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List of abbreviations

ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
AI	Artificial Intelligence
AIS	Automatic Identification System
AMQP	Advanced Message Queuing Protocol
AR/VR	Augmented Reality / Virtual Reality
CCNR	Central Commission for the Navigation of the Rhine
CEF2	Connecting Europe Facility – Transport (2021–2027)
CESNI	European Committee for Drawing up Standards in Inland Navigation
CO_2	Carbon Dioxide
CSA	Coordination and Support Action
EIB	European Investment Bank
EMSA	European Maritime Safety Agency
EU	European Union
ETS	Emissions Trading System
FC	Fuel Cell
GDPR	General Data Protection Regulation
HT-FC	High Temperature Fuel Cell
IA	Impact Assesment
IoT	Internet of Things
IPR	Intellectual Property Rights
IWT	Inland Waterway Transport
KPI	Key Performance Indicator
LIFE	EU LIFE Programme (Environment and Climate Action)
MBSE	Model-Based Systems Engineering
MRV	Monitoring, Reporting and Verification
NECP	National Energy and Climate Plan
NOx	Nitrogen Oxides
OEM	Original Equipment Manufacturer

OPS	Onshore Power Supply
PPI	Public Procurement for Innovation
PM	Particulate Matter
RD&I	Research, Development and Innovation
RIS	River Information Services
SAFs	Sustainable Alternative Fuels
SME	Small and Medium-sized Enterprise
SRA	Strategic Research Agenda
SRIA	Strategic Research and Innovation Agenda
TCP	Transmission Control Protocol
TEN-T	Trans-European Transport Network
TRL	Technology Readiness Level
WtW	Well-to-Wake (emissions measurement)
ZEWT	Zero-Emission Waterborne Transport

Executive summary

Deliverable 5.2 of PLATINA4Action presents the strategic advice for the Zero-Emission Waterborne Transport (ZEWT) Partnership's Strategic Research and Innovation Agenda (SRIA), focusing on Inland Waterway Transport (IWT). It presents the identified RD&I gaps, the analysed stakeholder perspectives, and the proposed actions for the ZEWT SRIA update under Horizon Europe.

The ZEWT SRIA was updated and published in June 2025, drawing on input from PLATINA4Action, and this deliverable is designed to feed subsequent revisions of the SRIA as well. It builds on earlier work from PLATINA3 and STEERER, on insights from multiple ongoing and completed EU-funded projects, and on contributions from the PLATINA4Action consortium partners.

This report is structured to support the development of the ZEWT SRIA with grounded, actionable recommendations based on technological, policy, and market evidence. It maps the current state of RD&I for zero-emission and smart IWT, focusing on six pillars: sustainable alternative fuels, electrification, energy efficiency, design and retrofitting, digitalisation, and ports.

By assessing both short-term achievements (2021–2024) and medium-term strategic orientations (2025–2027), the report highlights the systemic bottlenecks and the innovation potential within each domain. It identifies priority actions and capabilities that must be reinforced to accelerate the uptake of zero-emission technologies in IWT, while proposing the establishment of demonstration clusters, regulatory testbeds, and support mechanisms for technology validation and market rollout.

Key outcomes include a series of cross-sectoral recommendations aligned with global decarbonisation goals, the European Green Deal, and the twin transition of digital and green innovation. The report also introduces a Competitiveness Roadmap, presenting a forward-looking framework to ensure ZEWT technologies move from laboratory to real-world deployment, offering a new industrial model for sustainable and competitive inland waterway transport in Europe.

This strategic advice reflects the collective intelligence of the PLATINA4Action consortium, the IWT Projects Cooperation Platform, and the broader stakeholder ecosystem. It represents a shared commitment to making inland navigation a central actor in Europe's climate neutrality and industrial leadership agendas.

