The Eu's Inland Waterways: Sustainable Efficiency Improvement Strategy

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ABSTRACT

The aim of this study is to investigate the potential of Europe's inland waterways as a sustainable transport solution, focusing on the modernization of infrastructure, regulatory frameworks, and operational practices to enhance efficiency, resilience, and sustainability in the face of climate change. The research addresses several key questions: What are the current challenges facing inland waterway transport in Europe, particularly in relation to climate change? How can infrastructure modernization improve the navigability and operational efficiency of inland waterways? What role does regulatory harmonization play in facilitating cross-border cooperation among stakeholders in inland waterway transport? How can digital technologies be integrated into inland waterway operations to enhance sustainability and resilience? Finally, what best practices and innovative technologies can be adopted to support the transition to greener inland waterway transport? The study identifies significant infrastructure bottlenecks and maintenance issues that hinder the efficiency of inland waterways, exacerbated by climate-induced hydrological variability. Fragmented governance structures and inconsistent regulations across member states create barriers to effective cross-border operations and stakeholder collaboration. The integration of digital technologies, such as real-time traffic management systems and predictive analytics, is crucial for optimizing operational efficiency and reducing delays. Transitioning to low-emission vessel technologies and implementing climate-resilient infrastructure can significantly reduce the environmental impact of inland waterway transport. Enhanced participation from various stakeholders, including environmental organizations and local communities, is essential for developing adaptive governance frameworks that balance economic and ecological priorities. The research concludes that Europe's inland waterways hold significant potential as a sustainable transport solution, provided that comprehensive modernization efforts are undertaken. By addressing infrastructure deficiencies, harmonizing regulations, and leveraging digital technologies, inland waterways can enhance their operational efficiency and resilience against climate change. The study emphasizes the importance of collaborative governance and stakeholder engagement in achieving these goals, ultimately positioning inland waterways as a viable alternative to traditional road and rail transport systems in the European Union's decarbonization and sustainable mobility agenda. This research contributes to the broader understanding of how inland waterways can be revitalized to meet the growing demands for sustainable transport while addressing pressing environmental concerns.

Keywords: Integrated Water Resources Management (IWRM), Adaptive Management, Stakeholder Engagement, Ecosystem-Based Management, Sustainable Financing, Transboundary Cooperation, River Restoration, Climate Resilience.

Words: 57,624

Nothing nature makes is imperfect or in vain

-Aristoteles

Mange bække små gør en flod

Many rivlets make a flood

-Popular wisdom

Donau so blau,

so schön blau,

durch Tal und Au

wogst ruhig du hin,

dich grüßt unser Wien,

dein silbernes Band

knüpft Land an Land

und fröhliche Herzen

schlagen an deinem

schönen Strand.

-Johan Strauss II

INTRODUCTION

In the heart of Europe, rivers flow like veins through the continent, carrying more than water—they carry history, commerce, and culture. The Rhine, with its majestic curves, has witnessed the rise and fall of empires, while the Danube winds ambitiously through landscapes that have inspired generations of poets and artists. Once alive with the rhythm of boats and the clatter of trade, these waterways now face challenges that threaten to silence their currents.

Climate change reshapes the hydrological landscape, making rivers increasingly unpredictable. Sediment accumulates in their beds, turning navigable routes into treacherous shallows. The consequences ripple across industries reliant on bulk cargo—steel, chemicals, and energy—where supply chains tighten as river transport falters. The arteries of Europe, which once enabled seamless exchange, now demand urgent attention and innovative thinking.

Yet, within these challenges lies a story of opportunity. Imagine rivers revitalized not merely as freight channels, but as multifunctional spaces where economic vitality, ecological stewardship, and social engagement converge. Picture the act of navigating these waters as a symbol of Europe's commitment to sustainability and resilience.

This study embarks on a journey to chart this potential, exploring the intricate interplay of governance, infrastructure, and technology that will shape the future of inland waterway transport. By assessing current conditions and envisioning a transformative path forward, we uncover how Europe's rivers can become engines of connectivity, innovation, and environmental harmony. The narrative of Europe's inland waterways is not only one of obstacles—it is a story of hope, collaboration, and the enduring spirit that can turn the tide toward a sustainable future.

Aristoteles viewed nature as purposeful and ordered system, where everything exists for a reason. He believed that natural beings have an inner principle of motion and rest, guiding their growth and change. For Aristotle, nature does not nothing by chance, it always acts toward an end (telos). He emphazised form and function, arguing that understanding is for explains what it is. Nature, in his view, is rational, intelligible and inherently meaningful, not random or chaotic.Water exists to sustain life and enable transformation through movement, circulation, and renewal. The hydraulic water cycle functions to redistribute energy, nutrients and matter across the Earth. Through evaporating, condensation and precipitation, it regulates climate and balances ecosystems.

Rivers give the water cycle form, channeling moving water through the landscapes. Their function is to connect mountains, land, and seas, transporting life, sediments and meaning. And science is about being conscious about what you are doing.

Mircea Eliade conceives of rivers primarily as sacred symbols rather than merely physical waterways. For him, rivers often represent a cosmic boundary that seperates the profane world from the sacred. They function as sites of purification, where immersion signifies renewal, rebirth, or a return to origins. Eliade links rivers to mythical time, suggesting that flowing water allows humans to symbolically reenter primordial creation. In many traditions he studies, rivers, serve as *axes of spiritual passage*, guiding souls, heroes or gods between realms. Their con-tinuous flow expresses the paradox of permanence and change, a key theme in his understanding of the sacred. Eliade also emphasizes that rivers are frequently hierophanies, natural manifesta-tions through which the sacred reveals itself. Ultimately, he sees rivers as mediators between cosmos and chaos, sustaining life while making thresholds of transformation.

Women are often associated with rivers as sources of life, fertility and nourishment. Like rivers, women are linked to cyclical rythms, flow, and renewal. Myths frequently portray rivers as female deities or maternal figures. Both are sees as space of transformation, cleansing and rebirth. This association reflects ideas of *continuity, creativity and generative power*. The underlying assumption is that water as the fountain of and origin of life is there to help put something together that has been broken or whose unity we have forgotten how to make whole anew. The female ambition to inspire love loaded onto the function of water makes rivers powerful symbols of renewal, integration and unity.

The Impressionist movement of the late 19th century is closely associated with the exploration of natural light, transient atmospheric conditions, and the sensory experience of landscapes. Rivers, in particular, played a central role in shaping the visual language and thematic focus of many Impressionist painters. Waterways offered artists a dynamic subject in which reflections, ripples, and the interaction of light with moving surfaces could be observed and rendered with immediacy.

Impressionists were fascinated by the mutable qualities of rivers—the shifting colors, the interplay of sunlight and shadow, and the ephemeral effects of weather on water. This focus aligned with the movement's emphasis on capturing the momentary impression rather than creating detailed, idealized representations. Rivers also provided a compositional device for exploring perspective, depth, and spatial continuity, allowing artists to experiment with new brushwork techniques that emphasized movement and fluidity.

Beyond visual experimentation, rivers symbolized modernity and leisure, reflecting the social transformations of the period. Urban rivers such as the Seine in Paris and its surrounding suburbs became iconic subjects for artists like Claude Monet, Pierre-Auguste Renoir, and Alfred Sisley, who depicted boating scenes, riverbanks, and reflections in ways that merged natural observation with contemporary life. In rural contexts, rivers conveyed tranquility and continuity, offering a counterpoint to industrialization while providing a recurring motif around which Impressionist aesthetics could coalesce.

In this sense, rivers were both **medium and muse**. They provided the sensory richness that inspired the loose brushwork, vibrant palette, and atmospheric effects characteristic of Impressionism. The movement itself can be seen as "launched" from the banks of rivers, where painters gathered, observed, and experimented with the interplay of light, water, and landscape, translating these impressions into a new artistic idiom.

Inland navigation advances the EU's climate objectives by enabling a substantial shift of freight from road to low-emission transport modes, reducing greenhouse gas emissions and energy consumption. Although waterways account for a modest share of total transport, they exert a disproportionate influence on economic efficiency, regional development, cross-border trade integration, and the broader transition toward sustainable and resilient growth. Waterways play a crucial role in facilitating cross-border trade by providing efficient, low-cost transport links between inland industrial centers and major seaports, allowing goods to move seamlessly across multiple EU countries. By reducing dependence on road freight, inland navigation lowers transportation costs, alleviates highway congestion, and contributes to a more resilient and reliable logistics network. Investment in port modernization, including upgrades to locks, dredging, and terminal infrastructure, significantly increases cargo capacity, improves operational efficiency, and enhances the overall attractiveness of inland shipping for freight operators and supply chains. Beyond pure logistics, these investments stimulate regional economies by creating jobs, supporting industrial clusters, and fostering economic activity in areas often underserved by highways or rail networks. Inland waterways also serve as a backbone for sustainable growth: they reduce greenhouse gas emissions and energy consumption per tonne of cargo compared with road transport, helping the EU meet its climate objectives while maintaining competitiveness. By integrating seamlessly with rail and maritime transport, waterways enable low-carbon multimodal logistics chains, strengthening trade connectivity across the continent. The combined effect of economic efficiency, environmental performance, and regional development underscores the strategic importance of inland navigation within the EU's broader transport and industrial policy. Ultimately, inland waterways contribute not only to cost-effective freight movement but also to long-term resilience, sustainability, and cross-border economic cohesion, making them a vital component of Europe's integrated transport infrastructure.

In pulling together trade routes, seas-coastal areas-river systems play a connecting and integrating role. Coastal areas act as gateways between land and sea. Ports located on coasts link inland economies to long-distance maritime trade, allowing goods, people, and ideas to move efficiently. Seas function as major trade corridors rather than barriers. They enable bulk transport at lower costs and connect distant regions for example the Indean Ocean and the lands between the sea, aka Club Med, helping unify wide trading zones. River systems serve as natural highways into the interior. Navigable rivers connect inland production areas – agriculture, mineral and crafts – to coastal ports and seas, tying local and regional markets into international trade routes. Together , these systems reduce transportation costs, increase the volume and speed of trade, encourage economic specialization and promote cultural and technological exchange. In short, coastal areas, seas, and rivers knot together local, regional, and global trade routes into integrated trade networks.

No other trading power in the world matches the European Union in the volume and diversity of goods transported through seaborne trade. Leveraging its strategic geographic position with access to multiple seas and major ports, the EU serves as a central hub in global maritime logistics, facilitating the exchange of raw materials, manufactured products, and energy commodities across continents. Its integrated maritime infrastructure, combined with sophisticated regulatory frameworks and customs coordination, ensures that EU ports handle an unparalleled throughput of imports and exports, reinforcing the Union's pivotal role in global trade networks and supply chains.

Inland waterways are frequently perceived as a marginal component of the transport sector due to their relatively low modal share compared with road, rail, or maritime shipping. However, this perception overlooks the strategic, environmental, and economic roles that inland navigation plays in Europe and beyond. Firstly, inland waterways provide a **sustainable and low-emission alternative for freight transport**. Barges are highly energy-efficient, capable of moving large volumes of goods with a fraction of the fuel consumption and carbon emissions associated with road transport. In the context of the EU's Green Deal and the push for decarbonisation of transport, inland waterways can serve as a critical lever to reduce greenhouse gas emissions while supporting modal shift objectives.

Secondly, inland waterways underpin **economic connectivity in regions poorly served by rail or road networks**. Many inland ports function as logistics hubs linking industrial centers, agricultural regions, and urban markets, enabling trade and supply chain resilience. Even relatively low-traffic waterways can relieve congested roads, reduce transport costs, and maintain accessibility to inland areas, contributing to regional economic cohesion.

Thirdly, inland waterways have **strategic importance for transboundary water management, flood control, and climate adaptation**. Rivers are multifunctional infrastructures: beyond transport, they regulate hydrology, support water provision, and provide natural buffers against flooding. Investing in navigation infrastructure often coincides with ecosystem restoration, floodplain management, and sediment control, creating co-benefits for environmental sustainability and community resilience.

Moreover, inland waterways **link inland economies to global trade via ports and maritime gateways**, serving as the final leg of complex logistics chains. European rivers such as the Rhine, Danube, and Elbe exemplify corridors where inland navigation integrates industrial production, agriculture, and energy transport into international supply networks. Their operational reliability is essential for reducing bottlenecks, particularly for bulk commodities and heavy industrial cargo that are less suited for road transport.

Finally, inland waterways are a **platform for digitalisation and innovation in transport**. River Information Services, smart logistics systems, and automated vessels demonstrate how inland navigation can serve as a testing ground for sustainable transport technologies. In this sense, what appears marginal in volume is actually **marginal in perception, not in strategic relevance**, as waterways contribute to decarbonisation, economic cohesion, flood resilience, and innovation.

In sum, inland waterways matter not because they dominate modal share, but because they **deliver outsized benefits relative to their apparent scale**, combining environmental, economic, and strategic value in ways that are increasingly critical for a sustainable and resilient European transport system.

If we were to promote trade and investments in and around rivers, we would, first, have to modernize inland waterways to ensure year-round navigability for larger and greener vessels. Second, to improve multimodal links between rivers, railways, roads and seaports to reduce logistics costs and delays. Third, harmonize cross-border regulations , customs procedures, and technical standards along European waterways. Fourth, to invest in smart ports, digital tracking systems, and river information services to increase efficiency and transparence. Fifth, develop logistics hubs and industrial parks near inland ports to attract FDI. Sixth , promote Public-private partnerships to finance infrastructure, maintenance and innovation projects. Seventh , encourage the use of inland shipping through incentives for low-emission and energy –efficient transport. Eigth, strengthen workforce skills in logistics, port management and waterway engineering. Ninth, enhance climate resilience of waterways through flood control, dredging, and adaptive infrastructure. Tenth, market Europe’s inland waterways internationally as cost-effective, sustainable trade corridors for global investors.

And this is what we intend to demonstrate how to in this piece. It is an executive decision to know when the time for transformation is the right one. It will have to follow on the presentation of the EU port strategy and the update to the EU’s maritime security strategy so as to coincide with a strategy on the EU’s coastal communities to be beyond reproach.

Europe’s waterways have played a fundamental role in shaping the continent’s historical development, economic integration, and environmental systems. Rivers, canals, and seas have long served as essential routes for transportation, trade, and cultural exchange, linking regions and societies across vast distances. Even in the modern era, these waterways remain critical to Europe’s infrastructure and sustainability efforts.

Among the most significant rivers in Europe is the Danube, which originates in Germany’s Black Forest and flows through Central and Eastern Europe before emptying into the Black Sea. It connects numerous countries and has historically functioned as a major commercial and strategic route. The Rhine is another vital waterway, flowing from the Swiss Alps through Germany and the Netherlands to the North Sea. It is one of the most heavily used rivers in the world for inland navigation and industrial transport. The Volga River, the longest river in Europe, dominates the Russian landscape and plays a central role in transportation, energy production, and national identity. Other important rivers, such as the Seine, Loire, Po, and Thames, have supported the growth of major cities and agricultural regions.

In addition to natural rivers, Europe possesses an extensive network of artificial canals that enhance connectivity between river basins and seas. The Rhine–Main–Danube Canal represents a major engineering achievement, creating a continuous inland water route between the North Sea and the Black Sea. The Canal du Midi in France, now recognized as a UNESCO World Heritage site, historically linked the Mediterranean Sea with the Atlantic Ocean, facilitating trade and regional development. These canals have significantly expanded Europe’s inland transport capabilities.

Europe’s surrounding seas, including the Mediterranean, Baltic, North Sea, and Black Sea, further extend the importance of waterways by enabling international maritime trade, fishing industries, and tourism. Coastal ports and inland river ports together form an integrated transport system that supports both regional and global economic activity.

Beyond their economic significance, waterways have contributed to cultural exchange and urban development. Many of Europe's major cities emerged along rivers, where access to water enabled trade, communication, and defense. Over time, these waterways facilitated the movement of people, ideas, and technologies, contributing to Europe's shared cultural heritage.

However, Europe's waterways face significant challenges in the contemporary period. Pollution from industrial, agricultural, and urban sources threatens water quality and biodiversity. Climate change has altered river flow patterns, increasing the frequency of droughts and floods, which affects navigation and ecosystems alike. Maintaining and modernizing infrastructure such as locks, dams, and ports also presents ongoing technical and financial challenges. As a result, international cooperation has become essential in managing shared waterways responsibly.

Looking ahead, Europe's waterways remain central to sustainable development strategies. Inland water transport is increasingly promoted as an environmentally friendly alternative to road transport, helping to reduce greenhouse gas emissions. Restoration projects aim to improve ecological health, while advanced monitoring technologies support efficient navigation and environmental protection.

In summary, Europe's waterways constitute a vital network that has supported the continent's economic growth, cultural exchange, and environmental balance for centuries. Their continued preservation and sustainable use are essential to maintaining Europe's connectivity and resilience in the future.

Improving the performance of Europe's inland waterways requires a simultaneous modernization of physical infrastructure, regulatory harmonization, digital integration, fleet renewal, and strengthened governance mechanisms. The first step is a decisive upgrade of the core network. Removing bottlenecks along heavily used corridors—especially on the Rhine–Danube and Rhine–Main axes—demands expanded lock capacity, automated operations, and harmonized opening hours across borders. Ensuring year-round navigability is equally critical. This involves stabilizing riverbeds, implementing targeted dredging, managing water levels adaptively, and deploying climate-resilient structures such as adjustable weirs, together with low-water-optimized vessel designs. Ports must also evolve into high-capacity, trimodal logistics hubs, with expanded container terminals and efficient roll-on/roll-off interfaces that accelerate transshipment between water, rail, and road.

Regulatory coherence is central to unlocking the full potential of the network. Standardizing cross-border procedures through a single, EU-wide administrative platform would allow seamless reporting for customs, cargo, and crew, while aligning rules for vessel inspections, crew competency, and safety standards. Incentivizing a modal shift from road to waterways requires calibrated financial measures, ranging from charge reductions and tax neutrality to subsidies supporting the transfer of bulky freight along the TEN-T corridors.

Digitalization stands as the backbone of future competitiveness. A unified EU Inland Waterway Traffic Management System should build on and radically expand River Information Services into a continental, real-time platform integrating waterway conditions, congestion alerts, predictive ETAs, and digital lock-queue management. Mandatory adoption of electronic freight documents, harmonized e-invoicing, and standardized digital customs filings would create a coherent data environment. Smart solutions such as digital slot booking at ports and locks, along with AI-supported route-optimization tools, would further enhance operational efficiency.

A parallel priority is the modernization of the fleet and the acceleration of the green transition. EU-backed financing instruments are needed to replace or retrofit aging vessels with efficient hydrogen, electric, or hybrid propulsion systems, and to proliferate modular barge designs that allow flexible cargo configurations. Clean-fuel infrastructure—hydrogen, biofuel, and electric charging stations—should be strategically deployed along major waterways, accompanied by differentiated port fees to reward low-emission vessels.

Market integration must deepen as well. The sector remains fragmented, and encouraging consolidation among small operators—through incentives for cooperative fleets—can create economies of scale and stabilize capacity. Stronger partnerships between ports, shippers, and logistics companies will integrate inland shipping more tightly with rail freight networks, maritime gateways, and last-mile urban distribution. An EU-level marketplace for inland shipping capacity would bring transparency to pricing and availability, improving matching between carriers and shippers.

Scientific Argument

We argue that the effective management and modernization of Europe's inland waterways are not merely a technical necessity but a strategic imperative for the continent's transport system, economic competitiveness, and environmental stewardship. Efficient inland waterways can significantly enhance transport efficiency by enabling high-volume, low-cost, and low-emission movement of goods, reducing pressure on congested road and rail networks. At the same time, they represent a critical lever for reducing carbon emissions, supporting the EU's broader climate goals, and demonstrating the continent's commitment to sustainable mobility.

Current infrastructure, however, is increasingly ill-equipped to cope with the growing hydrological variability and the intensifying impacts of climate change, including low-water periods, floods, and sedimentation that disrupt navigability and increase operational risk. Governance structures, while well-established in principle, remain fragmented across national borders and often lack the adaptive capacity required for real-time management of such extreme conditions. These deficiencies undermine the resilience and reliability of inland waterway transport, limiting its contribution to both domestic and international supply chains.

Therefore, a comprehensive and forward-looking approach is essential. This approach must integrate economic, environmental, and social dimensions: economically, by optimizing freight flows and improving intermodal connectivity; environmentally, by designing climate-resilient infrastructure and promoting green propulsion technologies; and socially, by engaging local communities, industry stakeholders, and policy actors in collaborative decision-making. By harmonizing infrastructure modernization, adaptive governance, and operational innovation, Europe can secure the long-term viability of its inland waterways, transforming them into resilient, multifunctional corridors that simultaneously serve commerce, ecological sustainability, and societal well-being.

Objectives

1. To assess the current state of inland waterway infrastructure and identify key areas for modernization.

2. To evaluate the impact of climate change on navigability and transport efficiency in major European rivers.

3. To propose governance frameworks that facilitate cross-border cooperation and stakeholder engagement.

4. To explore technological innovations that can enhance the sustainability and efficiency of inland waterway transport.

The study focuses on major inland waterways in Europe, including the Rhine, Danube, Elbe, and Seine. It examines the interplay between hydrological dynamics, infrastructure management, and policy frameworks. The research encompasses a review of existing literature, stakeholder interviews, and case studies of successful inland waterway management practices.

Research questions

How can the governance, infrastructure, legal aspects and operational practices of inland waterway transport in Europe be modernized to enhance efficiency, sustainability, and resilience against climate change?

This study is significant as it addresses the urgent need for sustainable transport solutions in Europe, particularly in light of increasing freight demands and environmental concerns. By providing a framework for improving inland waterway transport, the research contributes to the EU's broader goals of decarbonization and sustainable mobility. It also highlights the importance of collaborative governance and stakeholder engagement in achieving these objectives, ultimately aiming to position inland waterways as a competitive alternative to road and rail transport.

LITTREVIEW

Scholarly approaches to European inland waterways integrate transport economics, environmental governance, and policy analysis to assess how institutional frameworks and infrastructure shape the development and sustainability of this mode (Baranyai, 2020). A growing body of literature emphasizes that inland waterway transport (IWT) continues to be one of the most energy-efficient and low-carbon freight modes in Europe, yet its modal share has stagnated due to infrastructural and regulatory challenges (European Parliament, 2022; European Parliament Research Service [Europarl], 2022). The EU's NAIADES Action Programme and related policy instruments illustrate a sustained commitment to enhancing IWT's competitiveness and environmental performance by aligning transport policy with climate targets and modal shift objectives (European Commission, 2025).

Institutional analyses indicate that EU governance structures, such as the Trans-European Transport Network (TEN-T) and the Connecting Europe Facility (CEF), are central to facilitating coordinated investment and harmonized regulation across member states, addressing cross-border infrastructure bottlenecks and promoting intermodal integration (European Commission, 2025; Baranyai, 2020). Studies of river corridors like the Danube highlight that despite strategic connectivity, modal volumes lag behind potential due to political, organizational, and infrastructural constraints, underscoring the need for integrated policy measures that combine economic forecasting with logistical planning (TRIMIS, 2025).

Scholarship also critically assesses the sustainability framing of inland waterways. Early work on sustainable policy for waterways on the Danube demonstrated the EU's ambition to embed environmental objectives into transport policy, arguing that comprehensive strategies are needed to reduce fossil fuel dependence while preserving ecological integrity (ScienceDirect, 2011). More recent research examines climate vulnerability and resilience; for example, analyses of inland navigation disruptions on major rivers such as the Rhine, Main, and Danube point to the operational impacts of inadequate infrastructure and coordination on freight flows, drawing attention to the gap between policy intent and on-the-ground performance metrics (ScienceDirect, 2025; Baranyai, 2020).

Legal and technical literature highlights regulatory complexities. The European Code for Navigation on Inland Waterways (CEVNI) and standardized infrastructure classifications (e.g., CEMT classes) provide interoperability norms, yet implementation varies across jurisdictions, reflecting persistent policy fragmentation (Wikipedia, 2019; Wikipedia, 2025). Moreover, research on autonomous inland navigation underscores the emergent governance issues around technological change, such as liability and legal adaptation, pointing to a broader need for regulatory frameworks that anticipate innovation as well as climate change (Domenighini, 2024; Baranyai, 2020).

The *Oxford Handbook of Water Politics and Policy* conceptualizes water as a fundamentally political resource whose governance is shaped by scarcity, mobility, and distributive conflict. Conca and Weinthal (2018) argue that water's physical properties—its transboundary flows, variability, and resistance to commodification—render it a paradigmatic case of political contestation. Far from being a purely technical or environmental issue, water governance is embedded in broader struggles over equity, efficiency, and sustainability.

At the distributive level, decisions regarding allocation among agriculture, industry, and domestic use generate clear winners and losers, situating water within debates on social justice and inequality. At the institutional level, water governance operates across multiple scales—local, national, regional, and global—often producing tensions between sovereignty and cooperative management. Transboundary rivers, lakes, and aquifers exemplify this dynamic, compelling states to negotiate frameworks that balance national interests with collective security.

The Handbook further emphasizes the epistemic and symbolic dimensions of water. Competing framings—whether water is understood as a commodity, a human right, or a sacred resource—shape policy outcomes and institutional design. Climate change intensifies these dynamics, politicizing allocation decisions and reinforcing the need for adaptive governance structures. In this sense, water is simultaneously material and symbolic, a vital public good and a contested site of political meaning.

To sum-up: Water is political because it is scarce, vital, and shared**.** Governance challenges stem from water's unpredictability and its role as both a human right and an economic input. Climate change intensifies these dimensions, making water crises more frequent and politicizing allocation decisions. EU and global governance frameworks increasingly recognize water as a strategic domain, linking it to security, migration, and development. Water is not a typical commodity: its essential nature and uneven distribution make market-based governance insufficient.

Massimiliano Grimaldi's work on inland waterway law constitutes a significant contribution to the doctrinal and systemic understanding of European inland navigation. His opus is characterized by a rigorous legal methodology that situates inland waterway transport at the intersection of international law, European Union law, and domestic regulatory regimes. Rather than treating inland navigation as a purely technical or sectoral matter, Grimaldi approaches it as a complex legal order requiring coherence, harmonization, and normative clarity.

Grimaldi adopts a predominantly doctrinal and analytical approach, grounded in close textual interpretation of legal instruments and case law. His scholarship emphasizes systematic legal reasoning, drawing on comparative analysis between national legal systems and supranational frameworks. A defining feature of his method is the integration of public international law, EU internal market law, and transport law, which allows him to assess inland waterway regulation as a multi-layered legal structure rather than a fragmented set of rules.

He also employs a functional perspective, examining how legal norms operate in practice within navigation, safety regulation, liability regimes, and market access. This approach enables him to evaluate not only the formal validity of rules but also their effectiveness in achieving policy objectives such as safety, legal certainty, and free movement. A central analytical focus of Grimaldi's work is the fragmentation of inland waterway law in Europe. He highlights the coexistence of international conventions, EU legislation, and national rules, arguing that this plurality often leads to legal uncertainty and uneven application across Member States. In this context, he closely examines the role of EU harmonization measures, particularly directives and regulations aimed at standardizing technical, safety, and professional requirements.

Another key point in his analysis concerns the legal status of inland waterways within EU transport policy. Grimaldi argues that inland navigation has historically been underdeveloped compared to road and rail transport, both normatively and institutionally. He scrutinizes the extent to which EU law effectively integrates inland waterways into the internal market and assesses whether existing legal instruments sufficiently promote modal shift and environmental sustainability.

Liability and safety regulation also occupy an important place in his work. Grimaldi analyzes regimes governing accidents, dangerous goods transport, and operator responsibility, emphasizing the need for coherence between inland waterway rules and broader EU safety and environmental standards. He frequently underscores the importance of legal predictability for operators and authorities alike.

Grimaldi's scholarship is often critical of the incremental and reactive nature of EU inland waterway regulation. He questions whether piecemeal harmonization, largely dependent on the incorporation of international agreements, is sufficient to establish a truly integrated legal framework. His critique extends to institutional coordination, noting the limited visibility and priority given to inland navigation within EU transport governance.

From a critical perspective, some commentators suggest that Grimaldi's approach, while doctrinally strong, places less emphasis on empirical or economic analysis. His work prioritizes legal coherence and normative structure, sometimes leaving questions of implementation costs, market behavior, or political feasibility less explored. Nevertheless, this focus is generally seen as a strength within legal scholarship, particularly in a field marked by technical complexity and regulatory overlap. Overall, Massimiliano Grimaldi's opus offers a systematic and intellectually rigorous examination of inland waterway law. His scholarly approach combines doctrinal precision with structural analysis, while his main contributions lie in exposing fragmentation, assessing EU harmonization efforts, and advocating for greater legal coherence. His work remains an important reference point for academics, policymakers, and practitioners engaged in the development of European inland navigation law. Suffice to say, to make EU inland waterway law more integrated and coherent, reforms are needed at the normative, institutional, and operational levels.

Here's a **merged, concise academic-style version** that integrates your summary with the application to Europe's inland waterways:

According to **Vasco Reis and Rosário Macário** in *Intermodal Freight Transportation*, the future of intermodal freight depends on overcoming organisational, regulatory, infrastructural, and technological barriers to build more effective and integrated transport chains (Reis & Macário, 2018). They highlight that **trends such as digitalisation, e-commerce, and autonomous technologies** will shape intermodal systems by improving coordination, efficiency, and visibility across modes. The authors emphasise that **physical, logical, financial, and contractual flows** must be integrated to create seamless operations, rather than treating modes in isolation. Improving **information systems**, including digital platforms and real-time data sharing, and reducing organisational barriers are essential to make combined transport more competitive relative to road-only freight. Technological advancements, such as automation at terminals, Internet of Things tracking, and more efficient transfer technologies, will help reduce time and cost inefficiencies. Reis and Macário also stress the importance of aligning **regulatory frameworks** across regions to reduce fragmentation and enable smoother cross-border flows, while performance metrics and analytical tools guide evidence-based planning and investment. They see intermodal transport becoming increasingly **sustainable**, with modal shifts toward rail and inland waterways contributing to lower emissions and environmental impact. Applied to Europe's inland waterways, these lessons suggest that integrated planning, harmonised regulation, digitalisation, and strategic infrastructure investment can unlock the waterways' potential as a vital, sustainable component of the continent's multimodal transport network.

Despite extensive policy documentation and technical studies, gaps remain in the academic literature. Comparative empirical evaluations of policy outcomes and cross-national implementation remain limited, and there is often insufficient integration of social dimensions, such as stakeholder participation and labor market effects, into inland waterway policy analysis (Baranyai, 2020). Furthermore, the global positioning of European inland waterways—relative to China's river freight modernization or US inland transport systems—has not yet been fully explored in transport policy research, suggesting a need for broader international comparative frameworks.

Scholarly contributions

Our scholarly contribution can be framed in several key areas based on the context of inland waterways governance and transport. Here are some potential contributions you might consider:

We tentatively contribute by analyzing existing governance models for inland waterways, identifying best practices, and proposing innovative frameworks that enhance collaboration among stakeholders. This research could provide valuable insights into effective governance structures that balance economic, social, and environmental objectives.

A comprehensive study on the environmental, economic, and social impacts of inland waterway transport can be a significant contribution, something we stop short of. However, we do evaluate the effects of current governance practices and propose improvements, thus our work could inform policymakers and stakeholders about the benefits and challenges of inland waterways.

We do outline the content of such a consultation process in relation to a unified legal framework for Europe's inland waterways. We elaborate policy recommendations based on empirical research in order to further shape EU's transport policy agenda concerning inland waterways.

By integrating perspectives from environmental science, economics, and political science, our work contribute to a more holistic understanding of inland waterways governance. This interdisciplinary approach can foster collaboration among different fields and lead to more comprehensive solutions.

We briefly conduct case studies of successful inland waterway governance in different regions to provide practical examples and lessons learned. A comparative analysis of various governance frameworks can highlight effective strategies and potential pitfalls, contributing to the broader discourse on inland waterways.

Researching effective stakeholder engagement strategies can enhance the governance process. Research contributions could focus on how to involve local communities, industry players, and environmental organizations in decision-making, ensuring that diverse perspectives are considered.

By focusing on these areas, our scholarly contributions can significantly advance the understanding and management of inland waterways, ultimately supporting the development of more sustainable and efficient transport systems in the European Union.

METHODOLOGY

This study employs a desk-based, multi-source approach to assess the potential of Europe's inland waterways for trade enhancement, regulatory improvement, and cultural valorisation. It combines descriptive, analytical, and AI-supported methods to synthesise data from existing literature, policy documents, and official reports. Quantitative datasets on navigability, freight volumes, and port connectivity are complemented by qualitative analysis of rivers' historical, cultural, and ecological significance, including the contributions of women in river-based livelihoods.

A comprehensive review of EU and national regulations, including directives such as NAIADES III, CEVNI, and harmonised River Information Services, identifies regulatory gaps, inconsistencies, and historical near-misses that have limited trade expansion or environmental compliance. Based on this review, a multidimensional analytical framework is constructed to examine inland waterways across economic, environmental, regulatory, and cultural-symbolic dimensions.

AI and computational tools are employed to synthesise textual, geospatial, and statistical data, enabling systematic analysis of legal texts and scientific literature, mapping of waterway networks and trade corridors, and modelling of scenarios for regulatory and infrastructure interventions. This desk-based methodology provides an evidence-driven basis for understanding the economic, environmental, and symbolic value of Europe's rivers, generating insights for trade promotion and policy development without requiring fieldwork or stakeholder engagement.

Structure

We begin by laying out the land on how the inland waterways are regulated in the European Union. This clearly allows to examine the policy-making system. We introduce different aspects of the role of the inland waterways in the EU in relation to the transport economy: market shares and cargo types. We would also want to examine how river governance works and the various aspects invoked under the Naiades-directive such as the role of inland harbor and river governance and propulsion systems, and by implication , the poverty of understanding and momentum in EU policy concerning uptake emission reduction at the nexus of oceans, coastal community and rivers essential for intermodality and transshipment. We are examining some of the niggling issues of the cities contribution to pollution of our rivers. As case-studies on the applicability of the objectives on the objectives of inter-modality and transshipment we use: The Sava river and the Dnistr.

All in all, rivers are sym-bols but their governance per see and as part of the seaborne trade and pristine environment is anything but impressive. In the conclusions, we summarise our findings and indicate where further research is needed. In the appendix, we outline a unified legislative framework for our inland waterways that combined with strategic practices will prove imminently practical in promoting EU public policy on the regulation of our seaborne trade and aquatic environment in Europe.

BACKGROUND

The Common Transport Policy of the European Union is established under Articles 90 to 100 of the Treaty on the Functioning of the European Union, which provide the primary legal basis for Union action across all modes of transport, including inland waterways, road, rail, maritime, and air transport. Within this framework, the European Union adopts secondary legislation through the ordinary legislative procedure in the form of regulations, directives, and decisions, laying down common rules on market access, safety, security, environmental protection, social standards, and technical harmonisation. Institutional responsibilities are clearly defined: the European Commission exercises the right of legislative initiative, ensures implementation, and monitors compliance, while the European Parliament and the Council act as co-legislators, supported by EU agencies and coordination bodies that contribute to technical implementation and enforcement.

The Common Transport Policy further seeks to ensure the proper functioning of the internal market by guaranteeing freedom to provide transport services, promoting fair competition, and eliminating discriminatory or restrictive practices between Member States. A central objective of the policy is the improvement of transport safety and security through the establishment of harmonised standards, certification systems, inspections, and preventive measures applicable across all transport modes. Environmental sustainability is fully integrated into the policy, with a strong emphasis on reducing emissions, improving energy efficiency, and encouraging the use of low-emission and sustainable transport solutions, in line with the objectives of the European Green Deal.

In addition, the Common Transport Policy supports the development of efficient, interconnected, and interoperable transport infrastructure, notably through the Trans-European Transport Network (TEN-T), which includes key inland waterway corridors. It promotes multimodality and the integration of mobility systems in order to optimise logistics chains and facilitate a modal shift towards more sustainable modes of transport, such as inland waterways and rail. The policy also addresses the social dimension of transport by setting minimum standards for working conditions, training, and professional qualifications within the transport sector. Finally, the Common Transport Policy incorporates an international dimension, fostering cooperation with third countries and international organisations and ensuring consistency with relevant international conventions and technical standards.

The European Union has established a comprehensive regulatory and institutional framework to govern inland waterways, balancing operational efficiency, environmental protection, and cross-border interoperability. Central to this framework is the **Trans-European Transport Network (TEN-T)**, which identifies key inland waterways as strategic corridors and integrates them with ports, rail, and road networks. TEN-T provides both a planning and financing mechanism, enabling the EU to prioritize investments in navigability, intermodal connections, and infrastructure modernization along critical river corridors such as the Rhine, Danube, and Seine. By designating these waterways as part of the core network, the EU ensures that modernization efforts are aligned with broader European transport and sustainability objectives.

The **EU Directive on Inland Waterway Transport (2006/87/EC)** sets binding technical standards for vessel design, crew certification, and traffic management systems, harmonizing operational practices across member states. This legal standardization reduces administrative complexity, facilitates cross-border navigation, and ensures safety and reliability for freight and passenger transport. Environmental considerations are embedded through the **Water Framework Directive (2000/60/EC)**, which promotes integrated river basin management, water quality preservation, and ecological continuity, alongside the **Floods Directive (2007/60/EC)**, which mandates flood risk assessment and management planning across transnational river systems.

Institutional coordination is reinforced through European River Commissions, such as the **Danube Commission** and the **International Commission for the Protection of the Rhine**, which provide platforms for member states to harmonize navigation rules, infrastructure maintenance, and emergency response procedures. These bodies are critical for addressing the operational and ecological challenges posed by climate change, including droughts, floods, and sedimentation, and for ensuring that infrastructure interventions respect transboundary environmental objectives.

Financial and technological support is provided through programs like the **Connecting Europe Facility (CEF Transport)**, which funds projects in smart navigation systems, automated locks, port modernization, and integrated traffic management. CEF also emphasizes innovation, supporting the deployment of digital twin river models, real-time waterway monitoring, and predictive maintenance technologies. By linking regulatory frameworks with targeted funding and institutional coordination, the EU creates a governance ecosystem capable of modernizing inland waterways while enhancing climate resilience, operational efficiency, and environmental sustainability.

This integrated EU-level approach ensures that Europe's inland waterways can continue to function as strategic, low-emission corridors for continental and global trade. It combines legal standardization, coordinated oversight, and targeted investment to transform rivers into adaptive infrastructure systems capable of withstanding hydrological variability, facilitating sustainable transport, and maintaining Europe's competitive position in the global economy.

Here's a **20-sentence summary** of the Combined Transport Directive that *explicitly incorporates the 2019 amendment and subsequent refinement efforts*, suitable for your policy context:

The Combined Transport Directive (Council Directive 92/106/EEC) is the EU's foundational legal instrument designed to promote freight operations that combine road transport with non-road modes, including rail and inland waterways, to reduce reliance on road-only haulage. It establishes common rules for combined transport between Member States and allows fiscal and regulatory incentives for such operations. Inland waterways are defined as a valid non-road leg under the directive, placing river freight within the EU's multimodal transport architecture. The directive historically contributed to modal shift from road to rail and waterways, but its provisions were widely seen as outdated and limited in scope by the late 2010s. In response, the European Parliament adopted a position in 2019 to amend the directive, aiming to create a more resource-efficient multimodal network and reduce the negative externalities of transport, such as greenhouse gas emissions and congestion, while clarifying ambiguities in the original text. The 2019 amendment proposal sought to broaden the scope of combined transport to include national operations, address ambiguous definitions, and extend support measures to inland waterways and maritime legs of transport. It also emphasised the need for expanded and harmonised transhipment terminals and the use of electronic transport information to simplify evidence of combined transport operations. The proposed reforms called for Member States to support investment in terminals and deploy incentives favouring non-road transport legs, including inland waterways, to strengthen their competitiveness. Amendments also envisaged improved data collection and reporting to allow clearer monitoring of combined transport activity and modal shifts. These changes were intended to make combined transport more attractive and competitive relative to road-only transport, especially for small and medium-sized enterprises. However, negotiations over the revision have been protracted, reflecting persistent institutional and political challenges in EU transport policymaking.

In November 2023 the European Commission adopted a new proposal under its Greening Freight package to update the directive and enhance its role in sustainable freight transport, reinforcing the link to Green Deal objectives. This proposal aimed to improve the competitiveness of intermodal freight by combining the flexibility of road with the lower-emission performance of rail, inland waterways, or short-sea shipping for main journey legs:

Intermodal freight transport including combined transport[1] (hereafter both together referred to as "intermodal transport") is essential in enabling a higher uptake of rail and waterborne freight transport, which alone only very rarely provide door-to-door transport solutions. At the same time, the average external cost for rail and inland waterway transport per tonne-km (tkm) are almost three times lower, at EUR 0.013 per tkm and EUR 0.019 per tkm, respectively, compared to the average external cost for Heavy Good Vehicles (HGV) at EUR 0.042 per tkm. Intermodal transport, which includes feedering road legs at the beginning and/or end of the operation, combines the better environmental performance and energy efficiency of these non-road modes with the accessibility and flexibility of road transport. Intermodal transport enables to use transport modes in an efficient combination, in particular promoting those

[1] Combined transport is a subset of intermodal transport meeting the definition in the CTD.

with comparatively lower environmental footprints, thereby optimising the use of the existing transport network and resources and reducing emissions and energy consumption. [2]

Despite these efforts, by late 2025 the Commission withdrew that recent revision proposal, signalling ongoing contention and the need for further work on aligning the directive with current policy ambitions[3]. Nonetheless, the directive's inclusion of inland waterways continues to be strategically important for multimodal integration and emission reduction in EU transport policy. Reform efforts consistently highlight the need for clearer eligibility, enhanced fiscal incentives, and stronger support for transhipment infrastructure linked to inland ports. The directive remains relevant to achieving modal shift targets, especially as EU policy increasingly emphasises sustainability and multimodal connectivity. Its modernisation is seen as critical to integrating inland waterways into efficient European logistics chains and meeting climate goals. Enhanced digitalisation, such as interoperable transport data and electronic documentation, is also a recurrent theme in proposed revisions to reduce administrative burdens and improve operational predictability. The directive's evolution reflects broader EU transport policy trends toward greener, more integrated freight systems, even as institutional and legislative hurdles persist. Strengthening the CTD would help cement inland waterways' role within the EU's multimodal framework, aligning legal incentives with NAIADES III objectives for digitalisation, decarbonisation, and competitiveness. Collectively, these amendments and refinement efforts illustrate the EU's ongoing attempt to adapt legacy regulatory frameworks to contemporary sustainability and efficiency goals in freight transport.

