STEERER

STRUCTURING TOWARDS ZERO EMISSION WATERBORNE TRANSPORT

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D2.5. STEERER Advice to 1st ZEWT Research Agenda and its Implementation Plan

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Executive Summary

The document starts by presenting STEERER, an EU-funded project designed to contribute to the update of the Strategic Research and Innovation Agenda (SRIA) of the Co-Programmed Partnership on Zero-Emission Waterborne Transport (cPP ZEWT) in the framework of Horizon Europe (HEU), to be able to reach its targets in time.

Chapter three covers the relevant policy developments and their implications for the update of the SRIA. It starts with the international developments – the International Maritime Organization – and then focuses on the EU level. The most important legislative updates concern the 'Fit for 55' package: the EU Emissions Trading System (ETS), the Effort Sharing Regulation, the Renewable Energy Directive (RED) update, the Alternative Fuels Infrastructure Regulation (AFIR), the FuelEU Maritime Initiative, etc. Most of these proposals concern the maritime segment of the waterborne transport sector, but there are also numerous provisions relevant for or directly addressing the inland waterway transport sector (IWT). After assessing their potential impacts on the waterborne transport sector, a short set of conclusions for the SRIA update is presented.

The fourth chapter presents a concise version of the decarbonization scenarios for the waterborne transport sector up to 2050, considering the carbon budget left to be able to achieve specific climate targets. A dedicated analysis on how these targets can be achieved or potentially missed are done for four out of the six ship segments outlined in the SRIA: IWT, container ships, cruise ships and ferries. The short-sea and offshore ships segments are presented in a more general manner.

Based on the information from the previous chapters, chapter five outlines numerous proposals clustered on the six ZEWT intervention areas, that STEERER recommends for uptake as part of the SRIA update. Many of them can also be fairly easily integrate in the texts of the future ZEWT calls. The different recommendations for each intervention areas can be found in their dedicated sections of Chapter 5 (pag. 40-59). Furthermore, at the end of it, there are a few overarching recommendations that the project partners have designed as a conclusion of this chapter (pag. 59). These will help ensure that the waterborne transport sector will meet its decarbonization targets by 2050.

Chapter six presents several waterborne transport data figures that need updating, as they contribute to better understanding not only the current situation of the waterborne transport sector, but also some of its foreseeable evolutions.

The last chapter gives a first overview of the different EU-funded RD&I projects focusing on zero-emission waterborne transport solutions. This overview provides a first insight in the possible RD&I gaps towards achieving the main objective of the ZEWT Partnership by latest 2030. The in-depth exercise will be conducted during the update of the document. A set of conclusions and recommendations is also presented at the end of this chapter.

Chapter 8 presents the conclusions of this deliverable, which is followed by three Annexes.

List of Abbreviations

AFID	The Alternative Fuels Infrastructure Directive
AFIR	The Alternative Fuels Infrastructure Regulation
CAPEX	Capital expenditure
CBAM	The Carbon Border Adjustment Mechanism
CCNR	The Central Commission for the Navigation of the Rhine
CFD	Computational fluid dynamics
CII	The Carbon Intensity Indicator
EEDI	The Energy Efficiency Design Index
EEXI	The Energy Efficiency eXisting ship Index
ESR	The Effort-sharing Regulation
ETS	The EU Emissions Trading System
EU	The European Union
FAME	Fatty acid methyl ester
FC	Fuel cell
FF55	The 'Fit for 55' Package (of the European Union)
FP7	The Seventh Framework Programme (of the European Union)
GDP	Gross Domestic Product
GHG	Greenhoue gas
GT	Gross tonnage
GSEG	Green Shipping Experts Group
HEU	Horizon Europe
HVSC	High Voltage Shore Connection
H2020	Horizon 2020
ICE	Internal Combustion Engine
IMO	International Maritime Organization
IWT	Inland waterway transport
LNG	Liquefied natural gas
LOHC	Liquid organic hydrogen carrier
MARPOL	The International Convention for the Prevention of Pollution from Ships

MBM	Market-based measures
MeOH	Methanol
MEPC	The Marine Environment Protection Committee
Mt	Million tonnes
MRV	Monitoring, reporting and verification
MW	Megawatt
NH3	Ammonia
Nox	Nitrogen oxides emissions
NRMM	Non-Road Mobile Machinery
OPEX	Operational expenditure
OPS	On-shore power supply
RD&I	Research, development & Innovation (often interchangeable with R&D and R&I)
RED	The Renewable Energy Directive
ROI	Return of investment
SAF	Sustainable alternative fuel
SC	Scientific Committee
SEEMP	The Ship Energy Efficiency Management Plan
SOx	Sulfur oxides emissions
STEERER	Structuring Towards Zero Emission Waterborne Transport
SRIA	Strategic Research and Innovation Agenda
SWOT	Strengths, Weaknesses, Opportunities, and Threats (Analysis)
TEN-T	Trans-European Network of Transport
TEU	Twenty-foot equivalent units
TRL	Technology readiness level
WAPS	Wind-assistend propulsion systems
WtW	Well-to-wake
ZEWT cPP	Co-Programmed Partnership on Zero-Emission Waterborne Transport

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1. Introduction

1.1 The STEERER Project

STEERER (Structuring Towards Zero Emission Waterborne Transport) coordinates the establishment and communication of a Strategic Research and Innovation Agenda[1] and an Implementation Plan **towards zero-emission waterborne transport, in cooperation with all key stakeholders needed to facilitate the transformation to clean waterborne transport**. In the definition of STEERER, as well as cutting greenhouse gas emissions, all harmful environmental emissions, water pollution and noise emissions have to be eliminated. STEERER's mission is to bring the various initiatives and sectors' stakeholders together to join forces for a combined effort with the maximum impact for the climate, people's health and Europe's economy.

STEERER is coordinated by SEA EUROPE, counting with the participation of a total of eight partners from six EU countries.

Figure 1. STEERER Partners

In sum, STEERER aims to:

- Jointly set emission targets towards 2050 (including targets for 2025 and 2030);

[1] The STEERER project will provide input to the Waterborne TP regarding the development and update of the Strategic Research and Innovation Agenda of the Candidate Co-Programmed Partnership on Zero-Emission Waterborne Transport in the framework of Horizon Europe (https://ec.europa.eu/info/sites/info/files/research_and_innovation/funding/documents/european_partnership_for_zero-emission_waterborne_transport.pdf).

- Contributing to the update of the Strategic Research and Innovation Agenda (SRIA) of the Co-Programmed Partnership on Zero-Emission Waterborne Transport (cPP ZEWT)[2] in the framework of Horizon Europe (HEU), to be able to reach these targets in time;
- Develop an Implementation Plan to reach the targets in due course while staying competitive and offering a valid business case;
- Developing and implementing a communication campaign, aimed at broader awareness of the waterborne transport sector and its commitment towards zero-emission transport, to become a fully sustainable mode of transport;
- Monitoring and assessing the implementation of the Strategy defined and adapting where necessary, after the project's conclusion, by the Green Shipping Expert Group.

The consortium functions as a Secretariat, where the broader expertise is involved in the **Scientific Committee (SC)** and the **Green Shipping Expert Group (GSEG)**[3] established by the project.

STEERER is funded by the European Commission research and innovation programme Horizon 2020, with a contribution by the EU of 1,5 million euro over the course of 36 months, and had started in December 2019. STEERER plays an important role in the execution of the co-programmed Partnership on Zero-Emission Waterborne Transport which is established in the context of the new programme for Research and Innovation: Horizon Europe.

[2] https://www.waterborne.eu/images/documents/201021_SRIA_Zero_Emission_Waterborne_Transport_spread.pdf
[3] https://www.waterborne.eu/projects/coordination-projects/steerer/green-shipping-expert-group/member-list?view=members

2. The Approach

2.1 Task Description

The following information is extracted from the STEERER Grant Agreement, Annex A, and describes the main lines that the project partners need to follow in order to fulfil their commitment and deliver the present document.

"Task 2.6 Recommendations towards the SRIA and Implementation Plan of ZEWT.

STEERER will support the regular revisions and update of the ZEWT partnership SRIA and its implementation plan. Based on the tasks previously described STEERER will draft contributions to the annual revision of the ZEWT SRIA, including detailed planning based on a rolling period of two years. In the same way, in coordination with the ZEWT partnership, the implementation plan will list the various actions which are needed to implement the ZEWT SRIA and will identify the main implementation challenges and the key stakeholders taking ownership to carry out the action (emerging from the work done in previous activities) including for example: (i) technical challenges, (ii) economic challenges entailing costs that need careful planning (risk of insufficient financial and human resources), (iii) legal challenges and requirements, (iv) timing challenges, etc. Suitable approaches and solutions will be presented to overcome the challenges and to cope with risks.

Each year, as a deliverable, STEERER will provide proposals for the revision of the ZEWT SRIA and its implementation, for the following two years, for example in 2021 for 22-23, in 2022 for 23-24, etc.

Strategic elements and actions of the Strategic Research and Innovation Agenda of the cPP ZEWT form the foundation for the Implementation Plan. The Implementation Plan will not only address the follow-up research and development actions (for example in Horizon Europe) but will also address required actions in the field of regulatory measures and financial solutions to ensure a business case and level playing field. The combination of (1) Strategic Research and Innovation Agenda and (2) Implementation Plan is the result of the fact that there is a close link between both elements and a number of limitations at the same time.

STEERER will support the wider presentation and discussion of the ZEWT SRIA and Implementation Plan and the contributions from STEERER towards the revision of these plans, including towards the Green Shipping Expert Group."

Due to the changes in the initial internal plannings for both STEERER and the ZEWT Partnership, the draft information from D2.5 and the previous STEERER deliverables had been shared with the internal Partnership groups in the preparation of the 23-24 calls and the current SRIA update. However, as a result of the internal evolutions, the D2.5 (and subsequently the D2.7) advice will contain information not just for the 22-23 and 23-24 SRIA updates and ZEWT calls, but will also look into the longer-term aspects that the SRIA should contain in order for the Partnership to be have an optimal impact.

2.2 General Framework

The Partnership ensures a coordinated and joint long-term vision and approach to develop the disruptive technologies needed to provide solutions to mitigate climate challenge. Waterborne transport is composed of many different stakeholders in a diversified sector (many different sub segments, different ship types, etc.). The Partnership will be key in coordinating initiatives to avoid duplication of efforts and to speed up the RD&I and (indirectly) market roll-out activities for the 'green' solutions.

The Partnership is one of the main instruments in transforming waterborne transport into a net zero-emission mode of transport, through the research to and demonstration of deployable zero-emission solutions suitable for all main ship types and services before 2030. It will contribute to maintaining and reinforcing Europe's global leadership in innovative, green waterborne transport solutions. The objective is to **provide and demonstrate zero-emission solutions for all main ship types, on both existing and newbuilds, and services before 2030, which will enable zero-emission waterborne transport before 2050.**

Greening the fleet on the short- to medium-term will happen simultaneously in two main directions: a part of the fleet will be converted through retrofitting, while the other will be replaced by new ships. This means close to 50,000 maritime ships and approximately 12,000 inland vessels that are now in operation. And new-builds will need to be ready to become zero emission (ready) as soon as possible, meaning compatibility with or adaptability to a range of potential sustainable alternative fuels, be optimised for efficiency (including digital), potentially deploy electric and/or battery drives, as well as integrate renewable energy assistance such as wind assisted propulsion. Onboard fuel storage should be suitable for alternative low to zero-carbon fuels, potentially based upon modular principles to facilitate conversion to full electric or hybrid powered units.

It is clear that there will be no 'silver bullet' to decarbonise the waterborne transport sector; instead, the best solution(s) will need to be chosen according to ship size, the type of traffic or market it is in, its energy demand, the required operating range, the regional energy carriers available and bunkering infrastructure, the national/regional (multi-national) legislation, policies and governance and the life cycle emissions balance and status. Integrated lighthouse projects will show best-practice examples to inspire the early adopters and to further develop these. An important factor in the selection and uptake of technologies in the waterborne transport sector, in addition to societal factors that also include aspects of health and education, is the service a vessel provides. A lot of focus is often put on larger vessels operating a liner service on long distance routes: transport cargo from port A to port B and back, sometimes including one or more stops. However, many ships are operating on a tramp service[4]: with a varying schedule, collecting cargo in port A and delivering it to port B, collecting cargo there for port C, etc. For liner services, ports and vessels can be more easily adapted to each other and to 'green solutions' – for instance, fuel choices, bunkering and recharging infrastructure can be aligned. With tramp services, especially calls at many ports at short notice, these alignments for and within every port are not possible. If ports worldwide, and European-wide for inland waterways transport (IWT), cannot ensure the availability of fuel(s), these ships either have to be able to carry relatively large amounts of fuel or electricity, or have

[4] In IWT there is the distinciton between the market for long term contracts and the spot market for shorter term contracts. Most of the IWT services are demanded via spot markets although some cargo flows are transported under longer term contracts. https://ce.nl/wp-content/uploads/2021/03/4330_IWT_EU_main_report.pdf

to be equipped with multi-fuel flexible energy (convertor) systems and, where applicable, with an optimised part of renewable sources of energy (including wind propulsion) to assist in reducing the fuel volumes required. At the same time, there are many other types of vessels, such as passenger vessels or highly complex work vessels (e.g. dredging vessels, offshore construction vessels, windfarm service operation vessels) and their numbers are growing. These vessel types often have a high energy demand while at the same time having the potential to operate worldwide.

It was therefore necessary to have a more systematized approach of the different ship types in waterborne transport, followed by the analysis and planning of how the decarbonisation challenges for these ship types needs to be addressed.

All this resulted in the development of implementation pathways for six different types of vessels (with a broader description in the Strategic Research and Innovation Agenda of the Partnership). This classification is adopted in this STEERER deliverable as well, to ensure that the results of the deliverable will easily feed in the process of updating the Strategic Research and Innovation Agenda of the Partnership.

Figure 2. Types of vessels for the development of implementation pathways

The technical content of the cPP on Zero-Emission Waterborne Transport is divided into six parallel activities, each of them with its subsections. These are:

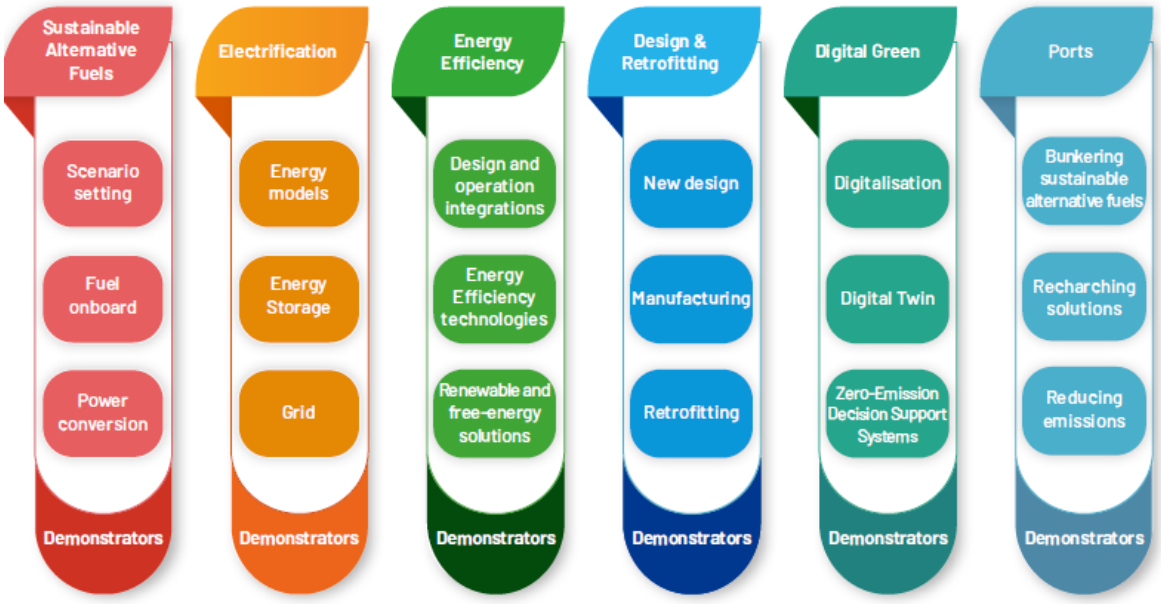


Figure 3 Activities of the Co-Programmed Partnership on Zero-Emission Waterborne Transport

2.3 Methodology

The update of the cPP main document requires gathering a large amount of information which then needs to be structured and analysed against the SRIA. In this manner, the results can be used to properly update the relevant chapters in the SRIA.

The analysis for the SRIA update is done according to the following steps:

1. **The analysis of the international and the European Union's (EU) legislative developments**, in particular the 'Fit for 55' package presented by the European Commission (EC) on the 14th of July 2021[5]. The decarbonisation general actions and directions had already been set at the international level first by the Paris Agreement, then the International Maritime Organization (IMO) for the maritime sector, and subsequently at the EU level through the Green Deal. However, the EU level still required a more detailed set of actions that would give the implementation means and the more detailed directions in order to achieve the Green Deal targets, especially those for the short- and mid-term outlook. And it is precisely the 'Fit for 55' proposal that offers these detailed directions and means. This section of the deliverable is partly based on the exercise done in D2.2 *Scenarios with quantified targets for 2025, 2030 and 2050 - "Common stakeholder target scenarios"* and partly on today's complementary analysis of these legislative developments.

2. **The inclusion of the scenarios with quantified targets for 2025, 2030 and 2050** that have been developed by the project in the D2.2 deliverable. The aim is to extract the necessary information in order to give the correct overview of the sector's qualitative (technologies business models, etc. that need to be developed and implemented) and quantitative (the reduction in GHG emissions by 2050 with intermediate steps in the decades before) decarbonization challenges. Where necessary, some updating and/or refinement of the information coming from D2.2 will be undertaken.

3. **The inclusion of the main actions to be undertaken under each of the SRIA intervention areas,** to speed the waterborne transport transition to a zero-emission mode of transport. As in the case of point (2), the essential information will be taken from the STEERER deliverable D2.3 *Areas of intervention and related actions - "implementation plan"*. It will also benefit from the subsequent SWOT analysis undertaken in the framework of this project.

4. **An update of the general data of the waterborne transport sector**, in particular in terms of operations, environmental impact (emissions), etc. Alongside the legal developments, this type of information provides the overarching framework for the SRIA update.

5. A first **analysis of the relevant EU-funded projects**, in particular those under H2020 but also from the recently awarded Innovation Fund Calls, is subsequently undertaken. Here, the information comes from the other STEERER deliverables (particularly D2.1 *State of play of decarbonisation of waterborne transport - "technology application atlas"*), as well as from

[5] EU economy and society to meet climate ambitions (europa.eu)

other sources of the waterborne transport community. This first analysis will be used not only to identify which research topics have already received more attention and which of them would receive a higher support; it will also be used to prepare a more in-depth analysis of the recent and current RD&I projects at the EU level. The latter will be a key aspect in calibrating the ZEWT support for the different topics preferred to be included in the Horizon Europe work programmes up to 2027, to achieve the first mature solutions for zero-emissions waterborne transport.

The information gathered under each chapter has a specific role. They will indicate which are the more urgent developments that the sector may be facing up to 2030 and then up to 2050, what RD&I progress has been achieved so far and which are the solutions that should receive the necessary attention (and funding) for faster development and subsequent roll-out, taking into account the current state-of-play in the transition to zero-emission waterborne transport.

3. New Relevant Policies and Legislative Developments and Their Implications

The International Maritime Organization (IMO)

The first set of international mandatory measures to improve ships' energy efficiency was adopted by the IMO in 2011. Ever since, the IMO has been working to further include regulatory measures for seagoing vessels. It shall be noted that IMO does not apply to the inland waterway transport sector, as for inland vessels there are separate legal frameworks in place.