1. Introduction

- **Purpose of the deliverable:** Deliverable 5.2 has been prepared to provide structured and evidence-based advice for the update of the ZEWT SRIA[1], focusing on the inclusion of Inland Waterway Transport (IWT) needs and cross-cutting themes applicable to both the IWT and maritime sectors. Its core aim is to ensure that the ZEWT SRIA reflects not only the highest-impact areas for research and innovation but also the specific operational contexts, challenges, and investment priorities of IWT stakeholders across Europe. The results presented in this Deliverable D5.2 have been taken into account in the ZEWT SRIA which was updated in June 2025.

- **Scope:** This deliverable reviews RD&I gaps and outlines policy and funding needs across six ZEWT innovation pillars relevant to IWT: ((1) Sustainable Alternative Fuels, (2) Electrification, (3) Energy Efficiency, (4) Vessel Design and Retrofitting, (5) Digitalisation, (6) Ports. While rooted in the inland navigation domain, the deliverable addresses areas with maritime applicability and fosters synergies that accelerate uptake and systemic impact. In particular, it draws attention to solutions that are scalable, modular, and well-suited for the highly diverse fleet and operational environments typical of inland navigation.

- **Methodology:** The analysis builds on desk research, interviews and targeted input from consortium partners, and critical review of Horizon Europe strategic planning documents. It incorporates feedback from key initiatives, notably PLATINA3 and STEERER, and extracts relevant findings from recent and ongoing EU-funded projects such as FASTWATER, FLAGSHIPS, RH2IWER, Current Direct, SYNERGETICS, and others. The deliverable also integrates expert commentary collected through the IWT Projects Cooperation Platform and is aligned with the overall objective of supporting the ZEWT co-Programmed Partnership process with grounded recommendations.

[1] Please find the SRIA (June 2025): https://www.waterborne.eu/images/250708_Strategic_Research_Agenda_Final_copy.pdf

2. Review of prior work and key EU funded projects

A series of previous and ongoing EU projects have directly or indirectly contributed to identifying RD&I needs for the greening and digital transformation of inland waterway transport. These projects serve as the technical and strategic foundation for many of the recommendations in this deliverable:

- **PLATINA3:** Identified key enablers for IWT decarbonisation including regulatory simplification, fleet renewal support, and greater harmonisation of data standards across Europe. It highlighted the pressing need for digital infrastructure and the modernisation of training and crewing regulations to support new technologies.

- **STEERER & NEEDS:** Provided transition pathways, including scenarios and targets for decarbonising waterborne transport by 2025, 2030, and 2050. The project outlined ZEWT research orientations and proposed a series of enabling actions, including early deployment of alternative fuels and the scaling of electrification.

- **FLAGSHIPS & RH2IWER:** Demonstrate the feasibility of hydrogen-powered vessels and bunkering solutions, contributing technical data and operational experience highly relevant for the inland sector.

- **FASTWATER, Current Direct, SYNERGETICS:** Provided insights into methanol, hydrogen, and battery-electric propulsion systems, as well as hydrodynamic optimization, particularly regarding retrofitting and cost-efficiency. These are critical aspects for replicability in the small-scale and fragmented IWT fleet.

- **MAGPIE, AEGIS:** Piloted multimodal logistics and port innovation. These projects underscore the importance of systems integration and data-driven planning in optimising cargo flows and energy use.

- **1S4IWT, LASTING,:** Addressed digitalisation, training frameworks, and sustainable energy systems. Their findings contribute to the human and systemic dimensions of innovation readiness, an essential complement to technology development.

Taken together, these projects provide a comprehensive knowledge base of what is technically achievable and what gaps remain for the inland sector. Their outcomes have shaped the structure and content of this deliverable and guide the formulation of targeted, evidence-based recommendations.