Europe's inland waterways form one of the largest interconnected navigable networks in the world, with over **37,000 km of rivers and canals** linking industrial regions, cities, and sea ports across at least 13 EU Member States, providing an efficient alternative to road and rail for freight transport. Inland waterway transport is valued for its **energy efficiency, reliability, lower emissions, and high cargo capacity**, helping to decongest road networks and support sustainable logistics chains.

The **European Union aims to strengthen the role of inland waterways** as part of its transport and multimodal integration strategy, supporting modal shift under initiatives like NAIADES III and digital transformation efforts such as the Digital Inland Waterway Area (DINA).

A cornerstone of EU regulatory action has been the **River Information Services (RIS) Directive**, first enacted in 2005, which sets harmonised standards for digital traffic and voyage information across inland waterways. This framework is currently being updated to improve interoperability, navigation safety, and data sharing across borders — a provisional political agreement between the European Parliament and Council has been reached and is expected to be formally adopted soon.

At the technical level, EU legislation such as **Directive (EU) 2016/1629** sets uniform technical standards and certification for inland vessels, contributing to a safer and more efficient internal transport market. Additional EU and international rules, like the European Code for Inland Waterways (CEVNI) developed under the UNECE and the ADN agreement on dangerous goods, help harmonise navigation rules and safety procedures across different Member States.

Overall, the regulatory framework combines EU directives and regulations with international standards and national law, aiming to balance operational safety, environmental protection, and logistical efficiency while facilitating the integration of inland waterways into Europe's broader transport system.

Directive 2008/68/EC governs the **inland transport of dangerous goods by road, rail, and inland waterways**. It ensures a high and uniform level of safety across all EU Member States and facilitates the free movement of goods while minimizing risks to people, property, and the environment.

The Directive is based on and regularly updated in line with three major international agreements. Road transport is regulated through the **ADR** (European Agreement concerning the International Carriage of Dangerous Goods

[2] https://www.eesc.europa.eu/en/news-media/press-summaries/revision-combined-transport-directive-92106eec?utm source=chatgpt.com
[3] https://www.trasportoeuropa.it/english/european-commission-withdraws-revision-of-combined-transport-directive/?

by Road). Rail transport is governed by the **RID** (Regulations concerning the International Carriage of Dangerous Goods by Rail), which forms part of the Convention concerning International Carriage by Rail. Inland waterway transport is regulated by the **ADN** (European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways). Inland waterway transport is comprehensively regulated by the ADN (European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways), which establishes a harmonized legal framework governing the safe, secure, and environmentally responsible transport of dangerous goods across European inland waterways. The ADN defines detailed technical, operational, and safety requirements for vessels, crew qualifications, cargo handling, documentation, and emergency response, ensuring consistency and compliance among participating states.

In addition to Directive 2008/68/EC, other EU legislation supports the safe transport of dangerous goods. This includes regulations on vehicle and vessel safety, worker protection, accident prevention, and environmental liability. Member States are responsible for enforcing these rules through national authorities, inspections, and penalties, while the European Commission oversees harmonization and updates to the legal framework.

Together, Directive 2008/68/EC and the ADR, RID, and ADN agreements form the core legal system governing the transport of dangerous goods within the European Union.

Policy-Making System

Policy-making theory provides analytical frameworks that explain how public policies are formulated, adopted, implemented, and revised. Among the most widely used approaches is **the Rational Comprehensive Model**, which views policy-making as a logical and sequential process. Under this model, policymakers clearly define the problem, identify objectives, assess all available policy options, evaluate their costs and benefits, and select the optimal solution. In practice, this approach is applied through impact assessments, cost–benefit analyses, and evidence-based decision-making, and is commonly used in structured regulatory environments such as EU legislative proposals.

In contrast, **Incrementalism** conceptualises policy-making as a process of small, gradual adjustments rather than radical change. Policymakers build on existing policies, making limited modifications that are politically feasible and administratively manageable. This theory is applied in practice when reforms are introduced through pilot projects, phased implementation, or technical amendments, particularly in complex sectors where consensus is difficult to achieve.

The Multiple Streams Framework explains policy change as the convergence of three largely independent streams: problems, policies, and politics. According to this approach, policy change occurs when a "policy window" opens, allowing decision-makers to link a recognised problem with a viable solution and favourable political conditions. In practice, this framework is applied by policy entrepreneurs who strategically frame issues, prepare policy solutions in advance, and act quickly when opportunities arise, such as during crises or political transitions.

Another influential approach is **the Advocacy Coalition Framework**, which emphasises the role of coalitions of actors who share common beliefs and seek to influence policy over time. Policy change occurs through learning, negotiation, and external shocks rather than through single decisions. This theory is applied by engaging stakeholders early, building alliances across institutions and sectors, and using evidence and dialogue to shift dominant policy beliefs.

Institutionalism focuses on how formal rules, legal structures, and informal norms shape policy outcomes. From this perspective, policy choices are constrained and enabled by existing institutions. In practice, institutional analysis is applied by assessing legal competences, administrative capacities, and governance arrangements before proposing reforms, ensuring that new policies are compatible with existing institutional frameworks.

Network Governance Theory views policy-making as the product of interactions among multiple public and private actors operating in policy networks rather than through hierarchical control. This approach is applied through stakeholder consultations, public-private partnerships, expert groups, and coordinated governance mechanisms, especially in technical or cross-border policy areas.

Finally, **Punctuated Equilibrium Theory** argues that policy systems are characterised by long periods of stability interrupted by short bursts of significant change. These shifts often result from crises, shifts in public attention, or changes in institutional power. In practice, this theory is applied by recognising moments when major reform is possible and preparing comprehensive policy packages that can be adopted rapidly when such opportunities arise.

Applied to the Transport system

Policy-making in the European Union, particularly in sectors such as transport and inland waterways, can be analysed through several complementary theoretical frameworks. The **Rational Comprehensive Model** applies when EU policymakers seek evidence-based solutions for technical and safety regulations, such as ADN standards for inland waterway transport. Here, problems are clearly defined, alternative policy options are evaluated using cost–benefit analysis, and the optimal solution is adopted through legislative procedures.

Incrementalism is evident in the EU's stepwise updates to existing directives or regulations, where adjustments to inland waterway rules are made gradually to maintain political feasibility and administrative manageability. For example, amendments to vessel certification or environmental standards often follow small, incremental changes rather than wholesale reform.

The **Multiple Streams Framework** is particularly relevant in EU policy windows, where transport problems, policy solutions, and political support converge. Crises such as major accidents or environmental incidents can create a policy window, enabling rapid adoption of improved safety or environmental rules. Policy entrepreneurs in the EU, including the Commission and member states, strategically use these windows to advance legislation.

The **Advocacy Coalition Framework** helps explain the role of stakeholders in inland waterway policy. Coalitions of industry associations, environmental NGOs, member states, and EU agencies influence long-term policy directions, negotiating technical standards, operational rules, and sustainability measures. Change often results from dialogue, evidence sharing, and external shocks, such as shifts in climate policy priorities.

Institutionalism shapes policy by emphasising the legal and administrative structures of the EU. For inland waterways, this includes competences assigned to the European Commission, the Council, and the European Parliament, as well as coordination through bodies like the EU Inland Waterways Coordination Body. Understanding these institutions is essential for designing feasible, compliant policies.

Network Governance Theory is applied through the EU's multi-level stakeholder consultations, expert committees, and international cooperation with bodies such as the CCNR. Policy outcomes often emerge from negotiations within these networks rather than unilateral decisions.

Finally, **Punctuated Equilibrium Theory** explains occasional rapid reforms in inland waterway policy, often triggered by crises, technological advances, or political priorities, such as the adoption of stricter environmental standards in response to EU Green Deal objectives. Policymakers must be prepared to implement comprehensive changes when such windows of opportunity arise.

EU Inland Waterway Policy: Policy-Making, Stakeholders, and Interests

Policy-making in the EU inland waterway sector can be understood through several complementary theoretical frameworks, each offering insight into how legislation, regulation, and operational standards are developed and implemented. The **Rational Comprehensive Model** underpins evidence-based rulemaking, exemplified by ADN safety regulations and environmental standards, where policymakers systematically define problems, evaluate policy alternatives, and adopt optimal solutions. **Incrementalism** characterises the gradual adjustment of existing rules, including phased updates to crew qualifications, vessel certification requirements, and environmental limits, ensuring political and administrative feasibility. The **Multiple Streams Framework**

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highlights how rapid policy adoption can occur when recognized problems, viable solutions, and favourable political conditions converge, such as in response to accidents, environmental crises, or new EU climate objectives.

The **Advocacy Coalition Framework** illustrates the long-term influence of stakeholders with shared beliefs, who shape technical standards, operational norms, and sustainability measures over time. **Institutionalism** emphasises the role of formal EU structures, including the European Commission, European Parliament, and Council, in setting, enforcing, and supervising the legislative framework. **Network Governance Theory** explains the importance of multi-actor collaboration and technical consultation, involving expert committees, the EU Inland Waterways Coordination Body, national authorities, and international organisations such as the CCNR. Finally, **Punctuated Equilibrium Theory** accounts for sudden, substantial policy shifts triggered by crises, technological innovation, or major EU initiatives, such as the rapid adoption of advanced propulsion technologies or stringent environmental standards.

Stakeholder	Representation / Location	Primary Interests	Objectives
Inland Ports (e.g., IVR ports)	National port associations; EU coordination forums in Brussels	Efficient, modern port infrastructure; connectivity to TEN-T network	Expand cargo handling capacity, improve hinterland connections, integrate digital logistics
Shipowners / Operators	European Shipping Federation; national shipowner associations	Operational efficiency, safety, compliance costs	Reduce regulatory burden, access financing, adopt sustainable propulsion technologies
Propulsion / Engine Manufacturers	EU industry associations	Promotion of low-emission and hybrid propulsion systems	Advance green technologies, align with EU environmental standards
Shipyards for Inland Traffic	National shipbuilding associations	Stable demand for vessels, design compliance	Construct vessels meeting ADN, safety, and environmental regulations
Miners / Bulk Cargo Suppliers	Industry associations (coal, aggregates, ores)	Reliable transport routes, low freight costs	Ensure uninterrupted cargo flows via inland waterways, influence TEN-T prioritization
EU Institutions	European Commission, Parliament, Council	Harmonised safety, environmental, and transport policy	Develop legislation, ensure cross-border compliance, align with Green Deal
National Authorities / Regulators	Ministries of Transport, maritime & inland navigation agencies	Local enforcement, infrastructure management	Implement EU regulations, conduct inspections, issue certificates
International Bodies	ADN Secretariat, CCNR	Standardisation and cross-border safety	Maintain harmonised regulations for international inland waterways
Civil Society / NGOs	Environmental NGOs, trade unions	Safety, sustainability, workers' rights	Advocate for stricter emission standards, crew protection, environmental measures

Policy-making in the EU inland waterway sector is shaped by a combination of analytical frameworks and the active engagement of diverse stakeholders, each influencing the development, adoption, and implementation of legislation and operational standards. The **Rational Comprehensive Model** underpins evidence-based rulemaking, as exemplified by ADN safety regulations and environmental standards, where policymakers systematically define problems, evaluate policy alternatives, and adopt optimal solutions. **Incrementalism** characterises the gradual adjustment of existing rules, such as phased updates to crew qualifications, vessel certification, and environmental limits, ensuring political and administrative feasibility. The **Multiple Streams Framework** highlights how rapid policy adoption can occur when recognised problems, viable solutions, and favourable political conditions converge, often triggered by accidents, environmental crises, or the EU's climate objectives.

The **Advocacy Coalition Framework** illustrates the long-term influence of stakeholders with shared beliefs who shape technical standards, operational norms, and sustainability measures over time. **Institutionalism** emphasises the role of formal EU structures, including the European Commission, European Parliament, and Council, in setting, enforcing, and supervising the legislative framework. **Network Governance Theory** reflects the importance of multi-actor collaboration and technical consultation, involving expert committees, the EU Inland Waterways Coordination Body, national authorities, and international organisations such as the Central Commission for the Navigation of the Rhine (CCNR). Finally, **Punctuated Equilibrium Theory** accounts for sudden, substantial policy shifts triggered by crises, technological innovation, or major EU initiatives, including the rapid adoption of advanced propulsion technologies or stringent environmental standards.

The EU inland waterway policy landscape involves a wide range of stakeholders, each with distinct roles, interests, and objectives. **Inland ports**, represented through national port associations and EU coordination forums, seek efficient and modern infrastructure, enhanced connectivity to the Trans-European Transport Network (TEN-T), and integrated digital logistics to expand cargo handling capacity and improve hinterland links. **Shipowners and operators**, organised via the European Shipping Federation or national associations, prioritise operational efficiency, regulatory compliance, cost-effective financing, and the adoption of sustainable propulsion technologies. **Propulsion and engine manufacturers** focus on advancing low-emission, hybrid, or alternative fuel systems in alignment with EU environmental and climate targets, while **shipyards serving inland navigation traffic** seek clarity in technical standards and stable demand for vessels compliant with ADN and evolving environmental regulations. **Miners and bulk cargo suppliers**, transporting coal, aggregates, or ores, rely on reliable inland waterway transport routes, cost-efficient logistics, and prioritisation within TEN-T corridors to ensure uninterrupted cargo flows.

EU institutions, particularly the **European Commission**, exercise legislative initiative, propose regulatory amendments, and ensure cross-border harmonisation. The **European Parliament** and **Council** act as co-legislators, while national authorities implement rules, conduct inspections, issue certifications, and oversee compliance. **International bodies**, notably the ADN Secretariat and the CCNR, maintain harmonised technical standards and facilitate international cooperation. Civil society, including environmental NGOs and trade unions, contributes by advocating stricter emission standards, crew protection, and sustainable inland waterway operations.

The interaction among these stakeholders occurs within the frameworks of multiple policy-making theories. Evidence-based decision-making, incremental regulatory adjustments, rapid responses to policy windows, coalition-driven influence, institutional enforcement, multi-actor consultation, and occasional transformative policy shifts collectively shape the EU inland waterway policy landscape, ensuring safety, environmental sustainability, operational efficiency, and alignment with broader European transport and climate objectives.

EU transport policy is handled in the Council by the Transport, Telecommunications and Energy (TTE) Council, where national transport ministers adopt positions and legislation. Below ministerial level, detailed negotiations take place in Council working parties, notably those on land transport, shipping, aviation, and intermodal transport and TEN-T networks. These working parties prepare dossiers for Coreper and ultimately for agreement at TTE level. They are chaired not by permanent figures but by officials from the rotating Council Presidency, reflecting Member State control of the process. On the parliamentary side, transport policy is concentrated in the European Parliament's Committee on Transport and Tourism (TRAN). TRAN is responsible for road, rail, air, maritime, and inland waterway transport, as well as TEN-T and mobility regulation. The committee drafts Parliament's legislative position, appoints rapporteurs, and leads negotiations with the Council and the Commission. The Chair of TRAN provides political leadership, represents the committee externally, and steers compromises during trilogues. Vice-chairs support the chair and ensure political balance across party groups. Together, the TTE Council and the TRAN Committee form the core interinstitutional axis through which EU transport policy is negotiated and adopted.

In the EU transport policy framework, the **European Commission serves as the primary driver**, proposing legislation, setting strategic objectives, and coordinating EU-wide transport initiatives. Its policy priorities focus on **market harmonization, regulatory implementation, infrastructure planning, and ensuring legal compliance across Member States**, aiming to create a **cohesive, competitive, and sustainable EU transport system**:

"The European Commission presented its 'Sustainable and Smart Mobility Strategy' … laying the foundation for how the EU transport system can achieve its green and digital transformation and become more resilient to future crises. … the result will be a 90% cut in emissions by 2050, delivered by a smart, competitive, safe, accessible and affordable transport system." "EU supports mobility and what it does to make transport more competitive, sustainable, and resilient, while ensuring safety…"

The **Council of the European Union** plays a complementary role by **defining political priorities and achieving intergovernmental consensus**. Its overarching principles emphasize **competitiveness of the transport sector, administrative simplification, and the green transition**, ensuring that EU transport policies are both **efficient and sustainable** while balancing the diverse interests of Member States:

"The European Council held an in-depth discussion on how to further reinforce EU competitiveness … focusing on simplification, a competitive green transition … and calls on the Commission and the co-legislators to take the implementation of the Single Market Strategy … forward."

The **European Parliament** provides **democratic oversight** and ensures that policies reflect **broader societal interests**. Its priorities include **improving mobility for people and goods, ensuring competitive companies, protecting workers, and reducing greenhouse gas emissions**, bringing a stronger focus on **social and environmental outcomes** alongside economic objectives:

"TRAN Committee's work focuses on improving mobility for people and goods, ensuring competitive companies, protecting workers, and reducing greenhouse gas emissions."

In practice, the roles of the three institutions can be summarized as follows:

- **Commission** → Leads policy design, drafts legislation, and coordinates EU-wide implementation.
- **Council** → Establishes political priorities and mediates compromises among Member States.
- **Parliament** → Oversees, amends, and ensures policies address social, environmental, and democratic considerations.

Together, these institutions form a **triangular governance framework**, balancing **efficiency, sustainability, competitiveness, and societal interests** in EU transport policy, with the **Commission as the lead policy driver**, the Council shaping political priorities, and the Parliament ensuring societal accountability.

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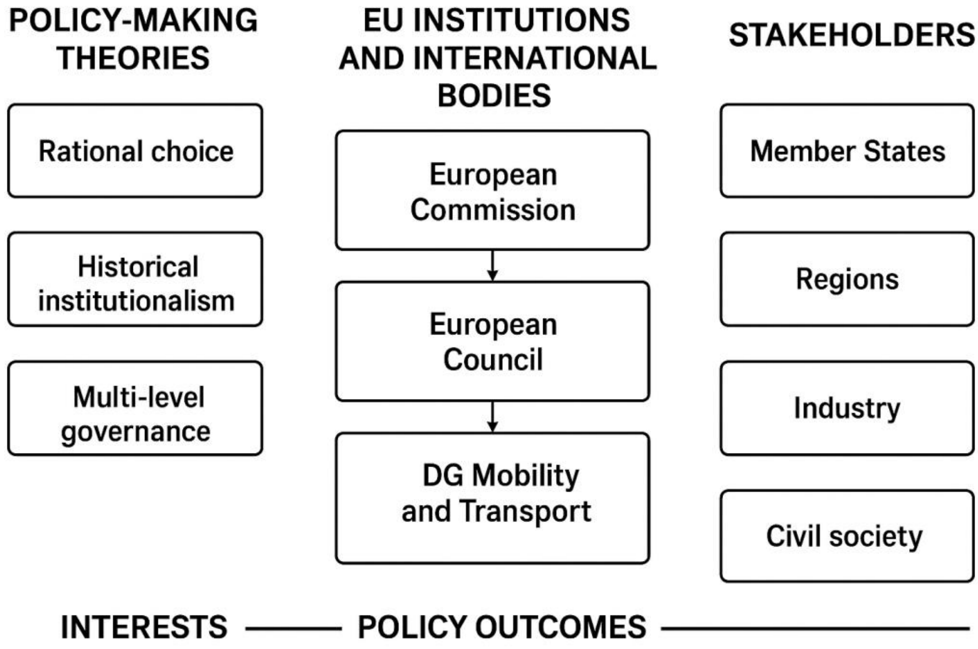

The diagram illustrates how European Union policy outcomes emerge from the structured interaction between ideas, institutions, and interests. On the left, policy-making theories frame how problems are understood and how solutions are justified. Rational choice highlights strategic behavior and cost–benefit calculations; historical institutionalism emphasizes path dependency and inherited constraints; and multi-level governance captures the dispersion of authority across European, national, and sub-national levels. These theoretical lenses do not determine policy directly, but they shape agendas, analytical methods, and the language through which choices are defended.

At the center, EU institutions translate these ideas into authoritative decisions. The European Commission acts as agenda-setter and policy designer, transforming political priorities and stakeholder inputs into legislative and regulatory proposals. The European Council provides strategic direction by aligning national interests and defining high-level objectives. DG Mobility and Transport functions as the sectoral engine, converting strategic mandates into concrete transport, mobility, and infrastructure policies, including regulation, funding instruments, and implementation guidance.

On the right, stakeholders articulate interests and exert influence throughout the policy cycle. Member States negotiate priorities and safeguard national competencies, regions contribute territorial and implementation perspectives, industry actors supply investment capacity and technical expertise, and civil society introduces societal, environmental, and social considerations. Arrows indicate that influence flows in multiple directions: stakeholders shape institutional choices, institutions structure stakeholder access, and policy outcomes feed back into future preferences and constraints.

Overall, the figure emphasizes that EU policy-making is neither purely technocratic nor purely political. It is a dynamic system in which theoretical frameworks condition institutional behavior, institutions mediate competing interests, and final policy outcomes reflect negotiated compromises within a multi-level European governance architecture.

Political Economy of Regulation

The political economy of regulation examines how political forces, economic interests, and institutional structures shape the creation and implementation of rules (Stigler, 1971). George Stigler argued that regulation is often captured by the industries it is meant to control, reflecting private rather than public interests (Stigler, 1971). Sam Peltzman emphasized that regulation balances competing political and economic interests, mediating between private benefits and social welfare (Peltzman, 1976). Robert Baldwin, Martin Cave, and Martin Lodge provided a comprehensive framework for understanding regulatory instruments, governance, and their effectiveness (Baldwin et al., 2012). Jean-Jacques Laffont and Jean Tirole highlighted the importance of incentives in regulatory design, ensuring compliance while promoting efficiency (Laffont & Tirole, 1993). Peter Drahos and John Braithwaite explored how power and knowledge asymmetries influence regulatory outcomes globally (Drahos & Braithwaite, 2002). David Vogel compared regulatory approaches across nations, showing how political cultures shape policy priorities and enforcement (Vogel, 1986). Richard Posner examined regulation through an economic lens, emphasizing cost-benefit calculations and efficiency (Posner, 1973). Clarke and Newman analyzed bureaucratic and managerial forces that guide regulation within modern states (Clarke & Newman, 1997).

In the EU transport sector, regulation reflects the interaction of member states, EU institutions, industry stakeholders, and civil society actors (Baldwin et al., 2012; Vogel, 1986). Shipping companies and port authorities often exert influence to shape rules in ways that reduce costs or enhance competitiveness (Stigler, 1971). Environmental organizations advocate for safety, sustainability, and emission reductions, pressing for stricter standards (Drahos & Braithwaite, 2002). Regulatory capture can occur when powerful actors dominate decision-making, prioritizing private advantage over public good (Peltzman, 1976; Stigler, 1971). Effective institutions, such as the European Commission and national authorities, are crucial for implementing and enforcing rules consistently (Baldwin et al., 2012). Regulations also guide market behavior, affecting investment, competition, and technological innovation (Laffont & Tirole, 1993). As trade, transport, and environmental priorities evolve, EU regulations must adapt to changing economic conditions and policy goals (Vogel, 1986; Drahos & Braithwaite, 2002). Inland waterways, for example, illustrate how regulation balances efficiency, environmental performance, and regional development (Baldwin et al., 2012). Ultimately, the political economy of regulation reveals why rules are never purely technical—they reflect the complex interplay of power, interests, incentives, and public purpose (Clarke & Newman, 1997).

Summary

Political economy approaches to regulation and policymaking frame the forthcoming exposition by highlighting the **interaction between political power, economic interests, and institutional structures** in shaping rules and policies. They emphasize that regulations are rarely purely technical; they are the product of **competing pressures from industry actors, civil society, and governmental institutions**. The theory explains how **incentives, influence, and regulatory capture** determine which rules are enacted, how they are enforced, and who benefits. It also underscores the role of **institutional capacity and governance frameworks** in ensuring compliance and effectiveness. By applying this lens, the exposition examines **EU inland waterway and transport regulation** as a site where economic efficiency, environmental objectives, and regional development intersect. PE theory highlights **the trade-offs inherent in policymaking**, such as balancing cost-efficiency with sustainability or national priorities with continental integration. It further clarifies why policy outcomes may diverge from stated objectives, reflecting the **dynamic interplay of political, economic, and social forces**. Overall, this framework provides a structured perspective for analyzing regulatory decisions, forecasting challenges, and assessing the broader implications for EU transport, trade, and sustainable growth.

NAIADES III: Strategic Framework for the Modernisation of European Inland Waterway Transport

In Greek mythology, **Naiads** are freshwater nymphs associated with springs, rivers, fountains, and lakes. Functionally, they operate as guardians of these aquatic sites, embodying both protective and symbolic roles within the mythological landscape. Naiads are often depicted as essential to the sustenance of human and animal life, mediating the availability of fresh water, which was crucial for agriculture, survival, and ecological balance. Their presence in myth, ritual, and literary sources underscores the cultural significance attributed to these entities, including their capacity to inspire human devotion, cautionary practice, and ethical engagement with natural resources.

The sacralization of nature, exemplified in the veneration of Naiads, reflects an early recognition of the intrinsic power and necessity of environmental elements. By ascribing divinity to water sources and other natural features, ancient Greek thought promoted both **aesthetic reverence and practical stewardship** of the environment. This theological framing functioned as a cultural mechanism through which ecological consciousness, ritualized respect, and societal norms regarding natural resource use were maintained. In this sense, the sanctification of natural phenomena constitutes a central component of Greek mythological and ethical thought, integrating cosmology, ritual practice, and environmental awareness.

Now, NAIADES III constitutes the European Union's comprehensive action programme for inland waterway transport (IWT) for the period 2021–2027. It responds to structural challenges affecting the sector, including declining modal share, infrastructure bottlenecks, skills shortages, and the imperative of deep decarbonisation. The strategy is embedded within the broader architecture of the European Green Deal and the Sustainable and Smart Mobility Strategy, positioning inland waterways as a systemic lever for achieving climate neutrality and transport resilience.

The strategy is structured around two overarching objectives:

First, NAIADES III seeks to induce a structural modal shift by increasing the share of freight transported via inland waterways, thereby alleviating congestion on road networks, enhancing energy efficiency, and strengthening territorial cohesion. This objective aligns with EU-level targets to significantly increase inland and short sea shipping volumes by 2030 and 2050 relative to 2015 benchmarks.[4]

Second, the strategy aims to place the inland waterway transport sector on an irreversible pathway towards zero emissions by mid-century. This entails a comprehensive transformation of vessel technologies, energy systems, and port infrastructure, complemented by regulatory and financial support mechanisms.

These objectives are cross-cut by horizontal priorities related to digitalisation, workforce development, and institutional coordination.

NAIADES III emphasises the integration of inland waterways into multimodal logistics chains. Central to this pillar is the improvement of navigability and service reliability across the core inland waterway network, including the achievement of "good navigation status" on major corridors. The strategy supports regulatory revisions—most notably to the Combined Transport framework—to reduce administrative friction and enhance interoperability between inland navigation, rail, and maritime transport.

A core pillar of the strategy concerns the transition towards zero-emission inland navigation. This includes the promotion of alternative propulsion systems (such as electric and hydrogen-based solutions), the retrofitting and renewal of existing fleets, and the deployment of clean energy infrastructure in inland ports. Research, innovation, and demonstration projects are identified as critical enablers for scaling up sustainable technologies within the sector.

NAIADES III prioritises the digital transformation of inland waterway transport through advanced traffic management systems, harmonised data exchange, and interoperable digital services. These measures aim to

[4] https://transport.ec.europa.eu/transport-modes/inland-waterways/promotion-inland-waterway-transport/naiades-iii-action-plan_en

increase operational efficiency, enhance safety, and reduce administrative burdens, while supporting real-time coordination within multimodal supply chains.

Recognising the sector's reliance on specialised labour, the strategy addresses workforce sustainability through the modernisation of training standards, the adaptation of qualification frameworks, and the promotion of flexible crewing models. Skills development is framed as a prerequisite for both the green and digital transitions of inland navigation.

NAIADES III is implemented through a set of 35 actions supported by EU funding instruments, regulatory initiatives, and stakeholder coordination platforms. The strategy encourages close cooperation between the European Commission, Member States, river commissions, port authorities, and industry actors. Implementation support is provided through dedicated coordination mechanisms, including research and innovation platforms that facilitate monitoring, knowledge exchange, and policy feedback.

Beyond its sectoral focus, NAIADES III contributes to wider EU objectives related to territorial cohesion, strategic autonomy, and infrastructure-based integration. By strengthening inland waterways as connective tissue between seaports, industrial regions, and hinterlands, the strategy reinforces the role of transport infrastructure as an instrument of continental integration and climate governance.

NAIADES III represents a shift from incremental sectoral support towards a system-level transformation of inland waterway transport. Its success depends on the effective alignment of infrastructure investment, regulatory reform, technological innovation, and governance capacity. As such, it serves as a test case for the EU's ability to operationalise green transition objectives through integrated infrastructure policy.

Strengthening Governance and Impact of NAIADES III by the 2027 Review

A central limitation of NAIADES III lies in its predominantly programmatic nature. By 2027, governance should shift from coordination-based implementation towards **quasi-binding mechanisms** embedded in existing EU transport governance frameworks. This can be achieved by formally integrating inland waterway performance benchmarks into TEN-T core network governance, the European Semester, and climate reporting obligations. Such integration would elevate inland navigation from a sectoral policy to a monitored component of EU infrastructure cohesion.

Impact by 2027 requires a transition from aggregate EU targets to **corridor-specific performance indicators**. Each major inland corridor (Rhine, Danube, Elbe, Seine–Scheldt, Po) should be subject to harmonised reporting on navigability days, modal shift performance, emission intensity, and digital service deployment. Assigning explicit responsibility to corridor coordinators—aligned with TEN-T governance—would create accountability without treaty change.

Inland ports should be formally recognised as **strategic infrastructure interfaces**, not merely operational assets. By 2027, governance should empower inland ports to act as local coordinators for multimodal integration, energy transition, and digitalisation. This requires clearer eligibility and prioritisation within CEF, cohesion policy, and state aid frameworks, coupled with governance obligations tied to funding.

To strengthen impact, EU financial instruments supporting inland waterways should be subject to **ex ante and ex post conditionality** linked to NAIADES III objectives. Funding allocation should prioritise projects that demonstrably improve navigability reliability, enable zero-emission operations, or remove cross-border bottlenecks. This would transform NAIADES III from an enabling strategy into a results-driven investment framework.

By 2027, digitalisation must evolve from pilot projects to a **mandatory governance layer**. This entails interoperable data standards for traffic management, emissions reporting, and multimodal logistics, overseen by a central EU coordination mechanism. Digital inland navigation services should be treated as critical infrastructure, ensuring continuity, comparability, and policy usability of data.

Human capital measures should be integrated into governance cycles rather than treated as ancillary actions. By the 2027 review, inland navigation skills development should be aligned with EU vocational training, mobility, and just transition frameworks, enabling workforce policy to support structural transformation rather than merely mitigating labour shortages.

Finally, governance strengthening requires a reframing of inland waterways as instruments of **continental resilience, decarbonisation, and cohesion**, rather than niche transport modes. Explicit linkage to energy security, industrial logistics, and climate adaptation would justify stronger coordination and elevate political ownership at both EU and Member State levels.

By 2027, the effectiveness of NAIADES III will depend less on the number of actions implemented and more on the **degree to which inland waterway transport is embedded within binding EU governance structures**. Strengthened accountability, corridor-level metrics, conditional funding, and institutionalised digital governance offer a realistic pathway to measurable impact within the current policy cycle.

Transport Economy

There are 40,000-48000 people employed in the inland transport sector in the EU across freight, passenger, and related water transport activities excluding in related logistics or supply chains. This means employment is only 0,4% of total transport sector employment. It makes a marginal contribution around 0,6 % of transport turnover, implying a very small share of transport GDP. The entire EU transport sector contributes around 5% to EU GDP and employs more than 6 million people, but inland waterways are only a tiny part of the total. This is a niche of the transport economy. Inland waterways in the Transport hundereds of million of tons of goods annually – 470 million tons in 2023 and inland freight performance at about 122 billion tonne kilometres. The primary goods transported are metal ores (23%), coke and refined petroleum products,chemicals, rubber & plastics as well as agricultural products and more.

Maritime transport take by far the biggest share of the total freight transport market with 67%, followed by road transport representing 25%, rail transport 5,5% and 1,6 % to inland waterways. Inland waterways are regionally important in countries like the Netherlands, Germany, Romania, Belgium and France, but they make up a small share at EU level.

Many of Europe’s major seaports are linked to inland waterways (e.g., **Rotterdam, Antwerp, Duisburg inland port** reached via Rhine/Elbe/other rivers), meaning a significant share of cargo **handled at these ports** will often move onwards by barge. Although there’s no single EU-wide percentage for this **port-to-inland transport share**, it’s recognised as an important multimodal link for reducing road congestion and emissions[5]

The distribution of freight transport modes across the European Union reveals a structural hierarchy that shapes both the geography and economics of EU trade. Maritime transport overwhelmingly dominates the movement of goods, accounting for more than two-thirds of total freight activity; this reflects the EU’s dependence on global supply chains, large-volume seaborne commodities, and the centrality of port gateways linking Europe to the world economy. Road transport, at just over one quarter, remains the principal mode for intra-European circulation and last-mile distribution, illustrating the fragmentation of supply chains and the continued reliance on flexible terrestrial logistics. Rail’s relatively modest share underscores persistent interoperability barriers, inconsistent electrification, and capacity constraints on major corridors. Inland waterways, representing only around 1.6% of total freight performance, remain structurally underutilized despite their significant energy efficiency and low-emission profile; their marginal share reflects infrastructure bottlenecks, low-water vulnerabilities, and the absence of unified EU-wide digital and regulatory frameworks. Air transport—used almost exclusively for high-value, low-weight goods—accounts for only a fraction of total freight. Overall, this modal configuration highlights the strategic importance of shifting more freight from road to rail and waterways,

[5]https://www.europarl.europa.eu/RegData/bibliotheque/briefing/2014/130684/LDM_BRI%282014%29130684_REV1_EN.pdf?utm_source=chatgpt.com

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not only to reduce emissions but to enhance resilience, optimize costs, and relieve congestion in Europe's densest logistics corridors.

Innovation will shape the next generation of inland waterway transport. Funding for autonomous and automated vessel trials, smart-port applications such as digital twins and predictive maintenance, drone-based inspections, and experiments with ultra-shallow-draft vessels will ensure resilience in low-water conditions and strengthen Europe's technological leadership.

At the same time, workforce development must keep pace: training programs should incorporate digital skills, alternative fuels, and automated systems, while mutual recognition of licenses across Member States would facilitate labor mobility and flexibility. This segment is more promising in terms of spending of RDI funding, since the propulsion technology is not mature enough for long haul routes.

Inland waterway transport plays very different roles in the freight systems of Europe, China, the United States, and Africa. According to *Key Figures on European Transport*, the European Union's inland waterways carried about 116 billion tonne-kilometres of freight in 2023, which is around 1.5–2 per cent of the EU's total freight performance. This shows that inland navigation has a relatively small role in Europe, where road transport still dominates, even though the Rhine–Danube axis and other major river basins remain strategically important.

When studying other major rivers on different continents, several factors should be considered:

1. The total volume of freight and the river's share of national or regional transport.
2. The river's share compared with road, rail, and coastal shipping.
3. The length of navigable waterways and how well they connect to ports and other transport modes.
4. The river's role in supporting industrial, agricultural, or urban supply chains.
5. The quality of infrastructure such as locks, ports, and dredging systems.
6. Government policies and investment supporting navigation.
7. Historical and cultural patterns of river use.
8. Environmental impact and energy efficiency compared with other transport modes.

Using these factors, it is possible to compare rivers such as the Rhine and Danube in Europe, the Yangtze and Pearl in China, the Mississippi in the United States, or the Congo and Nile in Africa. This approach helps to understand how important inland waterways are to the transport economy in each region.

Figure Evaluating Major Rivers

Inland waterways in Europe, while representing only a small share of total freight—around 1.5–2 per cent of EU transport performance—play a strategic role in supporting intermodal and transshipment operations. Rivers such as the Rhine and Danube connect major industrial and urban regions to seaports and rail networks, enabling the transfer of goods between road, rail, and waterborne transport. This intermodality allows inland navigation to serve as a low-cost, energy-efficient complement to road and rail freight, particularly for bulk commodities, containers, and heavy goods.

Comparatively, the EU's inland waterways are highly integrated into a multimodal transport system, with extensive networks of ports, terminals, and logistical hubs facilitating efficient transshipment. Locks, modern ports, and canal connections enhance operational reliability, while EU policy frameworks and funding encourage coordinated development across borders. This positions the Rhine–Danube axis not only as a transport corridor but also as a backbone for intermodal logistics chains, offering economies of scale, reduced environmental impact, and resilience against road congestion.

Evaluating the EU system against other continents, rivers such as the Yangtze or Mississippi carry larger absolute freight volumes, but their intermodal integration varies. The EU's emphasis on multimodal hubs, inland ports, and regulatory coordination illustrates how even a modest modal share can have outsized economic and strategic significance. Inland waterways thus function less as a dominant freight mode in isolation and more as an enabler of intermodal efficiency, sustainability, and regional connectivity within the EU's transport system.

Inland waterways in Europe, while representing only a small share of total freight—around 1.5–2 per cent of EU transport performance—play a strategic role in supporting intermodal and transshipment operations. Rivers such as the Rhine and Danube connect major industrial and urban regions to seaports and rail networks, enabling the transfer of goods between road, rail, and waterborne transport. This intermodality allows inland navigation to serve as a low-cost, energy-efficient complement to road and rail freight, particularly for bulk commodities, containers, and heavy goods.

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Moreover, inland navigation in Europe contributes to supply chain resilience by providing alternative routes when road or rail networks face congestion or disruptions. The combination of navigable rivers with advanced transshipment facilities also fosters international trade and cross-border economic integration, making European inland waterways a key component in the broader strategy for sustainable and competitive freight transport.

In comparative perspective, inland waterway transport occupies markedly different positions within the freight systems of Europe, China, the United States, and Africa. According to *Key Figures on European Transport*, the European Union's inland waterways generated approximately **116 billion tonne-kilometres of freight transport in 2023**, corresponding to **around 1.5–2 per cent of total EU freight performance**. This confirms the structurally modest role of inland navigation within a European transport system still dominated by road freight, despite the strategic importance of the Rhine–Danube axis and several high-capacity river basins.[6]

[6] https://ec.europa.eu/eurostat/web/products-key-figures/w/ks-01-24-021

By contrast, **China's inland waterways constitute a central pillar of national freight transport**. Recent national statistics indicate freight performances on the order of **1.8–2.0 trillion tonne-kilometres annually**, an order of magnitude larger than the EU. This reflects sustained state investment, very high volumes on the Yangtze River system, and strong integration between inland ports, coastal shipping, and industrial clusters. In China, inland waterways function not as a residual mode but as a backbone of bulk logistics and increasingly containerized flows.

The **United States** occupies an intermediate position. Freight performance on U.S. inland waterways—dominated by the Mississippi, Ohio, and Illinois river systems—amounts to **several hundred billion tonne-kilometres per year**, clearly exceeding EU levels but remaining far below China's scale. Inland navigation in the U.S. plays a decisive role in agricultural and bulk commodity transport, supported by long-standing federal infrastructure and lock-and-dam systems, yet it has not expanded into a comprehensive multimodal growth strategy comparable to China's.

For **Africa**, no consolidated, continent-wide inland waterway freight performance figure comparable to Eurostat or Chinese national statistics is available. While Africa hosts some of the world's longest and potentially navigable rivers—such as the Congo, Nile, Niger, and Zambezi—commercial inland navigation remains fragmented and limited in freight tonne-kilometres. Structural constraints include insufficient dredging, weak port and intermodal connections, seasonal hydrological variability, and limited regulatory harmonization. As a result, Africa's inland waterways currently account for a **very small share of continental freight transport**, despite their long-term strategic potential.

Summary

The differences in the prominence and efficiency of inland waterway transport across regions are not accidental, but result from a mix of economic, regulatory, institutional, and historical factors. First, **economic structure** matters: countries with heavy industry, bulk commodity production, and high-density trade corridors naturally benefit more from river transport, while economies dominated by road-dependent logistics see inland waterways as secondary.

Policy frameworks and regulation are also decisive. Europe, for example, has developed EU-wide directives, funding programs, and cross-border coordination, whereas many African or South American rivers lack consistent regulatory oversight or harmonized standards, reducing intermodal integration. **Governance and institutional capacity**—including planning, maintenance, and investment—determine whether rivers are reliable and navigable year-round. Weak governance, poor funding, or fragmented management often limit inland waterways' potential.

Political priorities and vested interests can reinforce inertia. Road and rail lobbies often dominate infrastructure planning, leaving rivers underutilized. Likewise, **historical inertia** and established transport habits create path dependency: once logistics networks have developed around trucks or trains, switching to river-based systems is costly and slow.

Finally, **knowledge gaps and siloed administration** hinder effective implementation. Poor understanding of intermodal advantages, limited data on river freight performance, and fragmented planning between ministries or agencies result in suboptimal investment and integration. In sum, the disparities reflect a combination of structural economic factors, policy and governance choices, vested interests, and institutional capacity, rather than a single technical limitation of inland waterways themselves.