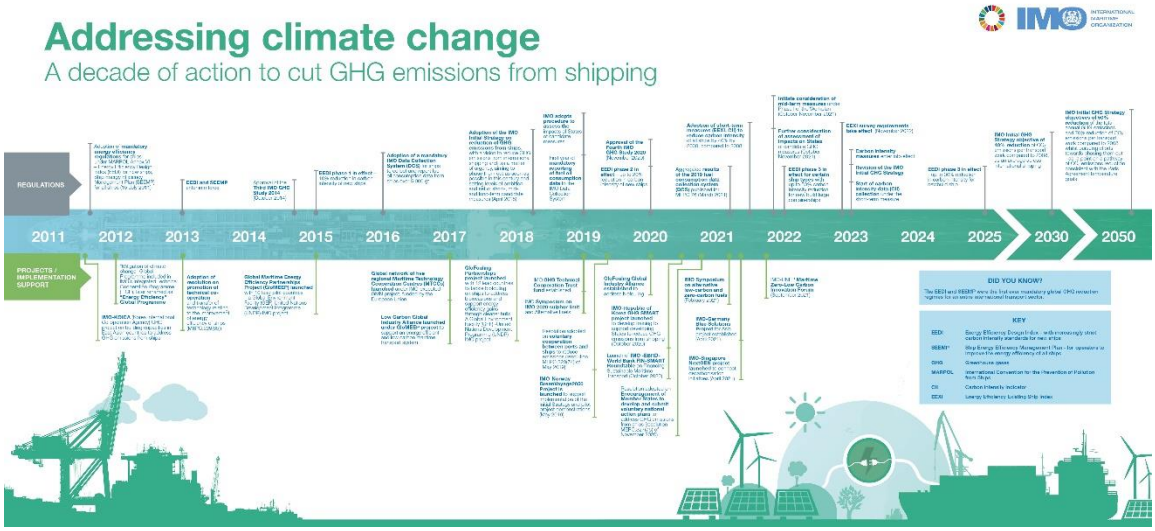


Figure 4. A decade of IMO actions to cut GHG emissions from shipping (Copyright IMO)

An important landmark was the adoption of the IMO Initial Strategy on the reduction of greenhouse gas (GHG) emissions from shipping in 2018 which has set key ambitions. Its main goals are:

- to cut annual greenhouse gas emissions from international shipping by at least half by 2050, compared with their level in 2008, and work towards phasing out GHG emissions from shipping entirely as soon as possible in this century.

- a reduction in carbon intensity of international shipping (to reduce CO_2 emissions per transport work), as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008.

The Initial GHG Strategy includes a series of candidate short-, mid- and long-term measures. Notwithstanding the difficulties that arose with the COVID-19 pandemic, which prevented IMO Member States to convene in real-life meetings, the IMO adopted in 2021 a work plan on the concrete way forward to make progress with candidate mid- and long-term measures, including measures to incentivize the

move away from fossil fuels to low- and zero-carbon fuels and possible market-based measures (MBM) in combination with other measures e.g. a fuel standard or fuel life-cycle guidelines.

In the meantime, progress was also made with the consideration and implementation of some short-term GHG reduction measures such as:

- commissioning, oversight and approval of the 4th IMO GHG Study 2020;
- further improvement of the existing energy efficiency framework with a focus on the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP), in particular by adoption of the amendments to The International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI on the early application of the EEDI Phase 3 requirements for certain ship types (resolution of The Marine Environment Protection Committee (MEPC) 324(75));
- adoption by MEPC 76 of amendments to MARPOL Annex VI on the short-term goal-based carbon intensity reduction measure setting out technical and operational energy efficiency measures for ships (EEXI and CII), together with approval of a comprehensive impact assessment;
- initial development of life cycle GHG assessment guidelines. Most recently, the IMO has facilitated informal discussion sessions on the lifecycle GHG/carbon intensity for potential future fuels for shipping. Shipping will need new fuels to achieve the levels of ambition of the IMO's Initial GHG Strategy. This includes a reduction in the carbon intensity of international shipping by at least 40% by 2030 and a significant further reduction in carbon intensity to achieve the 2050 level of ambition – cutting GHG emissions by 50%, in line with IMO's vision to ultimately phase out GHG emissions as soon as possible in this century. The lifecycle refers to the assessment of greenhouse gas emissions from the fuel production to the ship (Well-to-Wake); from primary production to carriage of the fuel in a ship's tank (Well-to-Tank, also known as upstream emissions) and from the ship's fuel tank to the exhaust (Tank-to-Propeller or Tank-to-Wake, also known as downstream emissions);
- initial consideration of other candidate measures listed in the Initial Strategy, including a proposal for the establishment of an International Maritime Research Board to coordinate and oversee R&D efforts;

Finally, the IMO Member States have pledged to revise the Strategy in 2023, to ensure it is kept in line with the targets as set out in the Paris Agreement. Although the objectives/goals agreed on IMO level are lagging behind the objectives defined by the EU, the introduction of new measures such as the Carbon Intensity Indicator will put a lot of focus on greening of operations of existing vessels. For the Partnership and the sector as a whole, this will first of all mean **more focus on retrofitting, energy efficiency and digital green measures**.

The EU Level

The publication of the 'Fit for 55 package' is the most recent development at the EU level. Launched on the 14th of July 2021, it is a package of proposals to make the EU's climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels[6]. They represent in fact the legislative tools to implement a major part of the European Green Deal and to achieve the targets set by the European Climate Law. All proposals are harmonised between themselves, in order to ensure a coherent overall approach.

Its components that have may have a significant impact on all the segments of the waterborne transport sector are outlined below, and a succinct analysis is presented.

This information serves two main purposes in relation to the SRIA update:

1. To provide the necessary information for the update of the SRIA parts on policies;
2. To give a first short analysis of the RD&I directions that need to be considered for the SRIA update given the foreseen policies for the waterborne transport sector and their impacts.

It must be underlined that the information below concerns the situation of the EU legislation as of Spring 2022. The latest policy developments are addressed in the D2.7 deliverable.

The EU Emissions Trading System

The EU Emissions Trading System (ETS)[7], is the instrument which puts a price on carbon and lowers the cap on emissions from certain economic sectors every year. The EC is proposing[8] to lower the overall emission cap even further and increase its annual rate of reduction, while at the same time **to include maritime transport emissions for the first time in the EU ETS**. Inland vessels are excluded from the ETS system based on the Fit for 55 proposal from the European Commission.

The phase in of the maritime transport sector, including seagoing vessels > 5000 gross tonnage (GT), shall make shipping companies liable to surrender allowances according to the following schedule: starting with 20 % of verified emissions reported for 2023; 45 % for 2024; 70 % 2025; 100 % for 2026 and each year thereafter.

In addition, a cap will limit the allowances, which will get adjusted and limited every year with a linear reduction factor of 4,2%. However, it has to be mentioned that all emissions from voyages within the EU (intra EU) and all emissions when ships are at berth in EU ports are being covered, but just 50% of the emissions from voyages starting or ending outside of the EU (extra EU) – though there are discussions at the EC to integrate the full voyage.

[6] EU economy and society to meet climate ambitions (europa.eu)
[7] EU Emissions Trading System (EU ETS) | Climate Action (europa.eu)
[8] Revision of the EU Emission Trading System | European Commission (europa.eu)

As complementary measures, the EC also proposes to increase the size of the Innovation and Modernisation Funds. However, the Member-States also have to complement the substantial spending on climate in the EU budget by spending the entirety of their emissions trading revenues on climate and energy-related projects – thus positively relevant also for the waterborne transport sector.

The Effort Sharing Regulation

The Effort Sharing Regulation[9] assigns strengthened emissions reduction targets to each Member State for buildings, road and domestic maritime transport, inland waterway transport, agriculture, waste and small industries. Recognising the different starting points and capacities of each Member State, these targets are based on their gross domestic product (GDP) per capita, with adjustments made to take cost efficiency into account.

The Renewable Energy Directive

The Renewable Energy Directive (RED)[10] update will set an increased target to produce 40% of the Union's energy from renewable sources by 2030. All Member States will contribute to this goal, and specific targets are proposed for renewable energy use in different sectors, including transport. *Thus, the proposal introduces a target for reducing the greenhouse gas intensity of transport fuels by 13% by 2030 compared to 2010 level*.

It must also be noted that the Fuel Quality Directive applies already for the IWT and includes a 6% reduction target to be reached already by 2020 and maintained afterwards as compared to 2010 level, setting a maximum limit of 88.45 grams CO2e per MJ of energy to fuel suppliers. This is to be replaced by the RED revision as part of the Fit for 55 package.

Another potentially relevant aspect for the waterborne transport sector is that in order to meet both the climate and environmental goals, sustainability criteria for the use of bioenergy are strengthened and Member States must design any support schemes for bioenergy in a way that respects the cascading principle of uses for woody biomass.

In more detail, the revised RED will impact the waterborne transport sector and the work that ZEWT is doing, notably:

- The increase of renewable electricity is foreseen to also be used to produce (more) *synthetic fuels for hard-to-decarbonise transport sectors* such as maritime transport;
- The roll-out of more renewable energy and electrification is translated into an expanding charging infrastructure. In view of the long life span of recharging points, *requirements for charging infrastructure* should be standardised (or at least harmonised) and kept updated in a way that

[9] Effort Sharing Regulation | European Commission (europa.eu)
[10] Amendment to the Renewable Energy Directive to implement the ambition of the new 2030 climate target | European Commission (europa.eu)

would cater for future needs, and would not result in negative lock-in effects to technology and services' developments;

- Increasing the level of the energy-based targets on advanced *biofuels and biogas*, coupled with the introduction of a target for renewable fuels of non-biological origin, should ensure an increased use of the renewable fuels with the smallest environmental impact in transport modes that are difficult to electrify. Consequently, for the 2050 milestone there is a likely increased demand for advanced biofuels, especially in the waterborne transport sector;
- The EU will maintain the 'multipliers'[11] as one of the incentives for the uptake of renewable energy in certain sectors (a multiplier of 1.2 for maritime), thus allowing to account more than the actual energy content consumed. A multiplier of 2 for biogas and advanced biofuels produced from certain feedstocks is also incentivised in such a manner;
- A key element intertwined with the RED is the forthcoming Offshore Renewable Energy Strategy. It *introduces an ambitious objective of 300 GW of offshore wind and 40 GW of ocean energy across all the Union's sea basins by 2050*. Member states should jointly define the amount of offshore renewable generation to be deployed within each sea basin by 2050, with intermediate steps in 2030 and 2040. These objectives should take into account the offshore renewable energy potential of each sea basin, environmental protection, climate adaptation and other uses of the sea, as well as the Union's decarbonisation targets. This is a tremendous opportunity for the ZEWT partners to not only get a better image of the energy sources that they could (almost) directly use, but also to be involved in some of these developments.

The revised Alternative Fuels Infrastructure Regulation

The revised Alternative Fuels Infrastructure Regulation (AFIR, the former AFID)[12] caters for the deployment of infrastructure for certain alternative fuels that require distinct infrastructure and that are market ready. Though this is aimed in particular at the road transport sector, some of its provisions are relevant for the waterborne transport sector as well – in particular, the Regulation requires that ships have access to clean electricity supply in major ports on the TEN-T network.

In more detail, the relevant provisions for the waterborne transport sector are the following:

- As stated in its explanatory memorandum, the proposed regulation "delivers on the clear requirement of the European Green Deal to oblige docked ships to use shore-side electricity. It is fully complementary to FuelEU Maritime Initiative by ensuring that *sufficient shore-side electricity supply is installed in ports to provide electricity while passenger ships (including ro-ro passenger ships, high speed passenger craft and cruise ships) and container vessels are at berth, and accommodating the demand for decarbonised gases*, i.e. bio-liquefied natural gas (LNG) and

[11] The achievement of RED targets by the Member-States is facilitiated by several 'multipliers' on energy content, both for the transport sectors and for specific fuels. This is done through thier use in the calculation of the share of renewable energy in the transport sector (via a methodology is provided by the EC). For the maritime sector it means that the renewable fuels consumed are counted with a weighting of 1.2 in the formula used for theshare of renewable energy targets.
[12] Revision of the Directive on deployment of the alternative fuels infrastructure | European Commission (europa.eu)

synthetic gaseous fuels (e-gas)". Further distinctions are made for other ship types and their needs;

- More precisely, the new legislation foresees that practically all maritime ports on the *Trans-European Network of Transport* (*TEN-)T Core and Comprehensive networks will have sufficient shore-side power output to meet at least 90% of the electricity demand from the ships*. On the other hand, the requirements for the IWT ports are less stringent: the only target is that all IWT ports on the TEN-T networks need to provide at least 1 on-shore power supply (OPS)[13].
- In addition, there needs to be a *sufficient coverage of LNG refuelling stations* in the maritime TEN-T ports in order to meet the current and future necessities of ships travelling within the TEN-T core network by 2025. However, *biogas and e-gas* should also be used for operations, not just the 'regular' LNG. This can also influence the IWT segment, especially the routes close to the larger maritime ports.
- Together with the FuelEU maritime initiative, it contributes to overcoming the current "chicken-and-egg" issue, which has meant that the very low demand from ship operators to connect to the electric grid while at berth has made it less attractive for ports to invest in short-side electricity – with a focus on the TEN-T ports. Both maritime and inland waterway transport are included in this Regulation.
- Within this context, the ZEWT cPP is specifically nominated as one of the non-legislative means to address these topics (on their R&I aspects).

The FuelEU Maritime Initiative

In relation to the proposed Alternative Fuels Infrastructure Regulation, the **FuelEU Maritime Initiative**[14] will stimulate the uptake of sustainable alternative fuels and zero-emission technologies by setting a maximum limit on the greenhouse gas content of energy used by seagoing ships calling at European ports. It will apply to all seagoing ships above a gross tonnage of 5000 with the following interim targets as compared to reference value in 2020: -2% from 2025; -6% from 2030; -13% from 2035; -26% from 2040; -59% from 2045; -75% from 2050. Inland vessels are not in scope of FuelEU Maritime.

In addition, there are zero-emission requirements of energy used at berth, fully complementary to the Revision of the **Directive on deployment of the alternative fuels infrastructure**.

[13] All TEN-T core inland waterway ports by 1 January 2025 and all comprehensive inland waterway ports by 1 January 2030. In the TEN-T network there are in total 173 comprehensive inland ports and 69 core inland ports with 15 hybrid comprehensive ports (sea and inland) and 26 hybrid core ports (sea and inland)
[14] FuelEU Maritime – green European maritime space | European Commission (europa.eu)

Revision of Energy Taxation Directive

A **revision of the Energy Taxation Directive**[15], proposes to align the taxation of energy products with EU energy and climate policies, promoting clean technologies and removing outdated exemptions and reduced rates that currently encourage the use of fossil fuels. It is to be seen as a strong complement to the new ETS proposals.

In the cases relevant for the waterborne transport sector, the proposals will support the *deployment and uptake of clean energy and fuels while removing fuel tax exemptions that are in place, and increasing the taxation on fossil fuels/energy. The proposal also seeks to exclude the bunkering of ships outside EU ports, thus preventing a de facto carbon leakage*.

Given the current and foreseen structure for the short to medium-term of the mix of energy sources used by the waterborne transport sector, this is likely to lead to a higher impact than on many other sectors. Consequently, it is another instrument in determining the waterborne transport stakeholders which R&I measures should be prioritised in the coming years.

The Carbon Border Adjustment Mechanism

The **Carbon Border Adjustment Mechanism (CBAM)**[16] will put a carbon price on imports of a targeted selection of products to ensure that ambitious climate action in Europe does not lead to 'carbon leakage'. This will ensure that European emission reductions contribute to a global emissions decline, instead of pushing carbon-intensive production outside Europe.

While the provisions of this initiative do not directly concern the R&I efforts of the waterborne transport sector, it can significantly impact on its future demands and business models. And in addition to this mechanism there are numerous other EU measures designed to mitigate climate change and stimulate circular economy targets, but also to strengthen and at the same time broaden the domestic (EU) industry. These measures can likely result in two major changes for the waterborne transport sector:

- *A decrease in the type of goods carried by deep-sea shipping, in particular by reducing the imports of several raw materials and manufactured goods*, corroborated with a change of the structure of the other types of imports. These changes will have an influence on the size of the deep-sea fleet and its structure (types of ships);
- *An increase in the short-sea shipping and inland waterways transport*, as more and more production sites are brought closer to or within the EU countries. These entail an increase in the short-sea and inland waterways traffic, as well as a change in the structure of the fleets (types of ships) dedicated to these traffic segments.

[15] Revision of the Energy Tax Directive | European Commission (europa.eu)
[16] Carbon border adjustment mechanism | European Commission (europa.eu)

These new operational demands and business models will likely impact the technological developments *per se*, as well as on the choices of which technologies should first receive more R&I efforts.

EU Taxonomy

The EU Taxonomy is a tool to help financial institutions and investors evaluate whether an economic activity can be classified as green. To qualify as green, an investment would need to contribute substantially to at least one of these six objectives without doing significant harm to the other objectives.

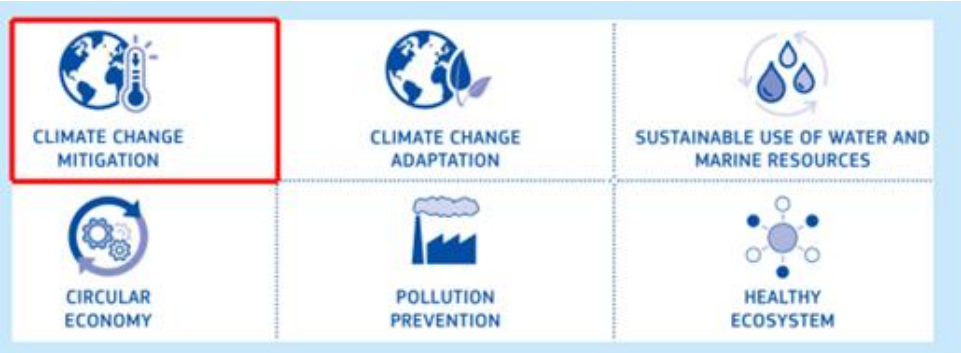


Figure 5. The six objective of the EU Taxonomy

Through delegated acts, for each of these goals, technical screening criteria are defined. The first delegated act, published in December 2021, focuses primarily on Climate Change Mitigation & Climate Change Adaptation. For maritime transport this resulted in three chapters:

- 6.10. Sea and coastal freight water transport, vessels for port operations and auxiliary activities;
- 6.11. Sea and coastal passenger water transport;
- 6.12. Retrofitting of sea and coastal freight and passenger water transport;

With respect to the climate change mitigation goal, the following technical criteria were defined:

1. The activity complies with one or more of the following criteria:
   a. the vessels have zero direct (tailpipe) CO2 emissions;
   b. until 31 December 2025, hybrid and dual fuel vessels derive at least 25 % of their energy from zero direct (tailpipe) CO2 emission fuels or plug-in power for their normal operation at sea and in ports;
   c. until 31 December 2025, and only where it can be proved that the vessels are used exclusively for operating coastal and short sea services designed to enable modal shift of freight currently transported by land to sea, the vessels have direct (tailpipe) CO2 emissions, calculated using the IMO EEDI, 50 % lower than the average reference CO2 emissions value defined for heavy duty vehicles (vehicle subgroup 5-LH) in accordance with Article 11 of Regulation 2019/1242;

d. until 31 December 2025, the vessels have an attained EEDI value 10 % below the EEDI requirements applicable on 1 April 2022 if the vessels are able to run on zero direct (tailpipe) CO2 emission fuels or on fuels from renewable sources.

2. Vessels are not dedicated to the transport of fossil fuels.

3. Until 31 December 2025, the retrofitting activity reduces fuel consumption of the vessel by at least 10 % expressed in grams of fuel per deadweight tons per nautical mile, as demonstrated by computational fluid dynamics (CFD), tank tests or similar engineering calculations.

For inland waterway transport this resulted in three chapters:

- 6.7. Inland passenger water transport
- 6.8. Inland freight water transport
- 6.9. Retrofitting of inland water passenger and freight transport

With respect to the climate change mitigation goal, the following technical criteria were defined for:

6.7. Inland passenger water transport:

1. The activity complies with one of the following criteria:

(a) the vessels have zero direct (tailpipe) CO2 emissions;

(b) until 31 December 2025, hybrid and dual fuel vessels derive at least 50% of their energy from zero direct (tailpipe) CO2 emission fuels or plug-in power for their normal operation.

