- Fully integrated logistics platforms linking vessels, terminals, hinterland corridors and energy networks
- Harmonised protocols for autonomous vessel operations
- Deployment of mature automation and robotics in container handling, inspection, maintenance and security operations
- Deployment of resilient and adaptive port-infrastructure models across Europe's main corridors
- Deploying workforce transformation with digital control rooms, advanced simulation training and new operational roles

By 2050 – Fully Integrated, Climate-Neutral Autonomous Port Ecosystems

- Complete decarbonization of port ecosystems and full integration into climate-neutral logistics chains
- Autonomous port operations functioning safely across terminals, waterways, and integrated logistics nodes
- Ports serving as central hubs for renewable energy import/export, hydrogen distribution and CO_2 management
- Fully circular material flows supported by advanced digital systems, reuse and recycling infrastructures
- Highly resilient and cyber-secure port systems protecting critical waterborne and energy infrastructures
- Global leadership of European ports in efficiency, sustainability, digital innovation and safety

3.3.5. EXPECTED IMPACTS

- Elimination of port-related emissions, contributing directly to climate neutral logistics chains
- Improved efficiency, capacity utilization and reliability across maritime-port-hinterland flows
- Enhanced climate resilience of critical port and coastal infrastructure
- Strengthened role of ports as enablers of Europe's energy transition, supporting hydrogen, ammonia, electrification and CCS
- Reduced operational risks and enhanced security through advanced cyber-physical protection systems
- Lower operational and lifecycle costs through automation, digitalization and predictive asset management
- Increased competitiveness of European ports and improved ability to attract investment
- New high-skilled job opportunities in digital port operations, energy systems, automation and resilience planning
- Improved integration of ports into the wider energy, industrial and logistics systems of Europe
- Greater strategic autonomy through resilient port infrastructure and secure energy and logistics supply chains
- Enhanced efficiency and safety through full integration of autonomous vessels with port operations, reducing human error and optimizing traffic flows across global maritime networks

3.4. UNLOCKING THE POTENTIAL OF THE BLUE ECONOMY

By 2050, Europe will be the global leader in the development, operation and maintenance of advanced solutions for the blue economy, ranging from specialized vessels and resilient offshore infrastructure to high-performance underwater systems. The sector will operate through sustainable, digitally integrated and circular business models, supporting climate neutrality, energy independence, economic resilience and security in Europe's seas, waterways and coastal regions.

3.4.1. VISION

By 2050, Europe will be the global leader in the development, operation and maintenance of advanced solutions for the blue economy, ranging from specialized vessels and resilient offshore infrastructure to high-performance underwater systems. The sector will operate through sustainable, digitally integrated and circular business models, supporting climate neutrality, energy independence, economic resilience and security in Europe's seas, waterways and coastal regions.

3.4.2. MISSION AND STRATEGIC OBJECTIVES

The mission is to strengthen Europe's leadership in the blue economy by developing and deploying innovative, zero-emission, digitally enabled and safe technologies across three core technology domains:

- Leadership in design, production, operation and maintenance of blue economy vessels
- Resilient, sustainable and interconnected infrastructure
- Excellence in the underwater domain

Together, these domains form an integrated technological ecosystem that enables sustainable growth, climate neutrality, economic resilience and maritime security across Europe's seas, waterways and coastal regions, underpinned by strong European industrial leadership, resilient supply chains, advanced digital tools and a skilled workforce capable of operating in increasingly complex waterborne environments.

Strategic objectives include:

- Supporting Europe's green and digital transitions by providing vessels, platforms and underwater systems tailored to renewable energy, aquaculture, CCS/CCUS, environmental monitoring and offshore logistics
- Designing and deploying resilient, sustainable and nature-based offshore and relevant infrastructure that can withstand extreme weather, climate-driven changes and new operational demands
- Strengthening capabilities in the underwater domain through long-endurance autonomous systems, advanced sensors, improved situational awareness and robust protection of subsea critical infrastructure
- Enabling circular and integrated business models that reduce environmental impact, increase asset utilization and optimize lifecycle performance
- Maintaining European technological sovereignty in the face of global competition by securing industrial capabilities and critical supply chains
- Preparing the workforce for the future through training and upskilling in emerging waterborne technologies

3.4.3. R&I PRIORITIES

Zero-emission, modular and multi-mission vessels for the blue economy

Future offshore operations will require specialised vessels that are highly flexible, energy-efficient and capable of supporting a wide range of blue-economy missions. Research and innovation will focus on modular vessel design, zero-emission propulsion systems tailored to offshore operations, enhanced station-keeping and manoeuvring capabilities, automation for repetitive or hazardous tasks, and the use of digital twins for lifecycle optimisation. These vessels will enable safe, sustainable and cost-effective operations across key blue-economy applications, including, aquaculture, marine science, CCS/CCUS, tourism and maritime security.