3. The PLATINA4Action Advice for the Zero-Emission Waterborne Transport Partnership's Strategic Research and Innovation Agenda

3.1 Use of sustainable alternative fuels

The transition towards sustainable alternative fuels is foundational to the ZEWT Partnership. While progress has been made in hydrogen, ammonia, methanol and biofuels for the overall Waterborne sector, more coordinated efforts are needed to ensure safe and economically viable integration into IWT. The RH2IWER and FLAGSHIPS projects show the technical potential for hydrogen fuel applications, yet they also reveal ongoing gaps in safety protocols, infrastructure harmonisation, and crew training. FASTWATER and SYNERGETICS illustrated that methanol is a promising option, though further action, including removal of regulatory barriers and investment is needed for Stage V methanol engine certification, in retrofit strategies and port bunkering infrastructure. Projects such as PATH2Zero and ENTRANCE also stress the importance of aligning new fuels with lifecycle carbon accounting and the capacity to retrofit.

Recommendations:

- Expand demonstration projects for ammonia and hydrogen propulsion, focusing on modular designs and safety-compliant integration for inland navigation: Broaden the scope of hydrogen carrier research beyond just ocean-going, short sea shipping vessels and ferries to include IWT vessels and floating equipment.
- Promote simulation and digital twin applications for integrating methanol, ammonia, and LOHC in IWT shipboard systems.
- Recommend decision tools for IWT operators to assess WtW energy impact of different hybrid combinations.
- Emphasise multi-fuel system design using MBSE (Model-Based Systems Engineering) tailored to small and modular IWT vessels.
- Highlight the need for real-world demonstration of alternative fuel integration, especially in retrofitted vessels.
- Advocate for clear certification schemes and after-treatment system validation (focus on NOx, PM, CO2).
- Advocate for time- and cost-efficient approval procedures for onboard implementation of innovative technologies applicable on EU level; the procedures should not be limited to approval of pilots but should lead to the product deployment.
- Address the lack of IWT-specific fuel safety standards and risk assessments, particularly for bunkering and storage.

- Stress the relevance of CCS only if linked to true zero-emission systems (e.g. Fuel Cell systems using renewable methanol), not legacy fossil-based engines.
- Develop a harmonised European framework for hydrogen bunkering and hydrogen storage, based on FLAGSHIPS and RH2IWER insights.
- Fund simulation-based safety modelling (digital twins) as recommended by FASTWATER and SYNERGETICS.
- It is recommended that the monitoring underpinning this Roadmap be aligned from the outset with the Count Emissions EU Regulation, which establishes a harmonised methodology for accounting greenhouse-gas emissions from transport services based on ISO 14083. The data-collection architecture set up under Deliverable D3.2 should feed this framework directly: operational and energy-use data gathered from inland vessels provide the evidence base for deriving default emission intensity values, which should in turn converge towards, and be reconciled with, the Count Emissions EU emission-factor database. Establishing this chain (data collection, default emission intensities, convergence to the common database) ensures that IWT monitoring rests on a single, regulation-compliant reference rather than on parallel or divergent accounting methods, and that modal-shift and decarbonisation claims for inland navigation are comparable across modes and verifiable at Union level.

3.2 Electrification

The electrification of vessels is increasingly viable due to battery innovation and energy management systems. ZEWT objectives highlight DC grids, hybrid solutions, and electrification in ports. For the IWT sector, electrification must reflect short ranges, small vessel sizes, and constraints in infrastructure and manoeuvrability. Demonstration of retrofit solutions and shore-to-ship energy transfer is crucial. Projects like FOREMAST, ENTRANCE, and AUTOFLEX emphasise how active propulsion optimisation, smart route planning, and hull design can significantly reduce energy use. However, these innovations are still under-represented in operational fleets. Energy efficiency measures remain fragmented due to lack of harmonised monitoring and reporting tools.

Recommendations:

- Prioritise investment in portside OPS systems and vessel-side retrofits.
- Support OPS retrofitting in existing inland passenger and cargo vessels.
- Highlight need for fast-charging and battery swapping infrastructure suitable for narrow inland ports.
- Emphasise hybridisation with solar, hydrogen FCs, , adapted to river navigation constraints.
- Recommend decision tools for IWT operators to assess WtW energy impact of different hybrid combinations.
- Co-develop electrification corridors with grid operators, as proposed in MAGPIE.
- Support integration of hybrid and fully electric propulsion systems in line with the operational requirements of inland vessels.