To sum-up, these comparisons underline that Europe's inland waterways are not marginal by geography, but by policy and system integration. The EU's freight performance remains far below that of China and below the United States, while Africa illustrates the latent potential of river systems absent sustained institutional and infrastructural investment. This asymmetry reinforces the argument that revitalizing European inland waterways is less a question of natural endowment than of strategic prioritization, governance coherence, and long-term capital commitment.

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Market Shares

The efficiency and competitiveness of Europe's inland waterways remain central to the EU's ambitions for sustainable, low-emission freight transport. Despite their potential, inland waterways continue to account for only a small share of total freight transport, reflecting both structural limitations and underutilization of certain river systems (Eurostat, 2023). Recent data indicate that the bulk of inland waterway freight is concentrated along two major corridors: the Rhine and the Danube. The Rhine corridor alone accounts for nearly 79% of total inland waterway transport performance within the EU, while the Danube contributes approximately 21%. Secondary rivers and smaller waterways collectively constitute only a marginal portion of the total, illustrating the concentration of traffic within a limited number of high-density industrial corridors (CCNR, 2025).[7]

Cargo transported along these rivers is dominated by heavy, low-value, and high-volume goods. On the Rhine and Danube, metal ores, petroleum products, chemicals, agricultural commodities, and construction materials represent the majority of freight tonnage. Containerized freight, while present, constitutes a minority of total volumes, reflecting the inherent comparative advantage of waterways in moving bulk commodities efficiently. This concentration of bulk goods has important implications for both logistics and infrastructure planning. The reliance on a limited number of rivers creates systemic risk, as disruptions—whether caused by droughts, low-water events, floods, or infrastructure failures—can propagate across supply chains. Furthermore, the predominance of bulk cargo limits the potential for diversification into higher-value or time-sensitive goods, which are more efficiently transported by road or rail.

Figure Europe's Inland Waterways

The concentration of bulk freight along Europe's primary rivers also presents both opportunities and challenges in the context of decarbonization. Inland waterways offer substantial reductions in CO_2 emissions per tonne-kilometre compared to road transport, providing a clear environmental advantage. However, the realization of these benefits depends critically on stable and predictable river conditions. Infrastructure upgrades, including the modernization of locks, dredging of channels, installation of adaptive weirs, and deployment of low-water-capable vessels, are therefore essential to maintain operational reliability under variable climatic conditions.

Moreover, policy measures must support modal shift incentives, particularly for bulk commodities, while integrating inland waterways into a broader multimodal logistics framework. Investments should prioritize both resilience and efficiency, encompassing climate-adaptive infrastructure, digital scheduling systems, real-time River Information Services, and fleet modernization with low-emission propulsion technologies. Secondary rivers and underutilized waterways represent additional opportunities to expand inland waterway freight, potentially alleviating congestion along primary corridors and promoting a more balanced, pan-European logistics network.

[7] https://www.ccr-zkr.org/

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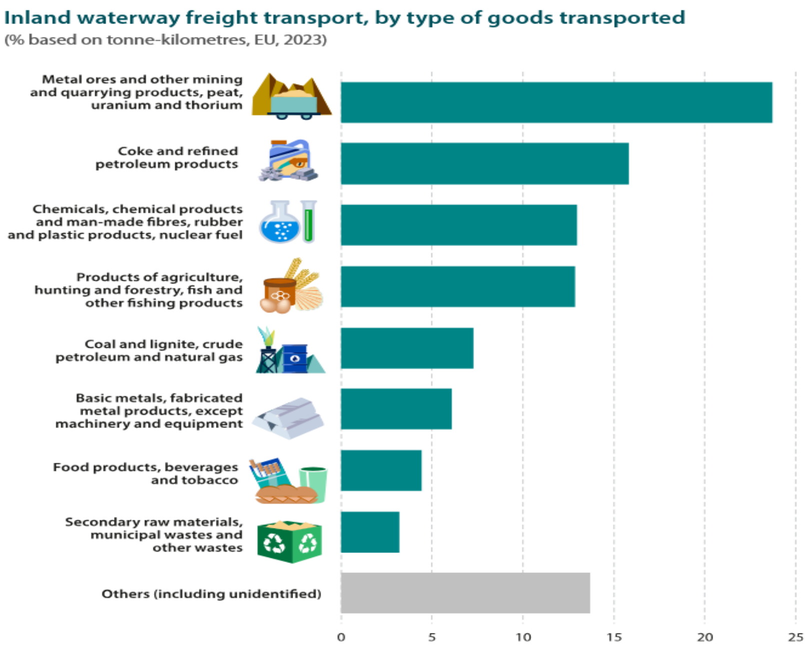
In sum, while the Rhine and Danube dominate European inland waterway traffic, their heavy concentration of bulk commodities underscores the strategic importance of infrastructure resilience, climate adaptation, and governance coordination. Enhancing data transparency and corridor-specific planning will be essential to maximize the environmental and economic benefits of inland waterway transport, reduce systemic risks, and increase the overall share of sustainable freight within the EU's multimodal transport system.

Cargo Type

Inland-waterway vessels in Europe are traditionally powered by diesel engines, which remain dominant due to their reliability and energy density for heavy and long-distance cargo transport. However, the sector is increasingly adopting low- and zero-emission propulsion technologies, including liquefied natural gas (LNG), hydrogen fuel cells, and fully battery-electric systems, particularly for smaller vessels and short-haul operations. Hybrid propulsion solutions, combining conventional engines with electric or alternative-fuel systems, allow vessels to operate efficiently over longer distances while reducing greenhouse-gas and particulate emissions. Hull design optimization, slow-steaming practices, and automated navigation systems further enhance energy efficiency and minimize environmental impacts. Shore-side electrification at inland ports complements these onboard technologies, allowing vessels to operate in zero-emission mode during loading, unloading, or periods of stationary operation.

The majority of inland-waterway cargo consists of bulk and heavy goods, including construction materials such as sand, gravel, and cement; ores and coal, particularly for steel production; agricultural commodities such as grains and fertilizers; chemicals; and containerized goods along major commercial rivers like the Rhine, Danube, and Rhône. Efficient digital logistics and scheduling platforms improve cargo throughput, reduce idle time, and lower fuel consumption, thus reinforcing environmental benefits. The greening of inland navigation aligns with EU climate and energy objectives, including the European Green Deal and the Sustainable and Smart Mobility Strategy, which seek to shift freight transport from road and rail to waterways where feasible. Multimodal integration, combining river transport with rail and short-sea shipping, maximizes both economic efficiency and environmental sustainability. Overall, the transition to clean propulsion technologies, optimized vessel operations, and smarter logistics positions European inland-waterway transport as a critical and climate-aligned component of continental trade, capable of handling large volumes of heavy and bulk cargo with reduced ecological footprint.[8]



Source: Key Figures on European Transport

[8] https://inland-navigation-market.org/

Taken together, these pillars—modernized infrastructure, harmonized regulation, real-time digital integration, green fleet renewal, multimodal connectivity, sustained innovation, and coordinated EU-level governance—form a coherent pathway toward reducing delays, enhancing predictability, lowering emissions, and positioning inland waterways as a genuinely competitive alternative to road freight in the European transport landscape.

Towards Resilient EU Inland Waterways: Hydrographic Constraints, Annual Maintenance Requirements, and Funding Structures

Inland waterways constitute a central component of the European Union's freight transport network, particularly along the Rhine, Danube, Elbe, Seine, Meuse, Oder, Vistula, and Po basins. While these rivers differ in geomorphology, governance arrangements, and commercial intensity, they share an increasing vulnerability to shallowness caused by hydrological variability, sedimentation dynamics, and climatic stressors. As a result, dredging, fairway realignment, and associated hydrographic works have become indispensable for maintaining navigability standards and preserving transport efficiency. This paper synthesises the primary hydrographic constraints observed across major EU waterways, identifies recurrent maintenance works necessary on an annual cycle, and evaluates the prevailing funding architectures and institutional challenges that condition the effectiveness of policymaking in this sector.

Figure Barque in the Rhine channel

Hydrographic surveys across EU rivers show recurring patterns of morphological change driven by sediment loads, lateral erosion, point-bar accretion, and channel migration. These processes create critical low-water sections that significantly restrict vessel draught and freight capacity. Since inland shipping economics depend heavily on available water depth, even small deviations from reference depths (such as −30 to −50 cm relative to fairway standards) result in disproportionate reductions in effective transport capacity.

The Rhine—Europe's most intensively used inland waterway—presents distinct hydrographic hotspots, particularly around the Middle Rhine valley (e.g., Kaub). Seasonal depth reductions have become more frequent, amplifying sediment entrapment in narrow meander belts. The economic consequences of these hydrographic conditions are significant, with low-water events forcing operators to reduce vessel loads, redeploy fleets, and shift cargo onto road and rail networks. From a policy standpoint, the Rhine thus represents the archetype of how hydrographic constraints translate directly into macroeconomic impacts.

The Danube exhibits a different hydrographic profile. While the Upper Danube is relatively stable through lock-regulated sections, the Lower Danube between Romania and Bulgaria remains highly dynamic. Sediment deposition along the Bulgarian–Romanian border routinely produces shallow bars, constraining passage even for standard Class VI vessels. Hydrographic monitoring data consistently indicate rapid changes in bed morphology following seasonal floods, making sustained annual dredging an operational necessity.

The Elbe features a mixed hydrographic regime influenced by environmental policy constraints and sediment supply from mountainous tributaries. Its Middle Elbe reaches show persistent shallow zones where conservation measures limit larger-scale morphological interventions, thereby amplifying the need for precisely targeted dredging and sediment management.

The Seine and Meuse, as predominantly regulated rivers, maintain a high degree of hydrographic stability. Nevertheless, localised shoaling still occurs upstream of Paris and along Meuse canalised sections.

The Oder, Vistula, and Po exhibit far more volatile hydrographic regimes, with frequent seasonal shallowness driven by limited hydrological regulation, high sediment transport, and low summer discharge.

Works Required on an Annual Cycle

Given the hydrographic conditions outlined above, most EU inland waterways require a recurring suite of maintenance works performed either annually or semi-annually:

Routine maintenance dredging remains the primary intervention across almost all EU rivers. Annual dredging volumes vary widely depending on basin hydrology (e.g., 50,000–250,000 m^3 per year in regulated rivers; several million m^3 in dynamic alluvial sections such as the Lower Danube). These works sustain minimum navigation depths and ensure uninterrupted freight movement.

Continuous monitoring is essential for targeting dredging interventions. Modern hydrographic work includes multibeam bathymetry, side-scan sonar mapping, sediment-core sampling, and hydrodynamic modelling. Annual surveys are typically supplemented by high-frequency monitoring during flood and low-water seasons to detect emergent shoals.

Sediment dredged from EU rivers must be processed and disposed of in accordance with environmental regulations, often requiring riverbank deposition, offshore disposal, or reuse for ecological restoration. This constitutes one of the most cost-intensive dimensions of annual maintenance, particularly where contaminants limit disposal options.

In dynamic rivers such as the Danube and Elbe, annual interventions may include bed armouring, groyne adjustment, bank reinforcement, and sediment guiding structures to stabilise channel alignment and reduce future dredging demand.

While not strictly hydrographic, annual maintenance of locks, sluices, weirs, and embankments ensures that hydrological control systems can sustain target depths for navigation.

Cost Structures and Scenarios for Addressing Shallow Sections

Estimating the financial requirements for addressing shallowness relies on standard dredging cost metrics and the volume of material requiring removal. While costs vary by location, sediment type, and disposal method, mechanical and hydraulic dredging within European inland waterways typically range from:

- **€15–20 per m^3** for routine, unconstrained operations
- **€40–60 per m^3** for more complex or deeper dredging with limited disposal options
- **€100–200 per m^3** for environmentally sensitive or technically challenging sectors, including contaminated sediment or difficult access

Using standardised geomorphological assumptions (typical channel widths between 80–150 m and depth deficits of 0.4–0.6 m), annual budgets for major river stretches easily reach tens to hundreds of millions of euros, depending on the sedimentation rate and navigational class to be maintained. For example, maintaining depth increases of 0.5 m over a 50–100 km critical segment may require annual expenditures ranging from €40 million (routine dredging) to several hundred million euros (complex disposal circumstances).

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River Governance

The Rhine and Danube Commissions are foundational institutions for transboundary waterway governance in Europe, providing the legal, technical, and operational frameworks that underpin navigation, trade, and river management. Despite their longstanding success, both commissions face new challenges associated with climate change, fluctuating water levels, aging infrastructure, and the EU's broader sustainability agenda. Strengthening these commissions requires an integrated approach that combines institutional reform, environmental stewardship, digitalization, and cross-border coordination.

First, institutional and governance enhancements are critical. Both commissions could adopt more agile decision-making structures to respond quickly to hydrological extremes, such as droughts or floods, which increasingly disrupt inland navigation. This could include establishing a dedicated climate adaptation and resilience unit within each commission to monitor water levels, coordinate real-time responses, and develop contingency plans. Moreover, harmonizing regulatory standards across member states—including vessel safety, crew qualifications, emissions limits, and reporting procedures—would reduce administrative barriers, facilitate cross-border operations, and enhance compliance with EU sustainability goals. Enhancing stakeholder participation, including port authorities, logistics operators, environmental NGOs, and regional authorities, would improve policy legitimacy and the integration of economic and ecological priorities.

Second, environmental sustainability should become a core mandate. Both commissions could implement binding targets for emissions reductions and energy efficiency for vessels operating on the Rhine and Danube, including incentives for low-emission propulsion technologies such as hybrid, electric, or hydrogen-powered vessels. Investments in green infrastructure, such as nature-based bank stabilization, adaptive weirs, and sediment management, can enhance river ecosystem health while maintaining navigability. Integrating ecosystem services into river management decisions would allow navigation and environmental protection to coexist, reducing conflict between economic and ecological objectives.

Third, the commissions could leverage digitalization and data integration to improve operational efficiency and sustainability. Expanding River Information Services (RIS) into comprehensive, real-time, EU-wide platforms would allow predictive traffic management, dynamic scheduling of locks and ports, and automated alerts for low-water conditions or environmental hazards. Digital twins of river systems could support scenario planning for climate change, optimize cargo flows, and anticipate congestion. Integration with EU-wide logistics platforms would facilitate modal shift to inland waterways, particularly for bulk and intermediate goods, while reducing road congestion and emissions.

Fourth, capacity-building and workforce development are essential for long-term sustainability. Training programs focused on digital competencies, climate-resilient navigation, and sustainable vessel operation would ensure that human resources are aligned with technological and environmental priorities. Mutual recognition of licenses and certification across countries would improve labor mobility and operational flexibility.

Finally, financing mechanisms must be strengthened. Both commissions could advocate for EU-level investment instruments, including the Connecting Europe Facility (CEF) and green transition funds, to support climate-adaptive infrastructure, fleet modernization, and digital systems. Performance-based funding could be tied to measurable outcomes in efficiency, emissions reduction, and navigational reliability, incentivizing member states and stakeholders to prioritize long-term sustainability.

In sum, strengthening the Rhine and Danube Commissions requires an integrated approach that combines governance reform, environmental stewardship, digital innovation, workforce development, and sustainable financing. By embedding climate resilience, operational efficiency, and ecological protection into their core mandates, both commissions can ensure that Europe's primary inland waterways remain reliable, competitive, and environmentally sustainable in the Anthropocene.

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Stakeholders

Inland-waterway transport (IWT) occupies a strategically significant position in the European Union's (EU) vision for sustainable freight and multimodal logistics. The European Commission (EC), under the broader frameworks of the European Green Deal and the Sustainable and Smart Mobility Strategy, emphasizes that rivers and canals provide energy-efficient, low-emission, and largely congestion-free alternatives to traditional road and rail freight. Policy initiatives such as the NAIADES III action plan, adopted in 2021, and the modernization of River Information Services (RIS) illustrate the EU's commitment to enhancing the efficiency, digitalization, and environmental performance of inland navigation. These measures aim to integrate inland waterways more fully into European supply chains, promote zero-emission vessel technologies, and strengthen the role of inland ports as energy and logistics hubs. The European Parliament (EP) has further highlighted the importance of improving working conditions for skippers and crews, decarbonizing fleets, and stimulating both freight and passenger transport on rivers, reflecting a comprehensive approach to supporting inland waterway development as a socially and economically sustainable transport mode.

Despite these institutional priorities, scientific and environmental organisations caution that the expansion and intensification of river-based transport carries significant ecological risks. Research conducted by institutions such as the Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB) documents that shipping activity, together with the construction of locks, dredging, bank reinforcement, and port development, has already contributed to substantial biodiversity loss across European rivers. Altered flow regimes, sediment redistribution, and increased wave activity threaten sensitive species, disrupt reproductive cycles of fish and invertebrates, and facilitate the proliferation of invasive organisms. These organisations stress that rivers are complex, multifunctional ecosystems that deliver critical services beyond transport, including flood regulation, water quality maintenance, nutrient cycling, and cultural and recreational value. As a result, they advocate for rigorous environmental impact assessments, habitat protection, restoration programs, and, where necessary, restrictions on navigation or infrastructure expansion in ecologically sensitive areas.

Figure The Loire Valley incarnates the dream of another Rennaissance

The development of inland-waterway trade in Europe is shaped by a network of key stakeholders, including the European Barge Union (EBU), the European Skippers Organisation (ESO), the European Inland Waterway Transport Platform (IWT Platform), the European Federation of Inland Ports (EFIP), and Inland Navigation Europe (INE). The EBU, representing the majority of barge owners and operators across Europe, emphasizes that inland waterways remain significantly underutilized and could absorb much more cargo, alleviating road and rail congestion, provided infrastructure is modernized and made climate-resilient. The ESO advocates for independent skippers and small-scale operators, ensuring that their interests in fleet renewal, safety, technical standards, environmental compliance, and working conditions are represented in European policymaking.

Through the joint IWT Platform, EBU and ESO coordinate efforts to professionalize inland shipping, increase its competitiveness, and integrate it more fully into Europe's broader logistics network. EFIP and INE focus on the port and infrastructure dimension, stressing that modernization, digitalization, and reliable energy supply are essential for efficient and sustainable inland transport. Collectively, these stakeholders share a strategic vision in which inland waterways increase their share of freight transport, support Europe's green logistics and decarbonization agenda, and enhance the resilience of supply chains. Achieving this potential requires coordinated investment, harmonized cross-border governance, and regulatory frameworks that align operational, environmental, and economic objectives, positioning European inland waterways as a critical component of future sustainable trade.

The contrasting perspectives of EU institutions and environmental actors reveal a fundamental tension in inland-waterway governance: the EU seeks to expand the modal share of IWT as part of a broader decarbonization and mobility agenda, while environmental stakeholders demand strict safeguards to preserve riverine ecological integrity. Reconciling these objectives requires integrated governance approaches that simultaneously address economic efficiency, energy transition goals, and biodiversity conservation. This entails investment in green shipping technologies, careful planning of port and navigation infrastructure, cross-border coordination along major waterways such as the Rhine, Danube, and Rhône, and alignment with EU environmental legislation, including the Water Framework Directive and Natura 2000 directives. Moreover, stakeholders recognize that maximizing the potential of inland waterways necessitates adaptive management strategies that account for climate-induced variations in water levels, seasonal hydrological fluctuations, and long-term ecosystem resilience.

Ultimately, the development of European river transport exemplifies the broader challenge of balancing economic modernization with environmental sustainability. When properly managed, IWT offers the EU an opportunity to reduce carbon emissions, relieve terrestrial transport congestion, and provide a reliable backbone for the movement of bulk goods, construction materials, and industrial inputs. Simultaneously, failure to integrate ecological considerations risks long-term degradation of riverine habitats, loss of biodiversity, and diminished ecosystem services, undermining both environmental objectives and social acceptance of waterway expansion. Consequently, inland waterways must be conceptualized not merely as transport corridors but as multifunctional spaces where economic, social, and ecological imperatives intersect, requiring collaborative governance among EU institutions, national authorities, shipping associations, scientific bodies, and environmental organisations. The successful development of inland-waterway transport in Europe will therefore depend on the ability of these diverse actors to negotiate trade-offs, implement adaptive management practices, and embed sustainability at the core of planning, policy, and operational decisions.

No single Authority on Dredging

The EU lacks a single authority responsible for inland waterway dredging. Instead, responsibilities are distributed among:

- **National waterway authorities** (e.g., Germany's WSV, France's VNF, Poland's Wody Polskie)
- **International river commissions** (CCNR for the Rhine, the Danube Commission, bilateral agreements in the Meuse and Oder basins)
- **Port authorities** (responsible for port-basin dredging)
- **EU Cohesion and CEF funding instruments** (supportive but not operators)

This fragmentation often slows interventions, particularly along cross-border stretches where hydrological changes occur faster than intergovernmental coordination.

National governments generally bear primary responsibility for maintenance dredging and fairway management within their territories. Budget reliability varies significantly across states, with some relying on ad hoc annual appropriations and others employing multi-year rolling maintenance programs.

The EU primarily supports inland waterway maintenance through:

- **Connecting Europe Facility (CEF) – Transport**
- **Cohesion Fund (for eligible Member States)**

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- **Interreg cross-border programmes**
- **Recovery and Resilience Facility (in select cases)**

These instruments typically co-finance major infrastructural upgrades or large-scale fairway modernisation projects; however, routine maintenance dredging rarely receives direct EU funding, despite its importance for ensuring the long-term viability of these assets.

Port authorities fund dredging within harbour zones, often financing works from port dues or public–private partnerships. In some basins, user charges or canal tolls contribute to maintenance budgets, though political sensitivity limits widespread adoption.

Effective policy for inland waterway management hinges upon aligning hydrographic realities with institutional capabilities. Three interlocking constraints shape policymaking effectiveness: (1) the inherently dynamic nature of river morphology; (2) fragmented governance structures that slow response times; and (3) inconsistent funding streams that challenge long-term planning.

To address these issues, academic and policy literature increasingly recommends that the EU adopt:

1. **Basin-wide, risk-based maintenance planning**, centred on high-resolution hydrographic monitoring.
2. **Dedicated cross-border contingency funds** for emergency dredging to prevent major disruptions on international corridors.
3. **Integrated sediment management frameworks**, reducing long-term reliance on repetitive dredging.
4. **Harmonised permitting and sediment disposal standards** across Member States.
5. **Performance benchmarks**, such as maximum allowable days per year of low-water-induced navigability restrictions.

Such measures would materially improve the resilience and efficiency of inland waterway transport while reducing the economic and environmental costs associated with repetitive emergency interventions.

Hydrographic variability and sedimentation dynamics constitute structural challenges to the EU’s inland waterway network. Ensuring stable navigational conditions requires a combination of annual dredging, advanced hydrographic monitoring, targeted morphological interventions, and reliable funding mechanisms. Current governance structures remain fragmented, but the increasing economic costs of low-water disruptions underscore the need for more integrated, basin-scale approaches. A comprehensive strategy combining stable maintenance funding, improved cross-border coordination, and long-term morphological management would significantly enhance the efficiency, resilience, and competitiveness of EU inland waterways.

Values are expressed in **rounded indicative ranges**, suitable for academic or policy analysis; they avoid false precision where official hydrographic datasets vary by year.

Table Hydrographics Table: Major EU Rivers

River	Length (km)	Mean Discharge (m^3/s)	Typical Navigable Depth	Key Shallow/Recurrent Critical Sections	Sedimentation Dynamics	Annual Works Required
Rhine	~1,230	2,900	2.5–3.5 m (fairway targets)	Kaub bottleneck; Middle Rhine gorge	Moderate sediment transport; bar formation	Targeted dredging, groyne maintenance, continuous

					during low flows	multibeam surveys
Danube	2,860	6,500	2.5–2.7 m (varies by sector)	Romanian–Bulgarian border; German–Austrian free-flowing sections	High sediment load; rapid post-flood bar formation	Large-scale annual dredging, fairway realignment, joint BG–RO works
Elbe	1,094	860	1.6–2.5 m (variable)	Middle Elbe, Magdeburg–Dresden	High variability; constrained by conservation zones	Seasonal dredging; bank stabilization; restricted morphological works
Seine	776	560	3.5–5.0 m (regulated)	Rouen–Paris upper sections	Low sedimentation due to regulation	Lock/sluice maintenance; periodic dredging
Meuse / Maas	925	925	3–4 m (canalised)	Maastricht–Liège	Moderate; silt accumulation at lock approaches	Routine dredging, lock maintenance
Oder	854	567	1.8–2.5 m (variable)	Polish–German border sections	High sediment mobility; frequent shoals	Cross-border dredging; river training structures
Vistula	1,047	1,080	Mostly non-navigable; 1.0–1.4 m in sections	Middle Vistula	Very high sedimentation; natural meandering system	Limited dredging; ecological constraints
Po	652	1,460	1.5–3.0 m (high variability)	Ferrara–Cremona sector	High sediment load from Alpine tributaries	Annual dredging; levee reinforcement
Ebro	930	425	Partially navigable; 1.0–1.5 m	Middle Ebro near Zaragoza	High silt content; delta infilling	Targeted dredging in port/estuary zones

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Mälaren (Mälar-system	Lake–waterway system ~120 km basin extent; linked via Södertälje Canal & Hammarbyleden	Not a river; lake level controlled; outflow via Norrström/ Söderström	6–7 m in key shipping lanes after upgrades	Low sediment load; glacial bedrock reduces shoaling	Channel marking, periodic dredging, lock maintenance	Swedish Transport Agency (Transportstyrelsen), Ports of Stockholm

Key Takeaways

Across Europe, inland waterways present a remarkable tapestry of hydrological and morphological diversity. From the regulated lakes and canals of Mälaren and the Seine to the dynamic, sediment-rich flows of the Danube, Vistula, and Po, it becomes clear that there is no single model of navigability that can be imposed uniformly. Shallow stretches appear again and again, a constant reminder that rivers, like living veins of the continent, resist complete control. Sedimentation drives much of the operational challenge, shaping bottlenecks, forming bars, and demanding continuous intervention—dredging, groyne maintenance, realignment—so that commerce may flow uninterrupted.

If rivers are the arteries of European connectivity, who then bears the responsibility for their care? Cross-border coordination emerges as not just desirable, but indispensable. Where commissions, joint works, and shared monitoring succeed, fairways remain open; where they falter, obstacles persist, and economic potential is diminished. Yet the pursuit of navigability exists in tension with environmental stewardship. Conservation zones, Natura 2000 designations, and ecological objectives limit structural modifications, reminding us that every engineering triumph carries an ethical cost.

Highly regulated waterways demonstrate what can be achieved when control, consistency, and maintenance converge, but they also reveal a paradox: stability comes at the expense of natural dynamism. Rivers teach us patience, adaptation, and the art of balancing human ambition with natural reality. European policy must therefore embrace flexibility, tailoring standards to the particularities of each waterway while fostering resilience against climate variability and hydrological extremes. Operational reliability must take precedence over rigid depth targets, and nature-based solutions should complement engineering where possible.

A final, often underestimated, dimension concerns **who is actually responsible for dredging**, and how this function sits at the intersection of European ambition and national sovereignty.

Dredging is formally a technical activity, but institutionally it is a *governance hinge*. Responsibility is typically fragmented: operational control rests with port authorities, river basin agencies, or national waterway administrations; environmental permitting is shared with national ministries and regional authorities; while funding, standards, and strategic orientation are increasingly shaped at EU level. This fragmentation explains why dredging—despite being essential to inland waterways, ports, and flood safety—rarely features as a strategic issue, even though it directly conditions connectivity.

At EU level, the Union does not dredge, but it **frames the conditions under which dredging becomes possible or impossible**. Environmental directives (notably water, habitat, and sediment rules), TEN-T corridor priorities, and funding instruments such as CEF, Cohesion Policy, and the EIB shape incentives, timelines, and design choices. The EU's role is therefore catalytic and constraining at once: it can unlock cross-border projects, but it can also unintentionally desynchronise them if national permitting regimes and interpretations diverge.

National authorities remain indispensable. They carry legal responsibility for waterways, environmental compliance, safety, and long-term maintenance. Yet purely national approaches are increasingly misaligned with the physical reality of rivers and maritime basins. Sediment flows, navigability, flood risk, and ecological impacts do not stop at borders. When dredging is planned nationally but experienced transnationally, inefficiencies and political friction are inevitable.

This is where **cross-border cooperation becomes strategic rather than optional**. Effective dredging governance requires joint river basin planning, shared sediment management strategies, synchronised permitting calendars, and mechanisms for cost- and benefit-sharing between upstream and downstream actors. Existing river commissions and corridor platforms provide a base, but they are often underpowered relative to the scale of the task.

In a continental unification perspective, dredging should be treated as **shared infrastructure stewardship**. Not a local technical afterthought, but a cooperative public function that sustains inland waterways, ports, ecological balance, and climate resilience across borders. Elevating it to this status would align EU frameworks, national authorities, and local operators around a common understanding: connectivity is not built once, it is continuously maintained—together.

In the end, inland waterways are more than channels for transport; they are living corridors of commerce, culture, and ecology. They demand foresight, collaboration, and unwavering commitment. They ask us to ask ourselves: how can a continent sustain its arteries, honor its rivers, and ensure that the lifeblood of European mobility continues to flow? The answer lies in continuous engagement, adaptive governance, and a recognition that navigability is a public good, a shared responsibility, and a testament to Europe’s ability to harmonize ambition with strong leadership and good governance.

Environmental Impact Assesments On Europe’s Rivers

Environmental Impact Assessments (EIA) are structured processes used to predict and evaluate the environmental effects of proposed projects before decisions are made. They ensure that environmental considerations are integrated into planning and decision-making, aiming to minimize negative environmental impacts, promote sustainable development, and comply with environmental laws. EIAs are preventive, identifying impacts before they occur, inclusive, involving stakeholders, experts, and the public, and often legally required for major projects such as dams, industrial plants, or river modifications.

A standard EIA report typically includes a project description, detailing location, size, and technical specifications, along with the purpose and alternative scenarios, including the “no project” option. It also presents baseline environmental conditions covering physical aspects such as water quality, soil, air, and climate, biological aspects like biodiversity, habitats, and species, as well as socioeconomic aspects including human population, land use, and cultural heritage. The report identifies and evaluates impacts, considering short-term and long-term, direct, indirect, and cumulative effects, both positive and negative. Mitigation measures are proposed to avoid, minimize, or offset impacts, along with alternative solutions. A monitoring plan outlines how environmental parameters will be tracked after project implementation and which parties will be responsible for compliance. Public and stakeholder consultation ensures community input, expert review, and government oversight.

The EIA procedure generally follows several steps. Screening determines whether a project requires a full EIA, with large-scale river projects almost always qualifying. Scoping identifies key environmental issues and the boundaries of study, establishing which environmental studies need to be conducted. The impact assessment and mitigation planning stage involves specialists modeling potential impacts and proposing mitigation and alternatives. A detailed EIA report or environmental statement is then prepared and submitted to authorities. Review by government agencies and experts, often including public consultations, assesses the report’s thoroughness. Decision-making results in project approval, conditional approval, or rejection based on the findings. Monitoring and compliance involve continuous assessment during project operation to ensure that mitigation measures are implemented effectively.

Participants in an EIA include the project proponent, who proposes the project; environmental consultants, who conduct studies, modeling, and reporting; regulatory authorities, who approve or reject the project; public stakeholders, such as residents, NGOs, and interest groups; scientific experts, including biologists, hydrologists,

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and socioeconomists; and agencies such as the European Environment Agency (EEA), which provide guidance, data, and oversight.

Simulating EIAs on Europe's largest inland rivers, such as the Danube, Rhine, and Volga, provides insight into potential outcomes. Proposed projects might include hydropower expansion, river dredging for navigation, industrial ports, and flood control systems. Screening identifies these projects as requiring full EIAs due to their scale and transboundary impacts. Scoping highlights key environmental issues, including water quality degradation from navigation and industrial pollution, habitat loss affecting fish spawning grounds and wetlands, flood risk alterations from dams or levees, biodiversity impacts on endangered species such as sturgeon, and transboundary socio-economic effects on multiple countries. During assessment, hydrological models predict changes in river flow and sediment transport, ecological models evaluate fish and aquatic plant populations, and socio-economic models assess effects on fisheries, tourism, and riverine communities. Mitigation measures may include fish ladders and bypasses around dams, water treatment for industrial discharges, wetland restoration for flood control, and riverbank reforestation to reduce erosion. Public consultation involves communities across Germany, Austria, Hungary, Russia, and other affected countries, with NGOs emphasizing endangered species protection. Review and decision-making by national authorities typically approve projects conditionally, requiring mitigation measures and cross-border coordination for sustainable river management. Monitoring ensures continuous water quality tracking and biodiversity surveys, with reporting to the EEA.

Figure Cerb in Danube Delta looking out on us

The Danube-Black Sea Area is designated as a Lighthouse region under the Mission Resotre Our Ocean and Waters. That means it receives targeted RDI funding to restore freshwater and transitional water ecosystems – including the Danube Delta. Projects focus on restoring river connectivity, improving water quality and boosting biodiversity. Danube4All, a large Horizon Europe consortium working on ecosystem restoration actiona planning across the Danube Delta. Danubelifelines funded under EU programmes safeguards migratory fish habitats in the Danube system. Interreg the Danube region program includes transnational cooperation towards environmental restoration and biodiversity measures available through EU co-financing.

The Natura2000 network co-finances protection of habitats like wetland and delta ecocsystems. EU funding guidance 2021-2027 supports Member States in managing and restoring these areas,total Natura 2000 financing needs over the period are estimated in the billions across the EU.

The EU's funded projects and strategies aim to deliver mmeasurable environmental and socio-economic benefits in the Danube Delta area. The point is to restore river and ecosystem connectivity through reduction of barriers hence enhance habitat connectivity for fish like sturgeon and migratory species. Improved water quality and resilience by reducing polliution and better watershed management. Biodiversity gains by re-establishing natural processes eading to anincrease in native populations of fish and other aquatic & delta species. Commnity involvement & research: Projects like Danube4all combine science, local engagement and resotiration planning.

The socio-economic & policy results can be listed in terms of capacity building for local govenance and cross-border cooperation, enhanced planning for climate risk management against flooding/drought resilience and integration into EU strategic framework, including Water Framework Directive objectives and biodiversity strategies.

In turn, this has led to the European Parliament to adopt resolutions to recognize the Danube Delta as an area with severe natural and demographic constraints, calling for strengthened and simplified EU support mechanisms. The delta habitats are protected under NAtura2000. Its protection align with the EU Biodiversity Strategy for 2030, the water framework directive and the Nature Restoration Law driving funding priorities and objectives for river, wetland and coastal ecosystem health. Planned ecological progress are therefore set in motion.

The EU, Ukraine and Moldova are jointly implementing the EU-Ukraine Solidarity lanes intiative, which includes the Danube corridor – a crucial route running along the river and facilitateting trade and logistics between Ukraine, MD and EU. This cooperation focuses on improving transport routes via rail, road and inland waterways through the Danube region, infrastructure upgrades, and coordination efforts to remove administrative and border bottlenecks, improve traffic management and enhance transport efficiency. There are also joint border controls to speed up border infrastructure upgrades and help transit efficiency in support of trade flows, logistics and integration with EU transport standards and procedures. There is a macro-regional strategy for the Danube region, Interreg has also a Danube region program supporting innovation, climate action, healthcare and education across borders.

The EU strategy for the Danube region (EUSDR) is a long-term cooperation framework that includes EU and non-EU riparians MD & US working together across economic, envrionmentl and transport priorities in the Danube basin. Ukraine participates actively and has even cochaired priority areas within the strategy, strengthening its involvement in regional planning and implementation of key projects. The strategy helps align projects, policies and cross-border actions, including on environmental protection, transport connectivity and economic development.

There are also protection programs in support of UA-MD for the sustainable use of Danube and Prut waters, which are linked to broader EU water policy goals like the Water Framework directive. IN UNECE cross-border environmental risks and planning take place between MD-Ro-UA setting the groundwork for coordinated action.

In summary, this EU-supported cooperation strengthens economic integration, improves connectivity and supports sustainable development along the Danube, benefiting Ukraine,Moldova and EU partners – especially crucial during regional chellenges and Eu integration processes.

The European Environment Agency would likely achieve several outcomes from such EIAs, including improved environmental data on Europe’s major rivers, identification of critical environmental risks and hotspots requiring conservation, implementation of mitigation measures to reduce habitat loss, water pollution, and flood risks, and cross-border coordination for shared rivers such as the Danube. Additionally, the EEA would generate policy recommendations for EU river management, hydropower, and industrial regulation. The long-term impact would be more sustainable river management, reduced ecological damage, better compliance with the EU Water Framework Directive, and improved public engagement.

How to rank Rivers

The ranking of Europe’s major rivers emerges not merely from raw measurements of length or discharge, but from a composite appreciation of navigability, freight intensity, hydrological predictability, and infrastructural integration. In this evaluative landscape, the Rhine inevitably rises to the top, its consistent depths and immense port system forming the steady bass-line of the continent’s inland transport fugue. The Danube, broad and ambitious, follows as a counter-theme: powerful yet interrupted, its recurrent shallow reaches disrupting the otherwise impressive sweep of transcontinental navigation. The Seine and Meuse sustain a quieter but confident motif, their canalised stretches offering a controlled and intelligible rhythm. The Elbe introduces a more fragile variation, its environmental limitations and erratic hydrological shifts unsettling the expected cadence of reliable flow. The Oder and Po, meanwhile, occupy a middle register—neither dominant nor recessive—reflecting waterways whose navigational melodies are frequently modulated by seasonal uncertainty. At the quieter end of the spectrum, the Ebro and Vistula enter only tentatively, their seasonal navigability shaping an incomplete and often interrupted theme. Across this polyphonic ranking, one central refrain reappears: where depth is dependable, efficiency follows. Stable rivers support stable logistics, and stable logistics sustain stable economies. Thus the ranking does not simply classify rivers; it reveals where strategic tuning can harmonise the entire system.

The funding needs of the EU inland waterway network form another contrapuntal movement in this broader hydrographic composition. Sedimentation rates, channel dynamics, and regulatory frameworks introduce recurring motifs that return with variations from basin to basin. The Danube and Po carry the heaviest burden, their restless beds demanding frequent and costly interventions. The Rhine, with its long history of engineering refinements, delivers a more measured and economical theme, its stability reducing the pressure on annual budgets. Yet the Elbe, Oder, and Vistula reintroduce tension by oscillating unpredictably between manageable conditions and sudden sedimentation crises. The Seine and Marne, shaped by hydraulic regulation, present a steady, almost metronomic pattern of maintenance. Still, the financial score is not evenly distributed: fragmented national budgets and inconsistent political will often create discord, delaying dredging and amplifying the economic consequences of low-water episodes. Cross-border stretches become the unresolved chords of this system, where cost-sharing slows action and uncertainty undermines navigational reliability. The recurring lesson is unmistakable: only a multi-year, basin-level funding approach can transform disjointed responses into a coherent, anticipatory strategy. Sustainable financing, like a well-maintained orchestration, is indispensable for keeping the waterway system in tune.

Hydrographic classification adds a final, reflective variation to this interconnected fugue of European rivers. Regulated rivers—such as the Rhine, Seine, and Marne—offer the steady, disciplined lines of an engineered composition in which lock systems, weirs, and structured banks ensure predictability. Semi-regulated rivers such as the Danube, Elbe, and Po introduce a more improvisational quality, where human intervention coexists with vigorous natural reshaping. The free-flowing Ebro and Vistula express a more untamed register, where sediment, seasonality, and ecological constraints resist the rectilinear ambitions of transport policy. This tripartite classification reveals a deep structural truth: hydrographic identity is inseparable from maintenance demand. Regulated rivers allow for planned and periodic interventions, while semi-regulated systems require constant monitoring and rapid adjustments. Free-flowing rivers resist standardisation altogether, rendering large-scale navigability improvements both costly and politically delicate. The policy implications echo across the system like a recurring melodic strain: management must be differentiated, governance must be basin-level, and response times must reflect the tempo of morphological change rather than the pace of administrative cycles. In this sense, hydrographic classification becomes more than a technical categorisation; it is a guide to strategic priority, institutional coordination, and the future coherence of Europe’s inland waterway symphony.

Summary

To keep the inland rivers of Europe humming, policymakers and engineers must treat these waterways not as static channels but as living, shifting systems whose performance depends on continuous care. The fundamental requirement is a commitment to reliable depths—achieved through routine dredging, fairway stabilisation, precise hydrographic surveying, and cross-border coordination that matches the tempo of natural morphological change. River basins must be governed as coherent hydrological units rather than fragmented administrative zones, with stable multi-year funding that avoids the stop-start cycle that so often leaves infrastructure lagging behind the rivers’ own restless rhythms. Digital twins, predictive sediment models, and AI-driven hydrographic monitoring can transform these interventions from reactive measures into anticipatory ones, turning maintenance from an emergency art into a disciplined science of foresight.

Why this matters is evident in the economic geography of Europe: inland waterways are the quiet arteries that feed its industrial basins, port clusters, agrarian hinterlands, and energy corridors. A humming Rhine, a steady Danube, a dependable Elbe or Po—these are not conveniences but structural advantages, enabling low-carbon freight flows that relieve congested rails and highways while sustaining Europe’s manufacturing competitiveness. When rivers falter, the entire logistics system modulates downward: capacity shrinks, supply chains tighten, prices climb, and industries reliant on bulk cargo—steel, chemicals, energy inputs—face immediate constraints. The drought years of recent decades have shown how swiftly a single low-water stretch can ripple across European commerce, turning geography into a bottleneck rather than a blessing.

The costs of neglect are therefore not confined to the riverbanks. Non-European competitors—whether the Mississippi system in the United States, the Yangtze and Pearl River deltas in China, or the Volga-Don corridor in Eurasia—continue to invest heavily in deeper channels, automated locks, large-vessel corridors, and AI-optimised port logistics. While Europe's river system remains extensive and historically integrated, the competitive gap widens if maintenance is deferred, coordination is slow, or funding remains fragmented. The global economy rewards resilience and penalises fragility, and in this calculus, a river that silts up is more than a physical obstacle—it is a strategic liability.