Resilient, sustainable and interconnected infrastructure

Europe's climate future requires infrastructure that is durable, adaptive and nature positive. Research will advance hybrid and nature-based designs, floating and modular platforms, offshore energy hubs, autonomous inspection and repair solutions, and integrated monitoring systems for structural health, environmental conditions and climate impacts. Interoperable digital infrastructures will enable real-time coordination with vessels, ports and onshore grids.

Advanced underwater autonomy, sensing and intervention capabilities

Underwater operations will increasingly depend on autonomous and remotely operated systems with long endurance, high intelligence and robust communication capabilities. R&I will target advanced AUVs / ROVs, AI-enabled mission planning, underwater situational awareness, environmental sensing, autonomous docking and charging, and cyber physical tools for inspection, maintenance and repair of subsea assets. These capabilities are essential for offshore renewable energy, CCS, aquaculture, defence and environmental monitoring.

Human-centred solutions, skills and workforce transformation

Offshore and underwater operations will demand new competencies in autonomy, robotics, sensing, data analysis and environmental management. R&I will advance ergonomic design, safe human-machine teaming and comprehensive training platforms using XR and simulation. Workforce development will be essential to operating the next generation of offshore assets and ensuring safe working conditions in challenging environments.

Regulatory frameworks, standards and governance for emerging blue sectors

To accelerate innovation and deployment, R&I will support new regulations and standards for floating infrastructure, multi-use platforms, autonomous underwater systems, CCS logistics, offshore hydrogen and digital interoperability. Regulatory sandboxes will enable real-world testing, while system-level planning tools will guide investments in offshore energy, coastal resilience and marine spatial planning.

3.4.4. DEVELOPMENT TRAJECTORIES

By 2035 – Demonstration and Initial Scaling

- Demonstration of zero-emission multi-mission offshore support vessels, specialised fishing and aquaculture service vessels as well as for the boating sector
- Pilot integration of modular vessel configurations and digital-twin-based lifecycle management for blue-economy vessels
- Operational pilots of floating energy hubs, modular offshore structures and early CCS/CCUS maritime logistics concepts
- Deployment of regional underwater monitoring networks and long-range AUV pilots for inspection and environmental sensing
- Integration of digital twins for vessels and waterborne operations supporting offshore wind, aquaculture and coastal protection assets, including inspection, maintenance and logistics interfaces
- Expansion and EU-level coordination of regulatory sandboxes for autonomous underwater operations and floating infrastructure, enabling large-scale testing, cross-border deployment and accelerated certification pathways
- Launch of dedicated training programs and digital competence centers for future offshore and underwater operations

By 2040 – Integrated Offshore Systems and Mature Digital Operations

- Fleet-level integration of digitally enabled, multi-mission blue-economy vessels, supported by digital twins and interoperable operational platforms
- Deployment of integrated offshore energy systems connecting wind, wave, hydrogen production and storage
- Safe, regulated operation of autonomous underwater and surface systems, integrated with smart coastal and offshore infrastructure
- Use of AI-driven monitoring, predictive maintenance and environmental intelligence across major offshore assets
- Widespread implementation of nature-positive, offshore, port and inland waterway infrastructure solutions
- Mature skills ecosystem supporting advanced offshore robotics, digital operations and multi-use platform management

By 2050 – Fully Developed, Climate-Neutral and Resilient Blue Economy

- Full decarbonization of specialized blue economy vessels and offshore operations
- Fully autonomous and digitally integrated fleets of specialised blue-economy vessels operating as part of interconnected offshore and coastal ecosystems
- Fully integrated offshore energy ecosystems providing stable renewable power and hydrogen for Europe
- Autonomous underwater systems conducting continuous inspection, maintenance and environmental monitoring of subsea assets
- Widespread deployment of floating port infrastructures, offshore logistics hubs and multi-mission platforms
- Circular and digitalized lifecycle models covering design, production, operation, repurposing and recycling of all major offshore assets
- A globally competitive European maritime technology sector leading in offshore innovation, underwater systems, and sustainable infrastructure