- Include cybersecurity standards in vessel-grid interactions, as flagged by NEEDS and AENAS.

3.3 Energy-efficiency

Energy efficiency plays a central role in reducing emissions cost-effectively. The SRIA sets out goals for onboard renewable integration, energy monitoring, and propulsion innovation. For IWT, shallow-draft and short-distance operations demand lightweight, scalable solutions and integration of passive measures (e.g., hull design) with real-time data-driven management.

Recommendations:

- Support the demonstration of energy management systems developed in FOREMAST and SYNERGETICS.
- Incentivise retrofitting of hull efficiency technologies.
- Develop real-time GHG monitoring tools with integrated AI, as seen in AENAS.

3.4 Design and retrofitting

ZEWT recognises the need to retrofit existing fleets and standardise design pathways. IWT stakeholders stress that retrofitting must be modular and affordable for small operators. The focus must be on scalable kits, digital tools, and life-cycle impact reduction, particularly for vessels with shallow hulls and variable operating environments.

Recommendations:

- Support R&I into modular, replicable retrofit kits for typical IWT vessels (pushers, tankers, day-cruise ships).
- Advocate for boosting European retrofit yards' capabilities, including training, supply chains, and inland-specific standards.
- Retrofitting of smart onboard degassing installations, NOx control, and fugitive emissions as priorities in refit design.
- Point to the urgent need for solutions that reduce retrofit costs and time, especially in micro-enterprises.
- Support development of the future-ready standard inland vessel designs to replace the current designs developed in the course of the second half of the 20th century.

3.5 Digital green

Digitalisation underpins modern fleet management, energy optimisation, and emissions tracking. The ZEWT SRIA promotes digital twins, real-time decision support, and data sharing frameworks. For IWT, the challenge lies in the digital integration of smaller vessels and infrastructure, requiring standardised but lightweight systems adapted to RIS, AIS and inland conditions.

Recommendations:

- **IA – Digital Powertrain Management:**
  - Emphasise development of tailored digital architectures for small, hybrid IWT vessels.
  - Support digital twins for predictive modelling, energy optimisation, and crew support in low-manpower operations.
  - Recommend targeted training for crews and shore-side operators to safely manage complex multi-energy powertrains.
- **IA – Remote Emissions Monitoring:**
  - IWT stakeholders see value in low-cost, mobile, and accurate sensors for inland operations.
  - Recommend R&I on calibration-free technologies and harmonised certification frameworks.
  - Urge that IWT-specific environmental conditions (e.g. bridges, narrow locks, shallow water effects) be considered in system validation.
- **IA – Secure Autonomous Monitoring:**
  - Strong support for IoT-enabled, real-time emission and activity monitoring onboard IWT vessels.
  - Suggest further work on ship-to-ship telemetry and fully automated bunkering verification in river contexts.
  - Propose IWT involvement in pilot use cases for blockchain-secured reporting systems.
- **IA – Open-Source Decision Support:**
  - Push for open-source decision-support tools integrating weather, waterway depth, port energy availability.
  - Recommend lightship weight on-board computing for smaller IWT vessels with limited energy budgets.
  - Highlight the need for GDPR compliance and user-centred design in tools used by small operators.
- **CSA – Data Sharing Frameworks:**
  - Stress the need for interoperability between different IWT vessel systems and port platforms.
  - Recommend specific guidance on IPR, cybersecurity, and secure standards (e.g. for AIS, RIS, telemetry).

- Flag the importance of EU Data Act compliance, especially for SMEs concerned about data ownership.
- Include data sharing for GHG calculation and reporting systems

3.6 Ports

Inland ports are emerging as critical nodes in the green transition. The ZEWT SRIA outlines the role of OPS, smart bunkering, safety frameworks, and energy exchange. IWT stakeholders emphasise that these must be adapted to smaller, mixed-use terminals and inland energy needs, and supported by funding mechanisms that make OPS and fuel switching economically feasible.