Sustained performance therefore requires a long horizon: basin-scale investment plans, harmonised permitting regimes, ecological integration that respects environmental constraints while protecting navigability, and governance structures that act at the same speed rivers change. Digitalisation becomes the great equaliser in this pursuit. AI can map riverbeds in real time, predict shoaling weeks ahead, optimise dredger deployment, automate lock scheduling, and integrate vessel draught data with hydrological forecasts to keep cargo flowing. A digitally augmented river network becomes a river system capable of self-diagnosis and near-continuous stability.

In a changing world, can a river be both fragile and formidable, both engineered and natural? Europe's waterways teach us: the quietest channels often carry the heaviest burdens, the shallowest stretches can sustain the richest flows. Resilience is cultivated in tension, stability thrives amidst flux, and efficiency is forged in the fires of constraint. Policy and engineering, technology and nature, human ambition and ecological reality—each element mirrors the other, entwined pf cause and consequence. The hum of the rivers, once secured, becomes the deeper hum of a continent that still knows how to move, how to adapt, and how to stay connected—because to preserve the future, we must navigate the contradictions of the present.

Thus internal waterways become the fountain of possibilities and the origins of life provided strong leadership and good governance goes hand in hand with scaling up on ship propulsion, incentives are provided to diversify goods traded and the environmental impact assesments are sized on to introduce stakeholder based approaches and good environmental status in the inland waterways of Europe.,-

Public Policy Spending Priorities

As we have examined in the Naiades, propulsion and the inland ports are rather central to the policy review.

The diagram "Greening Inland Waterway Transport in Europe" organizes inland navigation into three interconnected categories: **Propulsion**, **Greening Measures**, and **Traded Goods**.

Propulsion shows the core energy systems powering vessels: traditional diesel engines dominate, but the sector is transitioning toward lower-emission alternatives including LNG (liquefied natural gas), hydrogen fuel cells, battery-electric systems, and hybrid combinations. Each propulsion type has trade-offs in cost, range, infrastructure requirements, and emissions reduction potential.

Greening Measures include operational and technological interventions that complement cleaner propulsion. Hybrid propulsion combines conventional and alternative fuels for flexibility, while optimized hull designs and slow-steaming reduce energy consumption. Shore-side electrification allows vessels to use electricity while docked, minimizing emissions at ports. Automated navigation and digital logistics enhance efficiency, improve scheduling, and reduce fuel waste.

Figure Greening Inland Waterway in the EU

Traded Goods indicates the types of cargo that dominate inland waterways: bulk construction materials (sand, gravel, cement), ores and coal, grains, chemicals, and containerized goods. The cargo profile highlights that inland waterways are particularly suited for heavy, bulky, and steady-flow shipments that are less time-sensitive but energy-intensive if transported by road or rail.

Market Actors

The zero-emissions propulsion sector is rapidly growing, driven by battery-electric, hydrogen fuel-cell, ammonia, methanol, and hybrid systems, with major European and global technology providers leading innovation. Key players include ABB, Wärtsilä[9], Siemens[10], Ballard Power [11]Systems, Rolls-Royce Marine[12], and MAN Energy Solutions[13], offering propulsion systems, integration, and energy management for ships. Asia dominates shipbuilding capacity, making South Korean yards like Hyundai Heavy Industries, Samsung Heavy Industries, and Daewoo, as well as Chinese conglomerates like CSSC, natural partners for EU actors. These yards are increasingly developing or adapting vessels for alternative fuels, including LNG dual-fuel, hydrogen, and ammonia-ready ships. Cooperation between European propulsion firms and Asian shipyards combines EU technological expertise with Asian scale, cost-efficiency, and global production capabilities. Challenges remain in fuel supply, bunkering infrastructure, long-haul viability, and regulatory alignment, making interregional coordination essential. Strategic EU engagement can leverage demand-pull policies, incentivizing Asian yards to produce zero-emission vessels with European technology. Overall, EU–Asia partnerships offer a practical path to scale green shipping, enhance industrial competitiveness, and accelerate the global transition to sustainable maritime transport.

Given limited public resources, investment decisions should prioritize interventions with the highest combined environmental, economic, and system-wide impact. Key considerations include:

1. **Propulsion Transition**: Funding should target the adoption of zero- and low-emission technologies, particularly hydrogen, battery-electric systems, and hybrid solutions. Investments in propulsion modernization directly reduce greenhouse-gas and particulate emissions and help meet EU climate targets.

2. **Shore-Side Infrastructure**: Electrification of ports and river terminals enables vessels to operate in zero-emission mode while loading/unloading, reducing local air pollution. Funding here benefits multiple vessels simultaneously and can accelerate the adoption of green propulsion.

[9] https://www.wartsila.com/
[10] https://www.siemens-energy.com/global/en/home/products-services/solutions-industry/marine.html
[11] https://www.ballard.com/
[12] https://www.rolls-royce.com/products-and-services/power-systems/marine.aspx
[13] https://www.everllence.com/

3. **Operational Efficiency Measures**: Support for digital logistics, automated navigation, and optimized hull designs offers cost-effective emissions reductions without large-scale infrastructure expenditure. These measures also improve reliability and reduce congestion, which has knock-on benefits for the wider transport network.

4. **Critical Waterway Maintenance**: Investment in dredging, lock modernization, and navigable depth maintenance ensures that vessels operate efficiently and that inland waterways remain viable alternatives to road and rail freight. These measures maximize cargo throughput and reduce per-unit emissions.

5. **Cargo-Specific Strategies**: Heavy bulk cargo, such as construction materials, ores, and coal, yields the greatest emissions reduction per ton if shifted from road to water. Funding incentives could target operators handling these cargoes to increase modal shift and environmental impact.

6. **Integrated Multimodal Systems**: Public investment should prioritize projects that link waterways to rail, ports, and logistics hubs, as these provide economies of scale and amplify the environmental benefits of river transport.

7. **Stakeholder Platform**: Alternative Propulsion Stakeholder Platform to ensure strategic approach and that the technological possibilities and perspectives are understood by decision-makers and the civil-military intersection are understood in the process of scaling-up.

8. **Engagement of River Commissions:** This will become necessary under a holistic approach and should help set an example for the users of the rivers and address ongoing concerns about the navigability of Europe's rivers and the need for redundancy in transport planning.

Overall Guidance: Scarce public funding should focus on areas where environmental benefits, modal shift potential, and cargo volumes converge — namely, clean propulsion deployment, shore-side electrification, operational digitalization, infrastructure reliability, and multimodal integration. These priorities ensure that investments achieve measurable greenhouse-gas reductions, enhance inland-waterway competitiveness, and optimize the use of public resources while supporting Europe's decarbonization and logistics efficiency objectives.

Incentives

The EU could influence what is traded on inland waterways, though it cannot directly dictate private commercial decisions. The levers are mainly regulatory, financial, and strategic. One approach would be through regulatory measures, such as enforcing environmental standards that favor low-emission goods or sustainable supply chains. Stricter CO_2 or sulfur limits on vessels could incentivize the transport of goods that justify cleaner shipping. Sectoral restrictions or incentives could also play a role, for instance by encouraging the transport of agricultural products, renewable energy components, or materials for the circular economy through easier licensing or tax breaks.

Economic instruments could further shape trade. Subsidies for specific cargo types, similar to those provided for rail or road transport, could support shipping of green goods or essential industrial inputs. Adjusting port fees, canal tolls, or lock fees could make river transport more attractive for strategic cargo. Infrastructure alignment could complement these measures. Developing or modernizing terminals to handle specific goods efficiently, such as bio-based products, containers, or critical raw materials, makes river transport more competitive. Integration with rail and road networks ensures smooth intermodal transfers, reinforcing the preference for certain trade flows.

Strategic procurement by the EU could also influence trade patterns. EU-funded projects or programs could source materials or components in ways that favor inland water transport, for example, bulk procurement for renewable energy or construction projects shipped preferentially by rivers. Natural allies in this effort would include environmental and climate-oriented organizations such as the European Environmental Bureau, WWF Europe, and Transport & Environment, which would support modal shifts for green goods or low-carbon transport. Industry and trade associations, including the European Barge Union and inland waterway companies, would back initiatives that expand cargo volume, particularly if accompanied by incentives. Sector-specific trade associations in agriculture, chemicals, renewable energy, or steel that rely on bulk transport would also be aligned with such policies.

Key EU institutions would be involved, such as DG MOVE for transport policy, DG ENV for environmental incentives, and the European Investment Bank for financing river infrastructure in line with strategic goals. Member states with dense inland waterway networks, including the Netherlands, Germany, France, Belgium, and Romania, would be natural supporters of policies enhancing river transport. Challenges remain, particularly market resistance if river transport is slower or less flexible than road or rail, the need for cross-border coordination in rivers like the Danube and Rhine, and trade-offs with private interests, as some cargo types are less profitable to transport by river even if environmentally preferable.

By 2035, the EU could pursue a strategic reshaping of inland river trade that aligns with environmental, economic, and industrial priorities. The approach would combine regulatory incentives, infrastructure development, financial support, and strategic procurement to influence what goods are transported by waterways. Stricter environmental standards for vessels, including CO_2, sulfur, and particulate limits, would encourage the shipment of cargoes that justify cleaner transport, such as renewable energy components, recycled materials, and other green products. Incentive schemes, including targeted subsidies or reduced canal and port fees for these categories, would further tilt the market toward sustainable cargo flows.

Infrastructure investments would support this shift, with terminals modernized to handle selected goods efficiently and designed for smooth intermodal transfer between river, rail, and road networks. EU-funded projects could deliberately source materials in ways that favor inland waterways, for instance bulk procurement for renewable energy infrastructure, construction materials, or bio-based products. These interventions would create natural alliances with environmental organizations like the European Environmental Bureau, WWF Europe, and Transport & Environment, which advocate for low-carbon transport, as well as with industry associations such as the European Barge Union and sector-specific trade groups in agriculture, chemicals, and steel, which benefit from stable river cargo volumes.

EU institutions, particularly DG MOVE, DG ENV, and the European Investment Bank, would play a coordinating role, offering policy guidance, financial support, and technical assistance. Member states with dense inland waterway networks, including the Netherlands, Germany, France, Belgium, and Romania, would be key supporters, providing national-level alignment and investment. Cross-border coordination would be essential, especially along major corridors such as the Rhine and Danube, to harmonize regulations, tolling, and safety standards. While challenges remain, including potential resistance from private traders and the slower flexibility of river transport compared with road or rail, a coherent EU strategy combining incentives, infrastructure, and strategic procurement could gradually modify trade patterns, steering river traffic toward environmentally and economically desirable cargoes while enhancing the resilience and sustainability of Europe’s inland waterway network.

Table Cargo Type

Cargo Type	**Most Suitable Rivers / Corridors**	**Policy / Incentive Tools**	**Natural Allies**
Renewable energy components (wind turbine parts, solar panels)	Rhine, Danube, Rhône, Elbe	Subsidies for transport, reduced lock/port fees, infrastructure modernization for heavy cargo	European Barge Union, renewable energy industry associations, WWF Europe

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Recycled and circular economy materials (metals, plastics, paper)	Rhine, Danube, Seine, Scheldt	Environmental regulations favoring green cargo, EU procurement programs	Circular economy advocates, Transport & Environment, national recycling associations
Bulk agricultural products (grain, oilseed, sugar)	Danube, Rhine, Po, Elbe	Reduced transport fees, dedicated terminals, seasonal scheduling support	European farmers' associations, DG AGRI, national transport authorities
Industrial raw materials (steel, chemicals, cement)	Rhine, Danube, North Sea–Rhine–Meuse network	Investment in terminal upgrades, financial incentives for inland shipment	Chemical and steel trade associations, EBU, DG MOVE
Bio-based products (wood, biomass, biofuels)	Danube, Rhine, Elbe, Meuse	Subsidized transport, specialized loading facilities, environmental labeling	Renewable and forestry sector associations, Transport & Environment
Construction materials (sand, gravel, concrete)	Rhine, Danube, Rhône	Preferential canal tolls, EU infrastructure procurement aligned with river shipment	Construction industry, DG MOVE, local port authorities

The EU could coordinate this through regulatory and financial mechanisms, infrastructure investment, and strategic procurement. Major allies would include industry associations that benefit from inland transport, environmental NGOs promoting green logistics, and EU institutions (DG MOVE, DG ENV, European Investment Bank). Member states with extensive waterways, like Germany, Netherlands, France, Belgium, and Romania, would provide critical national support. Cross-border river corridors such as the Rhine and Danube would require harmonized rules and coordinated incentives to ensure seamless implementation.

Budgetary prioritization for inland waterway development involves careful trade-offs between investment in vessel and propulsion technologies versus infrastructure and cargo facilitation. One major consideration is whether the EU should focus more on greening the propulsion systems of vessels, such as adopting LNG, hydrogen, electric, or hybrid propulsion, or on modifying what is traded on rivers through infrastructure and regulatory incentives.

From a budgetary standpoint, investing in propulsion tends to be capital-intensive and requires long-term financial commitments, including subsidies for vessel retrofitting, grants for new low-emission ships, and research and development of innovative technologies. For example, transitioning a fleet of European inland vessels to hydrogen or electric propulsion could require several billion euros over a decade, depending on fleet size and energy infrastructure. These investments generate significant environmental benefits by reducing CO_2, NOx, and particulate emissions, aligning with the EU Green Deal and Fit-for-55 objectives, but they do not directly alter the types of cargo being shipped.

In contrast, investments aimed at influencing trade patterns—such as developing specialized terminals, improving intermodal connectivity, or subsidizing the transport of green goods—tend to have a lower per-unit cost but rely on economic incentives and market uptake. These measures often require careful Environmental Impact Assessments (EIA), particularly when building new terminals, dredging rivers, or expanding locks, because they can affect aquatic ecosystems, floodplains, and biodiversity. EIAs ensure that cargo-focused interventions do not degrade river environments, which could otherwise undermine the sustainability of inland waterways.

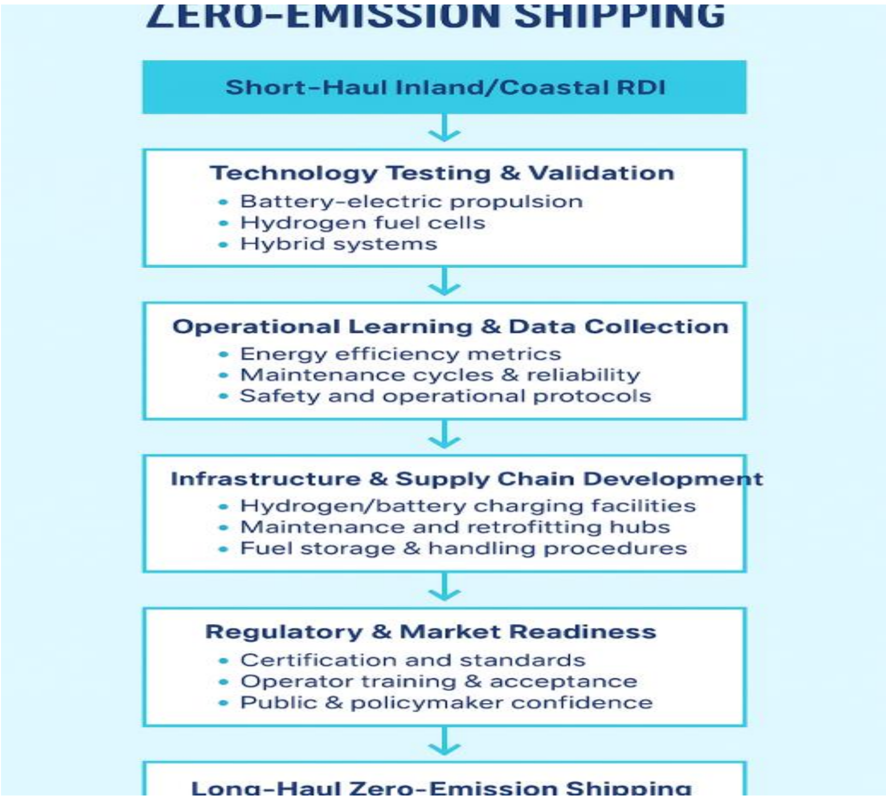
Thus, a tension arises: investing more in propulsion addresses emissions and climate targets directly, whereas investing in cargo facilitation can shift economic activity toward sustainable goods, potentially creating systemic changes in supply chains. Ideally, budgetary allocation would balance the two. For example, a combined approach could dedicate 60–70% of funds to green propulsion retrofitting and infrastructure upgrades for energy supply (charging stations, hydrogen terminals) while using 30–40% to develop cargo incentives, specialized terminals, and logistics programs that encourage sustainable trade flows. EIAs would need to assess both elements: the environmental footprint of new propulsion infrastructure and the ecological consequences of modifying trade flows.

In short, prioritization involves a strategic choice: investing in propulsion offers high-impact environmental returns but limited influence over trade composition, whereas cargo-focused interventions shape river economics and trade patterns but require smaller budgets and careful EIA oversight. The EU would need to calibrate spending to meet climate objectives while guiding inland waterways toward supporting sustainable supply chains.

From short haul to Long Haul

Yes, there is a clear link between research, development, and innovation (RDI) in short-haul, low- or zero-emission propulsion and breakthroughs in long-haul zero-emission shipping, though the connection is indirect and phased. Essentially, short-haul inland and coastal shipping acts as a testing ground and scale model for technologies that could later be deployed in longer oceanic routes. Here's how the linkage works:

Short-haul vessels are smaller and operate in predictable, controlled environments, which makes them ideal for testing new propulsion systems such as battery-electric, hydrogen fuel cells, or hybrid solutions. Operational lessons, performance data, and safety protocols generated in these contexts help reduce technical risk before scaling up to long-haul vessels that are larger, carry heavier loads, and face more demanding endurance and fuel storage requirements.



RDI in short-haul propulsion allows manufacturers and operators to optimize energy efficiency, powertrain integration, and control software. Economies of learning lower the cost of production, improve reliability, and identify failure modes. These insights directly inform the design of long-haul zero-emission ships, especially in areas like energy density, refueling infrastructure, and predictive maintenance.

The infographic effectively communicates the pathway from short-haul inland/coastal RDI to long-haul zero-emission shipping. Its vertical flow with arrows clearly shows the sequential stages, making it immediately understandable for a policy audience. The use of rectangular boxes with concise headings helps to segment the process, and the minimal supporting text highlights key points without overwhelming the reader.

The content emphasizes the progression from technology testing and operational learning to infrastructure development, cost reduction, regulatory readiness, and finally deployment in long-haul shipping. This mirrors how policy and investment decisions at the inland waterway level can have systemic impacts on global decarbonization.

Investments in ports, charging/fueling stations, and maintenance networks for short-haul vessels create the initial infrastructure base necessary for scaling to long-haul operations. For instance, hydrogen bunkering facilities developed for inland waterways can eventually support coastal or even transoceanic vessels once storage, distribution, and safety standards are validated.

Early deployment of zero-emission technology in short-haul shipping builds regulatory familiarity, operator trust, and public confidence. Policymakers gain experience implementing emission standards, monitoring systems, and certification protocols, which are essential for enabling regulatory approval and market uptake in long-haul shipping.

Breakthroughs in energy storage, fuel cells, or hybrid-electric systems often emerge in smaller vessels where iterative experimentation is feasible. Once mature, these technologies can be upscaled. For example, battery management systems for inland vessels inform hybrid-electric oceanic designs, and hydrogen fuel cell stacks tested in river barges provide a blueprint for larger ships with higher energy demands.

The Role of Europe's Inland Ports in the Transport Economy and Multimodal Systems

Europe's inland ports function as essential nodes within the continental transport network, linking navigable rivers, canals, and lakes to urban and industrial centers. These ports handle a diverse mix of cargo, including bulk commodities such as coal, steel, and agricultural products, as well as containerized goods and chemicals, facilitating both domestic and international trade. For instance, Duisburg in Germany, one of the world's largest inland ports, serves as a hub for container and bulk cargo with strong connections to the Rhine and broader European rail networks. Similarly, the inland terminals associated with the Port of Rotterdam extend seaport operations inland via river and rail connections, relieving congestion at coastal terminals and providing efficient cargo distribution. Inland ports significantly reduce transport costs for industries located along waterways and support regional economic development by generating employment and facilitating logistics services. Quantitatively, inland waterway transport (IWT) accounts for approximately six to eight percent of total EU freight measured in tonne-kilometers. However, in major river corridors such as the Rhine, Danube, or Seine, IWT may carry up to twenty to thirty percent of regional freight volumes, underscoring the strategic importance of these waterways.

Inland ports are pivotal in Europe's multimodal transport chains, facilitating seamless transfers between river, rail, and road networks. Container terminals and bulk cargo facilities in ports such as Antwerp, Strasbourg, and Vienna connect barges to rail services, enabling long-distance inland distribution with lower environmental impacts. Road networks complement these operations, providing last-mile delivery to urban centers and industrial districts. Many inland ports also serve as intermodal logistics hubs, hosting container yards, freight forwarding services, and warehousing facilities. This integration allows ports to optimize cargo flows, implement just-in-time delivery practices, and reduce reliance on road transport, contributing to both operational efficiency and EU climate objectives.

Europe's inland ports operate under a complex set of regulations spanning the EU, national, local, and international levels. At the EU level, the Trans-European Transport Network (TEN-T) policy supports investment in port infrastructure and multimodal connectivity, while the Water Framework Directive ensures environmentally sustainable port operations. EU action plans for inland waterways promote efficiency, safety, and interoperability in inland transport. National and local authorities typically manage ports through public port authorities or municipal entities, regulating navigational safety, environmental impact, dredging, waterway maintenance, labor standards, and industrial zoning within port areas. Additionally, ports along the Rhine and Danube are governed by international agreements, such as those established by the Central Commission for Navigation on the Rhine (CCNR) and the Danube Commission, which harmonize navigation rules, vessel standards, and safety protocols across borders.

Modernizing Europe's inland ports is essential to maintain competitiveness and align with broader EU logistics and environmental objectives. Digitalization is a key component, involving the implementation of Port Community Systems and IoT-enabled sensors for cargo tracking, predictive scheduling, and operational optimization. Infrastructure upgrades, including channel deepening, quay wall reinforcement, expansion of container yards, and automated cargo handling equipment, are necessary to accommodate larger vessels and higher cargo volumes. Environmental sustainability can be enhanced through electrification of port handling equipment and the adoption of low-emission or hybrid barges. Strengthening intermodal networks, particularly rail and road connections, further improves efficiency and reduces transit times. Finally, EU funding mechanisms, including the Connecting Europe Facility, the European Regional Development Fund, and the Cohesion Fund, can support port modernization projects, while harmonization of cross-border regulations reduces administrative delays and enhances the competitiveness of inland transport corridors.

Europe's inland ports play a central role in the continent's transport economy, serving as essential hubs that facilitate efficient cargo movement, reduce road congestion, and enable sustainable logistics. Through integrated multimodal connections, regulatory oversight, and strategic modernization, these ports can enhance trade efficiency, support regional development, and contribute to the EU's climate and sustainability goals. Investment in infrastructure, digitalization, and green technologies, alongside policy harmonization, will ensure that inland ports continue to function as key drivers of economic growth and environmental stewardship in the European transport network.

Inland waterway ports are explicitly recognized within the EU's strategic framework for ports and maritime transport, particularly under the Sustainable and Smart Mobility Strategy and the TEN-T Port Action Plan. The strategy emphasizes inland ports as critical nodes for multimodal connectivity, linking maritime ports with rail and road networks and enabling seamless freight movement across Europe. By integrating inland ports, the EU aims to optimize transport corridors, reduce congestion at seaports, and enhance supply chain resilience, especially for bulk and containerized cargo. Inland ports are considered essential for developing efficient port hinterland connections, facilitating transshipment and minimizing logistical bottlenecks in urban and industrial regions.

Inland waterway transport (IWT) is recognized as one of the most energy-efficient and low-emission modes of freight transport in Europe. Shifting cargo from road to inland waterways reduces greenhouse gas emissions per tonne-kilometer substantially, with studies indicating reductions of twenty to fifty percent compared to road transport. Inland ports serve as pivotal transshipment hubs in this process, allowing large-scale cargo to be transported via barges rather than trucks. The EU Port Strategy outlines several mechanisms for emission reduction through inland ports. By integrating these ports into logistics chains, freight can be diverted from road to waterways, reducing fuel consumption and traffic congestion. Green port initiatives, including electrification of cargo handling equipment, shore-side electricity for vessels, and the adoption of low-emission handling technologies, reduce both local air pollution and carbon dioxide emissions. Inland ports also function as sustainable logistics hubs, facilitating cargo consolidation, improving vessel fill rates, and thereby lowering overall energy use. These measures directly support the EU's climate objectives, including targets under the European Green Deal and broader decarbonization efforts in the transport sector.

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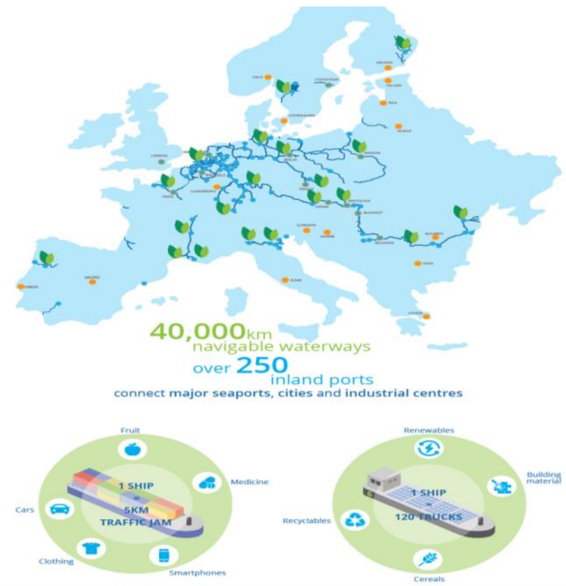
Interests and Role of the Inland Waterway Port Association in the EU Port Strategy

The **Inland Waterway Port Association (IWPA)** functions as the principal representative body for Europe's inland ports, advocating for their economic, environmental, and operational interests within EU policymaking forums. The association plays a critical role in bridging the needs of port authorities, local governments, logistics operators, and industry stakeholders with the strategic objectives of the European Commission and other regulatory bodies. Its mandate encompasses promoting sustainable inland waterway transport (IWT), fostering interoperability across national borders, and ensuring that inland ports are recognized as key nodes in the broader multimodal transport network.



Source: https://www.inlandwaterwaytransport.eu/inland-waterway-transport-agenda-2024-onwards/

The EU Port Strategy promotes the modernization and integration of inland ports through targeted policy instruments and investment mechanisms. Infrastructure projects at inland ports are eligible for co-financing under the Connecting Europe Facility, particularly when they enhance multimodal connectivity or improve energy efficiency. Digitalization is also encouraged, with ports implementing cargo tracking systems, automated scheduling, and predictive logistics solutions to optimize throughput. Harmonized regulations concerning vessel size, navigation safety, and cargo handling are promoted across member states to increase interoperability and reduce administrative delays. By combining infrastructure investment, technological innovation, and regulatory harmonization, the EU aims to maximize the contribution of inland ports to sustainable and efficient freight transport.

The IWPA's interests in the updated EU Port Strategy are multifaceted. First, it emphasizes the **integration of inland ports into multimodal freight corridors**, ensuring seamless connectivity with maritime ports, rail systems, and road networks. The association advocates for infrastructural investments that enhance cargo handling capacity, improve transshipment efficiency, and reduce bottlenecks in hinterland logistics. Second, the IWPA promotes the **green transition of inland ports**, supporting electrification of cargo handling equipment, adoption of low-emission or hybrid vessels, and energy-efficient infrastructure. By highlighting the contribution of IWT to decarbonizing the transport sector, the association seeks to position inland ports as central actors in achieving the EU's climate and Green Deal targets.

In addition to infrastructure and environmental priorities, the IWPA seeks **regulatory harmonization and simplification**. Its members often encounter complex administrative and safety requirements that differ across EU member states. The association advocates for standardization of vessel specifications, navigation rules, cargo handling procedures, and reporting obligations, to facilitate cross-border operations and reduce administrative burdens. It also emphasizes the importance of digitalization, encouraging the integration of Port Community Systems, automated logistics management, and real-time cargo tracking to enhance operational efficiency.

From a strategic perspective, the IWPA supports **financial and policy instruments that strengthen inland port competitiveness**, such as EU co-financing under the Connecting Europe Facility (CEF), the European Regional Development Fund (ERDF), and national investment programs. It stresses the need for inland ports to be considered on par with seaports in EU transport and trade strategies, particularly with respect to multimodal corridor planning and sustainability initiatives.

Overall, the IWPA positions inland ports as essential nodes in Europe's transport ecosystem. In the updated EU Port Strategy, it aims to ensure that inland ports are not only recognized for their logistical and economic significance but also empowered to contribute actively to emission reduction, green logistics, multimodal integration, and digital transformation. By advocating for coherent policies, targeted investments, and operational modernization, the association seeks to enhance the resilience, efficiency, and sustainability of Europe's inland waterway transport system.

Summary

Inland waterway ports occupy a central position in the EU Port Strategy, functioning as multimodal hubs that facilitate efficient cargo distribution, improve supply chain resilience, and support the EU's climate and transport efficiency goals. Through their integration into green logistics corridors, deployment of low-emission technologies, and promotion of modal shifts from road to waterways, inland ports contribute directly to reducing transport-related emissions. Simultaneously, they enhance cargo handling efficiency, strengthen connectivity, and improve the sustainability and competitiveness of Europe's transport network.

Best Practices

Best practices in river management worldwide provide valuable lessons for the European Union (EU) as it seeks to enhance the sustainability, efficiency, and resilience of its inland waterways. By examining successful approaches in Asia, Africa, and the Americas, the EU can adapt governance, infrastructure, and operational practices to meet the challenges posed by climate change and hydrological variability.

Integrated Water Resources Management (IWRM) is widely applied in Asia, notably in the Mekong River Basin, where transboundary coordination integrates water, land, and ecosystem management (MRC, 2021). In Africa, IWRM principles guide the management of the Nile Basin through cooperative frameworks like the Nile Basin Initiative (NBI, 2020). For the EU, adopting IWRM principles ensures inland waterway policies are aligned with broader water management strategies, balancing ecological, economic, and social objectives.

Adaptive Management has been applied effectively in North America, particularly in the Mississippi River Basin, where continuous monitoring informs flood control, sediment management, and navigation operations (USACE, 2022). Similarly, Asian rivers like the Ganges-Brahmaputra employ adaptive strategies to respond to monsoon variability. Implementing adaptive management in the EU can enable responsive governance structures that adjust to changing hydrological conditions and extreme weather events.

Stakeholder Engagement and Participation is a cornerstone of river management in Africa's Volta and Niger basins, where local communities, industries, and environmental organizations are actively involved in planning and decision-making (World Bank, 2019). North American river management practices also emphasize multi-level governance and stakeholder coordination. The EU can strengthen inland waterway governance by fostering inclusive participation, promoting shared responsibility, and improving compliance with regulations.

Ecosystem-Based Management is a central principle in North American river restoration projects, such as the Chesapeake Bay and the Great Lakes, where ecological health and biodiversity are prioritized alongside navigation and economic activity (EPA, 2021). Asian countries like Japan integrate ecosystem services into river planning, maintaining floodplains and riparian habitats. The EU can adopt similar ecosystem-based approaches to preserve biodiversity and ensure resilient inland waterway networks.

Use of Technology and Data is exemplified by advanced monitoring systems in China's Yangtze River, employing remote sensing, AI-based flood prediction, and real-time navigation management (China Ministry of Water Resources, 2022). In the US and Europe, digital platforms track vessel traffic and hydrological conditions. By investing in comparable technological solutions, the EU can enable proactive waterway management, improving safety, efficiency, and environmental monitoring.

Transboundary Cooperation is critical in regions like the Mekong, Nile, and Amazon basins, where countries share rivers across borders (MRC, 2021; NBI, 2020; FAO, 2022). The EU's experience with transboundary rivers like the Danube and Rhine can be enhanced by learning from these global mechanisms, reinforcing coordinated policies, dispute resolution, and joint investment strategies.

Sustainable Financing Mechanisms are increasingly used in North and South America through public-private partnerships and environmental funds for river infrastructure, maintenance, and restoration (IDB, 2021). African river basin authorities also mobilize international climate finance to support sustainable water projects. The EU can expand financing options for inland waterways, leveraging green bonds, CEF funds, and private sector investment for long-term infrastructure sustainability.

Restoration and Rehabilitation Projects in the US, such as Mississippi River wetlands restoration, and in Asia, like the Yangtze floodplain rehabilitation, demonstrate the value of investing in ecosystem health for operational and environmental benefits (EPA, 2021; China Ministry of Water Resources, 2022). The EU can implement similar restoration initiatives to improve habitat connectivity, sediment management, and ecological resilience, strengthening the overall sustainability of its waterways.

By learning from global river management practices, the EU can enhance its inland waterway governance, integrating lessons from Asia, Africa, and the Americas. Emphasizing integrated water management, adaptive and ecosystem-based approaches, stakeholder engagement, technological innovation, transboundary cooperation, and sustainable financing will be crucial for addressing climate change, hydrological variability, and operational challenges. Implementing these best practices will enable the EU to modernize its inland waterways, balancing economic efficiency with ecological sustainability and resilience.

Table Best Practices

Best Practice	Europe	Asia	Africa	Americas	Lessons for EU
Integrated Water Resources Management (IWRM)	Applied in Danube and Rhine basins; partially integrated across EU member states	Mekong Basin employs transboundary IWRM with coordinated land and water management	Nile Basin Initiative promotes cross-border IWRM and water allocation	Mississippi River integrates watershed management with flood control	Adopt EU-wide IWRM principles to align inland waterway policies with broader water and land management objectives
Adaptive Management	Limited; some EU projects implement real-time monitoring	Ganges-Brahmaputra Basin uses adaptive	Selected pilot programs adjust operations	Mississippi River Basin uses continuous monitoring to	Implement adaptive governance and operational

	and seasonal adjustments	strategies for monsoon variability	during extreme events	adapt flood control and navigation (USACE, 2022)	systems to respond flexibly to hydrological and climate variability
Stakeholder Engagement	Growing in Rhine and Danube commissions, but variable across countries	Community participation in local flood management and pollution control	Involves local communities, industries, and NGOs in decision-making (World Bank, 2019)	Multi-level governance models engage state, municipal, and community stakeholders	Enhance inclusive participation across EU inland waterways to improve policy legitimacy and compliance
Ecosystem-Based Management	Pilot restoration projects along the Rhine; limited integration in navigation planning	Japan and China integrate ecosystem services and floodplain preservation	Some wetland restoration and biodiversity conservation initiatives	Chesapeake Bay and Great Lakes projects prioritize habitat and water quality (EPA, 2021)	Incorporate ecosystem health into waterway planning to balance navigation, biodiversity, and resilience
Use of Technology and Data	Real-time vessel tracking in some TEN-T corridors; data integration is uneven	Advanced monitoring and AI-based flood forecasting on Yangtze River (China Ministry of Water Resources, 2022)	Limited; some pilot programs with remote sensing and basic data analytics	Extensive use of GIS, satellite imagery, and predictive models for navigation and flood control	Invest in digital monitoring, predictive analytics, and real-time management platforms for EU waterways
Transboundary Cooperation	Danube Commission, International Rhine Commission coordinate multi-state operations	Mekong River Commission fosters cross-border water agreements	Nile Basin Initiative and shared water treaties (NBI, 2020)	Amazon and Mississippi involve federal and multi-state coordination	Strengthen EU transboundary agreements and joint management frameworks for shared waterways
Sustainable Financing Mechanisms	EU funding through CEF and TEN-T; green transition funds emerging	Public-private partnerships for flood and navigation infrastructure	International climate finance supports basin projects	Public-private financing for infrastructure and restoration (IDB, 2021)	Expand EU financial instruments, green bonds, and PPPs to fund sustainable inland waterway modernization

Restoration and Rehabilitation Projects	Rhine and Danube floodplain rehabilitation initiatives	Yangtze River floodplain and wetland restoration (China Ministry of Water Resources, 2022)	Some river rehabilitation projects to improve habitats	Mississippi River wetlands and floodplain restoration (EPA, 2021)	Invest in restoration and rehabilitation to improve ecological health, connectivity, and resilience of EU waterways

Implications For Eu

Legal Implications

Harmonization of regulations is critical. Lessons from transboundary cooperation in the Mekong, Nile, and Mississippi highlight the importance of consistent legal frameworks. The EU must ensure uniform implementation of CEVNI rules and TEN-T standards across member states to reduce legal fragmentation. Adaptive legal frameworks are also necessary. Climate variability and hydrological uncertainty demand that EU legislation allows flexibility for operational adjustments, such as water-level adaptations, temporary navigation restrictions, or emergency dredging operations. Strengthening transboundary agreements is another key priority. The EU can enhance multilateral treaties and commissions, such as the Rhine and Danube, by incorporating mechanisms for rapid dispute resolution and coordinated management during low-water or flood events, drawing on global best practices. Finally, liability and technological governance need attention. Autonomous vessels, smart locks, and AI-based monitoring systems introduce novel liability and compliance challenges. Legal frameworks must anticipate these innovations while balancing operational efficiency and safety (Domenighini, 2024).

Economic Implications

Targeted infrastructure investment is essential. Global river management practices emphasize the need to prioritize navigable corridors, and the EU should focus funding on bottleneck areas and climate-resilient upgrades, such as adjustable weirs and shallow-draft locks. Improving modal shift efficiency can reduce road congestion, lower transport costs, and enhance the competitiveness of European freight transport. Lessons from the Mississippi and Yangtze rivers illustrate how operational reliability boosts trade and logistics performance. Public-private partnerships and green financing offer additional opportunities. Experiences in Africa and the Americas demonstrate successful mobilization of PPPs and climate finance for sustainable waterway projects. The EU can leverage CEF funds, green bonds, and partnerships to secure long-term financial sustainability. Investing in restoration projects also delivers economic benefits. Enhancing ecosystem health improves navigation reliability and reduces long-term dredging and maintenance costs, as evidenced in Rhine and Danube floodplain rehabilitation efforts.

Political and Financial Implications

Cross-border coordination and governance are crucial. Lessons from the Mekong, Nile, and Amazon highlight that political cohesion is essential for effective waterway management. EU member states must align strategic objectives, share real-time data, and coordinate investment priorities. Regional equity and social buy-in are equally important. Stakeholder engagement in Africa and Asia shows that local community participation increases legitimacy and compliance. The EU must integrate regional authorities, port operators, and environmental NGOs into governance frameworks. Climate-resilient policy signaling is also a political priority. Adopting adaptive management and ecosystem-based approaches demonstrates the EU’s commitment to sustainability and the green transition, reinforcing its credibility in international climate diplomacy. Financial accountability and transparency are fundamental. Establishing EU-level efficiency task forces and standardized KPIs, as seen in American best practices, ensures transparency in fund allocation and operational monitoring, supporting both political and fiscal legitimacy.

Summary

Global experiences indicate that effective EU inland waterway management requires an integrated approach. Legally, frameworks must harmonize and adapt to climate and technological change. Economically, investment must be prioritized, modal shift promoted, and innovative financing leveraged. Politically and financially, transnational governance must be coordinated, stakeholders engaged, and accountability maintained. Together, these measures can enhance navigational reliability, sustainability, and competitiveness of the EU's inland waterway network while reinforcing resilience against climate variability.

Urbanization, Rivers, and EU Transport Policy: Linkages and Environmental Considerations

Rivers have historically functioned as critical catalysts for urban development in Europe. Major cities, including Paris, Berlin, Vienna, London, Rome, Madrid, and Warsaw, are all situated along significant waterways, reflecting the historical importance of rivers for urban settlement. The primary drivers of this urban-river relationship include access to potable water, facilitation of trade and transport, provision of energy resources, and strategic defense. Consequently, rivers have served not only as lifelines for local populations but also as nodes of economic connectivity, enabling the growth of urban centers.

In contemporary Europe, rivers continue to play a strategic role in the transport infrastructure. Inland waterways facilitate the movement of substantial volumes of goods in a more energy-efficient manner compared to road and rail transport. Furthermore, rivers enhance connectivity between inland urban centers and maritime ports, forming integral segments of multimodal transport networks. This connectivity is explicitly recognized in the European Union's Trans-European Transport Network (TEN-T), which incorporates key inland waterways to strengthen economic cohesion across member states.

EU transport policy emphasizes the promotion of sustainable and environmentally responsible transport modes. Inland waterway transport (IWT) is encouraged as a low-emission alternative to road freight, contributing to the EU's broader climate objectives. Policy instruments, including investment in port modernization, lock systems, and navigability improvements, aim to enhance the efficiency and safety of river transport while fostering economic competitiveness.

Figure La Grenoiulle

Environmental sustainability remains a central consideration in the utilization of inland waterways. The EU Water Framework Directive (WFD) mandates that all European rivers achieve "good ecological status," requiring careful management of transport infrastructure to prevent ecological degradation. Measures to preserve water quality, maintain biodiversity, and mitigate flood risks are essential to ensure that inland waterways can simultaneously support urban development, commercial transport, and environmental integrity.

In summary, the interrelationship between urbanization, rivers, and EU transport policy is characterized by historical precedence and contemporary strategic planning. Urban centers historically emerged along rivers due to their utility for trade and resource provision. Today, rivers continue to function as sustainable transport corridors under EU policy, provided that their ecological health is maintained. This integrated perspective underscores the necessity of balancing economic efficiency, urban development, and environmental stewardship in the management of European inland waterways.

Given the role of rivers in urbanisation and nodal points along the inland waterways, the Inland waterway ports require a governance model that reflects their unique jurisdictional, ecological, and operational characteristics. The legal framework for inland ports is shaped by jurisdictional complexity, as these ports often span multiple administrative zones, necessitating intergovernmental coordination. Environmental regulation plays a more prominent role than in coastal ports, with freshwater ecosystem protection, riparian rights, and compliance with the EU Water Framework Directive being central. Navigation and safety laws are typically governed by river commissions such as the Central Commission for the Navigation of the Rhine (CCNR), which harmonize rules for vessel traffic, infrastructure, and emergency protocols.