3.4.5. EXPECTED IMPACTS

- Strong contribution to Europe's climate-neutrality objectives by enabling renewable offshore energy, low-impact aquaculture and zero-emission offshore operations
- Improved resilience of infrastructure to climate change, extreme weather and environmental stresses
- Enhanced protection and monitoring of marine ecosystems through advanced sensing, underwater autonomy and nature-positive infrastructure
- Increased security and resilience of critical subsea assets, including cables, pipelines and offshore installations
- Greater efficiency and cost-effectiveness in offshore operations through automation, digitalization and predictive maintenance
- Expanded economic opportunities across offshore energy, aquaculture, marine biotechnology, CCS/CCUS and sustainable tourism
- Strengthened European industrial leadership in specialized vessels, offshore platforms, underwater robotics and digital technologies for offshore and underwater operations
- Growth in high-skilled jobs in offshore engineering, underwater robotics, sensing technologies and environmental monitoring
- Greater strategic autonomy through resilient supply chains, domestic technological capabilities and reduced reliance on external energy sources
- Better integration of offshore sectors with ports, logistics systems and energy networks, enabling holistic value-chain optimization

4. INVESTMENTS

INVESTMENTS

To remain a waterborne (technology) leader, investments in the four interrelated pillars of the Research and Innovation Strategy are critical. First, the investments in research, development, innovation and its deployment to support market roll-out in the maritime technology sector will lay the fundamental foundations to be able to deliver the set of products identified. Similar requirements are related to the ports and infrastructure, which are an enabler of any of the transitions laid down in this document. The development of technology roadmaps per product category, indicating the pathways to transfer to a resilient, competitive and sustainable sector, will further detail the mix of research, development, innovation and deployment pathways. This all should be combined with the required amounts of fuel which is not included in this investment paragraph.

Whereas Horizon Europe will co-finance developments up to TRL 8, innovations need to become **economically and commercially viable.** Specifically, this last trajectory requires major investments, considering the **high risk and high capital investments** in testing technologies on waterborne assets. Finally, the deployment of the innovations will be a mix of **public and private investments** as well, where not only the difference in capital expenses, but certainly in terms of operational expenses needs to be bridged.

The current Co-Programmed Partnership on Zero-Emission Waterborne Transport has been a **catalyst of investments.** The European Commission invested up to € 530 Million in the framework of this Partnership, and the additional investments by the sector amount to **€ 3.3 Billion.** During the lifetime of the Partnership, investments have been made in developing and demonstrating energy-efficiency and zero-emission solutions for part of the ship types. For certain ship types, mainly those with lower power requirements and shorter operational autonomy, solutions **are approaching technical readiness.** For other ship types, particularly those with high power requirements and long operational autonomy, key technologies still require further development to reach **technological maturity.** Furthermore, the scope of the proposed Partnership is in line with current challenges, and oriented towards fully achieving the objectives regarding a competitive, resilient and sustainable future.

The proposed Partnership will focus on the entire chain **from fundamental research until deployment,** where significant efforts will be made to upscale solutions, and to bridge the **"valley of death"** by getting solutions commercially ready and subsequently deployed. Integrated areas of attention in future RD&I will be **sustainability solutions (including circularity) and digital solutions.** To stimulate deployment, dedicated **technology roadmaps** will be developed for different categories, notably: maritime technology sector, port ecosystems, inland waterway transport, short sea shipping, ferries, cruise, intercontinental shipping, offshore and blue economy. Where relevant, a further distinction will be made in liner versus bulk/tramp shipping and their business models, as well as retrofitting versus newbuilt. These roadmaps will include impact on jobs and skills, as well as on rules, regulations and standards to be able to deploy technologies.

It is envisaged that a total investment in **research, development, innovation, testing and upscaling** of a minimum of **EUR 9.9 Billion** will be needed (1/3 of the funding via Horizon Europe, 2/3 via private investments and investments made by EU Member States and Associated Countries).