Recommendations:

- **Safe Multi-Fuel Bunkering & OPS (IA):**
  - Urge inclusion of inland terminals and mixed-use river ports in bunkering risk assessments.
  - Call for standards development for ammonia, methanol and hydrogen bunkering during cargo operations or with passengers aboard.
  - Highlight inland port role in safety protocol testing, crew training, and automated OPS connectivity.
- **Smart Port-Vessel Energy Management (IA):**
  - Inland ports should be included as testbeds for advanced energy management and grid flexibility tools.
  - Push for demonstration projects with battery-electric IWT vessels supporting local grid peak shaving.
  - Emphasise need to adapt these systems for inland-specific operational cycles (e.g. short port calls, overnight layovers).
  - Business models must reflect different energy pricing and ETS impact for IWT, not only seagoing contexts.

3.7 Conclusion to current state of play

The current state of play highlights both the progress made and the persistent structural challenges facing the IWT sector. While promising technologies and policy frameworks are emerging, systemic fragmentation, insufficient deployment pathways, and underdeveloped incentives continue to inhibit scale-up and uptake. These realities underline the need for targeted, coordinated RD&I efforts that go beyond isolated pilots. As we transition to the next phase of the roadmap, it is essential to define concrete research directions and strategic actions that will enable a fully integrated and zero-emission IWT ecosystem by 2050—one that is not only technologically advanced but also economically viable and socially inclusive.

4. Strategic research directions for IWT in the ZEWT SRIA

Inland Waterway Transport (IWT) is the most energy-efficient transport modes in Europe. However, the path to zero-emission and smart inland navigation remains constrained by research and innovation gaps, fragmented pilot deployment, and regulatory inertia. To address these, the ZEWT Strategic Research and Innovation Agenda (SRIA) must better reflect the specific needs and systemic role of IWT.

Building on the outcomes of PLATINA3, the strategic orientations of STEERER, and the lessons from more than 20 recent and ongoing EU-funded projects (including FLAGSHIPS, FASTWATER, RH2IWER, SYNERGETICS, ENTRANCE, and others), the PLATINA4Action consortium has identified five core research directions that should shape the future evolution of the ZEWT SRIA. These should guide Work Programme development under Horizon Europe (2025–2027 and beyond) and strengthen the integration of IWT in the ZEWT Partnership's long-term strategy.

4.1 Strengthen deployment-oriented demonstration calls

Research alone will not decarbonise inland navigation. The next SRIA update should prioritise full-scale, corridor-based implementation projects, encompassing fleets, ports, and logistics operators. These initiatives should:

- Integrate alternaritve fuels (hydrogen, methanol, ammonia) with real-world port infrastructure.
- Focus on retrofitting the ageing IWT fleet and co-develop scalable vessel designs, there by considering low water challenges, as far as considered in the general framework of the document
- Use living lab formats and corridor testbeds to simulate, evaluate, and adapt complex multi-actor operations.
- Include robust replication and scaling components to support market entry beyond the implementation region.

Inspiration: FLAGSHIPS, FASTWATER, and SYNERGETICS all reveal the urgent need for integrated and replicable demonstrations.

4.2 Accelerate pre-normative research and certification frameworks

The absence of clear and harmonised certification, classification, and safety protocols remains a major bottleneck for new fuel systems and retrofitted vessels. Horizon Europe must fund:

- Co-design of standards for hydrogen bunkering, onshore power use, and modular energy systems.

- Development of interoperable battery-swapping systems and shore power interfaces for IWT-specific contexts.
- Integration of CESNI, ADN and other regulatory bodies in pre-normative consortia, ensuring early regulatory buy-in.

Inspiration: These issues are directly echoed in FLAGSHIPS & RH2IWER (hydrogen handling), FASTWATER (methanol safety), and the feedback of CESNI experts through the IWT Platform.