6.8. inland freight water transport

1. The activity complies with one or both of the following criteria:

(a) the vessels have zero direct (tailpipe) CO2 emission;

(b) where technologically and economically not feasible to comply with the criterion in point (a), until 31 December 2025, the vessels have direct (tailpipe) emissions of CO2 per tonne kilometre (gCO2/tkm), calculated (or estimated in case of new vessels) using the Energy Efficiency Operational Indicator245, 50% lower than the average reference value for emissions of CO2 defined for heavy duty vehicles (vehicle subgroup 5- LH) in accordance with Article 11 of Regulation 2019/1242. 245 The Energy Efficiency Operational Indicator is defined as the ratio of mass of CO2 emitted per unit of transport work. It is a representative value of the energy efficiency of the ship operation over a consistent period which represents the overall trading pattern of the vessel. Guidance on how to calculate this indicator is provided in the document MEPC.1/Circ. 684 from IMO. EN 145 EN

2. Vessels are not dedicated to the transport of fossil fuels.

6.9. Retrofitting of inland water passenger and freight transport

Substantial contribution to climate change mitigation

1. Until 31 December 2025, the retrofitting activity reduces fuel consumption of the vessel by at least 10 % expressed in litre of fuel per tonne kilometre, as demonstrated by a comparative calculation for the representative navigation areas (including representative load profiles) in which the vessel is to operate or by means of the results of model tests or simulations.

2. Vessels retrofitted or upgraded are not dedicated to transport of fossil fuels.

In 2022, the taxonomy screening criteria for climate mitigation will be revised, notably the criteria for post year 2025. It is expected that the scope will be broadened by means of a well-to-wake approach based on the fit-for-55 FuelEU Maritime proposal and RED emission factors for climate emissions. Thus, also combustion engines using fuels with significantly lower carbon intensity could be in scope after year 2025. Furthermore, the Taxonomy criteria will be expanded with topics for air pollution and water pollution.

The TEN-T Regulation Revision

TEN-T revision aims at **four main objectives**:

- making transport greener by providing appropriate infrastructure and more transport by more sustainable transport modes;
- facilitating seamless and efficient transport, fostering multimodality and interoperability between the TEN-T transport modes and better integrating the urban nodes into the network;
- increase the resilience of TEN-T to climate change and other natural hazards or human-made disasters;
- improving the efficiency of the TEN-T governance tools, at streamlining the reporting and monitoring instruments and at reviewing the TEN-T network design.

The completion of the network remains to be finalized by 2050 with intermediate **deadlines** in 2030 and 2040: the core network by 2030, the extended core network by 2040 and the comprehensive network by 2050. It also supports the uptake of recharging/refuelling infrastructure depends on synergies with a.o. the deployment of alternative fuels infrastructure (**AFIR** proposal).

Of the two horizontal priorities in TEN-T, one is the European Maritime Space. There are also numerous provisions dedicated to the IWT sector, which include: the deployment of alternative fuels' infrastructure (by 2030 and 2050), the introduction and promotion of new technologies and innovation for zero-carbon energy fuels and propulsion systems, stimulate energy efficiency, etc.

The NAIADES III Action Plan for inland navigation

The European Commission tabled in June 2021 a 35-point action plan to boost the role of inland waterway transport in our mobility and logistics systems. The core objectives are to shift more cargo over Europe's rivers and canals, and facilitate the transition to zero-emission barges by 2050. This is in line with the European Green Deal and the Sustainable and Smart Mobility Strategy.

The communication states that "*compared to other land-based modes of transport, inland waterway transport is energy-efficient, safe, almost congestion-free and silent. The Commission will propose measures to encourage investment in zero-emission and zero-waste technologies for inland vessels and inland ports and will also support research and innovation*."

The communication addresses the role and importance of the Zero-Emission Waterborne Transport Partnership to promote research in zero-emission vessels technology, innovative propulsion systems and sustainable fuels, also in close collaboration with the Battery Alliance, the European Clean Hydrogen Alliance and the Renewable and Low-Carbon Fuels Value Chain Alliance.

Flagship measures in NAIADES III relate to the speeding up of the certification process for innovative and low emissions vessels, the development of multimodal alternative fuel infrastructure hubs or the need to support the sector and Member States in the transition towards zero-emission, particularly regarding funding and financing, which are key to meeting the energy transition challenge. To meet this challenge, support for the initial deployment of zero-emission vessels and the related recharging/refuelling infrastructure is now proposed through the Alternative Fuels Infrastructure Facility under the 2021-2023 work programme of the Connecting Europe Facility 2. Where possible, funding under the CEF 2 could be combined with other sources of funding to achieve greater impact. Such a new instrument will partially contribute to closing the TCO gap and should be taken into account in the context of this report. In addition, this action plan indicates that the European Commission will facilitate the efforts by stakeholders and Member States to create a fund to complement EU and national financial instruments for the deployment of zero-emissions vessels. This confirms that the time is ripe to develop an instrument dedicated to IWT.

General Legislative Overview

A short and comprehensive overview of the main 'Fit for 55 Package' (FF55) provisions for the waterborne transport sector is outlined in the figure below[17][18].

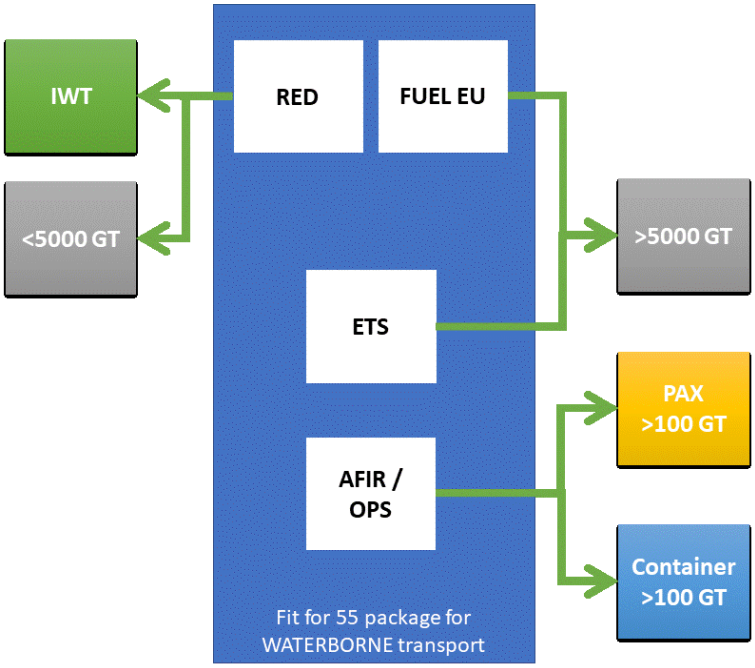


Figure 6. Fit for 55 – Relevance per ship-type

Based on the above mentioned currently proposed policies, the following trajectories have been elaborated per SRIA ship type and shall provide an indication on how the cumulative directives and allowances, capping the CO_2 emissions, will be reflected in terms of proportional reduction of CO_2 emissions as a direct result of the legislative proposals in FIT for 55, except for the impact of the Effort-sharing Regulation (ESR).[19]

[17] Elaboration of the STEERER partners, D2.2, pag 49
[18] Though the information refers to the direct applicability of these legislative acts, their implementation can also benefit other (smaller) waterborne transport segments – e.g. for AFIR/OPS, the new infrastructure can also be used by ships that are smaller than the indicated limits, thus helping to further decarbonize the sector.
[19] Idem, pag 50

Table 1. Emissions reduction according to direct impact of FF55 package concerning ETS, EU Fuel Maritime, RED, AFIR related to 2018 levels (ESR excluded).

	2025	2030	2035	2040	2050
Cruise, Ferries, Container Ships >5000GT	5,7%	26,7	47,7%	68,7%	100%
Cruise <5000GT	0%	17%	19%	20%	23%
Ferries <5000GT	0%	16%	17%	19%	21%
Container ships <5000GT	0%	14,9%	15,6%	16,3%	17,7%
IWT	6%	13%	13%	13%	13%
…					

The figure below shows that, following the FF55 package targets, waterborne transport will in fact not keep pace with the overall GHG reduction needed to stay within the 1.5°C climate goal. The overall budget for shipping (8970 Million tonnes (Mt) CO_2) is shown as the horizontal double red line. The yearly emissions starting with 1056 $MtCO_2/y$ and are continuously reducing according to the anticipated reduction based on the FF55 package are represented by the dotted grey line. The accumulated emissions over time are represented by the green line. It shows that even with this reduction trajectory the climate targets can be reached only if from 2028 onwards an active CCS will be performed, or additional measures are put in place[20], such as an immediate and very large implementation of the most efficient and available technical solutions.

[20] Idem, pag 51

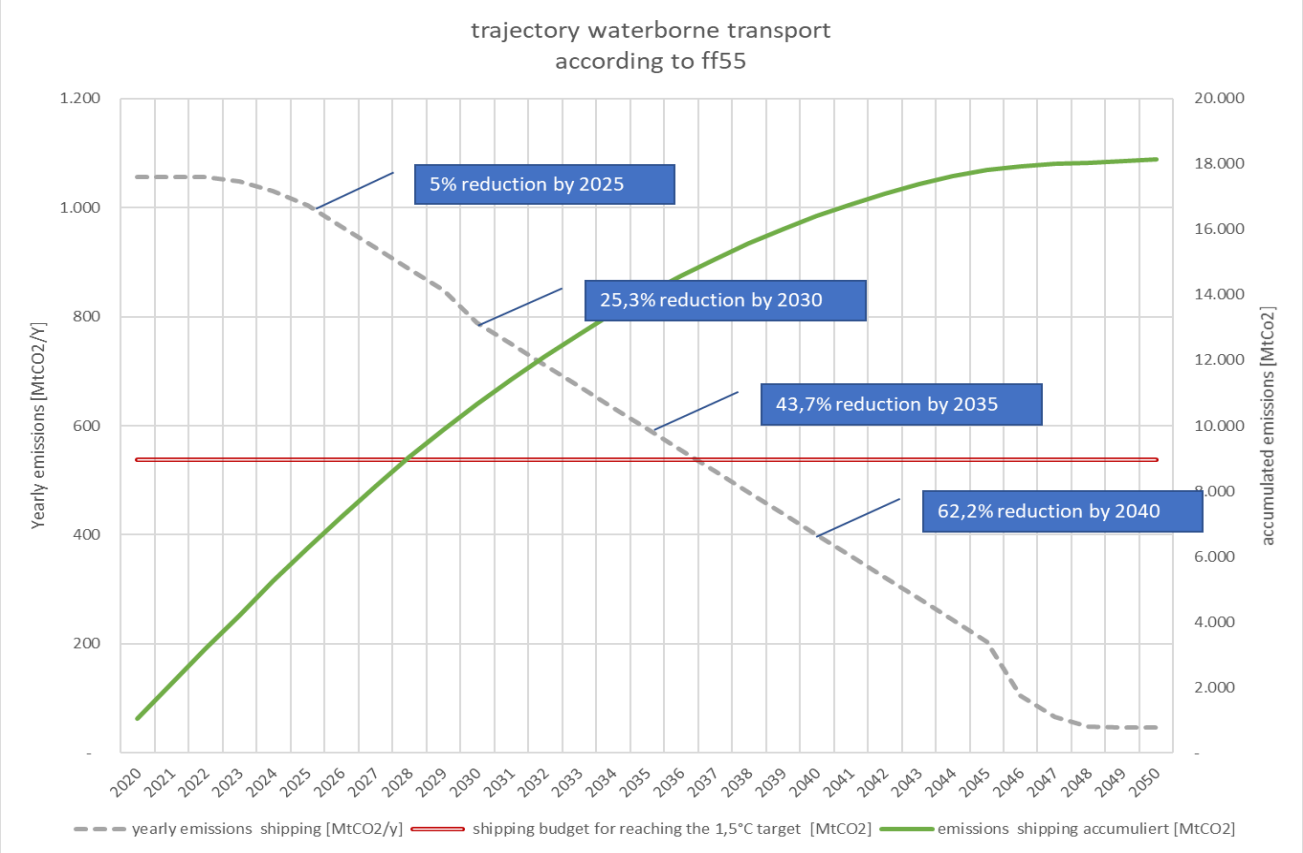


Figure 7. Trajectory of waterborne transport emissions according to FF55 package

Figure 8, respectively

2 on the next page indicate the difference of the trajectory of the partial FF55 package (which is eventually a target the sector can achieve) and the trajectory to stay within in the budget to reach the 1,5 °C climate target.[21]

[21] Idem, pag 51-52

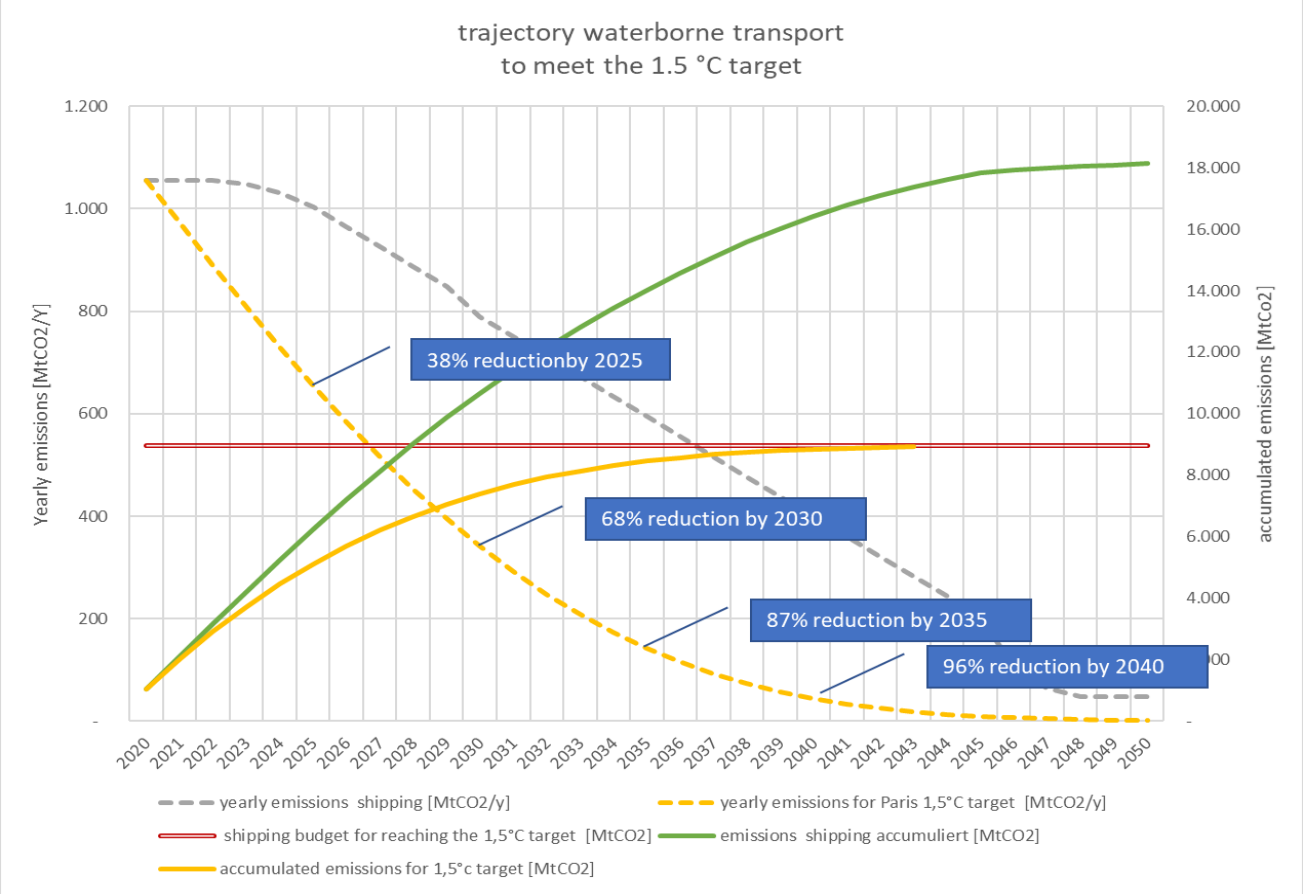


Figure 8. Trajectory of waterborne transport emissions to meet 1,5 °C climate target

Table 2. comparing required emission reductions to meet FF55 impacts due to the policy package proposed (e.g. ETS, EU Fuel Maritime, RED, etc.).and 1,5 °C global warming

Targets	2025	2030	2035	2040	2050
Reductions for meeting FF55 / EC policy	5%	25%	44%	62%	90%
Reductions for meeting 1,5°C	38%	68%	87%	96%	100%

Policy-Based Preliminary Recommendations

The analysis of the policy and legislative changes allows the identification of the main potential points for the update of the ZEWT SRIA, and in particular for the next ZEWT topics, covering both the maritime and IWT segments. These are outlined below, with the main policy initiatives referenced:

- Incorporation of and higher efficiency operations with synthetic fuels and (advanced) biofuels and biogas (ref. AFIR, ETS, FuelEU Maritime, RED);
- Development of future-proof and harmonised (or standardised) charging infrastructures – the parts covering the ship-to-ship and/or ship-to-shore aspects – to meet the demand of approx. 90% of the shipping traffic (ref. RED, AFID);
- Development and technical harmonisation (or standardisation) of bunkering facilities for (LNG and) decarbonised gasses to cover short-sea shipping – the parts covering ship-to-ship and/or ship-to-shore aspects (ref. AFID);
- Improvements for off-shore vessels design, propulsion and operations (ref. RED);
- Improvements in off-shore charging (ref. RED);
- More energy-efficiency technologies and operations for all ship types, to reduce the OPEX after the removal of tax exemptions (ref. Energy Taxation Directive);
- Prioritising (holistic) ship type developments based on in-depth analysis, in terms of size, operational profile and carbon footprint (ref. Carbon Border Adjustment Mechanism);
- Further electrification through either hybrid or fully electric propulsion systems (the latter being preferred, where possible) given the foreseen increase of both onshore and off-shore power availability. This is applicable in particular to the ship types operating in or close to EU waters: ferries, short sea shipping, offshore vessels and some of the IWT subcategories (ref. ETS, RED).

4. Scenarios with Quantified Targets for 2025, 2030 and 2050

The work achieved by the project partners and experts' group for D2.2 and D3.4 ¨*Results of the second consultation phase: Scenarios and Targets 25-30-50*¨ has shown that a wide array of the waterborne transport sector stakeholders is committed to the decarbonization of the sector that should respect as much as possible the limits of the carbon budget. In this context, four alternative scenarios – 'Business as usual', 'Independent green', 'Local Strength' and 'Planetary Stewardship' scenarios – have been determined as being the most likely pathways to achieve the sector's targets[22].

To gain further clarity on the scenarios and allow their implementation in a timely manner, the STEERER partners have also outlined the quantification of targets for 2025, 2030, 2040 and 2050 for each of the six waterborne transport segments as defined by the ZEWT SRIA.