The management model of inland ports tends to be hybrid, combining municipal ownership with private terminal operators or logistics firms. These ports are deeply embedded in multimodal transport systems, requiring governance structures that coordinate with rail, road, and urban logistics networks. Emphasis is placed on last-mile connectivity and modal shift incentives. Digital coordination platforms such as Port Community Systems (PCS) and River Information Services (RIS) are increasingly used to manage real-time traffic, cargo flows, and environmental monitoring.

Economically, inland ports rely on diversified revenue streams that go beyond container throughput. Income is often derived from bulk cargo, passenger services, logistics zones, and land leasing. Financial sustainability is supported by EU funding instruments, including cohesion policy allocations, TEN-T corridor financing, and green transition funds. Inland ports must also incorporate resilience and redundancy into their financial models, accounting for seasonal variability such as droughts and floods, and the costs of climate adaptation.

Sources of Pollution of Europe’s inland waterways

Agricultural runoff stands as one of the most significant contributors to the degradation of Europe’s inland rivers. Fertilizers rich in nitrogen and phosphorus are frequently washed from farmlands into nearby waterways, accelerating nutrient pollution. The widespread use of pesticides in crop production further contaminates river systems and threatens aquatic life. During periods of rainfall, animal waste from livestock farms is carried into rivers, increasing biological pollution.

Industrial activities contribute substantially to river pollution through the discharge of hazardous chemicals. Many factories release heavy metals, including mercury and lead, which persist in waterways and harm ecosystems.

Inadequate or untreated sewage remains a major source of contamination in numerous inland rivers. Urban wastewater transports bacteria and organic matter into rivers, reducing water quality. Stormwater runoff from cities carries oil residues and chemical pollutants into river channels. Plastic waste generated by households often finds its way into river systems. Microplastics originating from cosmetics and synthetic clothing pass through wastewater systems and enter rivers. Mining operations introduce harmful substances into surrounding waterways. Acid mine drainage poses a severe threat by altering water chemistry and damaging river ecosystems. Shipping and recreational boating occasionally cause oil and fuel spills that pollute rivers. Construction activities along riverbanks intensify erosion and destabilize natural boundaries. Without adequate controls, construction debris can easily be washed into rivers. Deforestation in river catchments increases sediment loads in waterways. Accelerated soil erosion clouds river water and disrupts aquatic habitats. Power plants contribute to thermal pollution by discharging warm water into rivers. Pharmaceutical residues enter river systems through human waste and insufficient filtration.

Improper waste management practices continue to exacerbate river contamination. Leachate from landfills can seep into rivers, carrying toxic substances.Tourism activities often increase litter and waste accumulation near rivers. Illegal dumping remains a persistent source of pollution in certain regions. Runoff from roads transports

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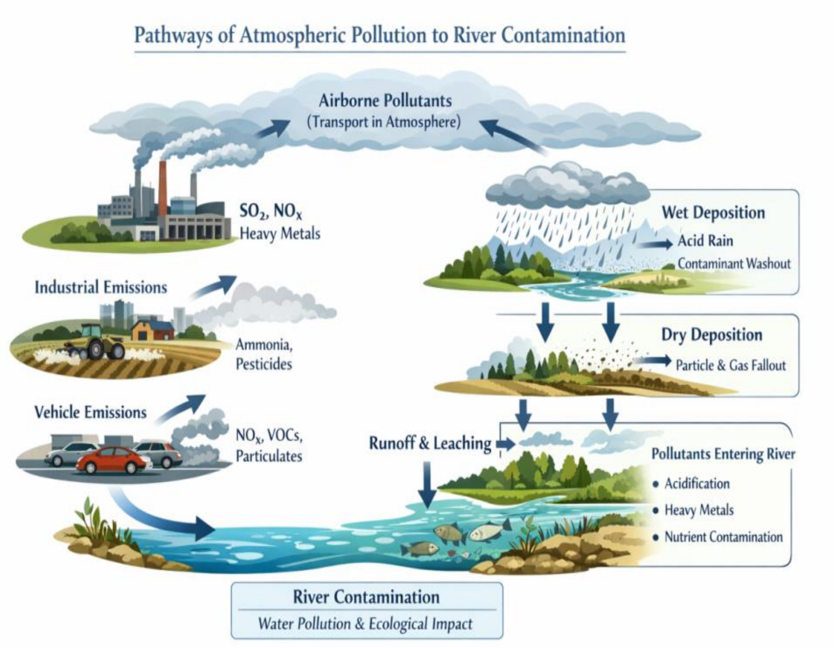
rubber particles and heavy metals into river systems. Salt applied to roads during winter is washed into rivers, altering water chemistry. Aging sewer infrastructure frequently overflows during heavy rainfall events. Flooding spreads pollutants from surrounding land into river networks. Invasive species can indirectly degrade water quality by disrupting natural ecosystems. Climate change intensifies pollution impacts by reducing river flow and dilution capacity.

Figure



To effectively address river pollution, it is essential to strengthen regulations on agricultural runoff while actively promoting sustainable farming practices. Farmers should be encouraged to reduce the use of fertilizers and pesticides through targeted subsidies, education, and professional training. Establishing vegetated buffer zones along riverbanks can serve as natural filters, preventing harmful pollutants from reaching waterways.

Modernizing wastewater treatment plants is vital to ensure the removal of hazardous chemicals, pharmaceuticals, and microplastics. Upgrading aging sewer systems will help prevent overflows during periods of heavy rainfall. At the same time, strict controls on industrial discharges must be enforced, requiring industries to adopt cleaner and more efficient production technologies. Effective monitoring systems and firm penalties will deter illegal dumping and ensure compliance.

Plastic pollution can be significantly reduced by promoting proper waste disposal and recycling practices. Urban stormwater pollution should be addressed through green infrastructure, such as rain gardens and retention basins, while cities are encouraged to replace impermeable concrete surfaces with permeable alternatives. Mining activities must be carefully regulated, with acid mine drainage treated before it enters river systems, and river transport should be monitored to prevent oil and fuel spills.

Restoring damaged riverbanks will reduce erosion and sedimentation, while limiting deforestation near rivers and supporting reforestation projects will protect catchment areas. Thermal pollution can be minimized by regulating the discharge of warm water from power plants. Improved management of pharmaceutical waste, along with enhanced filtration in wastewater systems, will further protect water quality. Preventing landfill leakage through secure containment measures remains equally important.

Public awareness and community involvement play a crucial role in river protection. Educating tourists and local residents, organizing regular river clean-up campaigns, and encouraging responsible behavior can foster a culture of environmental stewardship. Road runoff pollution can be reduced by improving drainage systems, limiting the use of road salt, and promoting environmentally friendly alternatives.

Strengthening cross-border cooperation in river basin management will ensure coordinated and effective action across regions. The use of real-time water quality monitoring systems and continued support for research into pollution-reduction technologies will enhance decision-making. Protecting wetlands, which naturally filter pollutants, should be a priority. Finally, adapting pollution control strategies to the impacts of climate change, increasing funding for river restoration, and promoting environmental education in schools and communities will secure the long-term health and resilience of Europe's inland rivers.

Integrated Environmental Strategy to Mitigate Riverine Contamination from Atmospheric Pollutants

Riverine ecosystems are increasingly threatened by atmospheric pollutants originating from industrial, agricultural, and vehicular sources. These pollutants follow complex deposition pathways, ultimately contributing to water quality degradation and ecological stress. This paper proposes an integrated environmental strategy that addresses pollutant sources, deposition dynamics, terrestrial transport, governance mechanisms, and ecosystem resilience. By combining preventive and restorative measures, the framework provides a comprehensive approach to safeguarding river systems and enhancing aquatic ecosystem sustainability.

Atmospheric pollutants, including sulfur dioxide (SO_2), nitrogen oxides (NOx), ammonia, volatile organic compounds (VOCs), and particulate matter, contribute substantially to riverine contamination through wet and dry deposition, followed by runoff and leaching processes (Smith et al., 2021). Industrial, agricultural, and vehicular activities constitute the primary emission sources, with both local and transboundary impacts. Effective mitigation requires integrated strategies that span technological, regulatory, ecological, and governance domains.

2.1 Industrial Emissions

Industrial processes release SO_2, NOx, and heavy metals, which contribute to acid deposition and metal mobilization in aquatic systems. Mitigation strategies include enforcing stringent emission limits, adopting best available technologies (BAT), integrating renewable energy, and deploying carbon capture and storage (CCS) in high-emission facilities (Johnson & Lee, 2020). Regulatory incentives can further stimulate the adoption of low-emission technologies.

Agricultural Emissions

Intensive agriculture contributes ammonia and pesticide emissions, which exacerbate nutrient loading and toxic contamination in rivers. Precision farming, slow-release fertilizers, integrated pest management (IPM), and conditional subsidies for nutrient management plans can reduce diffuse pollution while maintaining productivity (Garcia et al., 2019).

Vehicular Emissions

Transport-related emissions of NOx, VOCs, and particulate matter significantly impact air and water quality. Policy measures include promoting electrified and low-emission vehicles, establishing low-emission zones, expanding public transit infrastructure, and implementing fuel quality standards aligned with air quality objectives (Kumar et al., 2022). Such interventions reduce secondary pollutant formation and downstream aquatic impacts.

Wet Deposition

Acid rain, formed from SO_2 and NOx transformations, accelerates river acidification and mobilizes heavy metals. Strategies for mitigation include forest catchment protection, liming of acidified water bodies, and the establishment of vegetated buffer zones to intercept and neutralize acidic inputs (Chen et al., 2018).

Dry Deposition

Particulate and gaseous fallout deposits contaminants onto soil and surface water. Vegetative barriers such as tree belts act as biofilters, while urban air quality management—including particulate capture technologies—further reduces deposition prior to precipitation events.

Terrestrial deposition ultimately reaches river systems via runoff and leaching. Riparian buffer strips, constructed wetlands, and sediment retention structures are effective in intercepting nutrients and heavy metals (Zhang & Li, 2021). In urban contexts, sustainable drainage systems (SuDS) and permeable surfaces reduce impervious runoff, mitigating pollutant transport to rivers.

Coordinated governance is essential for integrating industrial, agricultural, and transport mitigation measures. Real-time air and water quality monitoring, coupled with environmental impact assessments (EIAs) for new developments, enable adaptive management. Transboundary coordination ensures compliance with regional agreements and harmonized regulatory frameworks (European Environment Agency, 2020).

Restoring riparian and wetland ecosystems enhances natural filtration, stabilizes riverbanks, promotes biodiversity, and sequesters heavy metals. Prioritizing native vegetation and continuous ecological monitoring supports ecosystem resilience to episodic and chronic pollution events, reinforcing both ecological and water quality objectives (Miller et al., 2019).

An integrated, multi-barrier approach—encompassing emission reduction, deposition mitigation, runoff control, governance, and ecological restoration—provides a comprehensive strategy to protect riverine systems from atmospheric pollution. By aligning regulatory, technological, and ecological measures, this framework fosters sustainable water quality and robust aquatic ecosystems.

Navigable River Links (NRL) and Their Role in EU Transport Policy and Inland Waterways

Navigable River Links (NRL) constitute a set of infrastructural and operational parameters that define the navigability of river sections for commercial and passenger transport. These parameters include channel depth, width, hydrological conditions, and allowable vessel classes, which collectively determine maximum draft, cargo capacity, and operational reliability. As such, NRL functions as a technical interface linking urban centers, inland waterway transport (IWT), and the wider European transport network.

Urban areas located along navigable rivers are highly dependent on NRL to sustain port activities, industrial supply chains, and multimodal transport connectivity. The maintenance of navigable links ensures that riverine cities remain competitive nodes within European logistics and trade systems. Reliable NRL conditions support urban economic resilience by facilitating bulk transport, reducing logistics costs, and strengthening connections between hinterlands and metropolitan markets.

NRL is closely aligned with EU transport objectives, particularly under the Trans-European Transport Network (TEN-T) framework and the European Green Deal. By enabling efficient, high-capacity, and low-emission inland waterway transport, NRL contributes to the EU's goal of achieving a modal shift from road to more sustainable transport modes. Investments aimed at improving NRL—such as dredging operations, lock modernization, and adaptive hydrological management—enhance network reliability while supporting reductions in congestion, energy consumption, and CO_2 emissions.

Enhancements to NRL must be carefully balanced with environmental objectives established under the Water Framework Directive (WFD) and related biodiversity legislation. Interventions to maintain or improve navigability, including alterations to river depth or flow regimes, may affect aquatic habitats, sediment dynamics, and water quality. Consequently, sustainable engineering and integrated river basin management approaches are required to reconcile navigational performance with the achievement of good ecological status.

NRL provides the technical backbone that enables urban rivers to function as contemporary transport corridors. Major European cities such as Vienna (Danube), Berlin (Spree/Havel), and Paris (Seine) depend on clearly defined navigability standards to ensure the continued viability of inland waterway transport. In these contexts, NRL supports economically efficient logistics while contributing to urban sustainability and climate objectives.

Navigable River Links represent a critical nexus between urban development, inland waterway transport, and European transport policy. By defining navigability standards, NRL ensures that rivers continue to function as efficient and environmentally advantageous transport corridors, supporting urban economic activity and facilitating modal shifts toward low-emission transport. At the same time, NRL governance must remain consistent with EU environmental directives to safeguard ecological integrity. Accordingly, NRL should be understood not merely as a technical specification, but as a strategic policy instrument underpinning sustainable urban and transport development in Europe.

Investment Needs for Europe's Inland Waterways

Modernizing Europe's inland waterways requires a multi-dimensional investment strategy that addresses infrastructure, climate resilience, environmental sustainability, and technological innovation. Maintenance of navigable depths in rivers such as the Rhine, Danube, Elbe, and Seine is essential, with routine dredging and sediment management estimated at approximately €500–700 million annually (Baranyai, 2020; European Commission, 2025). Upgrading locks and canals with climate-resilient structures, including adjustable weirs and modernized bottleneck corridors, is projected to require €2–3 billion over the next decade. In addition, port modernization and the development of intermodal hubs, including container terminals and roll-on/roll-off facilities, would likely demand €1.5–2 billion for strategic TEN-T corridors.

To address climate variability, low-water and flood adaptation measures, such as shallow-draft vessel compatibility and flood management systems, could require €1–1.5 billion over ten years. Real-time monitoring systems, AI-based predictive models, and digital traffic management platforms across the EU would cost approximately €300–500 million. Ecosystem restoration, including floodplain rehabilitation, biodiversity enhancement, and sediment control along major rivers, is projected at €1–1.2 billion to ensure ecological sustainability.

Investment in research, innovation, and workforce development is also necessary. Technological innovation, such as autonomous vessels, energy-efficient propulsion, and smart logistics systems, could require €200–400 million, while workforce training, including cross-border certification and skill development for operators and maintenance staff, may need €50–100 million. Overall, total estimated investment needs for the EU's inland waterways over the next decade range from €7–10 billion, depending on the pace of modernization and climate risk assumptions.

Funding for these investments should be shared across EU institutions, national governments, the private sector, and user-based mechanisms. EU-level funding, through TEN-T and CEF contributions as well as green transition instruments, should cover approximately 40–50 percent of total investment, prioritizing climate-resilient corridors and cross-border projects. National governments should contribute roughly 30–35 percent, focusing on country-specific segments of international rivers and matching funds for EU-supported initiatives. Private sector participation, through port operators, shipping companies, and green bonds, could account for 15–20 percent, particularly for intermodal infrastructure, smart logistics platforms, and low-emission vessels. Finally, navigation fees and tolls could contribute 5–10 percent, providing revenue for ongoing maintenance and incentivizing modal shift.

This allocation ensures that investments are targeted to the most critical areas, leverage cross-border cooperation, and balance economic, environmental, and operational priorities. Projects that combine navigational improvements with ecosystem restoration are particularly cost-effective, as they reduce long-term maintenance and enhance sustainability.

Table Estimated Investment Needs and Funding Distribution for EU Inland Waterways

Investment category	**Estimated Costs € bn**	**EU FUnding**	**National Funding**	**Private and PPP**	**User fees**
Dredging and Navigation Maintenance	5–7 annually	45	35	15	5
Locks and Canal Upgrades	2–3	40	35	20	5

Port Modernization and Intermodal Hubs	1.5–2	50	30	15	5
Climate Adaptation Measures	1–1.5	50	30	15	5
Monitoring and Digital Systems	0.3–0.5	50	30	15	5
Ecosystem Restoration	1–1.2	45	35	15	5
Technological Innovation	0.2–0.4	40	30	25	5
Workforce Training	0.05–0.1	40	35	20	5

Europe's inland waterways are the veins of its transport system, yet they face mounting pressures from aging infrastructure, hydrological variability, and climate change. Investment decisions over the coming decade will define the efficiency, sustainability, and resilience of these waterways. In a low-investment scenario, focusing primarily on routine maintenance and selective dredging, navigability would remain adequate for current freight levels but would be vulnerable to low-water events and extreme floods. Modal shift from road and rail to inland waterways would progress only marginally, as reliability constraints persist, and carbon reduction targets would see limited gains. Essential infrastructure bottlenecks would remain, curbing the economic potential of strategic corridors like the Rhine, Danube, and Elbe.

The medium-investment scenario envisions targeted upgrades to locks, canals, and ports, coupled with adaptive infrastructure measures and moderate technological deployment. Navigability would improve significantly, reducing disruptions during low-water periods and increasing cargo throughput by a projected 10–15 percent. Modal shift could accelerate as transport operators gain confidence in river reliability, while carbon emissions from freight could decline measurably due to greater use of energy-efficient vessels. Ecosystem restoration and climate-resilient measures would enhance floodplain connectivity and biodiversity, providing co-benefits beyond navigation. Stakeholder engagement and EU coordination under TEN-T and CEF frameworks would ensure efficient allocation of resources and cross-border harmonization of operations.

A high-investment scenario entails comprehensive modernization across all major rivers, extensive port and intermodal hub development, full deployment of autonomous and low-emission vessels, and advanced digital traffic management systems. Navigability would approach optimal levels, even under extreme climate conditions, allowing inland waterways to capture a substantially larger share of freight transport. Modal shift from road to river transport could increase by 20–25 percent, dramatically reducing congestion on highways and rail networks. Carbon emissions would decline sharply, contributing directly to EU climate targets, while ecosystem restoration projects would transform degraded floodplains into multifunctional landscapes. High investment would also support cutting-edge research, innovation, and workforce development, fostering technological leadership and operational excellence.

Across all scenarios, coordinated governance remains essential, with EU-level oversight, national co-financing, and private sector participation ensuring financial sustainability. Even in the low-investment case, transparent KPIs and adaptive management could maintain minimum operational standards. Medium and high investment pathways demonstrate the strategic leverage of financial instruments such as green bonds, CEF grants, and public-private partnerships. Ultimately, the choice of investment intensity defines the trajectory of Europe's inland waterways, determining whether they remain underutilized arteries or evolve into highly efficient, climate-resilient corridors. By linking investment to navigability, modal shift, and carbon reduction, policymakers can visualize tangible returns on financial commitments. This scenario framework allows for flexible planning, enabling adaptive responses to evolving hydrological and economic conditions. The high-investment scenario, while ambitious, illustrates the transformative potential of coordinated, forward-looking action. Medium investment represents a balanced compromise between cost and impact, achieving meaningful gains without overextending budgets. Low investment maintains continuity but risks stagnation and vulnerability. Together, these scenarios provide a structured roadmap for aligning financial, environmental, and

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operational objectives. The analysis underscores that inland waterways are not just transport corridors, but strategic instruments for Europe's green transition and economic integration. Scenarios illuminate the interplay between infrastructure, technology, governance, and climate resilience, offering a comprehensive vision for the future of European waterways. By embedding sustainability at every level, Europe can secure competitive, low-carbon freight solutions while enhancing ecological integrity. These investment pathways also signal to global partners that the EU is committed to innovation, efficiency, and transboundary cooperation in inland navigation. Finally, scenario planning empowers policymakers to prioritize, sequence, and monitor interventions, ensuring that inland waterways deliver maximum social, economic, and environmental returns.

Bringing in Dnistr & Sava Rivers

The **Dniester and Sava rivers** are selected as illustrative outliers for studying intermodality and transshipment within Europe's inland waterway system because they contrast sharply with major corridors like the Rhine and Danube.

The **Dniester River**, flowing through Ukraine and Moldova to the Black Sea, has historically supported regional freight transport but remains underutilized compared with major European waterways. Limited infrastructure, shallow navigable stretches, and fragmented governance across national borders constrain its potential for intermodal operations. Studying the Dniester highlights the challenges faced by smaller, cross-border rivers in realizing freight, transshipment, and multimodal integration, and illustrates the effects of governance, investment, and policy gaps.

The **Sava River**, passing through Slovenia, Croatia, Bosnia-Herzegovina, and Serbia, has higher navigational potential and moderate freight activity. Its connectivity to the Danube allows for transshipment into larger European networks. However, like the Dniester, it faces cross-border coordination challenges, seasonal variability, and limited infrastructure, making it a useful case to examine the practical limits of intermodal integration on secondary rivers.

By comparing the Dniester and Sava with the Rhine or Danube, researchers can analyze the full spectrum of inland waterway performance—from major, highly integrated corridors to smaller, underutilized tributaries. These outliers provide critical insights into the roles of governance, policy, infrastructure, and cross-border coordination in shaping the effectiveness of river-based intermodal transport.

Compared with the **Rhine** and **Danube**, the **Dniester** and **Sava** represent smaller, less integrated inland waterways. The Rhine is Europe's busiest river corridor, with dense multimodal networks, modern ports, and extensive transshipment facilities, while the Danube, though crossing multiple countries, supports high-volume freight and well-established intermodal connections along its central and western stretches.

In contrast, the Sava has moderate freight volumes and partial connectivity to the Danube, but suffers from seasonal navigation limits, fragmented cross-border governance, and limited infrastructure. The Dniester is even less developed, with shallow stretches, weak port facilities, and minimal intermodal integration, reflecting both institutional and economic constraints.

Studying the Dniester and Sava alongside the Rhine and Danube highlights the contrast between major, fully integrated European river corridors and secondary or underutilized waterways. This comparison underscores how infrastructure quality, governance, policy support, and cross-border coordination determine the effectiveness of intermodal transport and transshipment potential.

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The Rhine and Danube benefit from long-term investment strategies, EU funding, and harmonized regulatory frameworks, which encourage private-sector participation and logistic innovation. In contrast, the Sava and Dniester illustrate how underinvestment, inconsistent regulations, and weaker institutional capacity can limit the ability of rivers to serve as efficient freight corridors. Seasonal variations, navigational bottlenecks, and limited port networks further constrain the use of these smaller rivers for intermodal operations. Nonetheless, both rivers have strategic regional potential, particularly for connecting local industries to larger European networks if governance and infrastructure challenges are addressed.

The Dniester River, shared by Moldova and Ukraine, lies outside the EU but is strategically important for regional trade, biodiversity, and climate adaptation. To integrate it into EU governance frameworks, the EU can leverage **cross-border cooperation mechanisms**, such as the **EU Water Initiative (EUWI)** and **European Neighborhood Policy (ENP)** programs. Establishing a **Dnister River Basin Coordination Committee** aligned with EU river governance models, such as those for the Rhine and Danube, would enable harmonized standards for navigation, water quality, and infrastructure planning. This committee could involve national authorities, local governments, NGOs, and EU institutions like DG MOVE and DG ENV.

EU regulatory frameworks, including **CEVNI rules**, TEN-T standards, and the Water Framework Directive (WFD), can serve as benchmarks for Dniester governance. Harmonizing navigation standards, safety regulations, and environmental protection norms with EU best practices would facilitate potential trade integration and cross-border shipping. Pilot agreements or memoranda of understanding could set the stage for progressive alignment, even before formal EU accession or bilateral treaties.

The Dniester is ecologically sensitive, supporting critical habitats and agricultural livelihoods. Applying **ecosystem-based management** and **climate-resilient infrastructure** approaches ensures that modernization projects do not compromise biodiversity. Joint monitoring of water levels, sedimentation, and pollution, coupled with restoration projects (e.g., wetlands and floodplains), can enhance resilience while promoting sustainable navigation. EU funding instruments, such as **LIFE Programme** or ENI CBC projects, could co-finance these initiatives.

Introducing **adaptive navigation measures**—locks, low-water vessels, and climate-resilient ports—would improve reliability and promote regional trade. Digital waterway traffic management systems, similar to those in Rhine or Danube corridors, can coordinate flows, minimize congestion, and optimize cargo throughput. Collaboration with EU ports in Romania or Bulgaria could establish intermodal links, enhancing the Dniester's connectivity to the broader European inland waterway network.

Figure Evocative Hotyn Castle along the quiet flowing Dnipr and a village on the opposite bank

Successful governance requires inclusive participation. Local communities, port operators, logistics firms, and environmental NGOs should be actively involved in planning and monitoring. Training programs can upskill operators in digital navigation systems, sustainable vessel operations, and EU regulatory compliance. Cross-border knowledge exchange with EU river authorities can accelerate capacity development.

Financing could combine EU grant mechanisms, regional development funds, and public-private partnerships. Funding priorities should include port modernization, dredging, climate adaptation, and ecosystem restoration. Transparent KPIs and reporting aligned with EU standards would ensure accountability and attract private sector co-investment.

Summary:

Integrating the Dniester into EU governance requires a multi-layered strategy combining **legal harmonization, environmental stewardship, infrastructural modernization, stakeholder engagement, and targeted investment**. By creating a cross-border coordination mechanism aligned with EU best practices, the river can become a sustainable, reliable, and economically productive waterway, enhancing regional connectivity while promoting environmental resilience.

The Sava River

The Sava River flows through Slovenia, Croatia, Bosnia and Herzegovina, and Serbia, linking EU and non-EU states. To integrate it into EU inland waterway governance, the **International Sava River Basin Commission (ISRBC)** provides an existing cooperative structure that can be further aligned with EU frameworks. EU institutions, particularly DG MOVE, DG ENV, and DG REGIO, can engage in joint planning with the ISRBC to ensure compliance with **TEN-T, NAIADES, and Water Framework Directive (WFD)** standards. This creates a governance bridge for coordinated navigation, environmental management, and infrastructure investment.

Harmonizing navigation rules, safety standards, and port operations along the Sava with EU regulations is critical, especially for cross-border freight. Full application of **CEVNI rules** and standardization of infrastructure classifications (CEMT classes) would enable interoperability with other European waterways. Transboundary agreements could incorporate adaptive clauses for climate variability, low-water events, and emergency navigation, drawing lessons from Rhine and Danube frameworks.

Sava River management should embed **ecosystem-based and climate-resilient strategies**, including floodplain restoration, wetland protection, and sediment management. Joint environmental monitoring and early-warning systems for floods or droughts can reduce economic and ecological risks. EU co-financing through **CEF, LIFE, or Instrument for Pre-accession Assistance (IPA)** can support restoration, sustainable port development, and habitat conservation projects.

Modernizing the Sava requires climate-adapted locks, low-water vessels, and upgraded ports, enabling seamless navigation under variable hydrological conditions. Developing intermodal hubs along the river, connected to TEN-T corridors, would strengthen regional trade links. Digital traffic management and smart logistics platforms can optimize cargo flows, reduce congestion, and facilitate real-time coordination across borders.

Inclusive participation from municipalities, port operators, logistics companies, and environmental NGOs is essential. Training programs in sustainable vessel operation, digital management, and EU regulatory compliance will strengthen workforce capacity. Cross-border workshops can share best practices from Rhine, Danube, and European inland ports.

Figure Belgrade Skyline Imagined at the Sava River

Investment can be shared among EU funds, national governments, non-EU partners, and private stakeholders. Priority areas include climate-resilient infrastructure, port modernization, dredging, and restoration. Transparent monitoring of KPIs ensures accountability and supports co-investment opportunities. Public-private partnerships and green bonds can leverage EU and national contributions for long-term sustainability.

Transshipment & Multimodality

Achieving enhanced multimodality and efficient transshipment at inland harbour points along the Sava and Dniester requires a coordinated strategy that addresses infrastructure, digitalisation, environmental sustainability, and governance. Strengthening connectivity between inland waterways and other transport modes is essential. This involves mapping existing harbour infrastructure and identifying gaps in rail and road access, followed by the development of priority investment plans to link inland ports to regional rail terminals and logistics hubs. Complementing physical infrastructure, digital freight management systems should be introduced to coordinate shipments across river, rail, and road transport, thereby ensuring seamless cargo transfer, reduced dwell times, and an increased modal share of inland waterways.

Modernisation of transshipment infrastructure and equipment is a key component of the plan. Quay walls, cranes, and storage facilities need upgrading to handle containerised and bulk cargo efficiently, while the installation of standardised equipment can enable rapid transfer between barges, trucks, and trains. Modular and flexible warehousing near harbours should be developed to accommodate seasonal fluctuations in traffic, resulting in faster, safer, and higher-capacity transshipment operations capable of handling diverse cargo types.

Digitalisation and data interoperability play a central role in optimising multimodal operations. River Information Services (RIS) should be deployed along the Sava and Dniester corridors to monitor traffic, water levels, and cargo movement. Integration of inland ports into national and EU logistics platforms would allow real-time tracking and scheduling, while standardised electronic documentation for cross-border shipments would reduce administrative burdens. Together, these measures are expected to optimise scheduling, minimise bottlenecks, improve predictive planning, and facilitate smoother cross-border coordination.

Environmental and energy efficiency considerations must be embedded in all upgrades. Incentives for low-emission vessels and electrified cargo handling equipment can reduce operational emissions, while environmental monitoring at harbours ensures minimal impact on river ecosystems. Promoting bulk cargo consolidation reduces unnecessary trips and maximises vessel utilisation, contributing to the sustainability of inland transport.

Effective stakeholder cooperation and governance are also crucial. Establishing cross-border river commissions for Sava and Dniester harbour development, which include public and private actors, would provide a forum for strategic coordination. Regular workshops between port authorities, logistics companies, and local municipalities can foster shared operational standards, while the development of performance indicators and joint monitoring mechanisms allows assessment of progress on multimodality and transshipment efficiency.

Finally, securing financing is critical to enable these investments. Identifying funding streams from EU Cohesion Fund, TEN-T, the Connecting Europe Facility, and national programmes, combined with the development of public-private partnership models, can leverage private sector investment in transshipment infrastructure. Projects should be prioritised based on their potential to enhance multimodal impact and cross-border connectivity, ensuring sustainable financing, timely implementation, and long-term operational viability. Short-term actions over one to two years would focus on mapping, digitalisation pilots, and stakeholder coordination, while medium-term efforts over three to five years would include infrastructure upgrades, RIS deployment, and multimodal integration trials. Long-term objectives over five to ten years involve the full operationalisation of multimodal hubs, environmental optimisation, and cross-border standardisation.

The proposed action plan for enhancing multimodality and transshipment at inland harbour points along the Sava and Dniester directly supports the **NAIADES III Action Plan**, which prioritises digitalisation, decarbonisation, multimodal integration, and competitiveness of inland waterway transport. Strengthening multimodal connectivity aligns with NAIADES III's aim to integrate inland waterways into broader logistics chains, ensuring seamless transfer between river, rail, and road transport. Upgrading transshipment infrastructure and equipment supports operational efficiency, capacity enhancement, and interoperability, which are key pillars of NAIADES III for modernising inland ports and enabling cross-border cargo flows.

Digitalisation initiatives, including River Information Services (RIS), real-time tracking, and standardised electronic documentation, mirror NAIADES III's emphasis on data-driven optimisation and harmonised digital services. These measures enhance the reliability and predictability of inland waterway transport, a critical enabler for modal shift from road to river, reinforcing EU multimodal transport policy objectives.

Environmental and energy efficiency measures, such as incentivising low-emission vessels, electrified cargo handling, and bulk cargo consolidation, directly contribute to the EU's **emission reduction targets** and decarbonisation agenda under NAIADES III. By reducing CO_2 and particulate emissions from inland shipping, these measures help meet the Green Deal objectives and improve local air quality in urban areas connected to river corridors.

Stakeholder cooperation and governance structures, including cross-border river commissions and joint monitoring mechanisms, facilitate the **coordination of policy implementation**, ensuring that NAIADES III objectives are operationalised effectively. Finally, targeted financing strategies, leveraging EU Cohesion Fund, TEN-T, and public-private partnerships, provide the necessary resources to translate NAIADES III ambitions into tangible infrastructure upgrades and digital deployments.

In sum, the Sava and Dniester harbour action plan operationalises NAIADES III by integrating digitalisation, multimodality, and environmental sustainability, creating a **strategically coherent pathway** for inland waterways to contribute to EU transport efficiency, cross-border connectivity, and climate mitigation goals.

Sava and Dnistr as cases of EU River Governance

The governance of inland waterways in Europe is characterised by a persistent fragmentation of authority, particularly in relation to dredging, fairway maintenance, and the coordination of navigation with environmental protection and intermodal logistics. This structural condition is especially visible on secondary and peripheral rivers, where hydrological variability intersects with cross-border institutional complexity. The Sava and the Dniester rivers provide two analytically instructive cases through which the implications of this fragmentation can be examined in relation to intermodality, transshipment design, and environmental governance.

On the Sava River, governance is shaped by the presence of the International Sava River Basin Commission, which constitutes one of the few river-wide institutions in Europe covering both European Union and non-EU member states. While the Commission provides a platform for coordination, planning, and information exchange, it lacks executive authority over dredging operations, infrastructure delivery, and budgetary allocation. These functions remain primarily within the remit of national waterway administrations and port authorities. As a consequence, dredging and fairway maintenance are typically conceived as hydraulic interventions undertaken within national territories, rather than as components of a coherent river-wide logistics system. This disconnect has direct implications for intermodality. Along the Sava, the principal constraint on navigation is not solely insufficient depth or width of the fairway, but the weak integration of river ports with rail and road networks, particularly at intermediate nodes such as Sisak, Slavonski Brod, and Brčko. In practice, fairway improvements are frequently implemented without parallel investment in terminal design, rail sidings, customs facilities, or digital logistics systems, thereby limiting the transshipment potential of the river.

The Dniester River represents a more constrained and geopolitically sensitive governance environment. Unlike the Sava, the Dniester lacks a navigation-oriented river commission with a stable mandate. Governance is instead fragmented across bilateral arrangements between Moldova and Ukraine, further complicated by unresolved territorial and security issues in Transnistria. In this context, inland navigation does not function as a continuous corridor, but rather as a set of discontinuous, seasonal, and locally bounded transport opportunities. Intermodality on the Dniester is therefore necessarily modest in scale, oriented primarily towards regional bulk commodities and agricultural flows, and dependent on flexible, low-capital transshipment solutions. The absence of predictable dredging regimes and long-term environmental clearance discourages private investment in port infrastructure and reinforces a cycle of underutilisation.

Environmental impact assessment constitutes a critical interface between waterway development and governance capacity on both rivers. Under European and international law, responsibility for conducting environmental impact assessments lies with national competent authorities, typically ministries of environment or specialised environmental agencies, while the assessments themselves are commissioned by project promoters such as waterway authorities or port operators and carried out by accredited consultancies. For transboundary rivers, the Espoo Convention provides the procedural framework for notification, consultation, and information exchange between affected states. The European Environment Agency does not conduct environmental impact assessments; rather, it functions as a data and knowledge provider, supplying harmonised environmental indicators, hydrological datasets, and methodological reference frameworks that may inform national assessments.

Navigation on the Sava and the Dniester rivers entails a combination of hydrological, infrastructural, institutional, and geopolitical risks. Seasonal water-level variability and increasing hydrological volatility linked to climate change generate frequent depth constraints and unpredictable navigation windows. Insufficient and uneven dredging regimes lead to bottlenecks, sedimentation, and rapidly shifting fairway conditions. Ageing port infrastructure and weak rail and road connections reduce the reliability and economic viability of intermodal transport. Fragmented governance across national authorities complicates the coordination of maintenance, traffic management, and safety standards, particularly on cross-border sections. Environmental protection requirements, when addressed through project-by-project assessments, can create delays and legal uncertainty without resolving cumulative impacts. Limited availability of real-time hydrological data and river information services further increases operational risk for operators. On the Dniester, unresolved territorial and security issues introduce additional political and insurance risks that discourage commercial navigation. Regulatory instability and inconsistent enforcement of navigation rules undermine long-term investment planning. Taken together, these risks constrain the role of both rivers as predictable and competitive components of wider European transport networks.

While project-level environmental impact assessments remain the dominant instrument in practice, their effectiveness on rivers such as the Sava and the Dniester is limited by their narrow spatial and temporal scope. Incremental dredging projects assessed in isolation fail to capture cumulative impacts on river morphology, sediment transport, and ecosystems, and they often lag behind rapidly changing hydrological conditions driven by climate variability. Strategic Environmental Assessment offers a more appropriate scale of analysis, particularly when applied to navigation development plans, multi-annual dredging programmes, and intermodal corridor strategies. On the Sava, such an approach can be anchored in basin-wide planning processes coordinated by the International Sava River Basin Commission. On the Dniester, however, the absence of a robust basin institution has resulted in fragmented or incomplete strategic assessments, frequently dependent on external donors and international organisations.

From a policy perspective, these cases suggest that the European Union’s added value does not lie in centralising operational responsibility for dredging or environmental assessment, but in reconfiguring the scale and logic of governance. One critical step is the functional separation between assessment authority and data authority. While environmental assessments must remain the responsibility of national authorities, the use of shared, river-wide environmental baselines—drawing on European Environment Agency datasets and river commission coordination—would enhance consistency, reduce disputes, and improve the comparability of cross-border decisions. A second implication concerns the relationship between dredging and intermodality. EU financial instruments such as the Connecting Europe Facility and the Cohesion Fund could more explicitly condition support for dredging on demonstrable integration with port, rail, and road infrastructure, thereby reframing fairway maintenance as a logistics and climate policy instrument rather than a purely hydraulic intervention.

More broadly, the Sava illustrates the potential for mixed EU and non-EU river governance arrangements, even if their current mandates remain limited. Elements of this model could be adapted to the Dniester through lighter institutional platforms focused on navigation planning, environmental data sharing, and intermodal design, rather than full-fledged river commissions. Finally, both cases point to the need for a shift from project-based environmental assessment towards river-section environmental envelopes, defined through multi-annual strategic assessment processes. Such envelopes would establish agreed parameters for dredging volumes, ecological thresholds, and navigation performance over a defined period, allowing individual interventions to proceed within a predictable and environmentally bounded framework.

In analytical terms, the governance challenges observed on the Sava and the Dniester are not primarily the result of regulatory gaps, but of misalignment between environmental assessment practices, intermodal logistics design, and the fragmented allocation of authority across national and international levels. Addressing this misalignment requires a reconceptualisation of inland waterways as integrated socio-technical systems, in which navigation, environmental protection, and territorial development are treated as interdependent dimensions of river basin governance.

EU Governance and Investment Roadmap for the Dniester and Sava Rivers (2026–2036)

Year 1–2: Assessment and Institutional Alignment

Comprehensive baseline studies should be conducted to map hydrological conditions, infrastructure status, and ecological sensitivities. For the Dniester, a **Dnister River Basin Coordination Committee** should be established, modeled on EU river governance structures, while the Sava River should further align ISRBC operations with TEN-T and NAIADES frameworks. Initial stakeholder consultations, including port authorities, local governments, logistics companies, and NGOs, will ensure inclusive planning.

Year 2–3: Legal and Regulatory Harmonization

Draft agreements to harmonize navigation standards, safety protocols, and operational rules with EU regulations, including CEVNI and TEN-T standards. Adaptive clauses addressing low-water levels, floods, and emergency dredging should be integrated. For non-EU Dniester riparians, ENP or bilateral memoranda of understanding can formalize gradual compliance and operational alignment.

Year 3–5: Infrastructure Modernization – Phase 1

Invest in climate-resilient locks, dredging, low-water vessel adaptation, and port upgrades at key nodes. Focus on high-priority bottlenecks to improve navigability and reduce operational disruption. Intermodal terminals should be designed for compatibility with rail and road networks, establishing the foundation for modal shift.

Year 4–6: Digitalization and Technological Deployment

Introduce real-time traffic management systems, predictive maintenance platforms, and cargo flow optimization tools. Pilot autonomous or low-emission vessels to enhance efficiency and reduce carbon emissions. Implement integrated data-sharing protocols across border authorities to enable coordinated operations.

Year 5–7: Environmental and Ecosystem Measures

Execute restoration projects for wetlands, floodplains, and riparian habitats. Establish water-quality monitoring and early-warning systems for floods or droughts. Embed ecosystem-based management practices into navigation operations to ensure environmental compliance alongside freight transport efficiency.

Year 6–8: Financing and Investment Scaling

Mobilize multi-source funding combining EU CEF grants, LIFE Programme funds, IPA support for pre-accession states, and public-private partnerships. Explore green bonds to finance low-carbon vessels and smart port infrastructure. Establish transparent KPIs and monitoring systems to track progress and performance.

Year 7–9: Governance Consolidation and Stakeholder Engagement

Strengthen transboundary coordination by formalizing agreements on operational protocols, emergency response, and data sharing. Provide capacity-building and training for port operators, logistics personnel, and regulatory staff, focusing on EU compliance, digital navigation systems, and climate adaptation measures.

Year 8–10: Full Operational Integration and Review

Evaluate navigability, cargo throughput, modal shift, and environmental indicators. Refine policies, investments, and governance structures based on performance metrics. Integrate lessons learned into broader EU inland waterway strategies, ensuring that the Dniester and Sava are fully incorporated into the TEN-T network and sustainable freight corridors.

Projected Outcomes

By the end of the decade, both rivers are expected to demonstrate high navigability resilience, improved modal shift from road and rail, and measurable carbon reductions. Ports will function as climate-resilient, intermodal hubs, with ecosystem-based management fully integrated. Governance and monitoring systems will enable real-time decision-making and cross-border coordination, ensuring sustainable and efficient river transport.