4.3 Embed socio-technical innovation and workforce transitions

Transitioning to ZEWT-compatible operations requires more than technical adaptation: it demands institutional, behavioural, and workforce innovation. Accordingly, thehe SRIA should support:

- Research on crew acceptance, organisational adaptation, and the role of trust and safety culture in digital and automated systems.
- Research on human-machine interaction for safe and efficient use of power management systems for novel propulsion concepts and decision support systems for fuel-efficient navigation.
- Integration of training pilots and skills foresight into technology demonstration projects (e.g. AR/VR simulators for new fuels).
- Development of a ZEWT Skills Framework for IWT, with mutual recognition of certifications and micro-credentials.

Inspiration: ENTRANCE, PATH2Zero, and interviews with vocational institutions show that human capacity is a limiting factor for upscaling.

4.4 Prioritise interoperable digitalisation and real-time monitoring

The digitisation of IWT is uneven and often disconnected from the decarbonisation agenda. ZEWT's future calls must focus on:

- Digital twins for IWT vessels and infrastructure, enabling predictive maintenance and real-time routing.
- Secure, interoperable data exchange systems between vessels, ports, and multimodal chains.
- Monitoring platforms for real-time emissions and fuel use, connected to regulatory reporting (e.g. ETS, FuelEU).

Inspiration: Internal ZEWT work and projects like FOREMAST, AUTOFLEX and AENAS offer foundations for standardising data and modelling efforts.

4.5 Link research to market incentives and policy signals

To avoid the "valley of death", research must be synchronised with policy trajectories and financial tools. Future SRIA updates should:

- Require Horizon Europe projects to conduct policy readiness assessments and develop business models as part of their deliverables.
- Involve insurers, financiers, public procurers, and port operators in consortia to validate commercialisation pathways.
- Ensure alignment with EU Taxonomy, ETS, and the Alternative Fuels Infrastructure Regulation (AFIR), so that innovation projects anticipate regulatory incentives.

Inspiration: The PLATINA3 final report and PATH2Zero confirm that calls must go beyond TRL 5–6 and include systemic anchoring.

4.6 Facilitate alignment between R&I actors and deployment platforms

The IWT Projects Cooperation Platform, Waterborne 's Industry and Research Alignment Groups, and the Waterborne Technology Platform are essential channels to align research programming with market and regulatory needs. Accordingly, the SRIA should:

- Formalise feedback loops from these platforms into topic scoping, project evaluation, and results integration.
- Encourage joint initiatives between R&I consortia and deployment actors, especially ports and logistics networks.
- Support structured dialogue between regulatory agencies and projects working on pre-commercial technologies.

5. Aligning SRIA updates with IWT realities: concluding reflections and strategic next steps

Deliverable 5.2 has provided an in-depth analysis of the RD&I landscape for IWT in the context of the ZEWT Partnership. Through extensive engagement with the PLATINA4Action consortium, analysis of key EU-funded projects (e.g. PLATINA3, SYNERGETICS, STEERER, NEEDS, FASTWATER, FLAGSHIPS, RH2IWER), and feedback from the IWT Projects Cooperation Platform, a consistent message emerges: the ZEWT SRIA must now evolve from a high-level vision into a practical, deployable, and sector-specific innovation strategy for IWT.

While the SRIA lays a strong technical and policy foundation, the sector's realities demand a more targeted, IWT-tailored articulation of RD&I pathways. This means adapting the SRIA not only to reflect technological priorities but to recognise the operational, regulatory, and market-specific nuances of inland shipping.

Key areas for SRIA enhancement based on D5.2 Findings:

- Retrofit-Centric Technological Pathways: The long asset lifespan of IWT vessels makes retrofit solutions (e.g. dual-fuel systems, modular electrification, carbon capture add-ons) essential for short- and medium-term emission reduction. The SRIA should prioritise scalable, cost-efficient retrofitting technologies and address the unique certification and integration barriers they face.