[22] Ref STEERER D2.2 pag 18-30

Targets for the IWT Segment

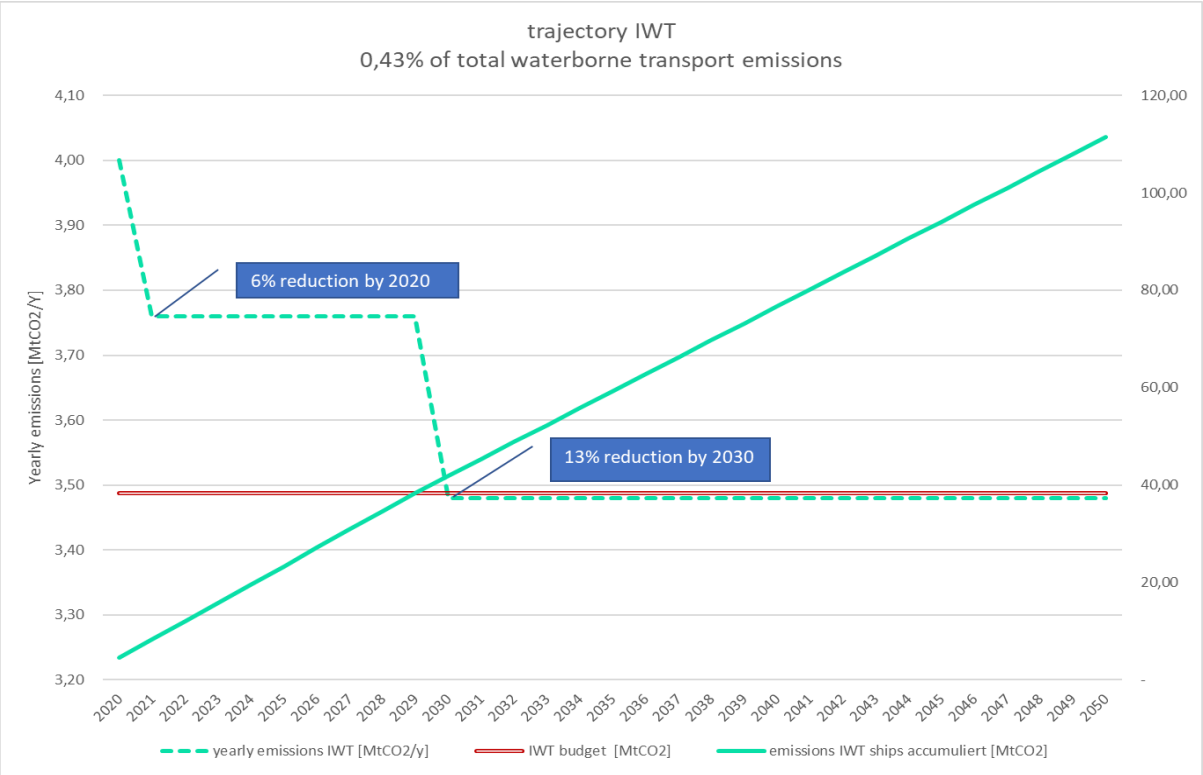


Figure 9. Emission reduction targets for IWT acc. to FF55 package excluding ESR

The STEERER project information has shown that the IWT sector emissions have a volume of 4,53 MtCO2 /y[23]. The regulations which sum up the reduction targets for IWT are derived from the Fuel Quality Directive (FQD), of 6%, and the RED, of 13%. Following only the selected set of Fit for 55 measures the IWT sector would miss the 2050 target by 87%. Obviously additional reductions and targets on national level are expected. Additional measures are needed to increase energy efficiency (reduce energy demand) and to apply less carbon intensive energy sources. These measures are to be elaborated on national levels in Europe in view of the Effort Sharing Regulation by which the IWT is covered. However, this needs to be harmonised at the international level as much as possible, to avoid a disturbance of the level playing field. Possibly, river commissions such as CCNR and DC can play a role here as well. CCNR made recently a roadmap report to define actions to support and stimulate the energy transition of the inland waterway transport fleet. Clearly, further specification of national and European policy measures and execution of RD&I tasks and supporting grant funds for deployment are necessary in order to enable IWT to take higher share in reducing emissions.

In this respect the NAIADES III policy document[24] and also the Central Commission for the Navigation of the Rhine (CCNR) have stated emission reduction ambitions and targets. The EC and CCNR work towards

[23] Based on data provided by CCNR and results from PROMINENT project, STEERER D2.2 pag 56
[24] https://transport.ec.europa.eu/transport-modes/inland-waterways/promotion-inland-waterway-transport/naiades-iii-action-plan_en

achieving near zero emission performance in 2050 as compared to 2015. For the medium term, CCNR aims to reduce at least 35% of GHG emissions in 2035 compared to 2015. Policy instruments are being prepared to achieve this and the recent CCNR Roadmap shows the technology pathways and the planned measures to support and promote the transition of IWT to a green transport mode[25].

Furthermore, additional emission reductions are expected from the installation of OPS for inland ports and impacts of national plans in the framework of AFIR.

Targets for the Long Distance Vessels Segment

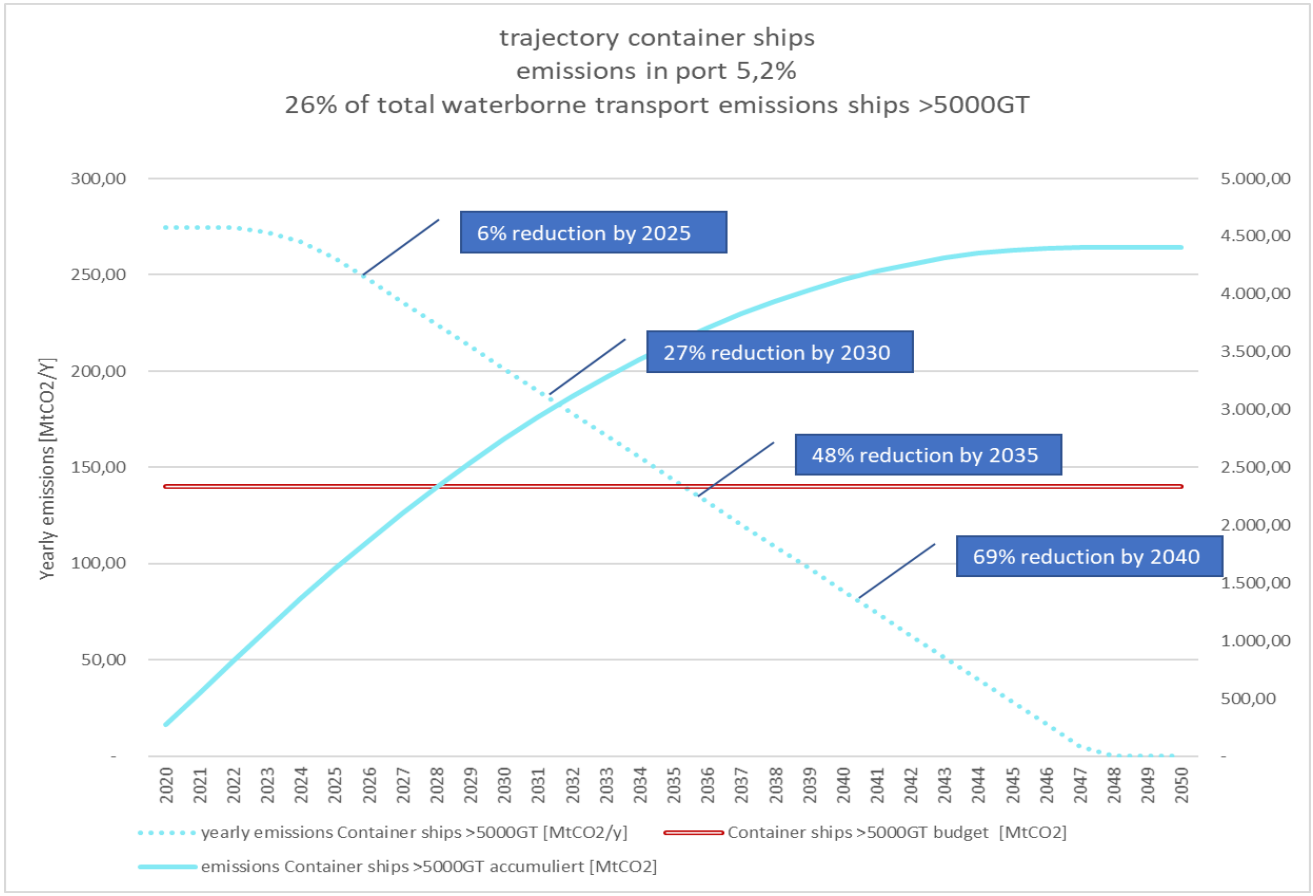


Figure 10. emission reduction targets for long distabce vessels >5000GT according to the FF55 package

The emission reduction targets from the FF55 package for long distance vessels operating in Europe would lead to zero emission operation in 2050 although the overshoot in carbon budget will be in the order of 2.000 MtCO2 worldwide. The targets are derived from the ETS, which defines for GHG emissions an absolute ceiling – with a CO2 allowance reduction of 4,2% yearly.

[25] https://www.ccr-zkr.org/files/documents/Roadmap/Roadmap_en.pdf

Consequently, this ship segment needs to *de facto* achieve a deeper decarbonization within the given timeframe in order not to affect the carbon budget. Alternatively, other ship segments need to achieve a faster decarbonization than the assumed targets in order to counterbalance this overshoot. The RD&I and subsequent deployment activities must take these factors into account.

Targets for Cruise Ships Segment

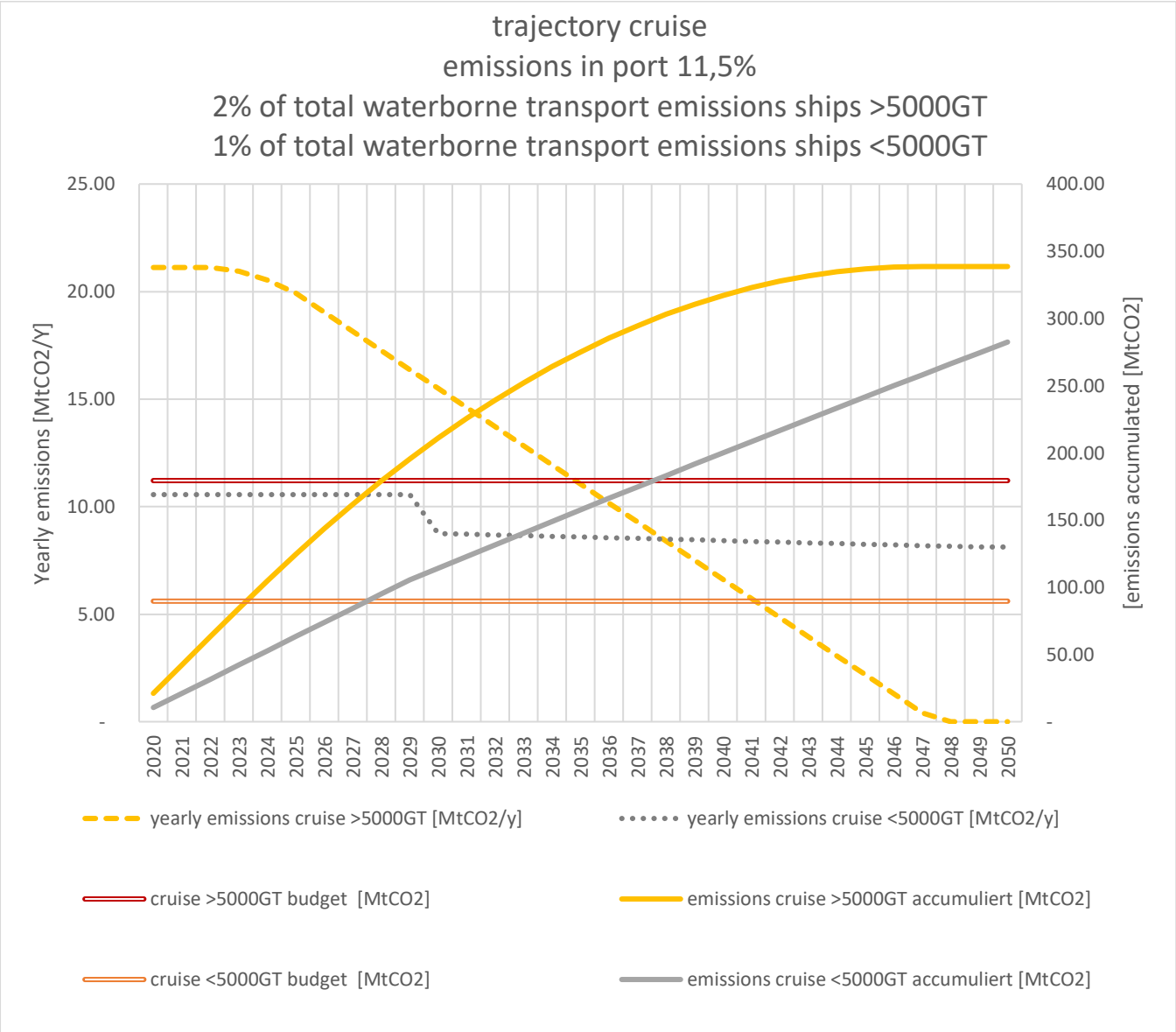


Figure 11. Cruise ship emissions

The figures above and below for cruise ships have been derived from monitoring, reporting and verification (MRV) data, and the correspondence with the relevant IMO data is considered plausible. The emission reductions required according to the FF55 package for Cruise ships would be:

Cruise ships	2025	2030	2040	2050
>5000GT	6%	27%	69%	100%
<5000GT	0%	17%	20%	23%

Cruise ships spend 11,5% of their energy in ports. However, for the calculation of their time spent in ports, the 2020 data have been excluded due to the pandemic reduction in cruise tourism.

Targets for the Ferries Segment

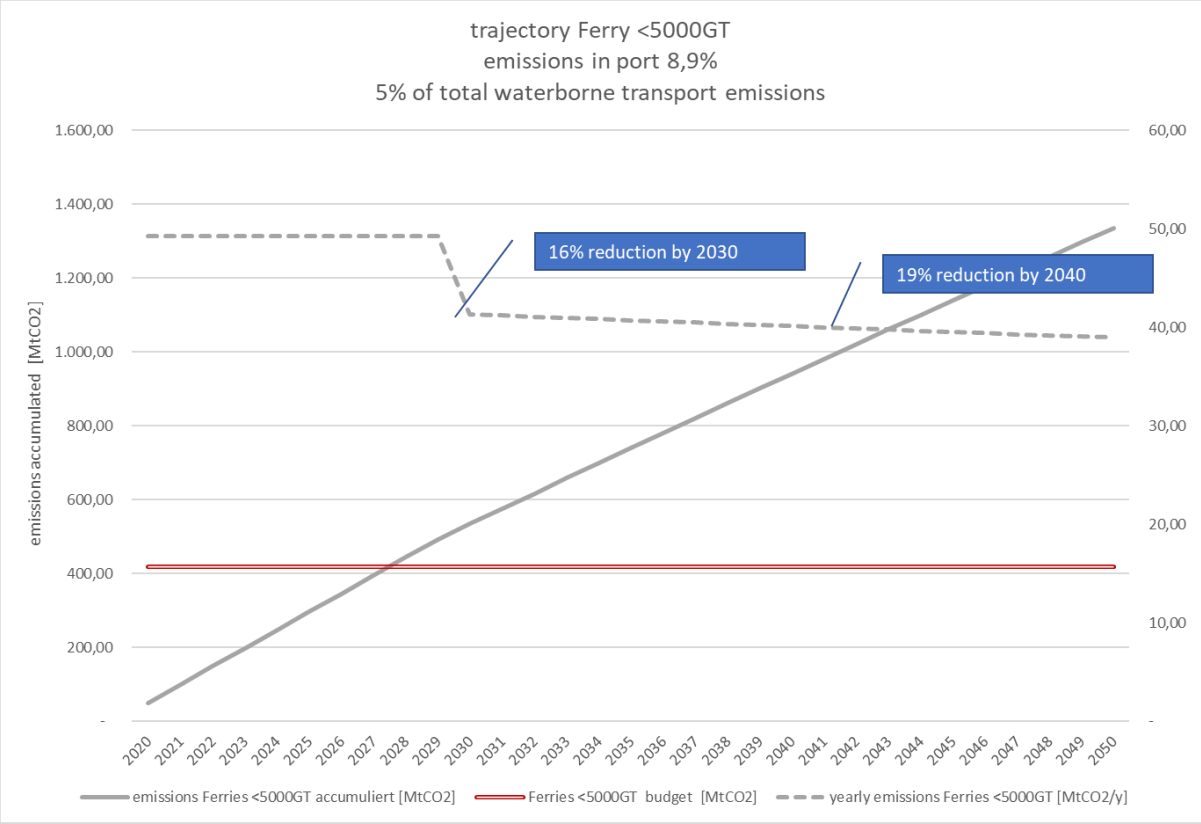


Figure 12. emission trajectory acc.to FF55 for Ferries< 5000GT

Small ferries (under 5000 GT) are some of the best candidates for full electric drives and thus becoming zero emission at the same pace as Europe's energy mix becomes 100% renewable-based. Or even sooner, depending on the regional context. Until this happens, the decarbonization (reduction) targets derived from the FF55 package are moderate: 16% by 2030 and 19% by 2040. These are based on RED legislation and the OPS to be installed in 90% of Europe's ports by 2030. It has to be noted that the power

for OPS is linked to the European energy mix. The emissions' share for these ferries in ports is about 8,9%. Ferries <5000GT contribute to 5% of Europe's waterborne transport emissions.

The small ferry segment has the opportunity to decarbonize ahead of schedule, thus reducing not only the emissions it creates, but potentially also some of the pressure coming from the likely overshoot of other ship segments. However, this achievement can only be realized with a lot of political will at the national and regional levels – via e.g. additional investments in (green) energy sources, funding for RD&I, more stricter regulations – not just through the EU framework and the necessary RD&I activities.

Regulations foreseen within the FF55 package for Ferries >5000GT are about the inclusion in the EU ETS and OPS, although it has to be noted that the EU ETS is putting the emissions' cap while OPS is a measure provided by the ports and thus contributing to the emission reduction (in particular the air pollution close to densely populated areas) without burning fuel, and thus without accounting for the EU ETS. The reduction targets resulting from this are the same as for all ships >5000GT operating in Europe.

Following this trajectory, Ferries >5000Gt will produce an overshoot of almost 750 MtCO2 worldwide, as presented in the figure below.

Although the challenge to decarbonize is for ferries above 5000Gt higher than for smaller ferries, this ship segment also has a good potential for fast decarbonization – with the use of both sustainable alternative fuels and electricity – as shown by some of the recent EU-funded RD&I projects. In addition to some further technological progress, the decarbonization of this ship segment is also heavily dependent on the political will at the regional and/or national levels, as mentioned above.

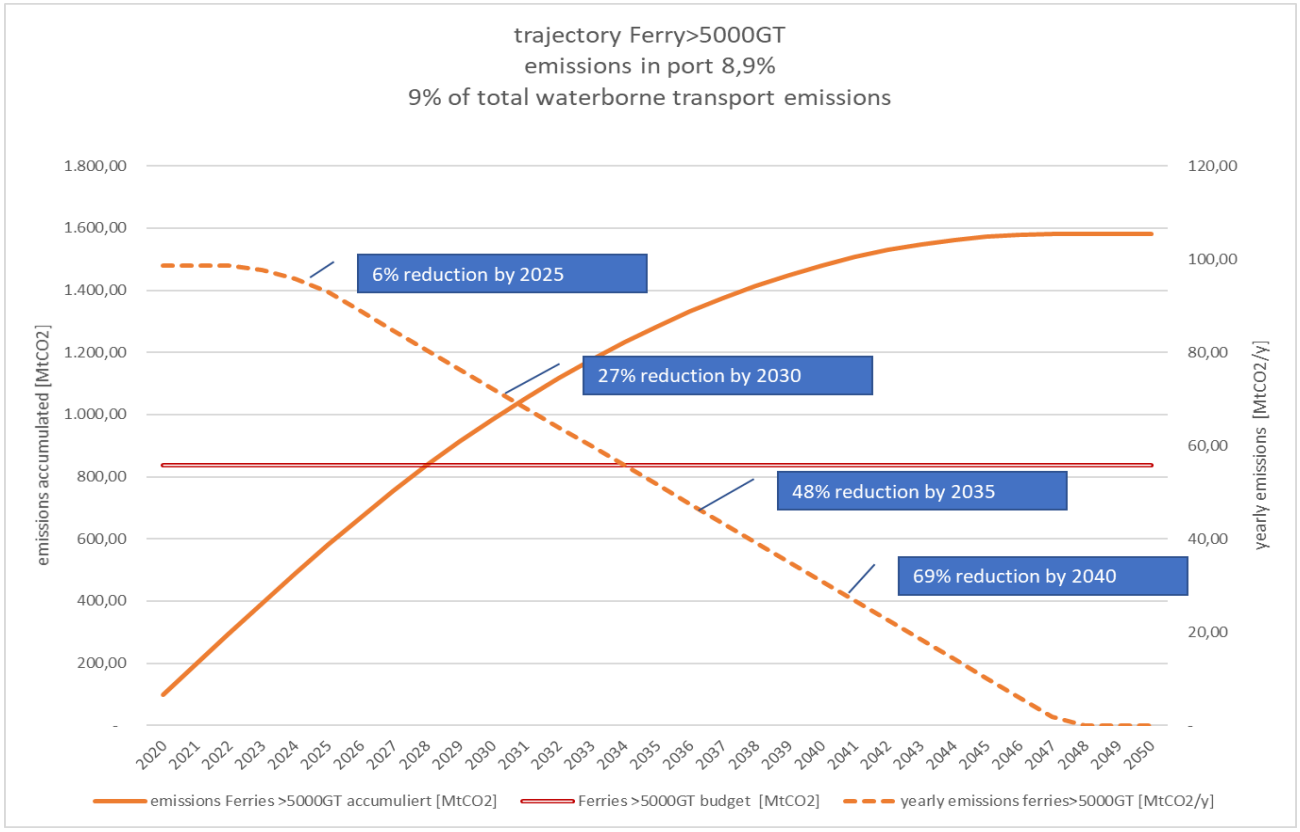


Figure 13. Emission trajectory acc to the FF55 packaage for Ferries >5000GT

Targets for Short-Sea Shipping Segment

The STEERER project has not calculated the targets for short-sea shipping, but aims to do so in the near future, and include the results in deliverable D2.7, which is the update of the present document.