This roadmap illustrates a **phased, multi-dimensional strategy** linking legal harmonization, infrastructure modernization, technology deployment, environmental stewardship, stakeholder engagement, and innovative financing. By aligning both EU and non-EU rivers with EU inland waterway governance frameworks, the Dniester and Sava can become exemplary corridors of **sustainable, low-carbon, and strategically integrated transport networks**, supporting the EU's economic and environmental objectives.

Implementing the Nature Restoration Law on EU Inland Ports

Restoring riverine systems has emerged as one of the most pressing and complex environmental imperatives of the twenty-first century. Across Europe and beyond, ambitious policy commitments—most notably the Nature Restoration Law—signal a renewed recognition of rivers as living systems essential to biodiversity, climate resilience, and human well-being.

The encroachment of the EU upon the planning processes of the Member States is revolutionary, comparable to the exercise of infrastructural power and is of a political nature in the name of good ecological status, since nothing else has worked to restore the environmental state of the waterways of Europe. German *genie –ohne Weissheit* and French *brio sans competence* nonostante, let us examine what this audacious imposition is all about.

Despite decades of scientific insight and technical capability, the ecological recovery of rivers has remained slow, uneven, and contested. This persistent gap between aspiration and outcome reveals that river restoration is not merely an engineering or ecological challenge, but a profoundly strategic one, shaped by governance structures, socio-economic trade-offs, and the realities of implementation.

Against this backdrop, a piece by various researchers offers a critical reframing of river restoration: shifting attention from what should be done to rivers, to why doing it at scale remains so difficult. By identifying the

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systemic constraints that obstruct action, the article provides a strategic lens through which riverine restoration can be understood, operationalized, and ultimately delivered.

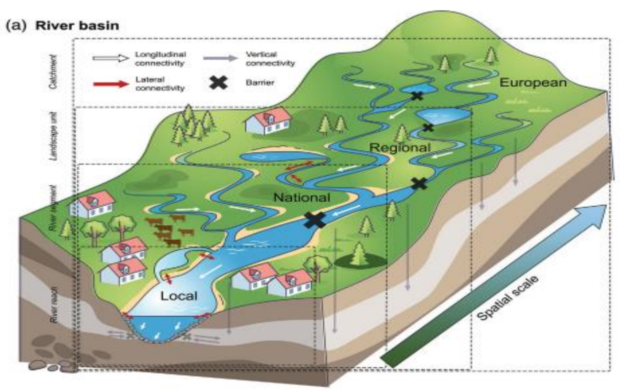
River Basin Connectivity Across Spatial Scales

The figure illustrates a river basin as an integrated system that operates across multiple spatial and governance scales, ranging from local to European levels. The river extends from upstream headwaters to downstream lowlands and is embedded within nested administrative frameworks. This highlights the fact that river systems do not align with political boundaries and therefore require coordinated management across scales.

The diagram emphasizes three fundamental dimensions of connectivity that structure river basin functioning. Longitudinal connectivity refers to the upstream–downstream linkage along the river course, enabling the movement of water, sediment, nutrients, aquatic organisms, and vessels. This form of connectivity is essential for inland waterway transport as well as ecological processes such as fish migration and sediment continuity. Disruptions to longitudinal connectivity, shown in the figure as barriers, can fragment the system and create bottlenecks for both navigation and ecosystems.

Lateral connectivity describes the interaction between the river channel and its adjacent floodplains. Through this exchange, rivers support flood retention, wetland habitats, and nutrient cycling. Human interventions such as embankments, channelization, and urban development often reduce lateral connectivity, altering natural flood dynamics and ecological functions.

Figure



Source: https://wires.onlinelibrary.wiley.com/doi/10.1002/wat2.1717

Vertical connectivity represents the exchange between surface water, soils, and groundwater systems. This interaction plays a critical role in maintaining base flows, regulating water quality, and supporting long-term ecosystem resilience. Changes in river morphology or water levels can therefore affect subsurface hydrological processes well beyond the visible channel.

The black crosses in the diagram indicate human-made structures such as dams, weirs, hydropower installations, and navigation locks. While these infrastructures provide benefits for energy production, flood control, and navigation, they also interrupt one or more dimensions of connectivity, requiring careful planning to balance competing objectives.

From a transport and navigation perspective, the figure demonstrates why navigable river conditions cannot be managed at isolated locations. A single barrier or shallow section can influence navigability along an entire corridor. Measures to maintain navigable depth or flow conditions may also affect lateral and vertical connectivity, reinforcing the need for basin-wide approaches. This is particularly relevant for European inland waterways integrated into TEN-T corridors, where reliability and continuity are essential.

Overall, the figure visually supports the principles of integrated river basin management promoted under EU water and transport policy. Rivers function as interconnected systems in which local interventions have regional and European-scale consequences. Sustainable inland navigation, flood protection, and ecological objectives must therefore be addressed together within a coherent, multi-scale governance framework.

The figure can be directly interpreted through the lens of **inland ports** and the implementation of **Navigable River Links (NRL)**, as it illustrates how navigability, infrastructure, and connectivity interact across the river basin.

Inland ports are typically located at strategic nodes along the river where **local urban systems intersect with national and European transport corridors**. Their functionality depends not only on port infrastructure itself but on the continuity of navigable conditions upstream and downstream. In this sense, NRL defines the minimum technical standards—such as fairway depth, width, and reliability—that ensure inland ports remain operationally connected to wider inland waterway networks.

Longitudinal connectivity is particularly critical for inland ports, as it determines whether vessels can reliably reach port terminals throughout the year. Barriers such as locks, weirs, or shallow sections shown in the figure can create bottlenecks that directly affect port throughput and hinterland accessibility. NRL implementation therefore focuses on removing or mitigating such constraints through coordinated measures, including lock upgrades, fairway maintenance, and water level management, applied consistently along the corridor rather than at isolated port locations.

Lateral connectivity also has implications for inland ports, especially in urbanized river sections. Ports are often situated on stabilized riverbanks where floodplains have been disconnected. NRL-related interventions must reconcile the need for stable navigation channels with flood risk management and ecological restoration, for example through controlled floodplains, secondary channels, or nature-based solutions that maintain navigability while enhancing resilience.

Vertical connectivity influences inland port operations through its effect on water level stability and sediment dynamics. Groundwater–surface water interactions affect low-flow conditions, which are critical for maintaining the design draft specified under NRL standards. Sediment management strategies associated with NRL implementation, such as dredging or sediment reuse, must therefore be aligned with basin-wide hydrological processes to avoid transferring problems downstream or upstream of port locations.

At the governance level, the multi-scale structure shown in the figure mirrors how inland ports are embedded within **local urban planning**, **national transport strategies**, and **EU-level frameworks** such as TEN-T and NAIADES. Effective NRL implementation requires coordination across these levels to ensure that investments in inland ports are matched by navigability improvements along the entire river link. Without such alignment, ports risk becoming isolated assets rather than functional nodes in the European inland waterway network.

Overall, the figure underscores that inland ports should be understood as **nodal points within a connected river basin system**, while NRL represents the corridor-wide technical and policy mechanism that secures their accessibility. Successful NRL implementation transforms rivers into reliable transport corridors, enabling inland ports to function as competitive, low-emission gateways between urban economies and European transport networks.

Table Challenge 1

Challenges	**Title / Summary**	**Key Strategic Issue**
1	Legal & Policy alignment	Difficulty aligning cross-sector laws
2	Connectivity restoration	Fragmentation by barriers (dams/weirs) impacts flow, species movement

3	Stakeholder integration	Multiple actors with conflicting priorities
4	Finance & incentives	Lack of sustainable funding for restoration
5	Monitoring & evidence	Limited data to guide adaptive implementation
6	Multi-scale governance	Tension between local and EU-level mandates
7	Socio-ecological complexity	Integrating human and ecological needs

The article by Altermmatt and Baldan (2023)provides a strategic diagnosis of why restoring riverine systems—especially free-flowing rivers—remains difficult despite strong policy ambitions, arguing that degradation is fundamentally an implementation and governance problem rather than a lack of technical knowledge. It identifies seven interlinked challenges, including fragmented policies, loss of connectivity, stakeholder conflicts, insufficient financing, weak monitoring, multi-scale governance mismatches, and socio-ecological trade-offs, all of which prevent restoration goals from translating into tangible ecological outcomes. Together, these challenges demonstrate that effective river restoration requires a long-term, adaptive, and governance-driven approach that integrates policy alignment, stakeholder coordination, and sustained learning rather than isolated technical interventions.

Table Challenge 2

Strategic Challenge	**Core Problem**	**Strategic Response**	**Key Actions**	**Primary Actors**	**Tools / Instruments**	**Expected Outputs**
1. Policy & Legal Fragmentation	Conflicting sectoral laws (water, energy, agriculture, navigation)	Policy harmonization & alignment	Review & align legislation; integrate restoration targets into sector plans	National ministries, EU bodies, regulators	Legal gap analysis; policy mapping	Coherent legal framework enabling restoration
2. Loss of River Connectivity	Dams, weirs, levees fragment rivers	Basin-scale connectivity restoration	Prioritize barrier removal/modification; reconnect floodplains	River basin authorities, engineers, ecologists	Connectivity indices; GIS barrier mapping	km of free-flowing river restored
3. Stakeholder Conflict	Competing interests & power imbalances	Inclusive governance & co-design	Establish river basin councils; participatory planning	Local governments, NGOs, communities, operators	Stakeholder mapping; facilitation methods	Shared ownership and reduced conflict
4. Financial Constraints	Short-term or insufficient funding	Long-term, blended financing	Combine public funds, incentives, private finance	Finance ministries, donors, private sector	Cost-benefit analysis; PES schemes	Financially viable restoration programs
5. Weak Monitoring & Data	Limited baselines and indicators	Adaptive management systems	Set KPIs; long-term ecological & social monitoring	Research institutions, agencies	Monitoring frameworks; dashboards	Evidence-based decision-making

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6. Multi-Scale Governance Gaps	Misalignment between local, national, EU scales	Vertical coordination mechanisms	Align basin plans with EU targets; cross-border coordination	EU, national & basin authorities	River basin management plans	Coherent multi-level implementation
7. Socio-Ecological Trade-offs	Restoration impacts livelihoods & land use	Just transition & benefit sharing	Compensation schemes; livelihood alternatives	Communities, policymakers, NGOs	Social impact assessment; co-benefit analysis	Social acceptance and long-term sustainability

The cross-tab matrix serves first as a **policy design instrument**, enabling decision-makers to read horizontally across each row to translate abstract strategic challenges into concrete, coherent policy responses and action pathways. By aligning problems, strategic responses, actions, actors, and instruments within a single framework, it reduces fragmentation and ensures that policy intent is systematically connected to operational choices.

When read vertically, the matrix becomes an **implementation planning and coordination tool**, clearly delineating who is responsible for what actions, how those actions will be delivered, and which instruments will be used to achieve defined outcomes. This vertical logic enhances accountability, supports inter-agency coordination, and reduces ambiguity during execution.

The "Expected Outputs" column provides a built-in **monitoring and evaluation mechanism**, allowing progress to be tracked against predefined performance indicators and enabling adaptive management where outcomes fall short. Finally, because the matrix uses a standardized structure that separates challenges from context-specific actions, it functions as a **scalable and replicable template**, capable of being applied across different river basins, jurisdictions, and governance settings while preserving strategic coherence.

Across Europe, river restoration success stories demonstrate that degraded rivers can recover when ecological ambition is matched by governance capacity and long-term commitment. Both urban and rural contexts reveal that restoration is most effective when rivers are treated as living systems rather than engineered channels. Urban rivers, once heavily polluted and constrained, have shown remarkable recovery when wastewater treatment, land-use planning, and public investment align. The restoration of the Emscher River in Germany exemplifies how large-scale, publicly coordinated infrastructure reform can transform a river from an open sewer into a functioning ecosystem. This transformation required decades of sustained funding, institutional leadership, and integration of water management with regional development. As water quality improved, biodiversity returned, and the river corridor became a social and recreational asset. Similar improvements in cities such as Paris, Copenhagen, Stockholm, and Munich highlight the importance of modern wastewater treatment in urban river recovery. These urban cases show that ecological restoration and improved quality of life can be mutually reinforcing goals. Successful city-based projects often embed river restoration within broader urban regeneration strategies, while public access, green spaces, and recreational uses help build long-term political and societal support for restoration.

Figure Swindale River Valley

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Rural river restoration provides complementary lessons rooted in reconnecting rivers to their natural processes. The Skjern River restoration in Denmark demonstrates how re-meandering and floodplain reconnection can rapidly improve ecological conditions. This project reversed decades of channelization and drainage that had degraded habitats and water quality. Wildlife recovery, improved flood resilience, and increased recreation followed the restoration[14]. Crucially, the project succeeded because landowners and farmers were compensated and involved in planning. The Swindale Beck restoration in the United Kingdom illustrates how even small-scale interventions can generate significant ecological benefits[15]. By restoring natural channel forms, the project enhanced habitat diversity and fish spawning. These rural examples show that working with natural processes is often more effective than rigid engineering solutions. They also reveal the importance of patience, as ecological recovery unfolds over time, and how long-term monitoring allows managers to learn, adapt, and demonstrate success.

Across both urban and rural cases, governance emerges as a decisive factor in success. Projects with clear leadership, stable institutions, and cross-sector coordination perform better, whereas fragmented responsibilities and short-term funding consistently undermine restoration outcomes. Stakeholder engagement proves essential in managing conflicts and building shared ownership, and restoration initiatives succeed when costs and benefits are distributed fairly. Economic co-benefits, such as tourism and reduced flood risk, strengthen political support, while monitoring and data collection are critical for accountability and adaptive management. Successful projects treat uncertainty as inherent and plan for learning rather than control. Urban and rural experiences alike show that restoration cannot be reduced to technical fixes, but requires institutional learning and cultural change in how rivers are valued. A key lesson is that scale matters, with basin-wide planning delivering greater ecological gains than isolated projects, and multi-level governance enabling local actions to contribute to regional and national objectives. Flexibility in policy implementation allows projects to respond to local conditions, while extended time horizons ensure lasting outcomes. Nature-based solutions often deliver superior ecological and economic returns, and social acceptance increases when rivers are restored as shared public goods. Urban success stories show that people reconnect with rivers once access and water quality improve, while rural examples demonstrate that productive landscapes and healthy rivers need not be incompatible. Together, these cases demonstrate that restoration is both feasible and beneficial when strategically designed. Ultimately, Europe's river restoration successes reveal that enduring recovery depends on aligning ecology, governance, finance, and society over the long term.

Effective large-scale river restoration in Europe demonstrates that ecological recovery is inseparable from robust governance and institutional coordination. Projects succeed when leadership is strong, roles are clearly defined, and cross-sector collaboration ensures coherence across water management, agriculture, energy, and conservation objectives. Early and continuous engagement with stakeholders—including landowners, local communities, farmers, and industry—not only builds trust but also manages conflicts and fosters shared ownership of outcomes. Long-term financing and investment, often leveraging a blend of public, private, and European-level funds, provide resilience against political cycles and budgetary fluctuations. Adaptive management, underpinned by systematic monitoring and data-driven feedback, allows interventions to evolve in response to emerging ecological or social conditions and ensures measurable progress. Restoration at basin or network scales, rather than isolated river stretches, maximizes ecological connectivity and the effectiveness of interventions. Nature-based solutions, such as re-meandering rivers and reconnecting floodplains, consistently prove more sustainable and cost-effective than purely engineered approaches. Aligning restoration with social and economic benefits—including recreation, tourism, flood risk reduction, and agricultural support—enhances public acceptance and long-term viability. Recognizing that river ecosystems recover over decades, project planning must adopt long-term horizons, resisting the pressure of short-term metrics that could compromise ecological integrity. Cross-scale policy alignment, harmonizing European directives, national strategies, and local implementation, mitigates legal and planning conflicts and enables coherent action. Finally, effective communication and education, highlighting visible environmental and societal benefits, consolidate public support and encourage continued investment in riverine restoration initiatives.

[14] https://www.visitvesterhavet.dk/vesterhavet/vesterhavsferie/skjern-aa-gdk602796
[15] https://www.rspb.org.uk/birds-and-wildlife/uplands/swindale-beck-a-river-restored

EU Nature Restoration Law: Riverine Implementation Challenges and Implications for Inland Waterways

The EU Nature Restoration Law (NRL) is a central component of the European Green Deal and aims to reverse the degradation of ecosystems across the European Union. A major focus of the law is river restoration, with binding targets to restore natural river functions, reconnect floodplains, improve ecological flows, and remove barriers that fragment river systems. One of the most ambitious objectives is to restore at least 25,000 kilometres of free-flowing rivers by 2030, making riverine ecosystems a key priority for implementation.

Implementing river restoration under the NRL presents significant challenges. Many European rivers have been heavily modified over decades through channelisation, dam construction, embankments, and river training works designed for flood protection, navigation, and hydropower. These interventions have disrupted sediment transport, blocked fish migration, and simplified river habitats. Reversing such alterations is technically complex, expensive, and often constrained by existing infrastructure and land-use patterns.

Another major challenge lies in balancing ecological restoration with competing water uses. Rivers serve multiple functions, including inland navigation, energy production, agricultural irrigation, and urban flood protection. Restoration measures such as barrier removal, re-meandering, or floodplain reconnection may conflict with these uses if not carefully designed. Achieving compatibility requires integrated planning approaches that consider ecological, economic, and safety objectives simultaneously.

Governance complexity further complicates implementation. Many river basins extend across administrative and national boundaries, resulting in fragmented responsibilities, differing regulatory frameworks, and uneven implementation capacity. Coordinating restoration measures across regions and countries requires strong river basin governance structures, long-term planning, and stable funding mechanisms.

Social and political acceptance is also critical. Local communities and stakeholders may perceive river restoration as a threat to flood safety, navigation reliability, or economic activities. Without early engagement and transparent communication, resistance can delay or weaken restoration efforts. Successful European river projects demonstrate that participatory planning and clear demonstration of benefits are essential for long-term support.

Experience from major European rivers such as the Rhine, Danube, Elbe, and Po illustrates recurring riverine challenges under the NRL. These include restoring floodplain connectivity while maintaining flood protection standards, removing obsolete structures without undermining navigation, managing sediment deficits caused by upstream dams, and ensuring sufficient ecological flows in regulated rivers. These cases show that river restoration is not a one-time intervention but a long-term, adaptive process integrated into river basin management.

River restoration under the NRL is highly relevant for inland waterways. Restored rivers are more resilient to climate change impacts such as floods and droughts, which improves the long-term reliability of navigation. Nature-based solutions can reduce sediment imbalances and lower dredging and maintenance needs. The NRL also promotes multifunctional waterways that combine transport, biodiversity conservation, recreation, and climate adaptation, aligning inland navigation with broader sustainability goals.

In addition, the Nature Restoration Law strengthens policy integration by linking river restoration with the Water Framework Directive, the Floods Directive, and EU transport policies such as TEN-T. This integrated approach encourages more resilient and future-proof inland waterway systems. Overall, the NRL represents a shift in European river management, showing that ecological restoration and inland navigation do not have to be opposing objectives. When well designed, river restoration enhances the environmental quality, resilience, and long-term economic value of Europe’s inland waterways.

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Table Executing on challenges

Challenge	**Duisburg (Rhine)**	**Rotterdam (Rhine–Meuse Delta)**	**Sevilla (Guadalquivir)**	**Orșova (Danube – Iron Gates)**	**Ports de Paris (Seine)**	**Dominant cross-cutting layers**
1. Definition of free-flowing rivers	Highly regulated industrial river; free-flowing defined at **regional scale**	Deltaic system; free-flowing framed as **functional connectivity**	Tidal river; free-flowing adapted to **estuarine dynamics**	Strongly fragmented; free-flowing mostly **upstream/downstream reference reaches**	Urban river; free-flowing defined as **ecological continuity within navigation**	Law misalignment (1), EU–local tension (6), human–ecological trade-offs (7)
2. Barriers & reference areas	Dense locks, port basins; limited reference reaches	Storm surge barriers, sluices; offshore reference areas	Navigation locks, port infrastructure; upstream references	Large hydropower dams (Iron Gates I & II); mountain tributaries as references	Weirs, embankments; peri-urban and upstream Seine as references	Physical fragmentation (2), funding gaps (4), data limits (5)
3. Network structure & connectivity	Strong longitudinal fragmentation, limited lateral links	High lateral complexity, disrupted longitudinal flow	Longitudinal and tidal connectivity altered	Severe longitudinal disconnection; fish migration critical	Moderate fragmentation; lateral floodplain loss	Barriers (2), conflicting actors (3), EU connectivity targets vs local needs (6)
4. Meta-ecosystem thinking	Sediment and habitat reconnection within industrial matrix	Delta sediment balance, biodiversity–safety nexus	Sediment, salinity, and biodiversity interactions	Basin-scale sediment, fish, and energy trade-offs	Urban metabolism, recreation, biodiversity	Integration of human & ecological systems (7), sectoral silos (1), data gaps (5)
5. Action prioritisation	Barrier mitigation, fish passages, side channels	Soft engineering, adaptive delta management	Lock operation optimisation, floodplain reconnection	Fish migration solutions, ecological flow regimes	Weir modification, green banks, side arms	Conflicting priorities (3), lack of sustainable funding (4), EU–local tension (6)
6. Stakeholder	Heavy industry, port	Port, municipalities, water	Port authority,	Energy sector, national	City, port authority, public users	Multiple actors (3), asymmetric

engagement	authority, NGOs	boards, citizens	city, agriculture	governments, NGOs		al power, local vs EU narratives (6)
7. Methods & legal conflicts	EU Water Framework Directive vs navigation	Flood safety law vs ecology	Navigation law vs ecological flows	Energy security vs biodiversity protection	Urban planning vs river restoration	Cross-sector law conflicts (1), governance fragmentation, adaptive capacity limits (5)

Implications for the EU

Shared definitions of free-flowing rivers across sectors are essential to enable coherent implementation of river restoration in regulated and urban contexts. Such definitions must be operational and legally applicable across water management, navigation, energy production, urban development, and nature conservation. A function-based understanding of free-flowing rivers, focusing on hydrological continuity, sediment transport, biological connectivity, and natural dynamics, allows for the recognition of different degrees of free-flowing condition rather than relying on a binary classification. This approach makes the concept applicable to heavily modified rivers while maintaining ecological ambition.

Connectivity indicators that can be applied at both local and European scales are critical for translating strategic objectives into practical action. A tiered indicator framework enables assessment, comparison, and prioritisation across spatial scales, with European-level indicators capturing overall river network continuity and local indicators reflecting site-specific ecological and functional performance. Standardisation of indicators supports comparability and accountability, while flexibility for local adaptation ensures relevance to diverse hydrological, ecological, and socio-economic contexts.

Blended finance models that combine European funding instruments with national, municipal, and private investments are necessary to establish long-term and resilient financing structures for river restoration. Linking restoration outcomes to co-benefits such as flood protection, climate adaptation, risk reduction, and improvements in urban quality of life increases the attractiveness of investment for non-environmental actors. In this way, financing becomes a strategic enabler of integrated river management rather than a constraint.

Co-design between ports, cities, and nature authorities embeds river restoration within collaborative planning and design processes from the outset. Early and sustained involvement of port authorities, municipalities, water managers, and civil society supports the development of multifunctional solutions that reconcile navigation, ecological restoration, and urban use. Co-design strengthens legitimacy, reduces conflict, and improves the feasibility of implementation in complex institutional environments.

Adaptive governance approaches that explicitly accept uncertainty and learning are fundamental in dynamic river systems affected by climate change and long-term human modification. Phased interventions, continuous monitoring, and iterative adjustment allow management strategies to evolve over time as knowledge improves. Recognising learning-by-doing as a legitimate governance approach shifts the emphasis from rigid compliance toward responsiveness and resilience.

Effective restoration of free-flowing rivers requires a shift from sectoral and fragmented governance toward integrative and cross-sector coordination. Shared definitions and connectivity indicators play a central role in aligning European policy objectives with local implementation, helping to reduce tensions between strategic mandates and place-based realities. Governance frameworks must institutionalise flexibility by formally accommodating uncertainty, experimentation, monitoring, and iterative adjustment rather than prescribing fixed end-states.

Co-design processes rebalance power and responsibility among actors, improving stakeholder ownership and enhancing the legitimacy of restoration decisions. At the same time, financial governance emerges as a strategic tool, with blended finance models enabling long-term investment and encouraging participation from sectors traditionally outside environmental policy. Together, these elements redefine governance not merely as regulation, but as an enabling, coordinating, and learning-oriented system.

Restoring free-flowing rivers in regulated and urban contexts depends on governance systems that are integrative, multi-level, adaptive, and financially enabling, rather than sector-specific and rule-bound.

It is by deploying the EU's infrastructural powers through revolutionary changes to something as political as the planning processes of the member states that the EU hope to bring forward the EU integration project and perhaps even ensure good environmental status returns to most of Europe's inland and coastal waters. The jury is still out whether this will lead to ecological state, but that is perhaps also less important, at this stage.

Rivers have held deep **philosophical and metaphorical significance** across cultures, literature, and thought, functioning simultaneously as symbols of **time, change, continuity, and connectivity**. At a fundamental level, a river embodies **flow and impermanence**: its waters are never static, reminding us that existence itself is dynamic, shaped by forces of movement, erosion, and transformation. Philosophers from Heraclitus onward have drawn on rivers to illustrate the nature of reality, famously noting that "one cannot step into the same river twice," highlighting the interplay between constancy and change, and the inseparability of observer and phenomenon.

Metaphorically, rivers also signify **paths, journeys, and thresholds**, connecting distant lands, communities, and ecosystems. They represent networks of interdependence, where upstream actions affect downstream outcomes, evoking ethical and ecological responsibility. In human life and political thought, rivers often stand for **lifelines and arteries**, carrying sustenance, trade, and culture, while simultaneously marking boundaries or defining territories. The river's duality—as a source of nourishment and a potential threat through floods—mirrors the ambivalent character of power, society, and nature.

In contemporary ecological and policy discourse, the river metaphor extends to **systems thinking**: just as a river integrates multiple tributaries and landscapes, complex human and environmental systems require attention to flows, feedbacks, and connectivity. In infrastructure, logistics, and transport policy, rivers exemplify the **interlinked nature of technology, governance, and sustainability**, reminding policymakers that interventions in one part of a network reverberate throughout.

Philosophically, rivers also invite reflection on **temporal continuity and human stewardship**. They carry the sediment of the past while shaping futures, embodying memory, history, and legacy. Their inexorable flow encourages humility and attentiveness: to engage responsibly with rivers is to engage responsibly with change itself. As metaphors, rivers thus operate on multiple registers—ethical, political, ecological, and existential—providing a rich lens through which to interpret both human society and the natural world.

The Danube flows not merely as water through Central and Southeastern Europe; it flows as a **thread of continuity connecting the past, present, and future of the continent**. From the Black Forest to the Black Sea, it carries the sediment of centuries, the layers of history, culture, and commerce that have shaped the territories along its banks. In its currents, one can read the **interdependence of European societies**: what happens upstream reverberates downstream, reminding policymakers that decisions in one region ripple across borders, economies, and ecosystems. The river's meanders mirror the complexity of Europe itself—diverse, intertwined, and resilient—while its inexorable forward movement evokes the inevitability of change and the necessity of adaptation.

Just as the Danube integrates tributaries from multiple lands, Europe's inland waterways demand **coordinated governance, shared responsibility, and vision**. Investing in the Danube's navigability, digitalisation, and sustainability is not simply an infrastructure task; it is an ethical and strategic engagement with **the flow of European connectivity, trade, and environmental stewardship**. In this sense, the river becomes a **living metaphor for Europe's ambition to harmonise integration with diversity**, efficiency with sustainability, and national prerogatives with collective responsibility. Each lock, port, and corridor along its length is both a practical intervention and a symbolic acknowledgment that the continent's prosperity, mobility, and ecological balance move together, as inevitably and ceaselessly as the waters of the Danube itself.

Fare Una Bella Passegiata

Building on this reappraisal of urbanism, **best practices in riverfront and waterfront development** offer concrete evidence of how cities can repair past mismanagement and reshape their relationship with rivers:

Well-designed riverfronts restore **physical and visual access to water**, transforming formerly industrial or infrastructural edges into inclusive public spaces that reconnect citizens with the river. They prioritize **flood-resilient design**, allowing seasonal inundation through terraces, parks, and wetlands rather than resisting water with rigid barriers. Successful waterfronts integrate **mixed uses**, combining housing, culture, recreation, and light economic activity without displacing ecological functions. They embed **nature-based solutions**, such as riparian vegetation and soft banks, which improve biodiversity while enhancing urban microclimates. High-quality riverfronts function as **active mobility corridors**, supporting walking, cycling, and water-based transport that reduce car dependency. They act as **social condensers**, fostering everyday interaction, cultural events, and informal gathering across social groups. Economically, regenerated waterfronts catalyze **place-based development**, attracting investment and tourism while increasing land and property values. Best practice avoids enclosure by ensuring **long-term public ownership or access**, preventing exclusive privatization of the river edge. Riverfront projects increasingly serve as **climate adaptation infrastructures**, mitigating heat, managing floods, and improving water quality. Ultimately, successful waterfronts reframe rivers as **structural elements of urban identity**, reshaping how cities perceive value, resilience, and livability

The development of river waterfronts should be guided by principles that ensure environmental sustainability, social inclusivity, and long-term resilience. A primary principle is the protection of the river's natural ecology. Development activities must preserve biodiversity, maintain natural flow regimes, protect floodplains, and incorporate native vegetation to minimize ecological disturbance. Pollution control and effective wastewater management are essential to safeguard river health.

Flood management and public safety form another critical consideration in river waterfront development. Planning must respect natural flood zones and avoid permanent structures in high-risk areas. Where development is permitted, flood-resilient design measures such as elevated structures and permeable surfaces should be adopted. Riverfront planning should be integrated with broader flood control and disaster management strategies.

Ensuring public access and social inclusivity is fundamental to successful riverfront development. Waterfronts should function as public spaces that provide pedestrian pathways, cycling tracks, and recreational areas. Designs must accommodate people of all ages and abilities, thereby promoting equitable use of riverfront spaces.

Cultural and heritage conservation plays an important role in waterfront development, particularly in regions where rivers hold historical or religious significance. Existing cultural assets should be preserved, and new development should reflect local identity and traditions while avoiding excessive commercialization of culturally sensitive areas.

Riverfront development should be integrated with overall urban planning frameworks. This includes alignment with transportation networks, land-use plans, and infrastructure systems. Mixed-use development can enhance vibrancy while ensuring coordinated action among urban planning, environmental, and water management agencies.

Improvement of water quality is a key objective of riverfront projects. This requires effective treatment of sewage, control of industrial effluents, and management of solid waste to prevent contamination of river systems. River rejuvenation and continuous monitoring are essential for sustaining water quality improvements.

Climate-responsive and resilient design principles are increasingly important in the context of climate change. Riverfront developments should anticipate extreme events such as floods and droughts and adopt adaptive strategies that allow flexibility and long-term resilience.

Community participation is vital for the success of river waterfront projects. Local communities and stakeholders should be actively involved in planning and decision-making processes. Development should respect and support the livelihoods of river-dependent populations such as fisherfolk and informal vendors.

Economic viability must be balanced with environmental and social objectives. Riverfront development should generate sustainable economic opportunities through eco-tourism, recreation, and local employment while avoiding environmentally harmful practices.

Finally, effective governance, long-term management, and regular maintenance are essential to ensure the continued success of river waterfront developments. Clear institutional responsibilities, continuous monitoring of river health, and adaptive management strategies are necessary for sustainable outcomes.

Western Europe

The early redevelopment of the Thames Docklands in London is often cited as a problematic case due to its market-driven, property-led approach. Initially, the focus was primarily on commercial real estate, leading to a lack of public space, social inequality, and limited environmental restoration. The absence of a cohesive master plan meant that long-term social, environmental, and public access issues needed to be addressed later through corrective public initiatives. In contrast, the Thames Riverfront Regeneration, which includes areas such as the South Bank and King's Cross, serves as a prime example of a more balanced and inclusive approach. This regeneration emphasized mixed-use spaces, public access, sustainable transport, flood resilience, and eco-friendly design. Public art, green spaces, and pedestrianized areas have enhanced the social and cultural value of the riverfront, turning it into a key urban amenity.

Northern Europe

In Northern Europe, the early phases of redevelopment in the Frihamnen Port Area in Gothenburg suffered from over-commercialization and privatized waterfronts that restricted public access. The heavy industrial legacy and limited integration with the surrounding city left the area underutilized and lacked public engagement. This approach was in stark contrast to the redevelopment of Copenhagen Harbour, which serves as a gold standard for sustainable urban waterfront planning. The Copenhagen project focused on the integration of residential, cultural, and recreational spaces, with an emphasis on climate resilience, clean energy, and ecological restoration. The waterfront now hosts public swimming areas, cycle paths, and extensive green spaces, promoting high levels of public accessibility. Green infrastructure, such as tidal wetlands and biofiltration systems, supports water quality and biodiversity.

Central Europe

The Elbe River Banks in Dresden, Germany, represent a failure in waterfront development. Historically, the riverbanks were heavily industrialized, with rigid flood defenses and little public engagement. The area became polluted, and access to the river was restricted, severing the connection between the river and the urban environment. In contrast, the Rhine Riverfront in Cologne represents an exemplary transformation. The project focused on pedestrianization, ecological restoration, and mixed-use development while ensuring flood protection. Extensive green spaces, cultural landmarks, and public squares now line the river, and the area hosts regular events and activities, turning it into a vibrant and accessible urban zone.

Mediterranean Europe

The Kifissos River Channelization in Athens stands as a significant failure in urban planning. The river was transformed into a concrete drainage system, eliminating its ecological functions and severing the physical and visual connection between the river and the city. Public access was also limited, and the river became an urban barrier. In stark contrast, the Besòs River Regeneration in Barcelona is a model of ecological renewal and public engagement. The transformation of the Besòs River included restoring natural floodplains, planting native species, and improving water quality through constructed wetlands. Today, the area is a vibrant urban district with recreational spaces, cycling paths, and parks that link the city to the coast while prioritizing sustainability.

Figure Water flowning on the Arno. What do you want ? What is it worth ?

Baltic States

In Riga, Latvia, the Daugava River Industrial Waterfront has suffered from a legacy of Soviet-era industrialization, with the riverbanks remaining heavily polluted and access restricted. The waterfront was disconnected from the city for many years, and public engagement was minimal. This is in stark contrast to the Tallinn Waterfront Redevelopment in Estonia, which has taken a slow and incremental approach to regeneration. The redevelopment process has integrated public parks, cultural facilities, and residential developments, while simultaneously restoring ecological habitats and providing public access to the water. The urban strategy in Tallinn has emphasized environmental protection, green mobility, and community involvement, reflecting a holistic approach to waterfront development.

Balkans

The Belgrade Waterfront Project in Serbia has been widely criticized for its top-down, speculative development model. The project prioritized private development at the expense of public land and had limited provisions for environmental sustainability or public access. Additionally, the lack of community consultation led to contested urban outcomes, with the plan disregarding flood resilience and ecological concerns. This contrasts with the Ljubljana Riverfront Redevelopment in Slovenia, which has been hailed as a success due to its people-centered, environmentally conscious design. The redevelopment of the Ljubljana Riverfront integrated public spaces, pedestrian walkways, and green infrastructure, while also enhancing flood resilience. The project revitalized the city center and fostered a social connection to the river.

Comparative Analysis Across European Riverfront Developments

A comparative examination of best and worst riverfront development cases across Europe reveals clear distinctions in how cities have addressed physical, visual, social, ecological, and economic relationships with water. Successful waterfront projects consistently improve both physical and visual access to the river, transforming formerly industrial or infrastructural edges into inclusive public spaces that reconnect citizens with the water. In contrast, unsuccessful developments tend to maintain barriers in the form of highways, flood walls, private developments, or channelized embankments, which perpetuate spatial and perceptual disconnection between the city and the river.

Best-practice waterfronts prioritize flood-resilient and adaptive design strategies. Rather than resisting water through rigid structural barriers, these projects accommodate seasonal inundation through terraced landscapes, floodable parks, wetlands, and multifunctional open spaces. This approach not only enhances safety but also restores natural hydrological processes and reduces long-term maintenance costs. Worst-case examples, by contrast, rely heavily on hard engineering solutions that control water at the expense of ecological function and urban experience.

Successful riverfronts integrate mixed uses in a balanced manner, combining housing, cultural institutions, recreation, and small-scale economic activities without displacing ecological systems. These developments avoid mono-functional zoning and instead promote continuous urban life throughout the day and across seasons. In weaker cases, single-use developments, often dominated by luxury housing, office complexes, or transport infrastructure, result in fragmented urban spaces with limited public benefit.

Nature-based solutions form a defining characteristic of high-quality waterfront regeneration. The incorporation of riparian vegetation, soft riverbanks, constructed wetlands, and green corridors enhances biodiversity, improves water quality, and contributes to more comfortable urban microclimates. In contrast, heavily engineered river edges characterized by concrete embankments and channelization eliminate ecological capacity and exacerbate urban heat and runoff.

Across leading European examples, riverfronts function as active mobility corridors that prioritize walking, cycling, and water-based transport. These projects reduce car dependency by integrating riverfront paths with citywide mobility networks, thereby reinforcing the role of the river as a linear public space. Poorer developments often prioritize vehicular movement or isolate riverfront paths from broader transport systems, limiting everyday use.

Socially, best-case riverfronts act as urban condensers that support informal gathering, everyday leisure, and programmed cultural events across diverse social groups. By providing accessible, non-commercial public spaces, these waterfronts foster social mixing and civic identity. In contrast, privatized or securitized waterfronts restrict spontaneous use and reinforce socio-spatial exclusion.

From an economic perspective, regenerated riverfronts frequently catalyze place-based development by attracting investment, tourism, and employment while increasing surrounding land and property values. However, successful cases manage this economic uplift through planning controls, public ownership, and phased development, ensuring that economic benefits do not undermine public access or ecological resilience. Worst-case examples often prioritize short-term real estate gains, resulting in exclusive developments and loss of public river access.

A defining feature of best practice is the protection of long-term public ownership or guaranteed public access to the river edge. By avoiding enclosure and privatization, successful projects preserve the riverfront as a shared urban asset. Conversely, developments that transfer control of riverfront land to private interests significantly weaken public value and long-term adaptability.

Increasingly, European riverfront projects function as critical climate adaptation infrastructures. They mitigate urban heat, manage flood risks, improve water quality, and enhance resilience to climate uncertainty. These multifunctional landscapes demonstrate a shift from viewing rivers as engineering problems to recognizing them as environmental and social assets.

Ultimately, the most successful riverfront developments reframe rivers as structural elements of urban identity. They reshape how cities understand value, resilience, and livability by positioning the river not as a boundary or utility corridor, but as a central, living component of urban form, culture, and everyday life.

Summary

Restoring European rivers has become a critical environmental and socio-urban challenge, underscored by policies such as the Nature Restoration Law. Despite decades of technical knowledge, ecological recovery remains slow due to governance, financing, stakeholder conflicts, and socio-ecological trade-offs rather than purely ecological limitations. Key barriers include fragmented legislation, river connectivity loss, weak monitoring, misaligned multi-level governance, and insufficient long-term financing. Successful restoration requires adaptive, governance-driven approaches that integrate policy, stakeholder coordination, and sustained learning. Large-scale projects demonstrate that basin-wide planning, rather than isolated interventions, maximizes ecological connectivity and resilience. Urban river restoration, exemplified by the Emscher in Germany, Paris, Copenhagen, and Munich, shows that integrating rivers into public life improves water quality, biodiversity, and social well-being. Rural projects, like the Skjern River in Denmark and Swindale Beck in the UK, highlight the importance of working with natural processes, compensating stakeholders, and allowing long-term ecological recovery. Strong governance, clear leadership, cross-sector coordination, and multi-year financing underpin project success across contexts.

Adaptive management, monitoring, and iterative learning enable responsive interventions and accountability. Nature-based solutions, including re-meandering, floodplain reconnection, and riparian restoration, are cost-effective and ecologically beneficial. Integrating social and economic functions—recreation, tourism, and compatible agriculture—enhances public support and sustains restoration efforts. Urbanism historically mismanaged rivers, treating them as infrastructure corridors, which fragmented governance and excluded citizens from waterfront access. Contemporary restoration reframes rivers as structural elements of urban form, identity, and resilience, correcting past urban planning blind spots. Exemplary riverfronts in Rotterdam, Paris, Vienna, Riga, Belgrade, and Porto show that multifunctional, flood-resilient, publicly accessible waterfronts reinforce ecological, social, and economic gains. Looking ahead, European river restoration requires long-term vision, policy coherence across scales, sustained financing, stakeholder co-ownership, and integration into urban and rural development, positioning rivers as central to both environmental sustainability and territorial identity.

Who owns the rivers? Legally speaking, rivers are rarely the private property of any single individual; yet, as Eurocities emphasizes, they become vessels of communal responsibility, social memory, and urban identity. [16]One might ask rhetorically, who truly claims the waters that flow through our cities: the municipalities that regulate them, or the communities that nurture them? In Braga, Portugal, local initiatives have experimented with decentralized stewardship, granting schools, families, and civic groups the care of particular stretches of the river. This approach transforms the river into a living text, a metaphorical mirror reflecting the collective consciousness and civic ethics of urban society. Rivers are, in this sense, simultaneously natural phenomena and social constructs, their currents carrying both ecological and cultural capital. The juxtaposition between formal legal ownership and practical communal care illuminates the tension between state authority and civic agency. Across European cities, frameworks established by municipal authorities provide resources and guidance, but the day-to-day protection, restoration, and celebration of the rivers emerge from the communities themselves. Thus, ownership here is less a question of title deeds and more a question of engagement, responsibility, and

[16] https://eurocities.eu/stories/who-owns-the-rivers/

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collective imagination, revealing that rivers belong as much to those who act upon them as to the laws that nominally govern them.

