GYROSCOPE

The Green Transition in Maritime Transport – Anticipatory Cooperation and Regulation for Sustainable Future

Policy and Action Recommendations of the GYROSCOPE Project

Gyroscope Consortium 12/2025

The share of global climate emissions from maritime transport is increasing at an alarming rate. To achieve international net-zero targets, it is essential to move rapidly to green energy sources and to enable the full utilisation of the latest technologies. This requires bold, yet considered actions, regarding regulation, markets, and the development and deployment of new technologies.

These recommendations are aimed at a broad and internationally influential range of stakeholders, from policy makers and authorities to commercial maritime actors, and the research and development sector. Recommendations are based on the research questions examined and the results obtained within the GYROSCOPE project.

1

The green transition must be implemented proactively and interactively

To make the green transition possible, the maritime energy mix will expand. New energy sources require changes to the fleet, port infrastructure, and ways to deliver and store fuels. Additionally, international and national regulation is needed to guide the market's green transition. The environmental risks of alternative power sources are also a subject of active discussion: the environmental burden should not be shifted from the air to the sea or onto the coastlines.

The green transition's systemic complexity limits the pace of change. Shipowners hesitate with ship investments without certainty regarding future fuels and related regulations. Cautious growth in demand slows the development of supply, which in turn increases the transition risk experienced by the operators, particularly regarding the profitability of infrastructure investments and the availability of energy sources. The difficulty of assessing the progress and direction of regulation, combined with the rapid pace of change in the political climate creates uncertainty for the whole industry.

Guidelines

1. The deployment of new solutions requires supporting both their supply and demand through stable regulation. Since large-scale infrastructure investments have long payback periods, operators must be guaranteed a good long-term investment outlook.
2. A paradigm shift is needed in the development of innovations: multidisciplinary development teams where engineers engage in dialogue with natural and social scientists as well as legal experts as early as in the design stage – not forgetting the end-users of the solutions. This will help to avoid missteps, manage risks, and develop the necessary standards and regulations proactively.
3. Environmental and sustainability impact assessments must include the life-cycle impacts of solutions that have an impact on the climate, ecosystems, and people. Risks related to operational disruptions – including additional costs arising from risk management – should be considered.
4. Emission reduction solutions that allow for the use of fossil fuels should be avoided. However, solutions such as multi-fuel engines reduce the economic and social risks of the initial phase of the transition and can thus support a sustainable transition. National self-sufficiency in fuel production is also a significant resilience factor.
5. Ports should prepare for the electrification of ships and enable the distribution of alternative fuels. Decisions regarding the range of fuels offered should be made transparently in cooperation with the shipowners using the port.
6. Foresight and scenario analysis enhance the capacity of operators to prepare for various future developments and assess associated opportunities and risks. Alternative scenarios open new decision-making horizons for operators, providing a framework to explore the impacts of technological, regulatory, and market changes in both national and global contexts.

2

Technological development must be harnessed to boost the green transition

The maritime green transition relies not only on new energy sources but also on the reliable performance of digital platform solutions that promote energy-efficient and safe operations. As these solutions are based on real-time data transfer, processing, and application of artificial intelligence (AI), they require a new level of consideration regarding cybersecurity and liability. Therefore, the use of these systems is not only a technological matter; it also demands new skills, training, and the creation of common rules.

As the level of autonomy in shipboard equipment increases, new legislative challenges emerge: who bears responsibility if an AI makes an error? The responsibility issues of autonomous systems are also strongly related to cyber security and the international compatibility of systems. Without clear and binding regulatory frameworks, investment planning and technology deployment will slow down, which could in turn slow down the transition.

Guidelines

1. The development of maritime automation should be supported, as it offers a direct path to emission reductions through the maximisation of energy efficiency and the optimisation of operations. By enabling shore-based operations, automation also provides a future solution to the prevailing crew shortage in the sector and promotes equal opportunities to work in the field.
2. New technology yields benefits only when applied correctly. The evolving roles of employees and resulting new skill requirements arising from digitalisation and automation must be addressed in educational planning and resourcing.
3. For the digitalisation and the automation to support the maritime green transition, political decision-making and regulation must promote efficient communications, cybersecurity, data accessibility, transparency of processes, and cooperation between operators.
4. The automation involves new types of legislative responsibilities, especially at the interface of human and machine decision-making. There is a need for regulation that clearly defines the responsibilities and rights of humans and machines in different situations.