5. STAKEHOLDERS

5. STAKEHOLDERS

The members of the Waterborne Technology Platform represent the broader waterborne sector and originate from 19 EU Member States and four European Countries associated to Horizon Europe. The following list includes the list of members when developing the strategy.

- Royal Belgian Shipowners Association
- Royal Association of Netherlands Shipowners
- Virtual Vehicle Research GmbH
- A.P. Moller - Maersk
- University of Warwick
- CMA CGM Group
- Union of Greek Shipowners
- DFDS A/S
- Columbia Shipmanagement
- Fincantieri
- Kongsberg Maritime AS
- Navantia
- Naval Group
- Damen Shipyard Group
- Chantiers de l'Atlantique
- Meyer Werft
- Wärtsilä Finland Oy
- Everllence
- Royal IHC
- ABB Oy Marine and Ports
- Elkon
- SEA Europe
- VSM
- Maritime & Offshore NL
- GICAN
- Assonave
- Danish Maritime
- Gisbir
- Foro Marítimo Vasco
- Pymar
- Siemens Energy
- Finnish Marine Industries
- LTH-Baas
- Thordon Bearings Inc
- Katradis SA
- Batis Mosa Group
- Hemexpo
- Meyer Turku Oy
- Rina Services Spa
- Lloyd's Register
- DNV
- Bureau Véritas Marine & Offshore
- ABS Hellenic
- Polish Register of Shipping
- ClassNK
- The European Inland Waterway Transport Platform
- Expertise- en InnovatieCentrum Binnenvaart
- Concawe Division European Petroleum Refiners Association
- Napa
- Cosnav Engineering
- SimFWD
- Equinor Energy AS
- Dassault Systèmes SE
- The State Enterprise Lithuanian Inland Waterways Authority
- Finntraffic Vessel Traffic Services ltd
- Digital Container Shipping Association
- Stillstrom
- Ladar-AI Limited
- G.M.S. Global Maritime Services Limited
- Compute Maritime Ltd
- European Dredging Association
- Kalmar Oyj
- Terminal Industry Committee 4.0 (TIC4.0)
- Sintef Ocean

- CNR
- Aimen Technology Centre
- Cetena S.P.A.
- Marin
- TNO
- Centre for Research and Technology Hellas
- BALance Technology Consulting
- Fundacíon Centro Tecnológico Soermar
- Fundacíon Valenciaport
- HSVA – Hamburgische Schiffbau- Versuchsanstalt GmbH
- Cerema
- VTT - Technical Research Centre of Finland Ltd
- Schiffbautechnische Versuchsanstalt in Wien GmbH
- RISE Research Institutes of Sweden
- CEA - Liten
- University College London
- Aalto University Foundation, School of Engineering
- Southampton Marine and Maritime Institute
- Kühne Logistics University
- National Technical University of Athens
- Delft University of Technology
- ECMAR
- WEGEMT
- Lighthouse
- Magellan Association
- Deutsches Maritimes Zentrum
- Maritime CleanTech
- M.A.R.E. FvG (Maritime, Aerospace, Renewable Energies Technology Cluster FvG)
- European Conference of Transport Research Institutes (ECTRI)
- Institute for Energy Technology
- Norwegian University of Science and Technology
- Fondazione CMCC
- Motor Oil Group
- National Maritime College of Ireland
- Eigen Vermogen Flanders Hydraulics
- Fraunhofer Gesellschaft zur Forderung der Angewandten Forschung e.V.
- INLECOM
- Rhoé
- EHT S.C.p.A.
- Turku University of Applied Sciences
- Deutsches Zentrum für Luft- und Raumfahrt
- CLEOS
- Tecnalia
- Abo Akademi University
- CMMI – Cyprus Marine & Maritime Institute
- University of Turku
- University of Ljubljana
- Eugenides Foundation
- University of Piraeus
- Flikkema Innovation Management & Consultancy
- Centrum Techniki Okretowej S.A. (CTO)
- Centrale Nantes
- Novia University of Applied Sciences
- Estonian Maritime Academy
- GCE Blue Maritime Cluster
- H-DEUX
- Danish Institute of Fire and Security Technology
- "Dunarea de Jos" University of Galati
- Physikalisch-Technische Bundesanstalt (PTB)
- Insitute of Transport Economics (TOI)
- Cenex
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