Riverine sustainability and waterfront development are closely interconnected, as the long-term success of waterfront projects depends on the ecological health and hydrological integrity of river systems. Sustainable riverfront development recognizes rivers as dynamic living systems rather than static edges to be controlled or enclosed. It prioritizes maintaining natural flow regimes, floodplains, and riparian ecosystems while accommodating urban uses. Waterfront projects increasingly adopt adaptive, flood-resilient design approaches that allow seasonal inundation through terraces, parks, and wetlands instead of relying solely on hard engineering. Nature-based solutions such as soft banks, riparian vegetation, and constructed wetlands improve biodiversity, water quality, and urban microclimates. Physical and visual public access to water is central to riverine sustainability, as connected communities are more likely to value and protect river systems. For inland waterways, sustainable development enhances navigability while reducing conflicts between transport, ecology, and recreation. Integrated planning ensures that housing, culture, mobility, and light economic activities coexist without degrading river functions. Well-managed waterfronts support climate adaptation by mitigating floods, reducing heat stress, and improving resilience to extreme events. Ultimately, riverine sustainability reframes inland waterways as multifunctional infrastructures that support ecological health, urban livability, and long-term economic vitality.

The EU's Coastal communities

We recall that the European Union has will advance its Maritime Power through the adoption of an EU Port Strategy[17] and the revision of the EU Maritime Security Strategy during 2026[18]. While these initiatives strengthen the Union's external connectivity and maritime situational awareness, they remain structurally incomplete if treated in isolation from the territories and communities that sustain them. We therefore argue that this strategic sequence should be complemented by a dedicated strategy for the EU's coastal communities, addressing socio-economic resilience, port–city relations, skills, and climate adaptation, alongside a comprehensive strategy for Europe's inland waterways. Such an inland waterways strategy would reconnect maritime gateways with their hinterlands, integrate rivers and canals into the Union's transport, energy, and security architectures, and provide a coherent framework for governance, environmental stewardship, and intermodality. Taken together, these two additional strategies would bridge the maritime–continental divide in EU policy-making, ensuring that ports, coasts, and rivers are treated as a continuous socio-economic and geostrategic system.

This does require understanding and better implementation for both the coastal communities issues and those of the Inland Waterways. Rather than treating these domains as separate policy silos, their interdependencies in logistics, labour markets, environmental governance, and regional development should be explicitly recognised. Coastal communities often function as gateways between maritime and inland transport systems, while inland waterways extend the economic and strategic reach of ports deep into the European hinterland. Strengthening implementation therefore entails aligning governance levels, investment instruments, and regulatory approaches across both spaces, ensuring that decarbonisation, resilience, and territorial cohesion objectives are pursued in a coordinated manner.

Approximately 40% of the EU's population lives in coastal regions. This equates to around 200 million people. The EU's coastline is estimated to be 66,000 kilometers (41,000 miles) long. This extensive coastline borders the Atlantic Ocean, the Mediterranean Sea, the Black Sea, and the Baltic Sea[19]. Several policies are dedicated to protecting and promoting the sustainable development of these coastal regions. Key among them is the Marine Strategy Framework Directive (MSFD), which aims to achieve a good environmental status of EU marine waters. The Integrated Maritime Policy (IMP) is another significant framework that coordinates various sea-related policies to foster sustainable development and growth in maritime regions.

[17] https://www.europarl.europa.eu/doceo/document/TA-9-2024-0025_EN.html
[18] https://oceans-and-fisheries.ec.europa.eu/ocean/blue-economy/other-sectors/maritime-security-strategy_en
[19] https://en.wikipedia.org/wiki/Geography_of_the_European_Union

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Europe is home to a vast number of islands, with estimates varying based on definitions and counting methods. Some sources suggest there are over 221,000 islands in Sweden alone, making it the country with the most islands in Europe. When considering all European countries, the number of islands could easily exceed 300,000. European islands are home to approximately 20.5 million inhabitants, which is about 4.6% of the EU's total population. The population distribution varies significantly across different islands, with some like Ireland having millions of residents, while others are much smaller. Regarding political and maritime interests, European islands are recognized as distinct territories with specific challenges due to their insularity and remoteness.

The Treaty on the Functioning of the European Union (TFEU) includes provisions for islands, particularly in Articles 174 and 349, which establish a legal basis for special measures. Islands are often grouped with mountain regions and sparsely populated areas under the EU's Cohesion Policy. Additionally, the European Strategy for Outermost Regions provides tailored support for the most remote regions, including many European islands[20]. The European Parliament is exploring an enhanced manner of addressing the islanders' situation from within the Cohesion Fund aimed at addressing issues such as connectivity, quality of life, sustainability, public services, and integrated development[21].

The European Union also has frameworks for Integrated Maritime Policy aand Coastal management. They aim to coordinate policies for marine and coastal areas, balancing economic, environmental and social goals. These integrated plans cover marine spatial planning, coastal erosion and climate adaptation, biodiversity and ecosystem protection, maritime transport and ports, tourism and economic development in coastal regions. The funding sources are the European Maritime, Fisheries and Aquaculture (EMFAF), LIFE Programme, and The European Regional Development Fund (ERDF) as well as Horizon Europe.

The Interconnectedness of Oceans, Coastal Communities, and River Systems

The linkages between oceans, coastal communities, and river systems are both fundamental and systemic. Together, they form a single land–river–coast–ocean continuum, meaning that environmental, economic, and social processes in one segment directly influence the others.

Rivers serve as the primary conduits through which freshwater, sediments, nutrients, and pollutants move from inland areas to coastal and marine environments. Sediment transported by rivers sustains deltas, beaches, and wetlands, which protect coastal communities from erosion and storm surges. Alterations to river flows—caused by dams, channelisation, or sand extraction—reduce sediment supply to the coast, accelerating erosion and increasing flood risk. Nutrients carried by rivers underpin coastal and marine food webs; however, excess nutrients from agriculture and wastewater discharge can trigger eutrophication, harmful algal blooms, and oxygen depletion, compromising fisheries and ecosystem health.

Coastal communities are intimately dependent on river systems for drinking water, agriculture, fisheries, transport, and tourism, while rivers link inland economies to coastal ports and global trade routes. Historically, many major EU ports and coastal cities developed at river mouths, capitalizing on access to both inland markets and maritime routes. Conversely, economic activities upstream—such as industry, agriculture, and urbanisation—directly shape the environmental quality and economic sustainability of downstream coastal livelihoods, particularly in sectors like fisheries, aquaculture, and tourism.

Climate change further intensifies these interactions. Rising sea levels increase saltwater intrusion into river deltas and estuaries, threatening freshwater supplies, agricultural productivity, and ecosystems. Extreme rainfall events elevate river discharge and flooding, which, when combined with storm surges, amplify risks for coastal communities. Conversely, healthy river floodplains, wetlands, and estuaries function as natural buffers, absorbing floodwaters and mitigating downstream impacts.

Ecologically, rivers, estuaries, and coastal waters are deeply interconnected. Many fish species migrate between freshwater and marine environments, relying on free-flowing rivers and intact estuaries for spawning and nursery

[20] https://ec.europa.eu/regional_policy/policy/themes/outermost-regions/strategy_en

[21] https://www.europarl.europa.eu/RegData/etudes/STUD/2021/652239/IPOL_STU%282021%29652239_EN.pdf

habitats. Wetlands and estuaries provide critical ecosystem services by filtering pollutants, sequestering carbon, and supporting high biodiversity, benefiting both inland and coastal populations.

Effective management of coastal communities thus requires integrated governance across river basins, coastal zones, and marine areas. Policies addressing rivers—such as water quality management and flood control—have direct consequences for coastal resilience and marine ecosystems. Fragmented governance that treats rivers, coasts, and seas in isolation often produces unintended environmental and socio-economic impacts. In contrast, integrated land–sea planning fosters long-term sustainability and resilience.

Strategic Implications

For coastal communities, a key implication is that resilience cannot be achieved without maintaining healthy river systems, and marine protection efforts will falter if upstream pressures remain unaddressed. Integrated "source-to-sea" approaches linking river basin management with coastal and marine planning are therefore essential for climate adaptation, biodiversity protection, and sustainable economic development.

Strengthening the connection between river systems and coastal communities requires a coordinated source-to-sea approach. River basin management should explicitly consider downstream coastal and marine impacts, including sediment delivery, water quality, and flood risk. Coastal planning must incorporate river flow and flood scenarios, particularly in deltas and estuaries. Nature-based solutions—such as restored floodplains, wetlands, and estuaries—should be prioritised to reduce risk and enhance ecosystem services. Governance frameworks should align river basin authorities with coastal planners through joint strategies and shared data. EU funding mechanisms should incentivise integrated river-to-coast projects rather than isolated interventions. Common indicators should link upstream management actions to downstream coastal outcomes. Collectively, these measures translate coordination into tangible environmental, social, and economic benefits.

Coastal communities

Coastal communities in the European Union face a set of interconnected strategic challenges that stem from high population concentration, environmental vulnerability, and economic dependence on coastal and marine resources. It is estimated that around **150–200 million people**, or roughly **40 % of the EU population**, live within 50 km of the coastline, making coastal zones critical for social cohesion, economic performance, and territorial stability (European Environment Agency [EEA], 2019; European Commission, 2021).

One of the most significant challenges is **climate change**, particularly sea-level rise, coastal flooding, and the increasing frequency of extreme weather events. These phenomena threaten housing, transport infrastructure, ports, and energy systems, while also increasing insurance costs and long-term public expenditure for adaptation and protection (EEA, 2020). Low-lying areas, deltas, islands, and outermost regions are especially vulnerable, raising concerns about displacement and long-term habitability in certain coastal zones.

Closely linked to climate impacts is the problem of **coastal erosion and ecosystem degradation**. Many European coastlines are experiencing accelerated erosion due to both natural processes and human activities such as coastal construction, river regulation, and hard engineering solutions that disrupt sediment flows (EEA, 2019). The loss of natural buffers like dunes, wetlands, and salt marshes reduces coastal resilience and increases exposure to storm surges, while also undermining biodiversity and ecosystem services essential for fisheries and tourism.

Population pressure and urbanisation present another strategic challenge. Coastal regions attract residents, tourists, and economic activities, leading to land-use conflicts, housing shortages, and rising property prices that can marginalise local populations. Urban sprawl and infrastructure development contribute to habitat loss, landscape fragmentation, and increased pollution loads in coastal waters (European Commission, 2021). Seasonal tourism intensifies these pressures, particularly in Mediterranean regions.

Environmental pressures are compounded by **marine and coastal pollution**, including nutrient runoff, wastewater discharges, marine litter, and emissions from shipping and port activities. These pressures affect water quality, human health, and marine ecosystems, leading to problems such as eutrophication and declining fish stocks (EEA, 2022). The economic consequences are significant for fisheries, aquaculture, and coastal tourism, which depend on clean and healthy marine environments.

From a socio-economic perspective, coastal communities face **structural economic vulnerabilities**. Traditional sectors such as small-scale fisheries and shipbuilding are in decline in many regions, while tourism-dependent economies are highly sensitive to climate impacts, environmental degradation, and external shocks. This creates challenges for employment stability, skills development, and demographic balance, particularly in remote coastal and island communities (European Commission, 2020).

Finally, **governance and spatial planning** represent a major strategic challenge. Coastal zones require integrated management across administrative boundaries and policy sectors, including climate adaptation, biodiversity protection, transport, energy, and economic development. Fragmented governance and short-term planning often hinder effective responses, despite EU-level frameworks such as Integrated Coastal Zone Management and Maritime Spatial Planning (European Commission, 2014).

In strategic terms, these challenges affect not only local communities but also EU priorities related to climate resilience, economic competitiveness, territorial cohesion, and environmental sustainability. Addressing them requires long-term, coordinated policies that combine climate adaptation, nature-based solutions, and inclusive economic development across Europe’s coastal regions.

Executing

EU action for coastal communities is executed according to several core principles. First, **subsidiarity and multilevel governance** apply: the EU sets strategic direction and funding frameworks, while Member States, regions, and municipalities design and implement concrete measures. Second, **policy integration** is essential, meaning coastal challenges are addressed across climate, environment, transport, energy, fisheries, regional development, and research policies rather than through a single instrument. Third, **place-based and evidence-driven approaches** are used, tailoring interventions to different sea basins (Baltic, Mediterranean, Atlantic, Black Sea, North Sea) and local risk profiles. Fourth, the EU increasingly applies **climate resilience and “do no significant harm” principles**, ensuring investments are future-proof and aligned with Green Deal objectives. Finally, **co-financing and leverage** are central, with EU funds designed to crowd in national, regional, and private investment.

The first area of effort is **climate adaptation and coastal resilience**. This includes flood protection, erosion control, nature-based solutions (wetlands, dunes, salt marshes), climate-resilient infrastructure, and risk mapping. Execution occurs through cohesion policy funds, LIFE projects, and technical guidance under the EU Climate Adaptation Strategy.

The second area is **environmental protection and ecosystem restoration**. Efforts focus on improving water quality, restoring coastal and marine habitats, reducing pollution and marine litter, and implementing the Marine Strategy Framework Directive and Natura 2000 at sea. These actions are critical to sustaining fisheries, tourism, and natural coastal defenses.

A third area is **sustainable coastal and maritime economies**. The EU supports diversification beyond seasonal tourism, including sustainable fisheries and aquaculture, offshore renewable energy, port decarbonisation, blue innovation, and coastal SMEs. This is largely executed through the European Maritime, Fisheries and Aquaculture Fund (EMFAF) and Horizon Europe.

The fourth area of effort concerns **territorial cohesion and social resilience**. Investments target transport connectivity, public services, skills development, housing affordability, and demographic challenges in islands, remote coastal areas, and outermost regions. Cohesion Policy instruments and social funds play a central role here.

The fifth area is **governance, planning, and data**. This includes Integrated Coastal Zone Management, Maritime Spatial Planning, cross-border cooperation between coastal regions, and improved coastal data, modelling, and early-warning systems.

The intended impact is to **reduce climate and disaster risk for coastal populations**, limiting economic losses and displacement. Environmentally, the EU aims to **restore and maintain healthy coastal ecosystems** that provide protection, food, and livelihoods. Economically, the objective is **resilient and diversified coastal economies** that generate stable employment while respecting ecological limits. Socially, EU action seeks to **maintain liveable, accessible, and inclusive coastal communities**, particularly in vulnerable regions. Strategically, these impacts contribute to EU climate neutrality, food security, energy security, and territorial cohesion.

Typical KPIs include reductions in **population and assets exposed to coastal flooding and erosion**, measured through risk assessments and hazard maps. Environmental KPIs track **coastal water quality**, extent of restored habitats, and biodiversity status under EU directives. Economic KPIs include **employment and value added in sustainable blue economy sectors**, diversification indices in tourism-dependent regions, and investment leveraged. Social KPIs measure **accessibility of services, transport connectivity, and demographic stability** in coastal and island regions. Governance KPIs assess **coverage and quality of maritime spatial plans**, cross-border cooperation projects, and uptake of nature-based solutions.

The EU does not use a single "coastal budget"; instead, funding is pooled across the **Multiannual Financial Framework (MFF)**. The largest source is **Cohesion Policy funding**, which supports coastal adaptation, infrastructure, and regional development through the European Regional Development Fund and the Cohesion Fund. The **European Maritime, Fisheries and Aquaculture Fund (EMFAF)** finances sustainable fisheries, aquaculture, coastal community diversification, and marine protection. The **LIFE Programme** supports environmental and climate adaptation projects, particularly nature-based solutions. **Horizon Europe** funds research, innovation, and demonstration projects relevant to coastal resilience and the blue economy. Additional support comes from **Connecting Europe Facility**, **InvestEU**, and the **Recovery and Resilience Facility**, especially for green and climate-resilient investments.

In aggregate, **tens of billions of euros per MFF period** are relevant to coastal communities, though allocations depend on national programming choices and regional priorities rather than earmarked EU-wide coastal envelopes.

Northern Europe (North Sea – Netherlands, Denmark, Germany).

State of affairs: High exposure of densely populated coastal zones to flooding and erosion, with strong governance capacity but rising climate risk. Intended target: Reduce population and asset exposure while maintaining economic activity. EU measures focus on large-scale flood protection, nature-based solutions (salt marshes, dunes), and integrated maritime–terrestrial planning. KPIs include reduced flood-risk exposure, increased restored coastal habitats, full coverage of maritime spatial plans, and stable or growing employment in offshore wind and port decarbonisation.

Southern Europe (Mediterranean – Italy, Spain, Greece).

State of affairs: Intense tourism pressure, water pollution, erosion, and seasonal economies vulnerable to climate impacts. Intended target: Improve environmental quality and diversify coastal economies. EU measures support wastewater treatment, habitat restoration, sustainable tourism models, and climate adaptation in urban coasts. KPIs track improved coastal water quality, restored seagrass and wetlands, diversification of coastal employment beyond tourism, and improved accessibility of services for permanent residents.

Eastern Europe (Baltic and Black Sea – Poland, Romania, Bulgaria).

State of affairs: Growing erosion, pollution from river basins, weaker institutional capacity, and underinvestment in adaptation. Intended target: Strengthen resilience and governance while improving environmental status. EU measures prioritise river–coast integration, flood risk management, port modernisation, and biodiversity protection. KPIs include reduced erosion hotspots, improved biodiversity status, increased uptake of maritime spatial planning, and higher EU investment leveraged in coastal infrastructure.

Western Europe (Atlantic – France, Ireland, Portugal).

State of affairs: Exposed Atlantic coastlines with strong wave action, rural coastal depopulation, and climate-sensitive fisheries. Intended target: Enhance coastal resilience and sustain viable coastal communities. EU measures support nature-based coastal protection, fisheries transition, blue innovation, and connectivity for remote areas. KPIs measure reduced exposure to storm damage, stable coastal populations, growth in sustainable blue economy sectors, and expanded cross-border cooperation projects.

Together, these examples show how **common EU KPIs** are applied flexibly across regions, linking environmental protection, economic resilience, social cohesion, and governance quality to deliver measurable impact in diverse coastal contexts.

A future EU strategy for coastal communities should build on the Union's established model of setting common objectives, mainstreaming them across sectoral policies, mobilising shared financial instruments, and requiring measurable outcomes, while implementation remains primarily the responsibility of Member States and regions. To strengthen this approach, the EU should move from implicit coordination toward a more explicit and strategic framework for coastal territories.

First, the EU should **articulate a clear, dedicated strategic vision for coastal communities** within the broader Green Deal and territorial cohesion agenda. While coastal objectives are currently dispersed across climate, maritime, environmental, and regional policies, a unifying framework would improve coherence, visibility, and political ownership, particularly in regions facing cumulative climate, economic, and demographic pressures.

Second, **enhanced coordination mechanisms** are essential to address the current fragmentation of responsibilities. This could include stronger alignment between Maritime Spatial Planning and terrestrial spatial planning, improved cross-border governance at sea-basin level, and clearer links between EU climate adaptation objectives and cohesion policy programming. Streamlined governance would reduce administrative burden and improve implementation efficiency at local level.

Third, the future strategy should **prioritise climate resilience as a core organising principle** for coastal development. This implies systematically integrating sea-level rise projections, erosion risk, and extreme weather scenarios into all EU-funded coastal investments, while scaling up nature-based solutions as cost-effective and adaptive forms of coastal protection.

Fourth, the EU should reinforce **place-based and socially inclusive approaches**. Coastal communities are highly diverse, ranging from large port cities to small islands and remote fishing villages. Future policy should

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better address housing affordability, access to services, skills development, and demographic decline, ensuring that adaptation and economic transitions do not exacerbate social inequalities.

Fifth, **economic diversification and innovation in the blue economy** should be strengthened as a resilience strategy. Beyond traditional sectors, the EU should support sustainable tourism models, low-impact aquaculture, offshore renewable energy, coastal circular economy initiatives, and research-driven innovation, linking local SMEs to European value chains.

Sixth, the EU should enhance **performance measurement and accountability** by introducing a more coherent set of coastal-specific indicators. These should capture not only environmental and economic outcomes, but also risk reduction, social resilience, and governance quality, enabling better monitoring of progress and learning across regions.

Seventh, Europol plays a critical role in securing Europe's inland harbours that are functionally linked to ocean ports. Its mandate focuses on preventing and combating organised crime that exploits the transport and logistics networks connecting seaports with inland waterways. Criminal activities such as smuggling, human trafficking, and illicit trade are key areas of Europol's intervention. The agency facilitates intelligence sharing between national law enforcement bodies, ensuring that threats detected at coastal ports are monitored along inland routes. Europol produces strategic reports and risk analyses to identify patterns of criminal activity across maritime and inland transport nodes.[22] These assessments inform both preventive measures and targeted enforcement operations. Europol also provides operational support for cross-border actions, coordinating multiple jurisdictions to disrupt criminal networks. Cybersecurity threats to port management and logistics systems are increasingly within Europol's remit, protecting trade and transport integrity. Its interventions strengthen the resilience and reliability of freight and passenger flows across the European port system. Overall, Europol functions as a central coordinating authority, enhancing security across the interconnected landscape of Europe's coastal and inland harbours.

Table

Region	**Main funding lines**	**State of affairs addressed**	**Intended EU target**	**Measures financed**	**Core KPIs**
Northern Europe (North Sea)	ERDF, Cohesion Fund, EMFAF, LIFE, InvestEU	High flood and erosion exposure in densely populated coasts	Reduce population and asset exposure while sustaining growth	Flood defenses, nature-based solutions, port decarbonisation, offshore wind integration	↓ people/assets at risk; ↑ restored habitats; full maritime spatial planning coverage; ↑ offshore wind & port jobs
Southern Europe (Mediterranean)	ERDF, Cohesion Fund, EMFAF, LIFE, RRF	Tourism pressure, pollution, erosion, climate stress	Improve environmental quality and diversify coastal economies	Wastewater treatment, coastal habitat restoration, sustainable tourism, urban adaptation	↑ coastal water quality; ↑ restored wetlands/seagrass; ↑ diversified coastal employment; improved service access
Eastern Europe (Baltic &	ERDF, Cohesion Fund, EMFAF, LIFE,	Erosion, river-borne pollution, governance and investment gaps	Strengthen resilience, governance, and	River–coast integration, flood risk management,	↓ erosion hotspots; ↑ biodiversity status; ↑ maritime spatial planning

[22] https://www.europol.europa.eu/publications-events/publications/criminal-networks-in-eu-ports-risks-and-challenges-for-law-enforcement

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Black Sea)	IPA/NDICI (where relevant)		environmental status	port modernisation, biodiversity protection	uptake; ↑ EU investment leveraged
Western Europe (Atlantic)	ERDF, EMFAF, LIFE, Interreg, InvestEU	High wave exposure, fisheries transition, coastal depopulation	Enhance resilience and sustain viable coastal communities	Nature-based coastal protection, fisheries transition, blue innovation, connectivity	↓ storm damage risk; stable coastal population; ↑ blue economy value added; ↑ cross-border projects

ERDF and the Cohesion Fund finance infrastructure, adaptation, and regional development; EMFAF supports coastal communities, fisheries, aquaculture, and blue economy diversification; LIFE finances environment and climate adaptation pilots; InvestEU and RRF leverage large-scale and private investment; Interreg **enables cross-border coastal cooperation**. Europol has its own projects and may form Joint Investigatory teams with the meber states such as the Netherlands, Belgium, France, Sweden, Spain and Polar and Romania on cost sharing basis.[23]

Finally, the future strategy should aim to reduce coordination complexity without undermining subsidiarity. This can be achieved through clearer strategic guidance, shared methodologies, technical assistance, and platforms for peer learning, rather than additional regulatory layers.

Taken together, these elements would transform the EU's approach from a collection of well-intentioned but fragmented interventions into a more integrated, resilient, and forward-looking strategy for the EU's seaborne transport arteries capable of addressing long-term climate, economic, and social challenges at the scale required.

Lessons Learned for Successful Large-Scale River Restoration in Europe

The EU Commission's failure to bring forward the revision of the directive on the Transport system and modernize the status of the inland waterways and redeem their potential has imposed a rethink.

Large-scale river restoration in Europe has evolved from isolated engineering interventions into long-term, territorially embedded transformation processes. Experience from major river basins demonstrates that success depends less on individual technical solutions and more on the coherence of governance, finance, ecology, and society over time.

Figure Lessons learned

[23] https://www.europol.europa.eu/partners-collaboration/joint-investigation-teams

At the core of effective restoration lies **strong governance and coordination**. Projects that deliver lasting results are anchored in clear leadership structures, well-defined institutional roles, and sustained coordination across water authorities, transport agencies, agriculture, energy, spatial planning, and environmental bodies. River systems cut across administrative and sectoral boundaries; without cross-sector governance, restoration efforts remain fragmented and vulnerable to policy reversals.

Closely linked to governance is **early and continuous stakeholder engagement**. River restoration reshapes landscapes, land use, and economic activities, making the involvement of local communities, landowners, municipalities, farmers, port operators, and industry essential from the outset. Successful projects treat stakeholders not as obstacles to be managed, but as co-owners of the river's future, thereby reducing conflict and strengthening long-term legitimacy.

Because ecological recovery unfolds slowly, **long-term and stable financing** is indispensable. One-off project funding rarely matches the temporal scale of river dynamics. Effective restoration combines national budgets, EU instruments, and private or semi-public investment into multi-year financing frameworks that ensure continuity through political and economic cycles.

Given uncertainty in ecological responses and climate pressures, **adaptive management and systematic monitoring** form another cornerstone. Continuous data collection, evaluation, and feedback loops allow projects to adjust interventions over time, refine techniques, and demonstrate tangible outcomes. Monitoring thus becomes both a management tool and a mechanism for accountability.

Spatial ambition also matters. Restoration efforts are most effective when conceived at the level of entire catchments. **Scale and connectivity**—including longitudinal, lateral, and ecological continuity—enable rivers to function as living systems rather than regulated channels. Basin-wide planning helps reconnect habitats, sediment flows, and hydrological regimes that piecemeal interventions cannot restore.

Within this broader framework, **nature-based solutions** have proven particularly powerful. Measures such as re-meandering, floodplain reconnection, and wetland restoration enhance biodiversity, improve water quality, and increase resilience to floods and droughts, often at lower long-term cost than hard infrastructure.

Equally important is the **integration of social and economic functions**. Restoration succeeds when rivers are reintegrated into everyday life through recreation, tourism, cultural landscapes, and compatible agricultural practices. These uses generate visible benefits that reinforce local support and embed ecological goals within regional development strategies.

All of this requires acceptance of a **long-term horizon**. River restoration is a generational project, demanding planning over decades rather than electoral cycles. Ecological recovery, social adaptation, and economic reorientation progress incrementally, rewarding patience and policy stability.

To sustain momentum, **policy alignment across governance levels** is critical. Harmonizing EU directives, national legislation, and local planning instruments reduces regulatory friction and ensures that restoration objectives are reinforced rather than undermined by parallel policies in transport, energy, or land use.

Finally, **communication and education** bind the entire process together. Making benefits visible—cleaner water, reduced flood risk, restored landscapes, and new economic opportunities—builds public understanding and political support. Clear narratives transform restoration from a technical exercise into a shared societal project.

Taken together, these lessons show that large-scale river restoration in Europe is not merely an environmental intervention, but a long-term governance and development strategy—one that reconnects ecology, economy, and society through Europe's rivers.

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Interpreted through the lens of **urbanism**, the mismanagement of Europe's rivers reveals a great deal about how cities and territories were conceived during the industrial and modernist eras—and why restoration today is as much an urban project as an ecological one.

Historically, European urbanism treated rivers primarily as **infrastructure corridors** rather than living systems. Rivers were straightened, embanked, culverted, or canalised to serve navigation, flood control, sanitation, and industrial throughput. This reflected an urban logic that privileged efficiency, predictability, and separation of functions: water was something to be controlled, accelerated, or hidden, not integrated into urban life. In this sense, river mismanagement is not accidental but deeply embedded in the epistemology of modern planning.

The way rivers were constrained also exposes a **fragmented governance model** of urban development. Urbanism evolved sector by sector—transport here, housing there, flood protection elsewhere—while rivers, which cut across all these domains, fell between institutional mandates. Cities expanded toward rivers without responsibility for upstream or downstream impacts, reinforcing a spatial myopia that treated river sections as local assets rather than parts of continuous systems.

Moreover, the degradation of urban rivers reflects an **extractive relationship between cities and nature**. Rivers were expected to absorb waste, provide cheap transport, enable energy production, and protect urban land from flooding, all while remaining invisible. This mirrors a broader urban ideology in which ecological processes were externalised, and environmental costs were displaced spatially (downstream) or temporally (to future generations).

From a socio-spatial perspective, river mismanagement also reveals **exclusionary urban outcomes**. Industrial riverfronts, port zones, and flood control infrastructures often severed access between citizens and water, turning rivers into backyards rather than civic spaces. The loss of floodplains and wetlands disproportionately affected peri-urban and rural communities, while urban centres benefited from land reclamation and risk transfer.

Seen this way, contemporary river restoration challenges the foundations of past urbanism. It implies a shift from **control to coexistence**, from linear engineering to adaptive systems, and from short-term land optimisation to long-term territorial stewardship. Restoration reframes rivers as structuring elements of urban form, public life, and regional identity rather than residual spaces or technical channels.

Taken together, these lessons suggest that large-scale river restoration is a corrective to the blind spots of twentieth-century urbanism. It signals an emerging paradigm in which cities are once again designed *with* their rivers, acknowledging ecological limits, reconnecting fragmented governance, and re-embedding urban life within living landscapes. In this sense, restoring rivers is inseparable from rethinking urbanism itself.

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Contemporary river restoration does not merely adjust the margins of urban practice; it unsettles the very bedrock upon which past urbanism was built. Where twentieth-century cities sought to bind rivers in concrete corsets and discipline them into obedient channels, restoration calls for a quieter, wiser posture—one of coexistence rather than command. The river is no longer a problem to be solved by straight lines and rigid embankments, but a living script, rewritten through adaptive systems that learn, bend, and endure. This transformation marks a decisive shift from the haste of short-term land optimisation to the patience of long-term territorial stewardship.

In this reframing, rivers emerge not as forgotten back alleys of the city nor as purely technical infrastructure, but as the spinal cords of urban form—structuring public life, shaping collective memory, and anchoring regional identity. They become civic stages where ecology and culture meet, rather than residual spaces pushed to the margins of planning maps.

Ultimately, large-scale river restoration stands as a long-overdue corrective to the blind spots of twentieth-century urbanism—an allegorical act of reconciliation between city and landscape. It announces the rise of a new paradigm in which cities are once again designed *with* their rivers, not against them: acknowledging ecological limits, stitching together fragmented governance, and re-embedding urban life within living, breathing landscapes. In this sense, restoring rivers is not a peripheral environmental gesture but a fundamental reimagining of urbanism itself—a return to the river as both mirror and mentor of the city's future.

CONCLUSIONS

Europe's inland waterways remain among the most extensive and strategically significant transport networks in the world, stretching thousands of kilometers through core economic regions. These physical corridors—including locks, channels, ports, and terminals—were built for an era when freight flows were concentrated, predictable, and heavily industrial. The network's strengths lie in its dense connections between major industrial and urban centers, established intermodal links with rail and road systems, and its high transport capacity for heavy and bulk cargo at relatively low cost. Yet, significant challenges remain. Many locks and weirs date from the mid-20th century and operate below modern standards of reliability and efficiency, causing frequent delays and maintenance closures. Sedimentation and variable water levels have narrowed navigable drafts in key reaches, particularly on the Rhine and Danube, reducing payload capacity and delaying schedules. Inland terminals often lack modern handling equipment and digital coordination systems, which hampers rapid transfers between modes. Moreover, heterogeneous technical and regulatory norms across countries increase operational complexity for operators. Addressing these challenges requires investment in lock renovation and channel deepening to restore reliable drafts and reduce delays, the introduction of integrated traffic management systems and real-time water level forecasting, upgrading terminals to support seamless transfers with rail and road, and the harmonization of technical standards across borders to reduce administrative friction. The infrastructure is not merely physical; it is a shared European asset whose current limitations ripple through economies and supply chains, shaping how actors—from barge operators to manufacturers—experience the network.

Climate change has transformed Europe's rivers from predictable arteries into dynamic, climate-sensitive systems. Hydrological patterns once taken for granted are now punctuated by extremes, including droughts, floods, and greater seasonal variability. Prolonged dry periods reduce draft levels, forcing vessels to carry lighter loads or suspend operations, raising unit costs and diverting cargo to less efficient road transport. Heavy precipitation events increase erosion and debris loads, damaging infrastructure and creating navigational hazards. Traditional seasonal windows for high-volume traffic have expanded or contracted unpredictably, complicating planning for shippers and ports. The consequences are profound: reduced payloads, operational disruptions, and pressure to shift cargo toward road or rail with associated environmental and congestion costs. Climate impacts are not peripheral; they redefine what "reliable transport" means in the European context. Inland waterways, once prized for resilience and sustainability, now confront existential questions about their future role in freight mobility.

Europe's rivers do not stop at nation-state boundaries, yet governance often does. Transboundary challenges—from water levels to infrastructure bottlenecks—require cooperative frameworks that bind actors across administrative and sectoral lines. Existing mechanisms, such as the Rhine and Danube Commissions and EU programmes like the Trans-European Transport Network (TEN-T), coordinate technical standards, safety, and finance cross-border links. However, gaps remain. Decision-making is often fragmented, with national priorities diverging on investment, environmental safeguards, and operational norms. Local communities, inland navigation operators, environmental NGOs, and private logistics actors often lack structured channels for input, while hydrological and traffic data are siloed, reducing situational awareness. Effective governance could include integrated river basin platforms with mandates for planning, data sharing, and conflict resolution; cross-border investment funds to co-finance modernization projects with clear performance criteria; stakeholder councils at regional and corridor levels bringing together public authorities, industry representatives, civil society, and scientific experts; and harmonized regulatory frameworks that align technical standards, safety norms, digital protocols, and environmental safeguards. Governance becomes the connective tissue that can either enable or impede collaborative transformation, moving from fragmented decision-making toward shared stewardship.

Technology offers pathways to leapfrog existing limitations, reducing emissions, improving reliability, and unlocking new forms of value from inland waterways. Real-time navigation systems, integrated with sensors and AI-driven forecasting, allow dynamic routing that adapts to water level fluctuations. Digital twin river models simulate hydrological and traffic patterns, informing infrastructure planning and emergency response. Green propulsion solutions, including electric, hydrogen, or hybrid systems for barges and terminal equipment, reduce emissions, while automation and remote operations, such as smart locks, automated scheduling, and remote piloting capabilities, improve throughput and safety. Port digitalization through blockchain and IoT platforms enables seamless cargo tracking, paperwork reduction, and coordinated intermodal transfers. The benefits include enhanced operational reliability and predictability, reduced carbon footprint per ton-kilometer, greater integration with broader digital logistics ecosystems, and increased appeal of inland waterways for shippers seeking resilient supply chains. Technological innovation should be embedded into planning, financing, and governance frameworks, ensuring interoperability and shared benefits across countries and sectors.

Improving the efficiency and competitiveness of Europe's inland waterways requires a multi-dimensional approach that integrates infrastructure modernization, regulatory harmonization, digitalization, and climate-adaptive governance. Inland waterways offer significant advantages in energy efficiency, low emissions, and the ability to transport large volumes of bulk goods, yet they remain underutilized compared to road and rail transport. Current estimates indicate that inland waterways account for only about 1.5–2% of total EU freight tonnage, highlighting the considerable untapped potential for modal shift, particularly along high-density industrial corridors (Eurostat, 2023).

Europe's major trading rivers—the Rhine, Danube, and Elbe—serve as critical arteries for international and intra-European trade. The Rhine, for example, connects the industrial heartlands of Germany, Switzerland, France, and the Netherlands with the North Sea, supporting high volumes of containerized cargo, chemicals, coal, petroleum products, and iron and steel. The Danube spans central and southeastern Europe, facilitating the transport of bulk agricultural goods, construction materials, minerals, and energy products. The Elbe primarily serves bulk commodities, including coal, ores, and timber, while also supporting specialized industrial flows. Along these rivers, cargo composition reflects the predominance of heavy, low-value, high-volume goods that are ideally suited to waterborne transport.

To move forward, Europe must address both physical and institutional bottlenecks. Infrastructure modernization is essential: this includes upgrading locks, stabilizing riverbeds, deepening channels, and ensuring year-round navigability. Ports and transshipment hubs must evolve into high-capacity, multimodal nodes that integrate waterways with rail and road networks, supporting containerized and bulk logistics alike. Digitalization and data integration—through real-time River Information Services, AI-based route optimization, and digital slot-booking—can enhance scheduling, reduce congestion, and increase overall predictability. Fleet modernization, including low-emission vessels and shallow-draft barges, is equally critical to accommodate changing river conditions and reduce environmental impacts.

Policy measures should incentivize modal shift, particularly for bulk commodities and intermediate goods where water transport is most efficient. Fiscal incentives, reduced port charges for low-emission vessels, and coordinated cross-border regulatory frameworks can encourage adoption. Climate adaptation must be embedded across all measures, recognizing the vulnerability of rivers to droughts, low water levels, and flooding. Governance coordination, including pan-European river basin management and corridor-level efficiency task forces, can ensure consistency, standardization, and monitoring of key performance indicators.

In terms of propulsion short-haul RDI acts as a low-risk experimental stage, Operational data feed directly into design improvements for long-haul ships, Infrastructure investments for inland/coastal vessels are scalable to oceanic routes, regulatory experience and market confidence developed at short-haul level accelerate adoption in long-haul shipping. This provides for a partnership with the wider shipping industry on propulsion and Asian shipyards notably from Korea and China.

By combining infrastructure upgrades, digitalization, regulatory alignment, fleet modernization, and climate-adaptive governance, inland waterways in Europe can significantly increase their share of freight transport. This would relieve congestion on roads, reduce emissions, enhance resilience, and leverage the inherent capacity advantages of waterborne transport for Europe's bulk and containerized trade.

Environmental Impact Assessments (EIAs) on major EU inland waterways identify ecological risks and prevent irreversible damage. They generate standardized baseline data, improving long-term monitoring of water quality and biodiversity. EIAs promote sustainable project design, including low-impact dredging and ecological corridors. They enable cumulative impact assessment, considering multiple pressures like navigation, hydropower, and agriculture. Basin-wide governance harmonizes environmental standards and reduces fragmentation across countries. Integrated planning under basin authorities balances economic uses with ecological protection. Multi-stakeholder platforms enhance transparency, participation, and conflict resolution. Shared monitoring and adaptive management improve ecosystem resilience and climate adaptation. Coordinated governance increases investor certainty, reduces mitigation costs, and strengthens compliance with EU directives. Together, EIAs and basin-wide governance optimize environmental protection, stakeholder engagement, and socio-economic outcomes across Europe's inland waterways.

Mobilising the inland waterway policy community in favor of implementing EIA recommendations depends on political, institutional, economic, and social factors rather than precise statistics. Key stakeholders include EU institutions, national ministries, river basin authorities, sector associations, NGOs, and researchers. Success is more likely when EIA recommendations align with EU priorities such as the Green Deal, Water Framework Directive, and Biodiversity Strategy 2030.Strong evidence, including ecosystem service valuation and cost-benefit analysis, increases stakeholder receptivity. Coalition building across environmental, transport, and regional actors enhances adoption and coordination. Public and local community support, amplified by media and NGOs, further strengthens mobilisation. Barriers include competing economic interests, legal and institutional fragmentation, and siloed policy communities. Political cycles and budget constraints can limit attention and resources for implementation. Overall, the realistic likelihood of successful mobilisation is moderate, approximately 45–60%, higher where legal obligations and co-benefits are clear. Strategies to improve odds include framing EIA recommendations as win-win, building trans-sectoral coalitions, leveraging public participation, linking to legal requirements, and presenting clear local case studies.

In summary, the case for sustainable modernisation of inland river waterways in Europe rests on their strategic role in transport, economic efficiency, and environmental sustainability. Inland waterways are a cost-effective and low-carbon alternative to road and rail freight, reducing congestion, emissions, and infrastructure wear. Modernisation, including upgraded locks, dredging, and digital traffic management, can increase capacity and reliability while accommodating larger, greener vessels. Integrating environmental safeguards, such as implementing EIA recommendations, ensures ecosystem protection, flood management, and biodiversity conservation. Sustainable waterways support regional development, connecting industrial hubs, ports, and urban centers, and promoting multimodal logistics networks. They are critical to achieving EU climate and transport targets under the Green Deal and Sustainable and Smart Mobility Strategy. Investments in clean propulsion technologies further enhance the sector's environmental credentials. RDI Partnerships between the EU and Industry are key for scaling up. Coordination across EU, national, and river basin authorities ensures coherent policy and operational standards. Public and stakeholder engagement fosters social acceptance and local benefits, including recreation and tourism. Overall, sustainable modernisation strengthens Europe's inland transport system, balancing economic efficiency with ecological responsibility and contributing to broader decarbonisation and mobility goals.

From an **policy-making theory** perspective, NAIADES suffers from a classic *soft-law deficit*. The framework relies heavily on strategies, action plans, and coordination mechanisms rather than binding obligations, clear deadlines, or enforceable targets. This produces what Pressman and Wildavsky would describe as a **long implementation chain with weak coupling**: multiple actors (Commission, Member States, river commissions, ports, private operators) are formally involved, but none bears decisive responsibility for outcomes. As a result, slippage accumulates without triggering sanctions or corrective feedback.

From a **political economy of regulation** angle, the policy lacks a strong distributive engine. While inland waterway transport generates efficiency and environmental benefits at the system level, these gains are **diffuse and long-term**, whereas the costs—fleet modernisation, infrastructure upgrades, administrative adaptation—are immediate and concentrated. This weakens political demand at national level, particularly in Member States where inland waterways are peripheral rather than central to economic geography. Unlike road or rail, the sector does not mobilise mass constituencies or large industrial coalitions capable of sustaining pressure for implementation.