3

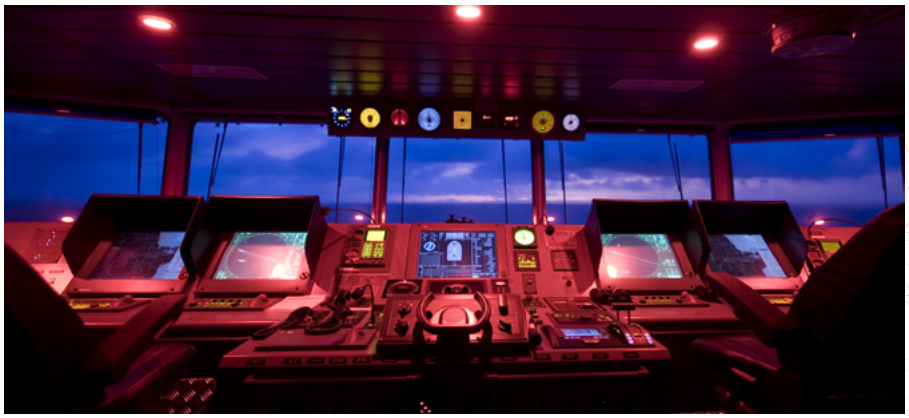
Market pressure towards sustainable green transition must be increased through targeted regulation

Maritime emission reduction targets continue to collide with regulations rooted in the fossil-fuel-based economic structures. The maritime transport is heading toward a future of increasingly diversified technologies and operating models. Situational factors (route, region, availability of the power source on the route, etc.) affect which solutions are functional and possible in each case.

While international actors, such as the International Maritime Organization (IMO), have set emission reduction targets, comprehensive global standards for the safe use of alternative energy sources are still developing. Fuels such as ammonia (toxic), hydrogen (highly flammable), and methanol (toxic) pose significant safety and operational risks. The lack of clear and mandatory rules complicates investment planning and increases the risk perceived by both shipowners and operators.

Guidelines

1. The maritime green transition should be guided by a combination of regulation and economic incentives that both require and encourage actors to invest in green transition solutions.
2. Finland must continue to contribute to the implementation of a legally binding global emission trading system within the IMO as part of the Net-Zero Framework.
3. Finland must continue its active influence within the IMO to establish global technological standards for the safe handling and use of alternative fuels in maritime transport.
4. Regulatory measures should be used to ensure the clear integration of the biodiversity perspective into the implementation of the maritime green transition, ensuring that air emission reduction efforts do not cause harm to the marine ecosystems.
5. The diverse life-cycle emissions of maritime transport, their impacts, and the opportunities for various actors to influence them must be made more visible. To achieve this, an internationally harmonized set of metrics must be developed. Transparency increases customer awareness of ways to influence emissions and grows the willingness to pay for low-emission solutions.



GYROSCOPE

The GYROSCOPE project (2023-2025) investigated opportunities provided by and risks associated with smart digital solutions in the context of green transition of the maritime sector. The project aimed to produce a multi-dimensional and systemic picture of the sustainable transition toward low-carbon maritime logistics. To achieve this, the project combined stakeholder-participatory processes, modern risk analysis methods, and the exploration of alternative implementation pathways. The project has received funding from the European Union's recovery instrument (Next-GenerationEU) via the Research Council of Finland.

For more information:

Altarriba et al. (2025):
Comparing fuels and emission reduction technologies for sustainable shipping: A sustainability index weighting life cycle emissions and costs.
Journal of Cleaner Production 495.

de Jong et al. (2025):
Trade-offs and synergies in the management of environmental pressures: a case study on ship noise mitigation.
Marine Pollution Bulletin 218.

Farokhi et al. (2026):
Identifying critical risk influencing factors for autonomous ship navigation in winter conditions.
Discover Sustainability7.

Janasik et al. (2025):
Cruel utopia of the seas? Multiple risks challenge the singular hydrogen hype in Finnish maritime logistics.
Energy Research & Social Science 129.

Knudsen et al. (2023):
Defining 'Future Generations': Epistemic Considerations on Conceptualizing a Future-Oriented Domain in Policy and Law-Making.
Journal of Futures Studies 28(2): 3-19.

Linnekoski (2025):
Uncertainties and risks in the adoption of new fuels in Finnish maritime logistics.
Master's thesis, University of Helsinki.

Monroe (2025):
Regulation as a Constraint and Enabler of Sustainability Transition to Alternative Maritime Fuels.
Master's thesis, University of Helsinki.

Vikkula et al. (2025):
Compilation and standardization of oil toxicity data on early life stages of fish to support population-level oil spill impact modeling.
Aquatic Toxicology 286.

Full list of project publications:
sites.utu.fi/gyroscope/publications/

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