- Port Infrastructure as an Enabler: ZEWT deployment is critically dependent on port infrastructure (shore power, bunkering for SAFs, battery charging/swapping). However, RD&I efforts on port-side enablers remain underfunded and underspecified in the current SRIA. There is a strong case for more ambitious, corridor-based infrastructure R&I programmes, including digital twin modelling, harmonised safety guidelines, and energy integration pilots.

- Digitalisation Adapted to SME Realities: Digital tools—monitoring systems, decision support tools, digital twins—are often designed with larger maritime players in mind. The SRIA should steer research toward accessible, low-cost digital innovations that can be realistically adopted by small operators and integrated into existing fleets and logistics systems.

- Just Transition and Skills: The energy and digital transition in IWT must not leave workers, regions, or SMEs behind. SRIA updates should strengthen attention to skills development, regional innovation hubs, and knowledge transfer mechanisms, particularly for eastern and southern EU Member States with high IWT potential..

- Stronger Research-Policy Interface: Several stakeholders highlighted the gap between research and regulatory reform. Projects often generate recommendations that do not reach policymakers or regulators in time to influence standards or funding design. The SRIA update should formalise a structured interface between RD&I outputs and policy feedback loops, including the use of testbeds..

- Commercial Uptake and Risk Reduction: Finally, SRIA priorities should reflect the realities of market readiness and investment constraints. This means supporting TRL 7–9 innovation, de-risking deployment through insurance schemes or carbon contracts for difference, and aligning research outputs with emerging EU instruments like CEF2 and the Innovation Fund.

5.1 Bridging to Deliverable 5.3: from strategic advice to strategic action

The insights and recommendations compiled here set the stage for Deliverable 5.3, which will build upon the RD&I priorities identified in this document and translate them into a coherent, forward-looking IWT roadmap. That deliverable will go beyond identifying innovation needs and tackle the 'how' of deployment: how to coordinate funding, overcome regulatory bottlenecks, align timelines, secure private-sector involvement, and track progress.

Deliverable 5.3 will be structured around four pillars: Market, Fleet, Jobs & Skills, and Infrastructure, combining a competitive decarbonisation agenda with an implementation strategy for ZEWT-aligned transformation. It will also provide a Competitiveness Roadmap—an actionable plan to move from lab to practice, from prototype to procurement, and from fragmented pilots to systemic impact.

Together, Deliverables 5.2 and 5.3 offer the ZEWT Partnership a twin compass: one to orient RD&I focus areas, and the other to guide strategic deployment across Europe's inland waterway transport system.

5.2 Strategic summary: research priorities and implementation levers

Deliverable 5.2 has been developed to provide targeted advice for updating the SRIA of the ZEWT Partnership, with a focus on IWT. The feedback from the PLATINA4Action consortium and the IWT Projects Cooperation Platform, complemented by findings from ongoing and recently concluded EU projects, has highlighted critical areas where further RD&I is essential.

This final section consolidates these inputs into a clear strategic direction for the ZEWT SRIA. It does not aim to prescribe deployment mechanisms—that is the remit of Deliverable 5.3—but instead sets the groundwork for impactful, inclusive, and investment-ready research in the IWT sector.

5.3 Cross-cutting research priorities for ZEWT

Research and innovation efforts in IWT must be designed not only to advance technological frontiers but also to respond to real-world operational contexts and systemic sustainability challenges. The following priorities are consistently supported across stakeholder feedback and project outcomes:

Fuel-flexible propulsion systems: Further RD&I is required into hydrogen, ammonia, methanol, and bio-based fuel pathways, particularly regarding safety, interoperability, and their retrofitting potential. Projects like FASTWATER,SYNERGETICS and RH2IWER demonstrate the need for ongoing support beyond TRL 6.

Electrification and hybridisation for IWT: New use cases and demonstrators must be explored for inland applications of full battery-electric, swappable storage systems, and hybrid solutions. Work from Current Direct and ENTRANCE demonstrates technical feasibility but highlights the lack of cost-effective deployment models.