According to the EU legal framework, short sea shipping is as maritime transport of goods between ports in the EU (sometimes also including candidate countries and EFTA countries) on one hand, and ports situated in geographical Europe, on the Mediterranean and Black Seas on the other hand, i.e. ports in EU maritime countries; EEA maritime countries (Iceland and Norway); candidate countries; the Baltic Sea area (Russia); the Mediterranean Sea area (Algeria, Bosnia and Herzegovina, Egypt, Israel, Lebanon, Libya, Morocco, Occupied Palestinian territory, Syria, and Tunisia); the Black Sea area (Georgia, Moldova, Russia and Ukraine). This can mean a route between a Black Sea and a Baltic Sea port which is longer than some 'deep sea' routes.

Thus, short-sea shipping poses a number of challenges due to its rather fluid boundaries. While there can be some solutions particularly dedicated to this ship category, it is clear that in most cases these have to overlap/be taken from the solutions from the other long distance ship types, but often scaled down. The local/regional context will also have a great impact on the solutions to be chosen.

Targets for the Offshore Vessels Segment

The STEERER project has not calculated the targets for this category, given its (current) small size. While this category of vessels is the smallest in terms of emissions, it is nevertheless a steppingstone to further upscale waterborne transport applications as it presents numerous interesting aspects. The most important ones are

- Based on the current predictions, they are some of the longest-lived ship types;
- They usually have high energy requirements, which makes them both hard to fully decarbonize but also interesting 'test beds' for novel green technologies and operations;
- They mostly operate near shore, including near densely inhabited areas, something which makes their pollution footprint relevant at local/regional levels;
- They are high-added value vessels, something that is reflected in both operational and retrofitting costs, aspects that can create both 'push' and 'pull' forces when it comes to their decarbonisation. It is also one of the vessel types where the EU industry is still a world leader;
- Due to the future investments in offshore renewable energy sources and other economic activities, including the investments stemming from the forthcoming Offshore Renewable Energy Strategy, it is expected that the number of such vessels will exponentially increase. And this reasoning is applicable not only for the EU, but also for other high- or mid-income regions around the Globe. It is therefore a risk that a significant future polluting source is slipping 'under the radar' with long-term implications.

Last but not least, all these features are interlinked one way or another, an aspect that further contributes to both the complexity and the partially disproportionate importance of this ship category.

Regardless of whether the greening of this ship segment will come through dedicated actions or through more transversal solutions applicable for several ship types, it is important that the ZEWT SRIA update takes into account all the aforementioned factors.

5. Actions Proposed for the SRIA Intervention Areas

This chapter encompasses the main information extracted from the *D2.3 Areas of intervention and relevant actions - "implementation plan"* for all the six intervention areas of the ZEWT SRIA. The information was then refined and updated in order to give a clearer direction of the RD&I and deployment activities that need to be undertaken by the Partnership and the waterborne transport stakeholders in general, to achieve the decarbonization targets by 2050.

All relevant actions foreseen had been listed in the STEERER D2.3 deliverable under three separate themes: technical, regulatory and business. This separation had been done in order to identify the various solutions and the better way to implement them, including through complementarity.

To clarify what each theme encompasses, a non-exhaustive list of questions is added below:

- Technical (T): How can emissions be further reduced or even eliminated? What is needed to increase the TRL of the related technologies? Are there any knowledge gaps? Is the RD&I pipeline moving?
- Regulatory (R): How can policy support and facilitate the innovations that are needed? Are the safety measures needed in place? Do class guidelines need to be developed or updated? What existing regulations need to be updated to increase uptake?
- Business (B): Is it economically feasible to invest in the technology? What is the return on investment? Is retrofitting an option? What is the perception of the technology? Is there enough access to capital for RD&I, pilots & deployment? Is enough information available for the shipowner to decide? Do commercial agreements need to be updated?

However, for the purpose of this deliverable, the focus has been on the selection and use of the technical key actions. A few actions under the regulatory theme have also been mentioned, as the future ZEWT Partnership calls could also include some policy-related activities.

Intervention Area 1: Use of Sustainable Alternative Fuels (SAF)

In this case, the focus of the deliverable (and that of the Partnership) lies on the use of sustainable alternative fuels in waterborne transport (such as onboard storage and energy conversion) and not on the production of the fuels (although key because the two go hand-in-hand). Bunker infrastructure will be covered in the sixth intervention area (Ports).

Before addressing each sustainable alternative fuel separately, the following key actions were defined that apply to all the possible sustainable alternative fuels[26].

Theme	Key actions
T	Further upscaling of **demonstrator projects** to identify the limits of the different fuels (**Priority**).
T	Development/ further optimization of **after-treatment systems** to (nearly) eliminate all types of air pollutants (not CO_2) for traditional fuels, as well as for some technologies converting sustainable alternative fuels.
T	Investigate the reliability and cost of fuel cells in the waterborne transport environment (tilting, acceleration, vibrations, etc.).
R	Class guidelines/ES-TRIN are/is yet lacking provisions for the use of hydrogen and therefore need to be updated/adjusted where needed to facilitate the use of sustainable alternative fuels. This can, e.g. be achieved by addressing the guidelines and technical regulations in current/new IA and RIA projects under Horizon Europe that are focusing on the use of sustainable alternative fuels **taking into account the different waterborne transport segments**.
R	Address full **life-cycle emissions** when assessing a fuel (upstream + downstream for **all** harmful emissions).
R	Fire- & safety regulations (training, operational rules, vessel design, etc.) need to be developed/updated where needed to facilitate the use of sustainable alternative fuels and guarantee safety.
R	Setting up of a regulatory framework regarding onboard storage and propulsion related to the new fuels (the IWT case).
R	Development and implementation of regulations for operating SOFC on board of a vessel.
R	Internationally standardized WtW information on bunker notes.
B	Insights in the cost comparison and broader impacts between the different options for the sustainable alternative fuels as fuel and energy convertors – internal combustion engines (ICE) or fuel cells (FC) – for different vessel types and operational profiles.

[26] A selection has been made for the actions that are most relevant for the RD&I activities that can be financed under the ZEWT Partnership.

Additionally, two consolidated actions were identified.

Area	Consolidated actions
SAF	Develop, demonstrate and test new propulsion systems in higher TRL levels to bring sustainable alternative fuels and propulsion systems closer to the market.
SAF	Develop , demonstrate and test high TRL cost-efficient and effective storage and bunkering systems for sustainable alternative fuels on board of vessels.

Furthermore, Annexes I and II give an overview of the well-to-wake (WtW) values of each of the sustainable alternative fuels addressed and their bio- and synthetic variants, which should be considered in complementarity to the recommendations from this chapter on SAFs.

Liquefied Natural Gas – bio and e-LNG

Theme	Key action
T	Minimize/eliminate methane slip by engine design (possibility of including after treatment systems) and proper design-for-operation.
B	Monitoring and reporting of methane slip will allow further differentiation between existing options and to incentivize the use of the better options (less methane slip). Lower slip levels are technically possible but come at a higher cost.

A large-scale continuous role for LNG is uncertain due to the uncertain GHG benefits, the additional capital expenditures, uncertain price projections for bio- LNG and e-LNG and therefore the risk of stranded assets. There are concerns about a possible technology lock-in with a GHG emissions trajectory which would be incompatible with the EU's and IMO's 2050 climate targets in case methane slip is not eliminated.

There is therefore a clear need for urgent and strong policy action to regulate methane emissions both in the supply chain of LNG (upstream) and in its use on board existing ships and any newbuilds. For inland waterway transport the already-existing Non-Road Mobile Machinery (NRMM) limits on methane slip would need to be more stringent. This will be important regardless of whether LNG becomes a significant bunker fuel or not. For example, although downstream methane emissions could be reduced using newer machinery with lower methane slip levels, this would still not address the risk of upstream and midstream methane emissions in the supply chain, the emissions of which are said to be much lower for bio- and e-LNG, compared to conventional LNG. These present a much more complex problem that is not strictly technological in nature, but would require regulatory changes and enforcement across the numerous jurisdictions where LNG is extracted and distributed.

Regular, bio- or e-LNG – is considered as an option only to the ships that require a higher engine and energy capacity: long-distance ships, cruise ships and some of the IWT ships. Any remaining RD&I activities that are necessary for this technology should primarily focus on these ship types and/or their

operations. The other ship categories will normally benefit from better alternatives, whether from other types of SAFs or electrification.

(e-)Hydrogen

Theme	Key action
T	Investigate the possibility to use reforming techniques to generate hydrogen onboard of the ship from different energy carriers (MeOH, NH3, etc.).
T	Investigate the maintenance needs of different hydrogen storage systems.
T	Investigate the optimal tank type selection for different operational profiles.
T	Clarify capabilities with regards to load variation and low load operations.
T	Assess operational fit with regards to energy efficiency / density.

Hydrogen will initially be mainly a suitable option for the smaller waterborne transport segments but not for the vessels with a long range due to its low energy density and extremely high fuel costs. This could however change in the future if a suitable liquid organic hydrogen carrier (LOHC) is found.

As hydrogen is one of the cleanest solutions available – provided that the hydrogen used is either 'blue' or 'green' – and considering the volume and/or weight requirements needed, hydrogen-propulsion technologies are first of all applicable to the short-sea and ferry categories, as well as many of the off-shore and IWT ships. Particular attention should therefore be placed on hydrogen RD&I actions for these ship categories. .

As a second step, hydrogen-related technologies, whether as main or auxiliary power sources, should become more and more applicable to the other ship categories – long distance and cruise – thus helping achieve the carbon targets.

(bio and e-)Methanol

According to the Clarksons' Fuelling transition report published in November 2020, at that moment 12 vessels were in service and 10 on order. The Fuelling Transition report of October 2019 indicated 11 in service, 1 on order. Unfortunately, no more information could be found from before that date. The interest in methanol as a fuel is growing substantially, which is reflected in a number of new orders for different ship types: Maersk ordered one 2,100 TEU methanol dual fuel container ship (delivery in 2023) and 8 16,000 TEU container ship (delivery in 2024-2025) and CMA CMG ordered six 15,000 TEU container ships (delivery in 2025). New orders for Methanol ships cover a wide range of different vessel types: Tanker, Offshore supply vessels, Ferries, Tugs and more.[27] In June 2022, MEYER TRUKU started the construction for the first Methanol-ready cruise ship for their customer TUI Cruises.[28]

[27] https://www.methanol.org/wp-content/uploads/2022/06/Final-On-the-Water-and-on-the-Way-5.pdf
[28] https://www.maritime-executive.com/article/first-large-methanol-ready-cruise-ship-begins-construction-in-finland

The increasing ordering activities are related to methanol fuel cells and engines (TRL 7-8) as well as tank systems (TRL 8) are available and demonstrated in operational environments for different vessel types, ranging from RoPax ferries (Stena Germanica) to pilot boats as in the FASTWATER project.[29]

The reason why the TRL does not have a higher score is linked to industry & safety standards that still need to be updated and technical regulations which are missing (e.g. missing for IWT as it is not addressed (yet) in ES-TRIN). On regulatory level there should also be a guarantee that the green variants of methanol are acknowledged as green fuels , e.g. to be acknowledged in the revision of EU Taxonomy via a WTW methodology

The availability of bio-/e-methanol is limited today[30], but shows rapid growth in the last two years and the increasing number of new ships using methanol as fuel are already on order (e.g. from Maersk, CMA CNG and more), will consequently increase the availability of bio-/e- methanol further. As an example, Maersk announced in March 2022 a global strategic partnership with six leading energy companies to boost the production of bio-/e-methanol with the intent of sourcing at least 730,000 tonnes/year by end of 2025.[31]

The high TRL in combination with a substantial number of vessels operating on methanol and the opportunity to convert existing vessels to methanol makes methanol a convincing option towards net-zero emission shipping.

Drop-in bio-fuels (bio-diesel and HVO)

Theme	Key action
R	Engines need to be certified and tested for the (blends) with biofuels as alternative for the fossil diesel, e.g. Stage V engines to be certified for higher blends of fatty acid methyl ester (FAME).
R	Fuel specifications need to be made stricter, including the measurement and enforcement due to fuel instability, corrosion, susceptibility to microbial growth, and poor cold-flow properties of certain biofuels. Also, proper government measures need to be more widely known and clear to the users and fuel providers.
B	Clear information on the technical applicability and the 'good housekeeping' measures to be taken into account to be provided by the fuel suppliers.

However, it is considered that no technical or research work is needed within the ZEWT Partnership in this case. Some coordination is however recommended to make sure that there are common standards and incentives to apply these type of drop-in fuels for existing diesel engines (e.g. an harmonised

[29] https://www.methanol.org/wp-content/uploads/2022/06/Final-On-the-Water-and-on-the-Way-5.pdf
[30] https://www.methanol.org/renewable/
[31] https://www.maersk.com/news/articles/2022/03/10/maersk-engages-in-strategic-partnerships-to-scale-green-methanol-production

approach by Member States in the implementation of RED and FQD regulation to ensure level playing field).

(e-)Ammonia

Theme	Key action
T	Further development and testing of ammonia ICE: - Determine optimal amount of pilot fuel (diesel: NH3 or H2:NH3); - Determine when and where the fuel will be mixed with the pilot fuel; - Determine effective and efficient engine management and aftertreatment (risk of ammonia slip and laughing gas).
T	Upscale ammonia fuel cell demonstrators – current limit 5 megawatts (MW)).
T	Further investigate optimal storage solutions.
T	Investigate the feasibility of ammonia cracking to hydrogen for reducing on-board hydrogen storage requirement/increasing vessel range.
T	Investigate alternative for operational venting (will it be acceptable to venting NH3 to atmosphere?).

Even though there are no ammonia-ready vessels yet in the orderbook, both MAN ES and Wärtsilä are developing ammonia engines. But both engines are still in the test phase. As with the other hydrogen-based fuels, fuels cells are being looked into as well: the ShipFC project will retrofit an offshore vessel with a large 2MW direct solid oxide fuel cells (SOFC) ammonia fuel cell.

Though ammonia is in principle one of the cleanest options for the waterborne transport sector alongside hydrogen, some of its implications are still not fully assessed – in particular the GHG impact of laughing gases (ammonia emissions) and the safety-related aspects are crucial topics for research. Ammonia as fuel is unsuitable for IWT due to the high external safety risks, lacking legislation in place (especially on safety), and may meet the same problems for maritime transport, in particular the short-sea, ferry and off-shore categories due to their operations in proximity of ports or the shoreline in general.

Intervention Area 2: Electrification

Even though full electrification will only be applied in waterborne transport segments that have shorter and/or fixed/predictable routes, hybrid solutions have an important role to play in terms of more optimal energy management of certain processes on board of a vessel. New technologies might require additional energy storage systems such as batteries, gensets or supercapacitors to cover the fluctuating load variations and increase the efficiency, reliability and flexibility of the entire power system. A big advantage of full battery electric drive is the high energy efficiency as there is hardly any thermal loss of energy. This amounts to around 5-10% compared to 50-60% of energy thermal loss for internal combustion engines and fuel cells. Especially if there is a shortage of green electricity (also to make e-fuels and green hydrogen), the option of full electric propulsion using batteries charged from the grid is very attractive. Furthermore, these batteries can also be used for peak-shaving and stabilising the electricity grid, seen also the expected increase of fluctuations due to more electricity coming from wind and solar power.

One **consolidated** action was identified:

Area	Consolidated actions
ELEC 1	Fuel Cell and battery technology development and application on board of vessels, taking into account the waterborne transport segments. Both low TRL level developments focusing on the further development and demonstration of promising new battery technologies on board of vessels and high level TRL developments aiming to bring FC and battery applications closer the market.

The full electric option should be as much as possible developed and deployed for vessels that have the possibility to recharge frequently or swiftly exchange swappable batteries (short distances and/or fixed routes and timetables). With increased technological performances in particular for the batteries and drivetrains, fully electric can also become a good option for some of the IWT segments on short term and on longer term depending on the land side infrastructure. Given the current and foreseen developments for both fully-electric and the sustainable alternative fuels, the hybrid option should be avoided as a principle by these ship categories, though the ultimate decision needs to rest on an in-depth analysis of the operational necessities for that ship and the available power/fuel sources in the region.

As expected, the uptake of hybrid solutions is also rising steadily and at a somewhat faster pace than fully electric. The ferry fleet is again the fleet type that opts most for a hybrid solution together with the offshore fleet (offshore supply vessels). A rise in order is noticeable for the general cargo fleet. There are also opportunities for further deployment in IWT by the application of swappable battery containers, such as those investigated by the EU-funded CURRENT DIRECT project and demonstrated by the ZES company in The Netherlands for inland waterway transport (short distance inland container service Alphen aan den Rijk <> Moerdijk).

Theme	Key actions
T	Developing more DC components to improve the energy efficiency.
T	Research needed to bring down the volumetric and gravimetric density of battery technology for storage onboard to make it modular and standardised and competitive with conventional fossil diesel. This could result in other types of hydrogen carriers and convertors and new types of electricity storage technology than the ones used today.
T	Demonstration of the battery design life.

Intervention Area 3: Energy Efficiency

In order to tackle GHG reduction at fleet scale with significant effect, the existing fleet needs to undertake major changes. Just the replacement of the existing fleet would be a too long process to achieve the greenhouse gas reduction objectives. Early emissions have more climate impact than delayed emissions, thus ship lifetime and its complete lifecycle (including ship construction, solutions lowering the carbon impact, etc.) need to be dealt with. Consequently, significant emphasis should be placed on retrofittable energy efficiency solutions.

Combined with the foreseen acceleration of regulation measures at European and international level, the development of European-manufactured energy efficiency solutions is a large source of competitivity and employment for shipyards, technologies designers and manufacturers, etc, besides the added value in relation to the GHG reduction targets.

Many energy efficiency solutions are demonstrated and available to the market. One of the main challenges is now to increase their individual performances for further opportunities. Once the technologies are demonstrated, regulations can accelerate the actions on GHG emissions reduction. On the other hand, without a strong European supply chain dedicated to energy efficiency solutions, the costs of solutions will be high and the solutions won't be available in large enough quantities which would make GHG targets unachievable.

One of the main pitfalls is a lack of data regarding the benefits of the energy saving technologies. Shipowners and/or developers are not always able or willing to share certain data which makes it more difficult to e.g. calculate estimates regarding fuel consumption reduction. It is also not clear what happens when different solutions are being combined and what the effect is on optimal engine load when for example using wind assisted propulsion systems. To get the most out of the systems, they will need to be integrated and the most ideal way to do this is on new builds.

Before addressing the main individual energy efficiency measures selected, the following key actions were defined that apply to all of them.

Theme	Key actions
T	Setting up an online knowledge platform where a clear overview can be found of different energy efficiency measures including the parameters that determine GHG reduction potential, the maturity level and which vessel or operating profile would be the best fit.
T	Development of advanced energy management systems that can determine the optimal use & storage of energy for different systems onboard.
T	Investigate which energy efficiency measures (technical and operational) are most interesting to combine (move away from a siloed approach). For example, certain WAPS can reach higher potential in combination with speed reduction.
T	Upgrade the performances of the panel of solutions using renewable energies including wind propulsion, to maintain competitivity and accelerate adoption.

Additionally, one **consolidated** action was identified:

Area	Consolidated actions
EEF1	Identification and (further) development of the most promising and future-proof energy efficiency measures, taking into account the waterborne transport segments. The energy efficiency measures need to fit with innovations, in particular those in the fields of sustainable alternative fuels and electrification, and support the transition towards zero-emission, including for the existing fleet.