The implementation deficit is further reinforced by **inter-institutional misalignment**. Responsibility for waterways is fragmented across transport, environment, regional development, and energy portfolios, both at EU and national level. NAIADES therefore competes for attention and funding within crowded policy mixes, and is frequently subordinated to rail decarbonisation or road electrification agendas that enjoy clearer political narratives and stronger industrial backing.

Finally, NAIADES illustrates a broader regulatory pattern in EU governance: policies framed as *coordination and facilitation* tend to underperform when they enter domains requiring **capital-intensive investment and long-term infrastructure commitment**. In the absence of binding obligations, ring-fenced financing, or a dominant lead actor, implementation becomes path-dependent on existing national capacities and priorities—producing uneven progress and, overall, a persistent implementation gap rather than outright policy failure.

Or as we sang in high school during classes in German: Ich Weiss nicht was soll es bedeuten dass ich so traurig bin, ein Märchen aus alten Zeiten das kommt mir nicht aus dem Sinn.

This doesn't mean you should identify with the luring blondes on rocks above you, but learn to navigate and confer coherence onto the EU's Transport Policy and give back Europe its sense of wholeness: In the words of a former Transport Commissioner, Adina Valean

As one of the most CO_2-efficient transport modes available, inland waterways have the potential to play a central role in decarbonising our transport systems. Yet today, our canals and rivers carry just 6 % of EU freight. With an inland waterway network of 41 000 km spanning 25 Member States, there is scope to do a lot more …"[24]

This quote underscores the *strategic position* of waterways in EU transport policy and links their **environmental and logistical potential** to broader objectives like decarbonisation. The Council of Naiades:

[24] https://transport.ec.europa.eu/transport-modes/inland-waterways/promotion-inland-waterway-transport/naiades-iii-action-plan_en?utm_source=chatgpt.com

"Inland waterways and ports are an essential component of multimodal transport and thus should be integrated in the revision of the Combined Transport Directive … ensuring seamless cross-border connections and interoperability … supporting research on climate resilience and smart shipping.

This institutional statement further emphasises the *multimodal integration* rationale — inland waterways are not peripheral but central to the EU's vision for an efficient, sustainable, and interconnected transport network.

The Sava and Dniester rivers can serve as strategic connectors linking EU candidate countries to the core European supply chains. The **Sava River**, flowing through Slovenia, Croatia, Bosnia and Herzegovina, and Serbia, links inland industrial and agricultural regions to the Danube, which in turn connects to major EU ports such as Rotterdam and Constanța. Modernising navigable sections, upgrading port and terminal infrastructure, implementing harmonised traffic and customs procedures, and digitalising river information systems would enable goods from the Western Balkans to move efficiently into EU markets. Interoperable multimodal hubs and digital traffic management can facilitate just-in-time delivery, reduce logistical costs, and enhance predictability for private operators, making the corridor a reliable, low-carbon alternative to road transport. Similarly, the **Dniester River**, running through Ukraine and Moldova, could act as a corridor for eastern candidate or partner countries, linking agricultural and industrial regions to Black Sea ports and, through them, to European markets. Investment in navigation safety, infrastructure improvements, and cross-border coordination—combined with alignment to EU vessel, environmental, and safety standards—would allow the Dniester to function as an efficient, low-carbon freight route complementing road and rail transport. Together, the Sava and Dniester form practical **strategic bridges**, integrating peripheral economies into the EU supply chains, supporting regional industrial clusters, fostering trade integration, enhancing economic cohesion, and providing candidate countries with tangible pathways to participate fully in Europe's multimodal logistics networks.

Theoretical implications from a policy-making perspective

The observed outcomes of NAIADES carry several important implications for understanding EU policy-making and the political economy of regulation. First, the persistence of limited progress illustrates that **policy frameworks relying on coordination and soft-law instruments are inherently constrained when policy costs are concentrated while benefits are diffuse**. In NAIADES, long-term efficiency, environmental, and multimodal integration gains accrue across the system, but the immediate costs—fleet modernisation, infrastructure upgrades, and administrative adaptation—fall on a narrow set of actors. From a policy-making perspective, this highlights the centrality of **distributional incentives**: policies are more likely to be adopted and executed when costs and benefits are sufficiently aligned with politically and economically organised constituencies.

Second, the case underscores the role of **agenda-setting and policy salience** in shaping outcomes. Inland waterways, while strategically important, lack the narrative and electoral visibility of sectors such as rail decarbonisation or road electrification. As a result, even well-designed EU frameworks compete for attention and funding within crowded policy agendas. This confirms policy-making theories that emphasise the importance of **sectoral coalitions, framing strategies, and issue salience** in explaining differential regulatory success.

Third, NAIADES highlights the challenges of **multi-level and inter-institutional coordination** in EU policy-making. Responsibility is fragmented across transport, environment, regional development, and energy portfolios at both EU and national levels. Policy coherence therefore depends not only on formal legal authority, but on the **alignment of incentives and priorities across multiple actors**, revealing how structural and organisational misalignment can limit the effectiveness of otherwise well-conceived policy initiatives.

Fourth, the persistence of limited progress demonstrates that **regulatory outcomes are shaped by the interaction of policy design and political economy constraints**, rather than technical efficiency alone. Even policies with clear operational and environmental benefits may underperform if they do not mobilise support from powerful constituencies, or if their benefits are long-term and geographically diffuse. This reinforces the theoretical insight that the success of EU policy often depends on **coalition-building, distributive leverage, and strategic framing**, not just the intrinsic quality of policy instruments.

Finally, the NAIADES experience suggests that soft-law and coordination-oriented EU instruments often function as **agenda-setting and signalling tools** rather than direct engines of structural transformation. From a policy-making perspective, persistent gaps should be interpreted as the outcome of **strategic policy design under conditions of diffuse benefits, fragmented authority, and limited political salience**, rather than as outright failure. Achieving transformative outcomes would require recalibrating both the **allocation of authority** and the **distributional and political incentives** embedded in the policy framework.

How to ?

First, Recalibrating allocation of authority**:** This means clarifying **who has decision-making power, enforcement capacity, and coordination responsibility**. For example, empowering river commissions or designating a lead EU coordinating body for inland waterways could align multi-level actors behind a shared mandate.

Second, aligning distributional and political incentives**:** Policymakers could introduce targeted funding, subsidies, or co-financing schemes that offset concentrated costs for early adopters, and ensure that the benefits of compliance are visible and politically salient. This could include linking digitalisation grants or decarbonisation incentives to measurable performance metrics, making compliance both economically rational and politically rewarding.

Third, Institutionalised feedback mechanisms**:** Establishing monitoring, reporting, and benchmarking systems would allow actors to see tangible progress and adjust behaviour, reducing risk of free-riding or neglect.

In essence: Transformative EU inland waterways policy requires not just technical planning or soft-law coordination—it depends on **structural authority alignment and the strategic shaping of incentives**, so that all actors perceive compliance as feasible, beneficial, and politically advantageous. Without such recalibration, policies remain aspirational rather than operational.

Why is this in everyone's interest ?

Europe's inland waterways are strategically positioned at the intersection of **transport policy, environmental objectives, and regional economic development**, making their success a shared interest for multiple actors. First, inland waterways provide a **low-cost, high-capacity transport mode** that complements road and rail. Their integration into multimodal logistics chains increases the efficiency of freight movement, reduces congestion on highways and rail networks, and enhances overall European transport resilience. This makes them important not only for transport ministries but also for economic and industrial policy actors who depend on reliable logistics infrastructure.

Second, waterways are inherently **transnational**, linking multiple rivers and ports across EU Member States—from the Rhine to the Danube and beyond. Their success therefore depends on cross-border coordination, harmonised regulations, and interoperable digital tools. For national governments, regional authorities, and port operators, investing in the efficiency and connectivity of these rivers aligns with broader **European cohesion and competitiveness objectives**, supporting trade, regional development, and cross-border economic integration.

Third, inland waterways play a central role in the EU's **environmental and climate objectives**. They offer a lower-emission alternative to road freight, and integrating greener propulsion technologies, digital traffic management, and port efficiency measures can further reduce CO_2 and particulate emissions. For the European Commission and national environmental agencies, modernising inland navigation thus contributes directly to EU decarbonisation targets, urban air quality improvements, and compliance with the Green Deal.

Finally, stakeholders such as shipping companies, logistics operators, and port authorities have **direct economic incentives** to improve waterway performance. Investments in digitalisation, fleet modernisation, and traffic management reduce operational costs, improve reliability, and strengthen competitiveness. At the same time,

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enhanced inland waterways support broader EU policy objectives—modal shift, multimodal integration, and climate mitigation—which ensures political backing and access to EU funding.

In sum, the success of Europe's inland waterways serves a **convergent set of interests**: transport efficiency, economic competitiveness, environmental sustainability, and regional cohesion. Their strategic position in EU transport policy, their connectivity across river networks, and their potential for emission reduction make investments in their modernisation not just sectoral priorities, but a **shared European interest** with benefits that are spatially and politically diffuse yet systemically significant.

Further research

Empirical assessments of inland waterway transport under NAIADES III indicate that structural constraints—hydrological volatility, fragmented governance, and uneven digital uptake—rather than lack of strategic vision, explain the sector's limited progress. Further research should therefore prioritise causal mechanisms and implementation conditions.

First, research should deepen the empirical analysis of **climate-induced hydrological variability** and its direct operational consequences. Studies on the Rhine and Danube already demonstrate that low-water events, sedimentation patterns, and seasonal unpredictability systematically undermine reliability. Future work should link hydrological data with traffic volumes, vessel utilisation rates, and logistics disruptions, enabling a clearer assessment of climate risk exposure and adaptive capacity across river corridors.

Second, empirical evidence on digitalisation suggests **heterogeneous adoption and limited interoperability** of River Information Services. Further research should examine why digital tools—despite proven technical effectiveness—fail to diffuse evenly. Comparative case studies could analyse the institutional, financial, and organisational conditions under which RIS, smart traffic management, and data-sharing platforms generate measurable efficiency gains, and where they remain underutilised.

Third, economic analyses should move beyond aggregate cost comparisons and investigate **context-dependent competitiveness**. Empirical work could assess how inland waterways perform relative to road and rail under different hydrological, regulatory, and digital maturity scenarios. This would clarify whether current investment shortfalls reflect structural economic limits or correctable coordination failures.

Fourth, regulatory research should focus on **implementation variance rather than formal legal design**. While EU-level frameworks appear broadly aligned, empirical evidence points to persistent national divergences in enforcement, administrative capacity, and cross-border coordination. Research should map these divergences systematically and assess their impact on operational continuity along transnational rivers.

Fifth, environmental impact studies should integrate **operational trade-offs** observed in practice. While inland shipping is often presented as environmentally superior, empirical findings show that low-water events, dredging, and port expansions can generate significant ecological stress. Research should therefore examine how environmental safeguards interact with navigability and competitiveness, identifying governance models that balance ecological protection with transport reliability.

In addition, empirical work on stakeholder engagement reveals **uneven participation and weak ownership** in many river basin initiatives. Comparative research could analyse cases where port authorities, operators, environmental actors, and local communities have successfully co-produced solutions, identifying institutional designs that reduce conflict and accelerate implementation.

Moreover, studies on multimodal integration should focus on **last-mile bottlenecks and data discontinuities**, which empirical evaluations repeatedly identify as barriers. Research could assess how digital interfaces, terminal governance, and investment sequencing affect the actual integration of inland waterways into logistics chains.

Case-based research should be prioritised, focusing on **corridors where implementation has exceeded expectations** despite structural constraints. Such cases can illuminate how governance capacity, funding alignment, or political prioritisation compensate for hydrological or market disadvantages.

Finally, research on public policy and funding should empirically assess **the effectiveness of existing EU instruments**, including CEF, cohesion funding, and green transition finance. Rather than assuming underfunding, studies should examine whether funds are misaligned with project readiness, governance capacity, or long-term operational needs.

Taken together, this research agenda reframes inland waterway transport not as a sector lacking strategy, but as one facing **implementation and coordination failures under conditions of climatic stress and institutional fragmentation**. Addressing these empirically grounded constraints is essential if digitalisation, decarbonisation, and multimodal integration are to move from policy ambition to operational reality.

Counter-arguments

Counterarguments against strengthening governance on inland waterways can be framed across political, economic, and legal dimensions:

In the political realm, one might argue that strengthening governance could lead to increased bureaucratic complexity and inefficiency. Enhanced regulations may create additional layers of oversight that slow decision-making processes, making it difficult to respond swiftly to emerging challenges. Furthermore, there is a concern that increased governance could lead to conflicts among various stakeholders, as differing interests and priorities may complicate collaborative efforts. This fragmentation could hinder effective management rather than enhance it.

From an economic perspective, critics may contend that strengthening governance could impose significant costs on stakeholders involved in inland waterway transport. Increased regulatory compliance may require substantial investments in infrastructure and operational adjustments, which could disproportionately affect smaller operators and lead to reduced competitiveness. Additionally, the potential for higher operational costs could deter investment in the sector, stifling innovation and growth. There is also the risk that overly stringent regulations could drive businesses to alternative transport modes, undermining the intended benefits of promoting inland waterways.

Legally, opponents might argue that strengthening governance could lead to an overreach of authority, infringing on the rights of local and regional stakeholders. Increased regulation may create legal challenges and disputes over jurisdiction, particularly in transboundary contexts where multiple countries are involved. This could result in a fragmented legal landscape that complicates compliance and enforcement. Moreover, the introduction of new legal frameworks may face resistance from established interests that benefit from the current governance structures, leading to prolonged negotiations and potential stalemates.

In summary, while strengthening governance on inland waterways aims to enhance efficiency and sustainability, counterarguments highlight concerns about bureaucratic inefficiencies, economic burdens, and potential legal conflicts. These factors must be carefully considered in any governance reform discussions to ensure that the benefits outweigh the drawbacks.Policy recommendations

Scenarios

Here are several scenarios regarding the strengthening of governance on inland waterways, considering various potential outcomes:

Scenario 1: Enhanced Collaboration and Efficiency

In this scenario, strengthening governance leads to improved collaboration among stakeholders, including government agencies, shipping companies, and environmental organizations. A unified regulatory framework is established, streamlining decision-making processes and reducing bureaucratic delays. As a result, inland waterways become more efficient, attracting increased investment and usage. The integration of digital technologies enhances operational efficiency, leading to reduced emissions and improved environmental outcomes.

Scenario 2: Increased Bureaucratic Complexity

In this scenario, the push for stronger governance results in a convoluted regulatory framework that complicates operations for stakeholders. The introduction of multiple layers of oversight creates confusion and delays in decision-making. Smaller operators struggle to comply with new regulations, leading to a decline in competition and innovation. As a result, the inland waterway transport sector experiences stagnation, with some businesses opting to shift to road or rail transport due to the burdensome regulatory environment.

Scenario 3: Economic Disruption and Investment Decline

In this scenario, the costs associated with compliance to strengthened governance deter investment in inland waterways. Increased operational costs and regulatory burdens lead to reduced profit margins for shipping companies. Consequently, some operators exit the market, resulting in decreased capacity and service availability. The decline in inland waterway transport leads to increased congestion on roads and railways, undermining the initial goals of promoting sustainable transport alternatives.

Scenario 4: Legal Conflicts and Jurisdictional Challenges

In this scenario, the introduction of new governance structures leads to legal disputes among stakeholders, particularly in transboundary contexts. Conflicts arise over jurisdiction and compliance with differing national regulations, creating a fragmented legal landscape. This results in delays in project implementation and increased costs for stakeholders. The lack of clarity in legal frameworks hampers effective governance, ultimately undermining the potential benefits of enhanced oversight.

Scenario 5: Successful Environmental Integration

In this scenario, strengthened governance successfully integrates environmental considerations into inland waterway management. Regulatory frameworks prioritize ecological sustainability, leading to the implementation of best practices for habitat protection and biodiversity conservation. Stakeholders collaborate effectively to balance economic and environmental objectives, resulting in healthier river ecosystems and improved public perception of inland waterway transport. This scenario enhances the overall resilience of the transport system while meeting EU climate goals.

Scenario 6: Resistance and Political Backlash

In this scenario, the push for stronger governance faces significant political resistance from various stakeholders, including local communities and industry groups. Concerns about overreach and loss of autonomy lead to public protests and lobbying against new regulations. Political backlash results in delays or rollbacks of proposed governance reforms, leaving the existing fragmented system in place. This scenario highlights the challenges of achieving consensus in governance reform efforts.

These scenarios illustrate the potential complexities and outcomes associated with strengthening governance on inland waterways, emphasizing the need for careful consideration of stakeholder perspectives and the broader implications of regulatory changes.

The future of Europe's inland waterways depends critically on investment decisions made over the coming decade, as these corridors face mounting pressures from aging infrastructure, hydrological variability, and climate change. A low-investment scenario, focused primarily on routine maintenance, selective dredging, and minor lock upkeep, would maintain basic navigability sufficient for current freight volumes. However, such a scenario leaves the system vulnerable to low-water events and extreme floods, constraining the potential for modal shift from road and rail to river transport and yielding only modest carbon reductions. While costs remain minimal, infrastructure bottlenecks would persist, and the economic potential of strategic corridors such as the Rhine, Danube, and Elbe would remain underutilized.

A medium-investment scenario, involving targeted upgrades to locks, canals, and ports, coupled with adaptive infrastructure measures and moderate technological deployment, would significantly improve navigability. Freight flows would become more reliable, reducing disruptions during periods of low water, and cargo throughput could increase by an estimated ten to fifteen percent. This reliability would encourage a measurable modal shift toward inland waterways, contributing to reductions in carbon emissions. Ecosystem restoration and climate-resilient measures would provide additional benefits, including enhanced floodplain connectivity and biodiversity. Coordinated governance under EU frameworks, such as TEN-T and the Connecting Europe Facility, would ensure efficient allocation of resources and promote cross-border harmonization of operations.

The high-investment scenario envisages comprehensive modernization across all major rivers, extensive port and intermodal hub development, full deployment of autonomous and low-emission vessels, and advanced digital traffic management systems. Navigability under this scenario would approach optimal levels, even under extreme climatic events, allowing inland waterways to capture a substantially larger share of European freight transport. Projected modal shift could reach twenty to twenty-five percent, alleviating congestion on roads and rail networks while significantly reducing carbon emissions. Ecosystem restoration projects would enhance ecological health and resilience, transforming degraded floodplains into multifunctional landscapes. High levels of investment would also support research, innovation, and workforce development, positioning Europe as a global leader in sustainable inland navigation.

Across all scenarios, coordinated governance and stakeholder engagement remain essential. Even under low-investment conditions, transparent monitoring and adaptive management practices can maintain minimum operational standards. Medium- and high-investment pathways demonstrate the strategic leverage of financial instruments such as public-private partnerships, green bonds, and EU funding mechanisms. The choice of investment intensity ultimately defines the trajectory of Europe's inland waterways, determining whether they remain underutilized transport arteries or evolve into highly efficient, resilient, and low-carbon corridors. Linking investment directly to navigability, modal shift, and carbon reduction provides a tangible framework for evaluating returns and prioritizing interventions.

Scenario analysis also underscores the importance of integrating environmental, economic, and operational objectives. High-investment strategies offer transformative outcomes, medium investment achieves substantial progress with balanced costs, and low investment preserves continuity but risks stagnation and vulnerability. By embedding sustainability and resilience in planning and governance, Europe can ensure that its inland waterways contribute meaningfully to both the green transition and the broader goals of economic integration. These scenarios demonstrate that inland waterways are not merely transport channels but strategic instruments capable of delivering environmental, social, and economic benefits when aligned with forward-looking policy and investment strategies.

POLICY RECOMMENDATIONS

To modernize the governance, infrastructure, and operational practices of inland waterway transport in Europe, several strategic policy measures should be pursued to enhance efficiency, sustainability, and climate resilience.

Governance Modernization should begin with the development of integrated policy frameworks that align national and regional initiatives with EU-wide sustainability objectives. Harmonizing regulations across member states will facilitate cross-border operations and reduce administrative barriers, creating a more seamless operational environment. Policymakers should also prioritize stakeholder engagement by fostering collaboration among port authorities, shipping companies, environmental organizations, and local communities. Inclusive participation ensures that economic, environmental, and social priorities are balanced while enhancing policy legitimacy. Adaptive management structures are essential to respond swiftly to hydrological extremes, such as droughts and floods. This may include establishing dedicated units within governing bodies to monitor water levels, coordinate real-time responses, and implement contingency measures efficiently.

Infrastructure Modernization requires sustained investment in dredging, lock refurbishment, and maintenance of navigable depths to mitigate sedimentation and maintain reliable transport routes. Climate-resilient infrastructure should be prioritized, including adjustable weirs and low-water-optimized vessel designs, enabling continued navigation under extreme hydrological conditions. Ports should be transformed into high-capacity, trimodal logistics hubs that support efficient transfers between waterways, rail, and road. Enhancements may include the expansion of container terminals, improvements to roll-on/roll-off interfaces, and adoption of intelligent cargo handling systems.

Operational Practices Enhancement must focus on digital integration and technological adoption. A unified EU Inland Waterway Traffic Management System can provide real-time data on waterway conditions, congestion alerts, and predictive arrival times, enhancing operational efficiency and reducing delays. The transition to sustainable vessel technologies, including hybrid, electric, or hydrogen-powered propulsion, should be incentivized through funding mechanisms and regulatory support. Smart logistics solutions, such as digital slot booking at ports and AI-supported route optimization, will improve cargo throughput, lower fuel consumption, and strengthen the environmental performance of inland waterway operations.

Research and Innovation policies should support the development and trial of emerging technologies, including autonomous vessels, drone-based inspections, and predictive maintenance systems, to enhance safety and operational resilience. Workforce development programs are essential to equip personnel with skills for advanced technologies and sustainable operational practices, alongside mutual recognition of professional licenses across member states to facilitate labor mobility and cross-border expertise.

By implementing these policy measures, Europe can modernize its inland waterway transport system to achieve greater efficiency, sustainability, and resilience against climate change. This holistic approach will ensure that inland waterways remain a vital component of the European transport network, supporting economic growth while safeguarding ecological integrity.

Effective modernization of EU inland ports is critical for enhancing transport efficiency, promoting modal shift, and achieving sustainability objectives. Firstly, **integrated planning and governance** should be strengthened. Ports should operate within a coordinated EU framework that aligns TEN-T priorities, national strategies, and regional logistics needs. Establishing a **dedicated EU Inland Port Coordination Task Force** could standardize operational protocols, monitor performance metrics, and facilitate cross-border cooperation.

Secondly, **infrastructure modernization** is essential. Ports should invest in high-capacity intermodal terminals to facilitate efficient transfer between water, rail, and road. Upgrading berths, cranes, storage facilities, and access roads will reduce bottlenecks and increase throughput. Climate-resilient infrastructure, including adjustable quays, flood-protected storage, and low-water access designs, should be prioritized to maintain operational continuity under extreme weather conditions.

Thirdly, **digitalization and technology adoption** can significantly improve efficiency. Implementing real-time port management systems, automated cargo handling, and digital slot-booking platforms will optimize logistics and reduce waiting times. Smart ports should integrate predictive maintenance, IoT monitoring, and AI-based traffic and cargo flow analysis to enhance reliability. Autonomous vessel compatibility and low-emission propulsion systems should also be incorporated to meet decarbonization targets.

Fourthly, **environmental sustainability** must be embedded in port operations. Ports should adopt ecosystem-based management, including shoreline restoration, water quality monitoring, and biodiversity protection. Energy-efficient lighting, electrification of cargo handling, and waste reduction measures can further reduce environmental impact. Ports could leverage EU green-transition funds to co-finance sustainability initiatives.

Fifthly, **financial and operational strategies** should leverage public-private partnerships (PPPs), green bonds, and climate finance instruments. These mechanisms can support modernization without overburdening public budgets while incentivizing private-sector innovation. Transparent financial reporting and standardized KPIs should be established to track performance, ensure accountability, and attract investment.

In summary, **stakeholder engagement and workforce development** are crucial. Port authorities should collaborate with shipping operators, logistics providers, regional authorities, and environmental NGOs to ensure policies are inclusive and operationally effective. Training programs should equip workers with skills in digital port management, autonomous vessel operations, and sustainable practices, with cross-border certification for labor mobility.

By implementing these measures, EU inland ports can become hubs of sustainable, efficient, and resilient inland waterway transport. This will not only enhance Europe's logistical capacity and economic competitiveness but also contribute to the EU's climate goals and environmental stewardship, positioning inland ports as strategic nodes in the continent's integrated transport network.

Sixthly, The European Union should move decisively away from a fragmented legislative landscape based largely on directives and partial harmonisation, and instead develop a unified and directly applicable regulatory framework for inland waterway transport. At present, divergent national transposition and varying administrative practices undermine legal certainty and distort competition between operators. A comprehensive EU regulation could consolidate existing rules on vessel technical standards, safety requirements, crew qualifications, market access, and operational conditions into a single coherent legal instrument. Such consolidation would not only simplify compliance for economic actors but also facilitate more effective supervision and enforcement by national authorities, thereby strengthening the internal market for inland navigation.

The European Union should also pursue a more systematic and transparent integration of international inland navigation regimes into its legal order. Instruments such as the ADN and standards developed within the framework of the Central Commission for the Navigation of the Rhine play a central role in practice, yet their legal status within EU law remains complex and, at times, ambiguous. Greater coherence would be achieved by explicitly incorporating these international norms into EU legislation while subjecting their interpretation and application to the principles of EU law and the jurisdiction of the Court of Justice of the European Union. In parallel, the EU should adopt a coordinated external stance in international inland navigation organisations, ensuring that Member States act collectively and consistently in the development and revision of technical and safety standards.

Institutional reform is equally important for improving coherence. Responsibility for inland waterway governance is currently dispersed among EU institutions, international river commissions, and national authorities, leading to overlaps and gaps in regulation. The establishment of a dedicated EU-level coordination body or agency for inland waterways would help centralise technical expertise and policy oversight. Such a body could support Member States in implementing EU legislation, issue interpretative guidance, collect and analyse data, and facilitate cooperation between administrations. By promoting consistent administrative practices, this institutional framework would enhance both legal certainty and regulatory effectiveness across the Union.

Finally, inland waterway law should be more firmly embedded within the broader framework of EU transport, climate, and environmental policy. Inland navigation has significant potential to contribute to decarbonisation, congestion reduction, and sustainable mobility, yet it remains underrepresented in policy design and funding priorities. Aligning inland waterway regulation with the objectives of the European Green Deal and EU transport strategies would require harmonised incentives, coordinated funding mechanisms, and common environmental standards. Greater legal coherence should also be achieved between transport law and water management legislation, ensuring that navigational, ecological, and climate objectives are balanced within a single, integrated governance framework.

Perspective

Europe's role in globalization is inseparable from its infrastructure networks, particularly inland waterways, ports, and intermodal transport corridors. The EU's dense and interconnected transport system underpins its participation in global trade by enabling efficient movement of goods across member states and into international markets. Inland waterways, such as the Rhine and Danube, serve as low-cost, high-capacity arteries that connect industrial hubs to major seaports, linking Europe to Asia, the Americas, and Africa. This internal connectivity allows the EU to remain competitive in sectors requiring reliable bulk transport—chemicals, steel, and energy commodities—while supporting just-in-time supply chains for complex manufacturing.

By contrast, **China's participation in globalization** relies on massive, centrally coordinated investments in port infrastructure, high-speed rail, and extensive river transport networks. China's inland waterway modernization, particularly along the Yangtze River, complements its "Belt and Road" strategy, ensuring that goods move efficiently from industrial heartlands to global shipping nodes. The scale and integration of Chinese infrastructure enable rapid industrial output and global supply chain dominance, illustrating how well-planned waterways and logistics systems can underpin economic clout.

In the **United States**, inland waterways such as the Mississippi and Ohio Rivers form a critical backbone for domestic freight, particularly bulk commodities like grain, coal, and petroleum. However, the US relies heavily on road and rail for higher-value goods, and infrastructure maintenance has lagged in some regions, affecting efficiency and global competitiveness. Unlike Europe, the US lacks the same density of cross-border coordination, as most infrastructure serves national rather than regional or transnational integration.

African economies, while experiencing rapid urbanization and industrial growth, often face infrastructure bottlenecks that limit their integration into global trade networks. River transport potential is underutilized, and inland connectivity is frequently constrained by limited dredging, insufficient port capacity, and fragmented governance. As a result, Africa's economic participation in globalization is hampered by higher transport costs and slower movement of goods, highlighting the critical role infrastructure plays in unlocking trade competitiveness.

Within this comparative framework, the EU's inland waterways and transport networks confer both advantages and challenges. On the one hand, they provide environmentally efficient, high-volume corridors that facilitate trade with global partners, reinforcing the EU's strategic positioning in international markets. On the other hand, aging locks, sedimentation, and fragmented regulations can reduce reliability, limiting the EU's capacity to fully compete with infrastructure-led strategies in China or the scale of the US inland network.

Modernizing EU infrastructure—through climate-resilient waterways, smart ports, interoperable digital systems, and cross-border governance—would strengthen the continent's role in globalization. Improved waterways can lower transportation costs, enhance supply chain reliability, and expand Europe's capacity to handle both bulk commodities and higher-value goods efficiently. In doing so, the EU would maintain a distinct competitive advantage in sustainable, high-quality logistics, reinforcing its position alongside the infrastructurally-driven economies of China, the US, and emerging African markets.

APPENDIX 1 – Towards an Integrated and Coherent Legal Framework on Europe's Inland Waterways

The first priority must be to establish a minimum of order and cutting slack with Charlina, and the broader governance of Europe's inland waterways. Creating this foundational clarity ensures that regulatory responsibilities, enforcement mechanisms, and logistical oversight are coherent and consistently applied across ports and waterways. Without such a baseline, coordination becomes fragmented, vulnerabilities multiply, and the system's resilience is undermined.

Over time, however, regulations often "blossom" in an uncontrolled manner. Initial rules, designed to address specific issues, tend to expand in scope, layer upon layer, as bureaucracies grow and new mandates are added. This expansion frequently occurs without strategic reflection on effectiveness, cost, or coherence with overarching transport objectives. Regulatory proliferation can create duplication, conflicting interpretations, and gaps in enforcement, which in turn diminish operational efficiency and provide opportunities for exploitation.

To move from reactive regulation to strategic governance, authorities must prioritize harmonization, clear allocation of responsibilities, and performance-based oversight. Strategic regulation should focus on risk management, data-driven enforcement, and adaptability to evolving transport and security challenges. The 2025 debacle surrounding the revised EU transport directive exemplifies the consequences of regulatory mushrooming and inadequate coordination. Loopholes in enforcement, overlapping responsibilities between inland and coastal authorities, and insufficient cross-border intelligence sharing allowed illicit activities to circumvent controls, revealing the limits of a fragmented approach. Addressing these failures requires not only refining rules but embedding a strategic, system-wide perspective into the regulation of Europe's transport networks, linking inland waterways, ports, and broader logistics chains under coherent governance.

Massimiliano Grimaldi's work provides a comprehensive analysis of the European legal framework governing inland waterways, examining both EU legislation and national implementation. He emphasizes that establishing a clear baseline of order is essential to ensure safety, interoperability, and integration between inland waterways and ocean ports. Over time, regulations often "blossom," expanding in scope without strategic pruning, leading to overlapping rules and fragmented enforcement. Bureaucracies grow alongside these regulations, focusing on technical compliance rather than systemic outcomes. This regulatory complexity can create gaps, inefficiencies, and opportunities for exploitation, weakening both operational effectiveness and security. The 2025 revision of the River Information Services Directive exemplifies these issues, with fragmented implementation and technical delays undermining safety and multimodal connectivity. Grimaldi highlights the need for strategic governance that aligns regulations with clear objectives, performance metrics, and cross-border coordination. Ultimately, his analysis underscores that inland waterway law must balance legal detail with practical effectiveness to strengthen Europe's integrated transport system. Allow yourself to play broader.

The European Commission exercises legislative initiative within the EU inland waterways regulatory framework, proposing new legislation and amendments, while also providing strategic coordination and legal oversight to ensure consistency with broader EU transport, safety, and environmental objectives. The EU Inland Waterways Coordination Body operates as a central technical, advisory, and monitoring mechanism, supporting regulatory harmonisation across Member States and facilitating structured cooperation with relevant international organisations. Member States, through their designated national authorities, are responsible for implementing and enforcing the framework at national level, including conducting inspections, monitoring compliance, and issuing certificates and approvals. International bodies, notably those responsible for the ADN and the Central Commission for the Navigation of the Rhine (CCNR), develop overarching technical and safety standards that are incorporated into the EU regulatory system. Vessel operators and crews bear direct responsibility for complying with all operational, technical, safety, and environmental requirements, including the accurate maintenance of documentation and digital records, thereby ensuring safe, secure, and sustainable inland waterway transport.

A unified regulatory framework for inland waterway transport shall establish a coherent and comprehensive set of rules applicable across all Member States, with the following provisions:

General principles and scope. The framework shall set out the objectives of inland waterway transport policy, including the promotion of safety, environmental sustainability, and the integration of inland navigation into the internal market. It shall define the territorial and material scope of application and specify the relationship with relevant international conventions and national law.

Institutional governance and coordination. The framework shall designate the roles and responsibilities of the European Union institutions, Member States, and a dedicated inland waterways coordination body, where established. It shall provide for coordination and cooperation with international inland navigation organisations and national authorities to ensure uniform application and oversight of the regulation.

Vessel technical standards. Uniform requirements shall be established regarding vessel design, construction, equipment, maintenance, certification, and digital documentation. Such standards shall be recognized across all Member States to facilitate free navigation and interoperability.

Safety and navigation rules. Rules shall be established concerning operational safety, vessel traffic management, accident prevention, reporting obligations, emergency procedures, and risk management, including provisions specific to the transport of dangerous goods.

Crew qualifications and working conditions. The framework shall harmonize professional qualifications, training, certification, medical fitness, working hours, rest periods, and social standards applicable to crew members, ensuring safety and fair competition.

Market access and freedom to provide services. Conditions for access to the inland waterway transport market shall be regulated, including non-discrimination, cabotage, and mutual recognition of authorisations, consistent with the principles of the internal market.

Liability and insurance regimes. Clear rules shall be established on carrier liability, claims for passengers and cargo, environmental damage, compulsory insurance, and the limitation of liability, in alignment with applicable EU civil liability and environmental legislation.

Environmental protection requirements. Requirements shall address emissions, fuel and energy use, waste management, noise reduction, and protection of water quality and aquatic ecosystems, in accordance with EU environmental and climate law.

Infrastructure and waterway management. Standards shall be provided for waterways, locks, ports, and digital traffic management systems, including coordination between transport authorities and water management authorities to ensure efficient and safe navigation.

Digitalisation and data exchange. The framework shall establish harmonized rules for electronic documentation, vessel tracking, smart traffic management, and interoperability with EU transport and customs systems.

Enforcement, inspections, and sanctions. Common procedures for inspection, mutual assistance between authorities, proportionate sanctions, and mechanisms for cross-border enforcement shall be established to ensure compliance.

Monitoring, reporting, and review. Member States and the Commission shall collect relevant data, establish performance indicators, and conduct periodic evaluations. Provisions shall be made for the regular updating of technical standards and other rules to maintain the effectiveness, safety, and coherence of the framework.

Regulation Of The European Parliament And Of The Council On Unified Rules For Inland Waterway Transport

The European Parliament And The Council Of The European Union,

Having regard to the Treaty on the Functioning of the European Union, and in particular Articles 91 and 100 thereof,

Having regard to the proposal from the European Commission,

After transmission of the draft legislative act to the national parliaments,

Having regard to the opinion of the European Economic and Social Committee,

Acting in accordance with the ordinary legislative procedure,

Whereas:

(1) Inland waterway transport is a strategic component of the internal market, contributing to sustainable mobility, the reduction of road congestion, and the decarbonisation of the transport sector in line with the European Green Deal.

(2) Current EU legislation on inland waterway transport, including Directive 2008/68/EC on the inland transport of dangerous goods, Directive 2005/44/EC on vessel traffic monitoring, and Directive 2006/87/EC on technical requirements for inland vessels, is fragmented and leaves significant discretion to Member States.

(3) International agreements, including the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN) and the Central Commission for Navigation of the Rhine (CCNR) standards, form an essential part of the regulatory framework, but their integration into EU law requires clarification and harmonisation.

(4) A unified EU legal framework is necessary to ensure safety, environmental protection, legal certainty, and uniform application of rules across the Union.

(5) Digitalisation and interoperability of data systems are essential to modern inland navigation and should be promoted throughout the Union.

(6) Institutional coordination between EU bodies, Member States, and international organisations is required to guarantee effective implementation, monitoring, and enforcement of inland waterway legislation.

Have Adopted This Regulation:

Chapter I – Subject Matter And Scope

Article 1 – Subject Matter

This Regulation establishes a unified legal framework governing inland waterway transport within the territory of the Member States. It aims to ensure:

(a) Safety of navigation and operational efficiency;

(b) Environmental protection and sustainability;

(c) Harmonisation of technical, operational, and market rules;

(d) Integration of inland navigation into the internal market.

Article 2 – Scope

1. This Regulation shall apply to all vessels engaged in inland navigation, including commercial and passenger transport, on navigable inland waterways within the territory of the Member States.
2. This Regulation shall apply without prejudice to the provisions of relevant international conventions to which the Union or its Member States are parties, including ADN and CCNR regulations.
3. Member States may adopt stricter rules only insofar as they are compatible with this Regulation and EU law.

Chapter Ii – General Principles

Article 3 – Objectives

Inland waterway transport shall be conducted to:

(a) Guarantee high levels of safety and operational efficiency;

(b) Ensure protection of water, ecosystems, and air quality;

(c) Promote uniform technical and legal standards;

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(d) Facilitate free movement of goods and services.

Chapter Iii – Institutional Governance And Coordination

Article 4 – Roles of EU Institutions and Member States

1. The European Commission shall coordinate implementation, monitor compliance, and propose amendments where necessary.
2. Member States shall designate competent authorities responsible for enforcement, certification, and reporting.

Article 5 – Inland Waterways Coordination Body

A dedicated EU Inland Waterways Coordination Body may be established to:

(a) Provide technical guidance and advice;

(b) Monitor compliance and collect operational and safety data;

(c) Facilitate cooperation with international inland navigation organisations.

1. The Body shall submit an annual report to the Commission on implementation and compliance.

Chapter Iv – Vessel Technical Standards

Article 6 – Design and Construction

1. Vessels must meet harmonised technical standards for design, stability, construction, and hull integrity.
2. Certificates issued by one Member State shall be recognised throughout the Union.

Article 7 – Equipment and Maintenance

1. Vessels shall maintain approved safety equipment and undergo regular inspections.
2. Maintenance records must be documented digitally in accordance with Article 18.

Chapter V – Safety And Navigation Rules

Article 8 – Operational Safety

1. Member States shall ensure uniform safety rules for vessel operations, traffic management, and accident prevention.
2. Risk management and emergency response procedures shall be harmonised across the Union.

Article 9 – Dangerous Goods Transport

1. The transport of dangerous goods shall comply with ADN regulations.
2. Member States shall maintain inspection regimes to ensure adherence to ADN standards.

Chapter Vi – Crew Qualifications And Working Conditions

Article 10 – Professional Qualifications

Crew members must meet harmonised standards for training, certification, and medical fitness.

Article 11 – Working Hours and Social Conditions

Working hours, rest periods, and social conditions shall comply with minimum EU standards, ensuring safety and fair competition.

Chapter Vii – Market Access And Freedom To Provide Services

Article 12 – Market Access

1. Conditions for access to inland waterway transport services shall be non-discriminatory.
2. Cabotage rights shall be respected and authorisations issued in one Member State shall be recognised across the Union.

Chapter Viii – Liability And Insurance

Article 13 – Liability

1. Carriers shall be liable for damages to passengers, cargo, and the environment in accordance with harmonised rules.
2. Member States shall require vessels to maintain compulsory insurance consistent with EU civil liability law.

Chapter Ix – Environmental Protection

Article 14 – Emissions and Energy Efficiency

1. Vessels shall comply with EU standards on emissions, fuel consumption, and energy efficiency.
2. Waste management and noise reduction measures shall also be implemented.

Article 15 – Waterway Protection

Member States shall implement measures to protect water quality and aquatic ecosystems in line with EU environmental legislation.

Chapter X – Infrastructure And Waterway Management

Article 16 – Infrastructure Standards

Waterways, locks, and ports shall meet harmonised EU standards. Member States shall coordinate infrastructure maintenance to ensure safe navigation.

Article 17 – Traffic Management

Digital traffic management systems shall be interoperable across borders and integrated with EU transport and customs networks.

Chapter Xi – Digitalisation And Data Exchange

Article 18 – Electronic Documentation

1. All vessels shall maintain harmonised electronic documentation for navigation, cargo, and certification.

2. Data systems shall be interoperable with EU transport, customs, and safety databases.

Chapter Xii – Enforcement, Inspections, And Sanctions

Article 19 – Inspections

Member States shall carry out inspections and apply proportionate sanctions for violations.

Article 20 – Mutual Assistance

Authorities shall cooperate and provide mutual assistance to ensure cross-border enforcement.

Chapter Xiii – Monitoring, Reporting, And Review

Article 21 – Data Collection and Reporting

Member States shall submit regular reports to the Commission on implementation and operational performance.

Article 22 – Review and Updating

The Commission shall periodically review this Regulation and propose amendments to technical or operational rules as necessary.

Chapter Xiv – Final Provisions

Article 23 – Entry into Force

This Regulation shall enter into force on the twentieth day following its publication in the Official Journal of the European Union and shall apply from [date to be determined].

Article 24 – Transitional Measures

Member States shall adopt measures necessary to ensure a smooth transition to the harmonised rules within [X] months of the entry into force.

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