Operational optimisation through digital tools: Real-time emissions monitoring, route planning, port synchronisation, and AI-assisted diagnostics must be prioritised for their role in improving energy efficiency. Results from FOREMAST and AENAS show the importance of integrating software development with onboard systems engineering.

Advanced vessel design and retrofitting: Modularity, lifecycle thinking, and systems-based retrofitting need further investigation, especially under constraints of space, mass, and safety. RETROFIT55, SYNERGETICS, and RESHIP offer blueprints for scalable retrofit schemes. AUTOFLEX, though it adresses new designs, it provides guidance for design of small, complex ships incorporating several innovative technologies.

Green port integration and smart energy infrastructure: To ensure seamless transitions between vessels and infrastructure, research is needed into OPS, multi-fuel bunkering, port-based charging, and shared data environments. Lessons from MAGPIE and MOSES underline the importance of aligning port strategies with IWT use cases.

Circularity and end-of-life vessel systems: Recycling, reuse of materials, second-life batteries, and waste heat recovery are essential to close the loop. Horizon Europe calls should incentivise circular systems design across the value chain.

Social and organisational innovation: Research into transition support, skills anticipation, inclusion of SMEs and peripheral actors, and cross-sectoral labour mobility is still underexplored but critical to ensure a just and inclusive ZEWT transformation.

5.4 Implementation levers for a responsive SRIA

To ensure the above priorities are successfully embedded into the ZEWT SRIA and future Horizon Europe calls, a number of structural enablers and guiding principles should be adopted:

From TRL targeting to transition pathways. Each technology area should define TRL entry and exit points and a clear pathway towards validation, certification and scale-up. Research consortia are responsible for reaching the targeted TRLs and generating the validation and safety evidence; certification and approval, however, lie with classification societies, CESNI, the CCNR and the competent authorities. These bodies should therefore be engaged from the outset of each technology pathway, and pre-normative research, regulatory sandboxes and the mutual recognition of testing and approval should be used to bridge the gap between demonstration and deployment.

Project clustering and peer learning: The ZEWT SRIA should encourage the creation of thematic clusters (e.g. digital IWT, alternative fuels, port integration) with shared learning objectives, enabling better alignment between projects and efficient knowledge diffusion.

Feedback loops into regulation and standardisation: Call topics must be explicitly linked to regulatory bottlenecks, such as energy and emission reduction regulations, certification of NRMM combustion engines using alternative fuels (e.g. methanol, hydrogen), safety certification for hydrogen and systems or standards for automated navigation. Research outputs for IWT should feed directly into the relevant CESNI, DC, CCNR and EC expert group discussions.

Stakeholder accountability mechanisms: Projects receiving Horizon Europe funding should include deliverables for stakeholder engagement, especially with regional authorities, river commissions, and training providers.

Open benchmarking frameworks: The SRIA should support open data platforms and reporting tools for emissions, energy use, digital integration, and innovation uptake. This would enable policymakers, industry, and civil society to track progress and compare interventions.

Dedicated IWT project advisory board: A rotating advisory panel composed of experts from demonstration projects (e.g. FLAGSHIPS, FASTWATER, RH2IWER, SYNERGETICS, Current Direct) should be established to advise on call design, thematic updates, and bottleneck resolution.

5.5 Concluding remarks

This strategic summary consolidates the research and innovation directions most urgently needed to advance ZEWT goals in the IWT sector. It also defines the institutional, financial, and regulatory levers necessary to ensure that ZEWT-related RD&I is not only technologically sound but also systemically relevant and implementation-ready.

Deliverable 5.2 thus serves as a policy-anchored compass to inform the next iteration of the ZEWT SRIA. It ensures that innovation funding aligns with both scientific opportunity and industrial feasibility—setting the stage for Deliverable 5.3, where these priorities will be linked to deployment pathways, investment channels, and industrial competitiveness.

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