Wind-assisted propulsion systems (WAPS)

The uptake of the technology is rather slow since large-scale deployment of this technology is still in its early phase, but progress has been made in the last decade to enhance the design of wind assisted propulsion systems, demonstrate and calculate the expected performances and integrability.

International standards are now also set to certify or assess the performances of WAPS. Wind assisted solutions are of very various types, and there are many potential solutions that can fit to multiple vessel types , especially seagoing vessels. This will depend on several factors such as the type of vessel and the route where the vessel will be sailing (which is for most maritime vessels also not fixed). For application on inland waterways the fixed bridges are barriers which limit the application of WAPS. Additionally, the levels of the fuel prices play an important role in the level of the return of investment (ROI), which makes the investment more risky as prices can be volatile and unpredictable. Obviously policies such as EU ETS and FuelEU Maritime support the business case of WAPS.

In order to (fully) benefit from the extra power that is generated by the WAPS, a system integration is required so that the engine does not run sub-optimally. Working with supercapacitors or multiple main engines instead of one could be an option. For instance, replacing a single 2-stroke main engine with multiple smaller medium speed engines can be done at similar or even lower capital expenditures (CAPEX) whilst bringing benefits in operational flexibility and vessel utility since smaller engines mean more cargo space.

Most WAPS are better suited for (1) slower sailing vessels (2) with free deck-space (3) that sail on windier routes on sea. Due to the different parameters that impact the efficiency gains of installing WAPS, **benefits should be investigated on a case-by-case basis**. Another factor that should be taken into account is the robustness of the systems since some vessels might encounter sandstorms in certain regions or harm the systems during loading & unloading (e.g. ore carriers).

Theme	Key action
T	Enhance the development of a **plug-and-play system** so that it's easier to swap between solutions.
T	Upgrade the performances of the panel wind assisted propulsion system, to maintain competitivity and accelerate adoption.
T	Investigate how excess wind energy can be used. For example, recharging onboard battery system or generation of e-fuels.

T	Investigate means to optimally integrate wind-assisted propulsion in a fuel/energy mix on-board.
T	Demonstrate a range of wind solutions to get an idea of which one produces the most power.
T	Create generally agreed methods to restore radar and line of sight in wind solutions.
R	Ensure that sea trials with wind solutions are executed in different weather conditions.
R	Certify EEDI performances of wind assisted propulsion systems under the international established framework of wind propulsion, and include EEDI referential in European policies.

Air-lubrication systems

The technology works best on flat-bottomed, slower sailing vessels. But when looking at data from Clarkson's, no less than 9 other ship types apply it (over 40 ships in service). Experiments with air lubrication systems for inland navigation yet failed to be successful (e.g. Ecoliner vessel). Surprisingly, the (fully cellular) container fleet is also applying this technology. The system promises fuel savings of up to 10%, which are significant; however, it is not yet clear what the impact of such a technology is on the ship hull in the long term. Some EU-funded projects have been/are investigating these technologies, and more action in this direction at the EU level would be welcomed.

Waste-heat recovery systems

Despite the low uptake, there is a wide variety in the vessel types that choose this technology. It generally applies to the larger and/or higher energy demand ships, for the technology to deliver tangible and cost-effective results. The reduction potential is up to 8% of the main engine fuel consumption.

Intervention area 4: Design & retrofitting

Before addressing some specific design and retrofitting measures (section below), the following key actions were defined that apply on a more general level.

Theme	Key actions
T	Development and implementation of new vessel designs that support multi-fuel engines.
T	Development and implementation of new vessel designs (aerodynamics) that support wind-assisted propulsion solutions.
T	Development and implementation of new vessel designs that support the variable energy supply from wind-assisted propulsion solutions.
T	Retrofitting existing vessels by the (optimal) integration of green available solutions, including solutions using renewable energies.
T	Investigate the benefits of using multiple main engines to optimize engine load distribution and increasing energy management flexibility.
T	Investigate the possibility of using H2-ICE or MeOH-ICE as auxiliary engines in larger vessels (priority).
T	Further investigate the integration of lightweight materials in the vessel design and building.
T	Further improvement of simulation tools to faster evaluate new vessel designs.
T	Investigate whether an electric drivetrain is the future best solution to guarantee flexibility when working with different energy sources.
T	Design compact exhaust cleaning systems.
T	Optimize design for real operating conditions instead of mainly one load case and one speed.
T	Investigate how a ship design can be improved to deal with the impact of operating at different engine loads.

Additionally, one **consolidated** action was identified.

Area	Consolidated actions
DER 1	Improved ship designs and designs for retrofits, specifically related to the developments in the field of adoption of wind assistance, sustainable alternative fuels and electrification, covering all waterborne transport segments and hence various vessel types (modular design). Also, new initiatives should be launched by shipyards and technology suppliers to develop and demonstrate new materials and production processes to improve the production and retrofit processes, and work with sustainable materials.

Advanced materials

Lloyd's Register's Global Marine Technology Trends 2030 categorizes following materials as advanced:

- Materials Fine-Tuned at Microscale or Nano-scale: the characteristics (strength, toughness, malleability and corrosion resistance) of metals will be enhanced by adjusting their structures;
- Thriving Composite Materials: can offer lightweight, stronger, and tougher materials that do not corrode;
- Bio-Inspired and Bio-Based Materials: to protect the surface from external challenges such as abrasion, fouling or icing.

Theme	Key actions
T	Investigate the life expectancy and performance (durability, degradation, etc.) of the new advanced materials.
T	Investigate the connection between different materials.

Intervention area 5: Digital Green

The following key actions were defined that apply to all technologies in this pillar.

Theme	Key action
T	Standardisation of data interfaces to facilitate modularity.
T	Development of digital tools that quantify the value of the wind on any ship and any route.
T	Setting up of waterborne transport demonstrator projects: many technologies are mature but need to be tested and further tailored for vessels.

Digital Twin

The conclusion of the STEERER partners and the waterborne transport experts that have advised the project is that there is a lot of mature technology in place within this intervention area but **one of the biggest hurdles is the standardization of modules**. Because standardization is a more general key action that can apply to all technologies that fall under digital green, the digital twin will not be described separately.

Automation

The IMO defines the following four degrees of automation:

1. crewed ship with automated processes and decision support;
2. remotely controlled ship with seafarers on board;
3. remotely controlled ship without seafarers on board;
4. fully autonomous ship.

One of the main Partnership members, Kongsberg, even went further in the classification of autonomy vs. manning taking into account the markets (vessel types) and expected timeframe.

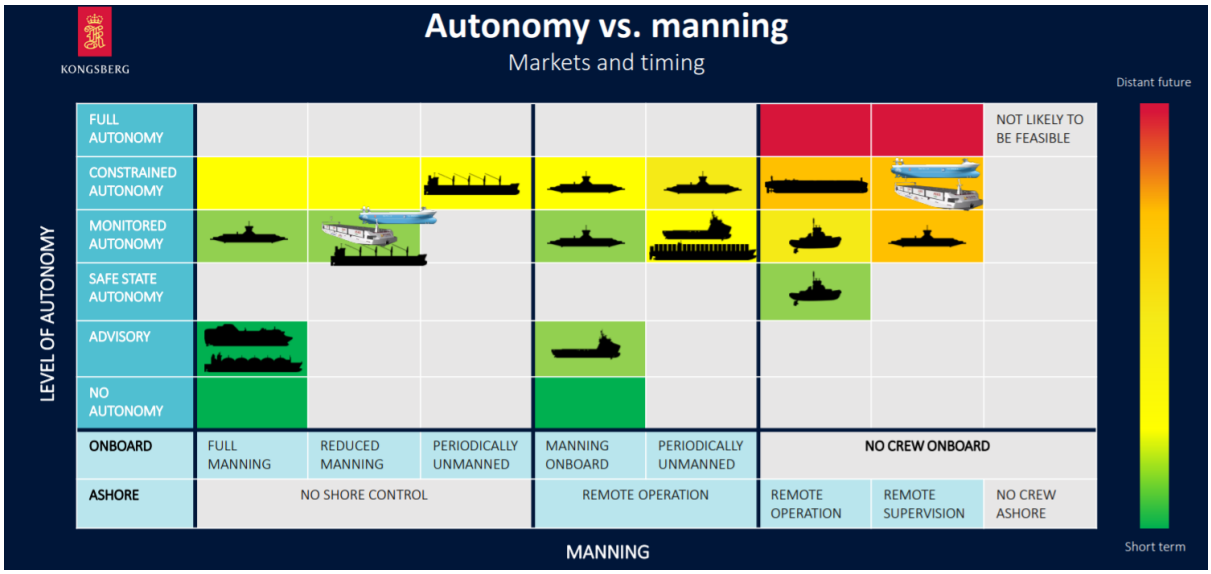


Figure 14. Levels of autonomy by Kongsberg[32]

Several inland/estuary vessels are already controlled remotely with seafarers onboard in Belgium, the Netherlands and Norway (degree 2). Through the use of sensors, AI is also already being applied for the detection and identification of objects (situational awareness), which is needed to further evolve to degree 3. Other EU-funded projects such as MOSES look at more complex operations such as AI controlled tugboats to automate mooring and docking of large vessels in order to reduce time spent on manoeuvring, reduce docking time and reduce human error.

Theme	Key action
T	Investigate how connectivity issues can be handled when crossing borders.
T	Investigate how connectivity issues can be handled in area with many users (lock).
T	Investigate the best means for ship to shore communications in open sea.

[32] Kongsberg: MASS session 27 January 2022

Intervention Area 6: Ports

One key action was defined for future RD&I activities applicable to all ports..

Theme	Key action
T	Research is needed to cost-effective, widely applicable and standardised bunkering/charging solutions, considering various potential bunkering/charging locations in different ports and the different types of vessels.

Additionally, one **consolidated** action was identified.

Area	Consolidated actions
Ports	Initiatives are needed that focus on the development of cost-effective, high TRL and standardised bunkering and charging concepts on the ships and the ship-to-shore and/or ship-to-ship interfaces, taking into account the various vessels in the different waterborne transport segments and the various geographical locations.

Sustainable Alternative Fuels (on-shore)

As the sustainable alternative fuels may require more complex storage and transfer facilities than for conventional fuels (particularly for those that are stored at high pressures and/or low temperatures, such as hydrogen and ammonia), the additional facilities may have significantly higher costs. The figure on the next page gives an overview of estimated CAPEX and operational expenditures (OPEX) related to the bunkering infrastructure of sustainable alternative fuels[33]:

[33] Ricardo Energy & Environment: Technological, Operational and Energy Pathways for Maritime Transport to Reduce Emissions Towards 2050, p.95

Table 3. Assumed costs for refuelling infrastructure for alternative fuels[34]

Fuel type	Bunker capacity (tonnes/annum)	Port facility lifetime (years)	CAPEX ($ million)	OPEX ($ million per year)	Source
HFO	1,000,000	30	10.00	0.50	No detailed data found. Estimated value to provide some balancing cost reductions.
MDO	1,000,000	30	10.00	0.50	Assumed same as HFO
LNG	1,935,000	30	53.27	5.03	LNG bunkering financing opportunities (Ocean Shipping Consultants, 2016[59])
BioLNG	1,935,000	30	53.27	5.03	Assumed same as LNG
Hydrogen	255.5	30	23.00	0.92	Feasibility of hydrogen bunkering (ITM Power, 2019[60])
Ammonia	255,500	20	41.00	1.33	A blueprint for commercial-scale zero-emission shipping pilots (Energy Transitions Commission, 2020[61])
Methanol	255,500	20	8.00	0.17	Same source as Ammonia
FAME	1,000,000	30	10.00	0.50	Assumed same as HFO
HVO	1,000,000	30	10.00	0.50	Assumed same as HFO

Theme	Key action
T	Demonstrator projects on bunkering sustainable alternative fuels at larger ports.
T	Monitoring and sampling methods for fuel contamination in port.
T	Development of high durability bunker fuel pipes.
T	Demonstrator projects on bunkering at sea.
T	Availability of swappable battery containers.
T	Further development of fast charging infrastructure.
R	Development of a roadmap that sets energy and alternative fuels supply targets for ports.

[34] Ricardo Energy & Environment: Technological, Operational and Energy Pathways for Maritime Transport to Reduce Emissions Towards 2050, p.95

Onshore Power Supply (OPS)

The number of vessels with a high-voltage shore connection (HVSC) is rather low. The biggest uptake can be seen in the container, offshore, bulker and ferry fleet. Currently only 66 ports worldwide, scattered over 16 countries, are equipped with high voltage OPS systems for ocean going vessels, but without full coverage. This amounts to 150 berths equipped with the necessary infrastructure. Most of these OPS installations are intended to be used by cruise and RORO vessels. A few exceptions can be found in China and the US, where the Port of Long Beach made the use of OPS mandatory for container vessels. The aforementioned numbers do not include the low voltage OPS systems for inland navigation, of which there are a multitude. The port infrastructure is characterized by a high capital cost. Because of that, all OPS projects finished to date are made possible only by public support.[35]

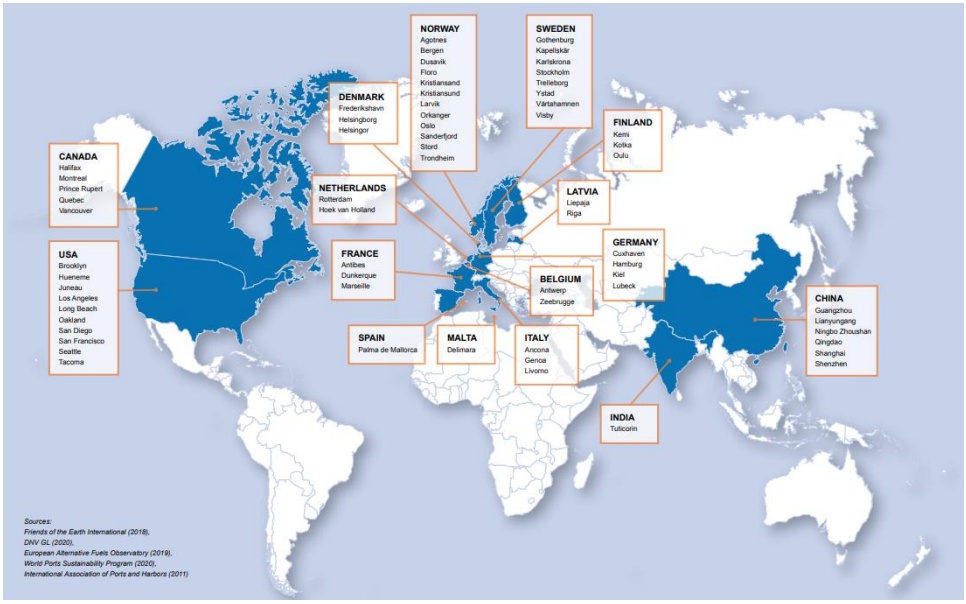


Figure 15. Map of high voltage OPS facilities[36]

Even though uptake is still rather low, in 2021 there was an increase of more than 51% amongst the vessels in service and a 213% increase for the vessels on order. This increase is expected to grow even more rapidly in the container and passenger fleets in the coming years following the Fuel EU Maritime proposal under the Fit-for-55 package, which makes it mandatory for these ship types to connect to OPS as from 2035.

Theme	Key action
T	Standardized components on vessel side (length of cables).
T	Connection process (can take up to 3 hours): can the process be automated to decrease time and human error.
T	Buffer impact on the grid: vessels have different average peak and power demand.
T	Connection points need to be flexible in case vessels have variable mooring points.

[35] World Ports Sustainability Program 2020
[36] World ports sustainability report 2020

T	Possibility to connect multiple vessels to one installation in order to cut costs.
T	Mobile solutions (barges).
T	Development of specific compressors to fasten bunkering.
R	Development of standards & procedures for bunkering at sea and bunkering at seaports and inland ports (the ship-to-shore interfaces) as well as ship-to-ship bunkering.

Technical and GHG Target-Based SRIA Recommendations

Based on the maturity of the different technologies related to sustainable alternative fuels/electrification and their availability, several **main conclusions** have been made for the time period covered by the ZEWT Partnership (up to 2030). They are supplemented by a set of secondary recommendations that consider the decarbonisation targets up to 2050 (see cap 4):

1. Further electrification (fully electric/hybrid) of the waterborne transport fleet should be the main focus on short term due the high energy efficiency of the solution as there is hardly any loss of energy (5-10% compared to 50-60% of energy thermal loss for internal combustion engines and fuel cells). **Therefore, a priority should be put on setting frequency standards and further advance technologies related to electrification of vessels.**
    i. The electrification efforts should focus on the most suitable ship categories: ferries, short sea shipping and part of the IWT and off-shore subcategories. Where the techno-economic conditions allow, the **focus should be on fully-electric solutions**.
2. Promote the uptake of methanol related technologies such as the FASTWATER retrofit kit. **Current levels of bio-/e-methanol supply are limited today, but an increasing order book for methanol ships and solutions such as the retrofit kit allow flexibility to upscale when supply increases.** More vessels installing methanol related technologies can reassure the methanol industry to increase production infrastructure. Methanol related technologies have a high-TRL level and bunkering infrastructure is also widely available. Thus, methanol has an advantage over ammonia and hydrogen as a marine fuel (at least) until the mid-term of the transition phase.
    i. Due to its gravimetric and volumetric density as well as safety requirements, methanol is currently a very good choice for larger ship types for the net-zero emissions targets – cargo ships or cruise ships, also for longer distances. It can also be used as a solution for some of the subcategories of the other smaller ship types, although using electricity from grid would be the preferred technical solution for decarbonisation seen the higher energy efficiency (less thermal loss) of fully electric power.
3. There is a need for urgent and strong policy action to **regulate methane emissions** on board existing ships and any newbuilds. Even though LNG is still a fossil fuel, as long as there is not enough renewable energy to supply the waterborne fleet with sufficient quality and quantity of sustainable alternative fuels, LNG will have a role to play. A lock-in of the technology is not expected since vessels with the technology installed can opt for the sustainable variants once available or blends towards 100% with advanced Bio-LNG or e-methane, while blends with e-hydrogen can be done to a certain extent.
4. Even though there is not enough renewable electricity currently being produced to generate abundant synthetic fuels, it is still recommended for large ocean-going vessels that do not choose methanol to focus on ammonia and make sure the vessels are designed in a way that an ammonia retrofit is relatively easy once e-ammonia is available and competitive with other sustainable fuel types.
5. Even though digital green is considered a very important intervention area, shipowners are generally investing more in other technologies that have a more direct impact on lowering emissions. Therefore, it might **be better to see whether the digital green pillar can be integrated in the other pillars as a horizontal pillar instead of a separate intervention area**

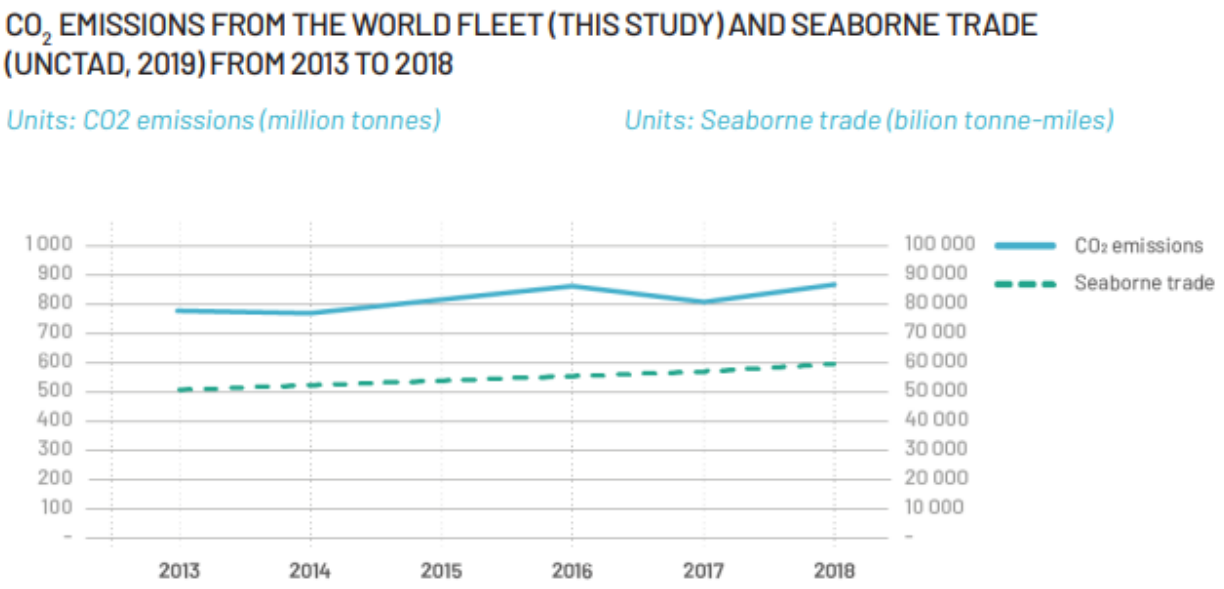
6. Updated Waterborne Sector Data

This chapter focuses on the main data of the waterborne transport sector as included in the ZEWT SRIA.

Since these datasets are changing, they are updated at every revision of the SRIA. Alternatively, even if there are no (significant) changes in the SRIA required at this moment, the analysis can serve to identify trends that, if they continue, ill certainly lead to a change in the waterborne transport landscape, and may impact RD&I needs and priorities.

The work undertaken in this chapter does not focus on the preparation for the next ZEWT calls. However, just like in the case of some of the policy and legislative developments, the information extracted here can also be used as one of the basic elements for shaping the future ZEWT calls.

Current information (pag 9):



Proposed change :

CO2 emissions

Fuel Consumption & CO_2 Emissions	2008	2018	2019	2020	2021	2022F	22 v 08
World Fleet Fuel Consumption (mt)*	327.6	269.7	268.8	259.5	271.7	282.0	-13.9%
World Fleet CO_2 Emissions (mt)*	1,024.3	845.4	843.3	812.8	850.7	882.8	-13.8%

Seaborne trade 2021: 12.0 bt, 2020: 11,62 bt (not in ton-miles)

2019: 11055 metric tons in millions

2020: 10631 metric tons in millions
Source: Clarksons WFM Vol 13 No 4 April & UNCTAD STAT

Current information (pag 9): *European CO_2 emissions from waterborne shipping are a major challenge. In 2018, more than 130 million tons of CO_2, or around 13% of total EU transport emissions, were emitted from maritime ships over 5,000 gross tonnage visiting European ports.*

Source : (SRIA footnote 8) https ://ec.europa.eu/clima/news-your-voice/news/commission-publishes-information-co2-emissions-maritime-transport-2019-07-01_en

Proposed change: *In total, the monitored fleet emitted 144.6 million tonnes of CO2 emissions in 2019 2019: transportation excl maritime transport 956,3 -> 13,1%*

Source: https://ec.europa.eu/clima/system/files/2021-08/swd_2021_228_en.pdf

https://www.statista.com/statistics/1200660/carbon-dioxide-emissions-transport-sector-european-union/

Current information (pag 9): *The EU project PROMINENT calculated that inland waterway transport in the EU results in 3.8 million tons of CO2 emissions per year*.

Source: (SRIA footnote 9) PROMINENT Deliverable D6.3&D6.5

Proposed change: *The EU project PROMINENT calculated that inland waterway transport in the EU results in **roughly** 3.8 million tons of CO2 emissions per year.*

Source: (SRIA footnote 9) PROMINENT Deliverable D6.3 & D6.5.

Current information (pag 10) : *Even if the energy mix used for waterborne transport is changed in accordance with the objectives of limiting the temperature increase and the economic developments are commensurate with this goal, shipping emissions are projected to increase by 20-50% between 2008 and 2050 (or by between 50%-250% according to the third IMO GHG study, to be updated in 2021).*

Source: (SRIA footnote 10) CE Delft, Update of Maritime Greenhouse Gas Emission Projections, 2019

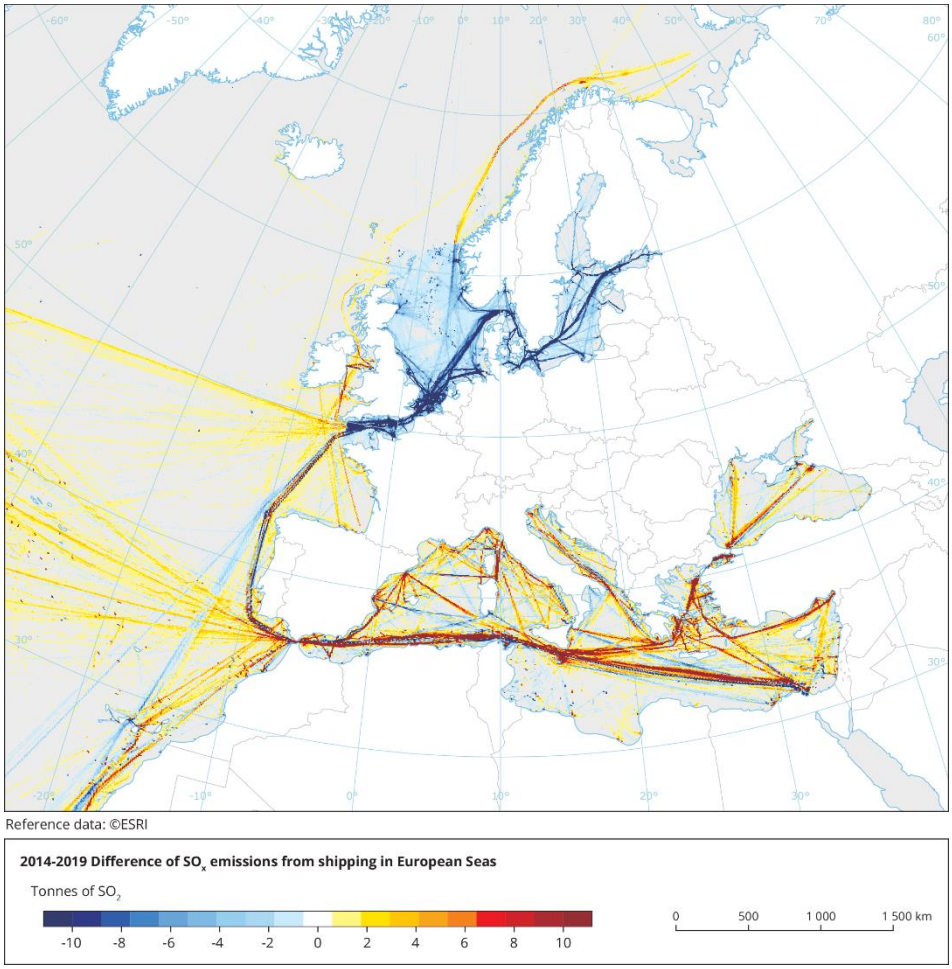
Proposed change: *In these BAU scenarios, the emissions of shipping are projected to increase from 1,000 Mt CO2 in 2018 to 1,000 to 1,500 Mt CO2 in 2050. This represents an increase of 0 to 50% over 2018 levels and is equal to 90-130% of 2008 levels.*

Source:
https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20-%20Full%20report%20and%20annexes.pdf

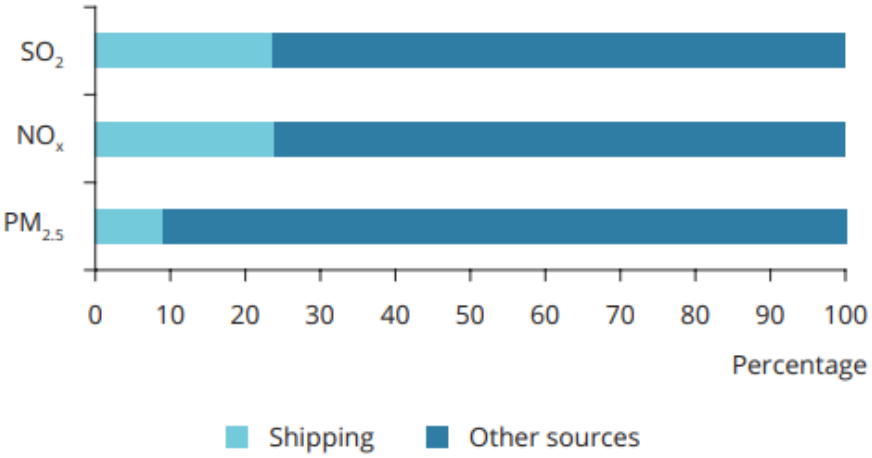
Current information (pag 11): *The stricter sulphur in fuel requirements that have been agreed by the IMO will cut SOx emissions by 50-80 percent up to 2030, but in the absence of additional regulations, emissions will rebound afterwards. Without introducing additional measures, CO2 and NOx emissions are expected to further increase the latter emissions becoming significantly higher than those emitted by land sources*

Source: (SRIA footnote 15)
https://previous.iiasa.ac.at/web/home/research/researchPrograms/air/Shipping_emissions_reductions_main.pdf

Proposed change:



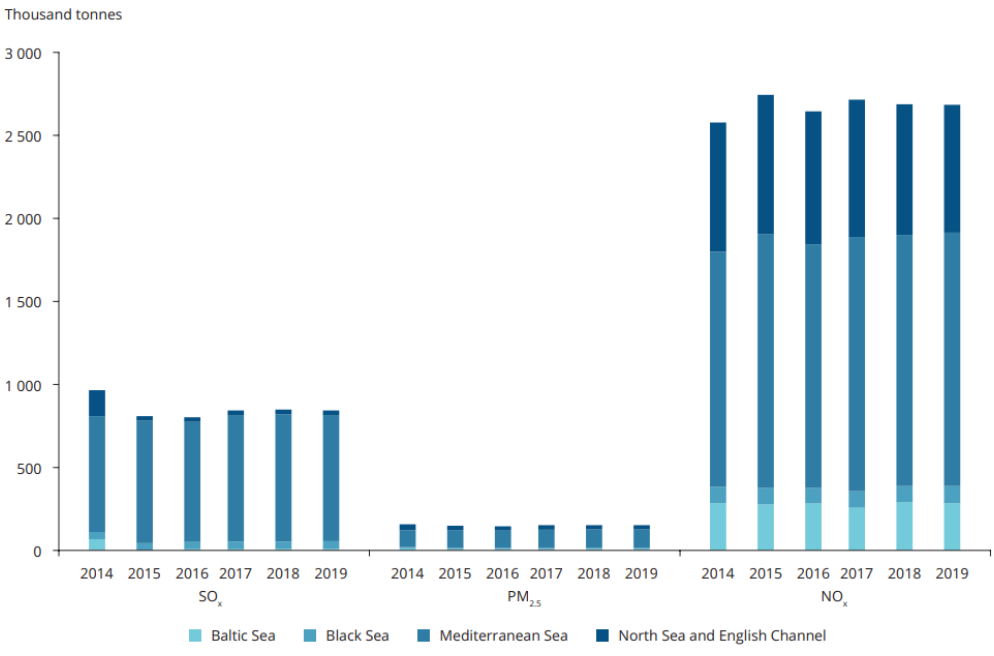
Source: European environmnet agency EEA



Note: No_X, nitrogen oxides, $PM_{2.5}$, particulate matter with a diameter of less than 2.5 µm, SO_2, sulphur dioxide.

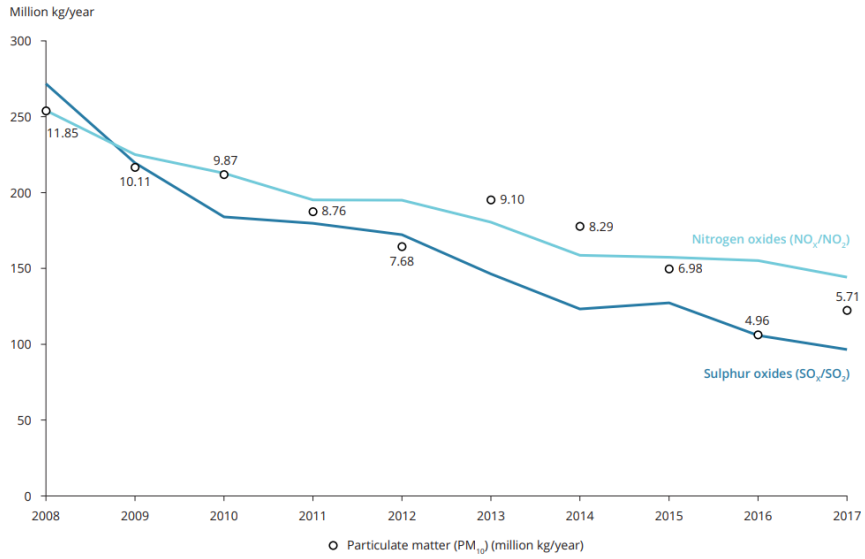
Source: EEA (2020b).

Source EMSA EMTER report 2021



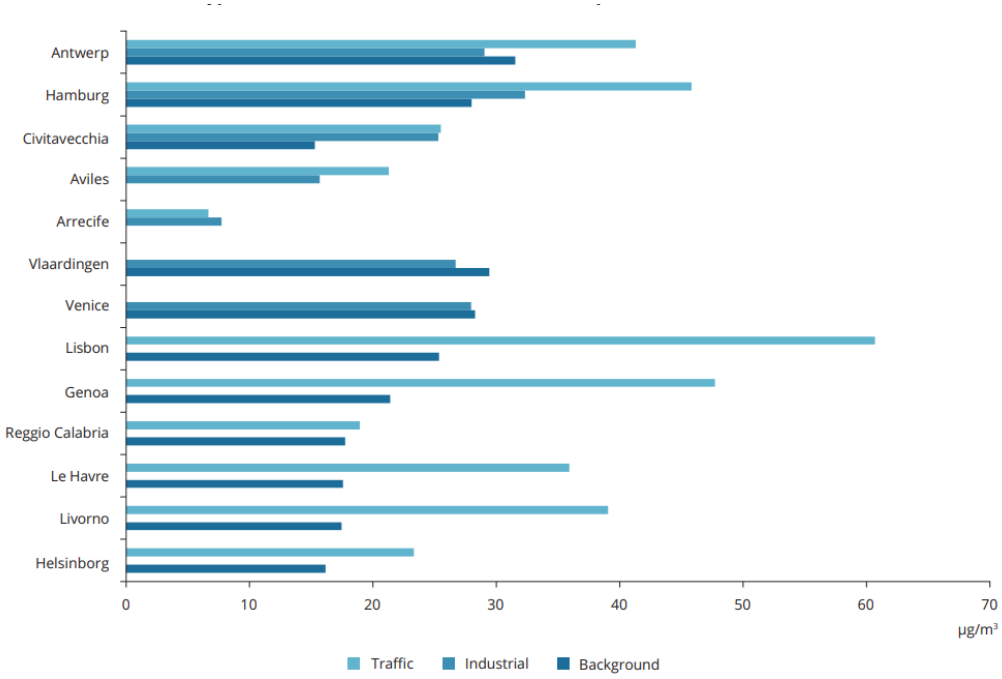
Source: STEAM (2021).

Source EMSA EMTER report 2021



Source: EEA (2020c).

Source EMSA EMTER report 2021



Source: EEA (2020c).

Source EMSA EMTER report 2021

Current information (pag 12): *Maritime shipping transports nearly 90% of international trade and is therefore of crucial importance to the world economy.*

Source: n.a.

Proposed change: ***In spite of the COVID-19 context that reduced global trade, waterborne transport still moves nearly 90% (or 'over 85%') of all international trade*** *and is therefore of crucial importance to the world economy.*

Source : https ://unctad.org/webflyer/review-maritime-transport-2020

Current information (pag 14) : *Half of the active fleet in Germany, the Netherlands and Belgium, as well as 80% of the French fleet, was built more than 50 years ago. 15% of the European fleet was built more than 75 years ago, in particular in the Netherlands. Switzerland is the country with the newest fleet (87% of the fleet was built in the last 35 years), which can be explained by the large share of inland cruise ships in their register*.

Source: (SRIA footnote 21) https://inland-navigation-market.org/

Proposed change: *Half of the active fleet in Germany, the Netherlands and Belgium, as well as 80% of the French fleet, was built more than 50 years ago. 15% of the European fleet was built more than 75 years ago, in particular in the Netherlands. Switzerland is the country with the newest fleet (87% of the fleet was built in the last 35 years), which can be explained by the large share of inland cruise ships in their register*.

The tanker fleet is the youngest fleet segment in Rhine countries, with a share of 52% of all tanker vessels built in the 21st century, whereas this share amounts to 16% for dry cargo vessels and 29% for passenger vessels.

Source: https://inland-navigation-market.org/wp-content/uploads/2021/09/CCNR_annual_report_EN_2021_WEB.pdf , pag 86-87

Current information (pag 25): Close to 50,000 maritime ships and approximately 12,000 inland vessels are in operation and will need to be converted into zero emission vessels, through retrofitting as well as replacement.

Source: n.a.

Proposed change: ***Around 55,000 merchant ships*** *and approximately 12,000 inland vessels are in operation and will need to be converted into zero emission vessels, through retrofitting as well as replacement.*

Source: https://www.statista.com/statistics/264024/number-of-merchant-ships-worldwide-by-type/

7. First Analysis of Relevant EU-funded Projects

FP7 and H2020 Projects' Analysis

Throughout the past years both the public (particularly the EU) and the private sector stakeholders have invested a considerable amount of resources in developing new technologies, procedures, skills, business models and other types of solutions that address the different challenges faced by the waterborne transport sector. Many of these investments directly address the climate-related challenges while others, though having a broader spectrum or a different main focus, still provide relevant information and achievements in terms of climate-oriented solutions.

Among the myriad of projects to date, those funded through the FP7 and in particular H2020 instruments stand out due to their enhanced focus on climate mitigation, their size in terms of both sheer numbers and the associated efforts (budgets and numbers of partners), but also due to their ever more coherent organisation and approach. The latter elements come not only from the experience and results built during the past EU R&I funding programmes, but also from the ever growing concern in the public and private sectors alike for the negative effects of climate change.

Moreover, these continuous developments have also led the private sector to propose and then team-up with the EC in order to create the ZEWT cPP, which enables them to better focus the research, coordinate their efforts and concentrate the resources available.

It is therefore only natural that there needs to be a clear and strong link between the FP7 and H2020 projects and the ZEWT SRIA and projects to be funded through this cPP, in order to ensure a smooth transition and progress. And this needs to take into account of two factors which go hand in hand.

The number one factor is to build upon, where possible, the FP7 and H2020 results – a prerequisite for the transport sector if it is to deliver by 2030 reliable technologies that would decarbonize the sector, and in particular achieve the zero-emissions target by that year. This needs to be realized by ensuring a delicate balance between on the one hand the IPR of the partners from the previous projects, and on the other hand the adequate stakeholder access to the designed calls and the relevant information, in order to build upon some of the previous achievements. Otherwise, the calls risk either tilting the balance in favour of those few stakeholders that had been involved in the previous projects, or giving a lower TRL at the start, thus delaying the developments.

The second factor is avoiding the duplication of efforts on subjects that have already been brought to a high TRL level, or that have been proven inadequate for the sector's requirements.

Based on the research done in D2.1 and the work within the Waterborne TP, below is a table with a broad yet still intermediate analysis of the FP7 and in particular H2020 projects that have been undertaken by the waterborne transport sector.

Table 4. List of EU-funded RD&I projects in the waterborne transport sector (H2020 and FP7)

CSAs	Energy Eff. And Zero Emissions	Ship and Shipping Safety	Digitisation & Autonomy	Ship design & production
Columbus	*Aircoat*	AnchorGuardian (SME 1)	*AUTOSHIP*	ARICE
CSA Oceans 2	AQUASONIC DIESEL (SME 2)	*BugWright2*	*H2H*	CHEK
DOCKSTHEFUTURE	BioSFerA	*Efficiensea 2*	*MARINA*	COMPA 2GO (SME 2)
LASTING	Current Direct	FLARE	MOSES	*FIBRESHIP*
LeMO	*E-ferry*	LASH FIRE	VesselAI	*FIBRE4YARDS*
MARIBE	e-SHyIPS	*LYNCEUS2MARKET*		*GATERS*
MESA	*EcoSail*	PALAEMON		HOLISHIP
PLATINA	EEECSM-2 (SME 2)	*PREPARE Ships*		*LINCOLN*
PLATINA II	EMERGE	Ranger		*Mari4_YARD*
PLATINA III	ENGIMMONIA	*ROBINS*		*NAVAIS*
SCORE	*EONav*	SAFEMODE		*NEXUS*
SETRIS	*eSHaRk*	SafePASS		ProZero (SME 2)
STEERER	*FASTWATER*	SEDNA		*RAMSSES*
	FLAGSHIPS	*ShipTest*		*RESURGAM*
	FLEXI-GREEN FUELS	SMARTER-2 (SME 2)		SEABOAT (SME 2)
	FUELSAVE (SME 2)	*spyGLASS*		SHIPLYS
	GASVESSEL			SmartWings (SME 2)
	GLAMOUR			*TrAM*
	GreenDrive (SME 1)			
	H2Engine (SME 2)			
	HCR (SME 2)			
	Hercules			
	HERCULES-2			
	HyMethShip			
	HySeas III			
	HyShip			
	IDEALFUEL			
	LeanShips			

	LoCOPS (SME 1 & 2) MARANDA Nautilus RotorDEMO (SME 2) SATURN SEABAT SEAHUB (SME 1) *SeaTech* ShipFC *SleekShip* *Streamline* SulPure (SME 2) SuPREmE (SME 1) VIRTUAL-FCS			
Off-Shore Multi Use	**Logistical and Modal Shift**	**Port Operations**	**Inland Navigation**	
OPTILIFT 2 (SME 2) *Space at Sea* STEMM-CCS *The Blue Growth Farm* *UNITED*	4FOLD Phase 2 (SME 2) AGRO HIGHWAY (SME 2) Next Gen Bluetech (SME 2) COG-LO LOGISTAR ORCHESTRA RESIST SYNCHRO-NET	COREALIS *DataPort* H2Ports *HiSea* *LOGIMATIC* PIXELPortForward RAPID RCMS SafePort (SME 2) Toolbot (SME 2)	IW-NET NOVIMAR NOVIMOVE Prominent SCIPPER	

Legend (examples):

- GASVESSEL – RIA projects
- *E-ferry* – IA projects
- AnchorGuardian (SME 1) – SME instrument

The CSA projects are directly placed in their dedicated category

The analysis of the list of projects shows that there are 86 projects that address either fully or partially the scope of the ZEWT partnership, based on the 6 main areas covered by the SRIA.

Below, the projects are further categorised.

Energy Efficiency and Zero Emissions. This category is the most important, as it covers the first three intervention areas of the ZEWT cPP: 'Use of Sustainable Alternative Fuels', 'Electrification' and 'Energy-Efficiency'. There are 42 projects in this category, out of which:

- 15 IA Projects;
- 14 RIA Projects;
- 13 projects through the SME instruments: 4 through SME-1 and 9 through SME-2.

The 29 RIA and IA projects can provide a set of results which can be used in the process to shape the next ZEWT calls. The RIAs would in principle be the best suited due to the lower TRL level achieved, though some of the IAs can also be relevant. In addition, the information can be used in the discussions with other partnerships, to create cross-fertilization and convergence common efforts and results.

High TRL results from these projects can also be used in the process of shaping some of the next Innovation Fund calls that can also address the waterborne transport sector needs.

Even if their contractual and legal approach is partly different, projects funded through the SME instruments should also be considered as potential contributors to the ZEWT calls.

Digitisation and Autonomy. There are 5 projects listed in this category, our of which 3 are IAs. As ZEWT has among its main intervention areas the 'Digital Green', these projects can be used to extract information on which solutions can be either further developed through a dedicated ZEWT call, or which complementary solutions need to be addressed through a ZEWT call in order to achieve in a short period high TRL comprehensive solutions.

Alternatively, this information can be fed into the digital-focused partnerships.

Ship Design and Production. It is an almost full overlap with the 'Design and Retrofitting' intervention area. There are 18 projects, divided as follows:

- 10 IAs;
- 4 RIAs;
- 4 SME-2 instruments.

This section displays the 2nd biggest concentration of high-TRL projects, especially if considering the SME instrument, surpassed only by the 'Off-shore multi-use' section in percentage. However, the latter is much smaller and only partly covering the ZEWT scope. We can therefore conclude that the biggest proportion of high TRLs has been achieved or is about to be achieved within this type of projects.

This fact calls into question two main aspects: which solutions from or related to these projects should be consider for further developments, and which solutions that have not been researched should still be addressed. It should also be taken into account that other EU funding sources, either within the HEU or

other instruments, offer few opportunities to address this type of research, including the continuation of the results from these projects.

Off-Shore Multi-Use. There are 5 projects listed under this section: 3 IAs, one RIA and one SME-2 instrument. Though this section does not fully match any of the ZEWT intervention areas, it is still relevant, in particular to 'Design and Retrofitting' and 'Electrification'.

The results from this section could be used during the discussions for the aforementioned intervention areas. Outside ZEWT, part of this information can be very relevant for the Innovation Fund Calls while at the same time providing topics of discussion with stakeholders from the energy sectors.

Port Operations. It is another clear match with one of the partnership's intervention areas – the 'Ports' – though the scope covered by the waterborne transport sector is wider. There are 11 projects:

- 2 IAs;
- 6 RIAs;
- 3 projects from the SME instruments: one SME-1 project and two SME-2 projects.

After having selected here the projects that are relevant for the 'Ports' intervention area (and/or other intervention areas, if applicable), the cPP members can again analyse which project results could be used in the discussions for the ZEWT calls.

While the scope of ZEWT in this case is quite limited, there is a wealth of information to be extracted and used in the discussions with the other partnerships, in particular the ones involved in the energy sector (e.g. the Clean Hydrogen Partnership). The results here would also be very relevant to future Innovation Fund calls as well as for the additional investments to be made by the private side or by the public authorities.

It must also be noted that a lot of technologies which are of interest for the shore-side are either already mature or are approaching the roll-out level. The problems arise from the high investment costs necessary, e.g. for the production, transport and distribution of energy, and these investments are already competing with other infrastructure-related needs from other sectors.

Inland Navigation. There are 5 projects in this category, all of them RIAs. As the ZEWT partnership does not have a dedicated intervention area for inland waterways but does have a dedicated ships' category, and it tries to address the needs of all waterborne transport segments within the same topics, we can consider that the projects here are in principle relevant to the entire partnership. Furthermore, these projects also include maritime-related topics, just as the projects mentioned above, though focusing more on the maritime, also include many IWT aspects.

It is up to the cPP members to analyse and decide which projects results can be considered when designing the ZEWT calls, or which complementary research needs to be undertaken by ZEWT in connection to these projects.

The other sections from the table with technical projects - **Ship and Shipping Safety** (16 projects) and **Logistical and Modal Shift** (8 projects) – do not address any of the partnership's intervention areas.

However, it is likely that some projects are useful for the shaping of the next ZEWT calls, either in this 2-year period or later.

The **CSAs** (12 projects) present a separate case. They do not provide any technical developments, however they all address different aspects of relevance for the partnership. Moreover, three of them are closely related to the partnership developments: STEERER, LASTING and (to a somewhat lesser extent) the 3 PLATINA projects. Some of the results of these CSAs, corroborated with the results of other ZEWT and non-ZEWT project, are relevant for the SRIA update and the next ZEWT calls,.

It must be noted that some of these projects already have a link with the first ZEWT calls and/or projects, because of their content-related relevance. However, this interrelation must go beyond individual cases. A coherent overview must be established between the FP7 and H2020 on the one hand, and the present and future ZEWT calls and projects on the other. For this purpose, the STEERER partners will select a number of relevant projects from the list above (with any necessary updates). Subsequently, interviews will be conducted with the project coordinators and/or other key partners, to gather more details about what their projects have been developing and how do their (intermediate) results fit in with the ZEWT planning and activities. For this purpose, a draft questionnaire has been designed and it is presented in the next clause.

This activity will start during summer 2022 and its results will be integrated in D2.7, a document which is the update of this deliverable.

STEERER
STRUCTURING TOWARDS ZERO EMISSION WATERBORNE TRANSPORT

Questionnaire for H2020 Waterborne Transport Projects

This draft questionnaire will be used by the STEERER partners during summer and autumn of 2022 in order to gather the relevant information from the FP7 and H2020 waterborne transport RD&I projects. The purpose of the exercise is to gain a broader and deeper understanding of where the current EU-funded RD&I activities are in relation to the climate-related waterborne transport targets, and how the ZEWT activities can be harmonized with them.

The current version of the questionnaire may record some further adjustments before the start of the exercise and/or during its first steps, in order to ensure a good collection of data.

Introductory questions

Q1. Name of the respondent

Q2. Organization, position and contact details

Q3. Name of the project for which s/he is answering

Q4. Role of his/her organization and role of the respondent within the project consortium

Q5.Project duration

SRIA-related questions

Q6. Which of the 6 SRIA pillars is your project addressing? Please describe the technological solutions researched under each pillar. In the case of the SAFs, please also include which fuel supplier(s) you had included as consortium partner(s), if applicable:

1. SAFs:...
2. Electrification:...
3. etc.

Q7. Please indicate for each ship type outlined by the SRIA which technological solution(s) does your project target, or at least for which it would be applicable:

1. Long distance:...
2. Cruise:....
3. Ferries: ....
4. Etc.

Q8. Please indicate for each technological solution which outcome was sought (e.g. % reduction in fuel consumption). Please specify the outcomes per ship type where available.

Q9. Please indicate for each technological solution the TRL level at the beginning of the project, the TRL level targeted at the end of the project and the one actually achieved (where applicable).

Q10. Have you been working together with CESNI/Classification Societies/Flag state and if yes, how long did it take before the solution was approved? Please indicate the situation for each solution.

Q11. Would it be possible for you to provide the relevant data recorded from the demonstration(s) you have conducted for the researched technological solutions? Please also indicate the ship type(s) used in the demonstration.

Q12. In your estimation, based on the project achievements, how much time and what level of investments would be necessary for each technological solution to become available on the market?

Questions on connected projects

Q13. Are you aware of other projects (H2020, FP7, etc.) that have been working on similar technological solutions? Could you please indicate the project for each technological solution, according to the SRIA pillars?

1. SAFs: Project ABC (H2020, 2014-2018), solution x
2. Electrification:…
3. etc.

Q14. Could you please indicate, if it is the case, what cross-fertilization has taken place with each of the aforementioned projects?

Q15. Are you aware of other project(s) (H2020, HEU, etc.) that are/will be working on the continuation of your project? Please indicate, to the extent known, the project name, coordinator and funding programme?

Q16. Which other technological solution(s) have to achieve market readiness level so that the technological solution(s) of your project should be completed or rolled out easier/faster? Please indicate the three main complementary technological solution(s) for each of your technological solution.

Q17. Please also indicate the current (approximate) TRL level for each these complementary technological solutions.

Q18. In the time frame up to 2030, for which technological solution(s) are you planning to pursue further research by using EU and/or other public funding sources?

Q19. In the time frame up to 2030, for which technological solution(s) are you planning to pursue further research by using only private funding – your own, that of a new consortium, etc.?

Innovation Fund Projects' Analysis

The EU Innovation Fund[37] is one of the world's largest funding programmes for the demonstration of innovative low-carbon technologies. It will provide funding until 2030, depending on the carbon price, for the commercial demonstration of innovative low-carbon technologies, aiming to bring to the market industrial solutions to decarbonise Europe and support its transition to climate neutrality.

The ultimate objective of this programme is to assist businesses to invest in clean energy and industry to boost economic growth, create local future-proof jobs and reinforce European technological leadership on a global scale. This is done through calls for large and small-scale projects focusing on:

- innovative low-carbon technologies and processes in energy-intensive industries;
- including products substituting carbon-intensive ones carbon capture and utilisation (CCU);
- construction and operation of carbon capture and storage (CCS);
- innovative renewable energy generation;
- energy storage.

The EU Emissions Trading System (EU ETS), the world's largest carbon pricing system, is providing the revenues for the Innovation Fund from the auctioning of 450 million allowances from 2020 to 2030, as well as any unspent funds from the NER300 programme. For the period 2020-2030, the Fund will likely go over €20 billion, depending on the carbon price. In parallel to the Innovation Fund, the EU ETS provides the main long-term incentive for these technologies to be deployed.

On the 27th of July, the European Commission published the first set of projects (pre-)selected in the framework of the EU Innovation Fund[38]. Out of these, there are four projects that are relevant to the ZEWT cPP and the waterborne transport sector as a whole:

- two smaller-scale projects for a grant: FirstBio2Shipping (First Bio-LNG to marine shipping) and E-PROOF (Integrated Battery Power for MS Piret – E-PROOF – Electric Propulsion for Ferry);
- two larger projects for project development assistance: HYDROGEN EU-ROPAX (Zero-emission vessel powered by a large-scale fuel cell system and green hydrogen) and WAVE (Large sailing cruise ship featuring an innovating wind propulsion technology).

While the Innovation Fund is meant to finance the deployment of high TRL projects that are out of scope for HEU calls, its current projects and its future calls are of relevance for the ZEWT cPP. The Innovation Fund calls and their results can signal not just research areas that may not need further activities and funding, but also the connected topics which still require (relatively high TRL) research in order to obtain a holistic and efficient approach.

[37] Innovation Fund | Climate Action (europa.eu)
[38] EU invests €122 million to decarbonise the economy (europa.eu)

Projects' Preliminary Conclusions and Recommendations

Based on the preliminary analysis of FP7 and H2020 projects there are two main recommendations for the update of the ZEWT SRIA, in particular for the next ZEWT topics, for all the six SRIA intervention areas:

- creating a short-list of RD&I topics to be taken up from the previous (mostly RIA) projects;
- creating a short-list of RD&I topics complementary to the work done in the previous (mostly IA) projects;

In addition, some specific recommendations are proposed for some of the SRIA intervention areas.

- Energy Efficiency: a deeper analysis needs to be undertaken in order to assess where dedicated ZEWT projects are needed for this area, and where the energy efficiency aspect should be (better) embedded in the research activities done in the other areas. This will allow for a better allocation of resources within the ZEWT calls planning;
- Design and Retrofitting: a high number of IA and SME2 projects have been identified, many of which are still either on-going or have recently been finalised. It is therefore necessary to undertake a deeper analysis of these projects, in order to better understand which aspects they have covered and which ones still need to be addressed within the ZEWT cPP, before another set of calls is launched.

While the Innovation Fund analysis will require more information from the calls and projects of this initiative, two main aspects are becoming increasingly noticeable:

- some waterborne transport technologies and ship types may be more suitable for this type of funding. It is therefore advisable that the next ZEWT cPP calls offer a broader support to technologies and ship types that can then benefit from the Innovation Fund calls, thus speeding up part of the decarbonization process. This approach would also mean to reduce the financial burden and the risks for the Partnership members involved in developing these technologies;
- some waterborne transport technologies and ship types may be less suitable for this type of funding. Consequently, both the next ZEWT calls and the planning of additional activities and investments should take into account this aspect.

8. Conclusions

Based on the previous STEERER deliverables and the additional information retrieved from public data, the SC and GSEG experts as well as from the partners' (and their members') knowledge, deliverable D2.5 presents a comprehensive set of information that can be used for the update of the ZEWT SRIA.

The first content-focused chapter outlines the international and EU-level policies that are and will be impacting the waterborne transport sector in relation to its decarbonization targets. Many of these have not yet been adopted, in particular the FF55 ones, yet the available information gives a clear indication of the mounting challenges but also some of the solutions and opportunities that come along. For the latter, D2.5 indicates a short set of policy-based recommendations (pag. 31) that should be considered by the ZEWT partners, in particular regarding their RD&I activities, with or without EU-funded support.

Subsequently, the data on the carbon budget, the detailed risks of overshooting it by the sector and the sector targets up to 2050 are presented in order to consolidate the framework within which the waterborne transport sector must design and implement its emissions-reduction solutions. This gives way to the set of actions, clustered on the six ZEWT intervention areas, that STEERER recommends for uptake as part of the SRIA update. Many of them can also be fairly easily integrate in the texts of the future ZEWT calls. The different recommendations for each intervention areas can be found in their dedicated sections of Chapter 5 (pag. 40-59). Furthermore, at the end of it, there are a few overarching recommendations that the project partners have designed as a conclusion of this chapter (pag. 59).

The third element of this document is the analysis based on the past and current FP7 and H2020 RD&I projects. While this requires further developments, it already outlines topics where more support is needed, at least in the shorter term.it also draws the attention on the need of information access and cooperation between these projects and the ones to be developed under the ZEWT umbrella. These preliminary conclusions and recommendations can be consulted at pag. 75 of this document.

While the three elements outlined above are tightly intertwined and with a certain 'chronological' order to them – both in terms of the STEERER developments and as a general approach – the deliverable also sheds light on another aspect. This is the accompanying waterborne transport data – emissions, social and economic facts, etc. – that help set the overall sector framework. While the deliverable is mostly focused on the (more specific) climate-related targets and the RD&I activities and solutions to them, the added-value of this data is to give a more concrete, 'real world' sense of why all these investments and actions are needed, and what would the impact look like in case they would (not) continue. Also, unlike much of the other recommendations presented here, the proposed data can be directly introduced in the SRIA update. Chapter 6 on the updates of the relevant waterborne transport data (pag. 60-65) can therefore be wholly considered as a recommendations chapter for the SRIA update.

Many of these recommendations have already been shared with the ZEWT Partnership, and this deliverable will be used as the main external source for this year's update of the ZEWT SRIA. Its next version, D2.7 *STEERER Advice to 2nd ZEWT Research Agenda and its Implementation Plan* due at the end of 2022, will refine and expand the current data for the purpose of the 2023 SRIA update.

9. Annexes

Annex I: FUEL EU Maritime

PART 3: ILLUSTRATION BY THE COMMISSION OF THE DIFFERENT SOURCES IN ANNEX II

Colour code:

Directive (EU) 2018/2001 in its up to date version
IMO GHG studies (1 to 4) and tech. literature for LNG
Regulation (EU) 2015/757 MRV
ESSF SAPS
5th JEC Study 2020 (values are presented along with a corresponding pathway label. The same study provides values also for other production pathways of the same fuel product).
Miscellanea: technical, literature, self-evident (to be further discussed in ESSF)

In the table:

- TBM stands for To Be Measured
- N/A stands for Not Available
- The dash means not applicable

Table 1 – Default factors

1	2	3	4	5	6	7	8	9
	WtT			TtW				
Class / Feedstock	**Pathway name**	LCV LCV [MJg]MJg	$CO_{2eq\ WtT}$ $CO2eq\ WtT$ [gCO2eqMJ]gCO2eqMJ	**Energy Converter Class**	Cf_{CO_2} $Cf\ CO2$ [gCO2gFuel]gCO2gFuel	Cf_{CH_4} $Cf\ CH4$ [gCH4 gFuel]gCH4gFuel	Cf_{N_2O} $Cf\ N2O$ [gN2O gFuel]gN2OgFuel	C_{slip} $Cslip$ As % of the mass of the fuel used by the engine
Fossil	HFO ISO 8217 Grades RME to RMK	0,0405	13,5	ALL ICEs	3,114 MEPC245 (66) Regulation (EU) 2015/757	0,00005	0,00018	-
				Gas Turbine				
				Steam Turbines and Boilers				
				Aux Engines				
	LSFO	0,0405	13,2, crude 13,7 blend	ALL ICEs	3,151	0,00005	0,00018	-
				Gas Turbine				
				Steam Turbines and Boilers				

				Aux Engines				
	ULSFO	0,0405	13,2	ALL ICEs	3,114	0,00005	0,00018	-
	VLSFO	0,041	13,2	ALL ICEs	3,206 MEPC245 (66) MRV Regulation	0,00005	0,00018	-
	LFO ISO 8217 Grades RMA to RMD	0,041	13,2	ALL ICEs	3,151 MEPC245 (66) Regulation (EU) 2015/757	0,00005	0,00018	-
	MDO MGO ISO 8217 Grades DMX to DMB	0,0427	14,4	ALL ICEs	3,206 MEPC245 (66) Regulation (EU) 2015/757	0,00005	0,00018	-
	LNG	0,0491	18,5	LNG Otto (dual fuel medium speed)	2,75~~5~~ MEPC245 (66) Regulation (EU) 2015/757	0	0,00011	3,1
				LNG Otto (dual fuel slow speed)				1,7
				LNG Diesel (dual fuel slow speed)				0~~,~~2
				LBSI				~~N/A~~ -
	LPG	0,046	7,8	All ICEs	3,03 But~~h~~ane 3,00 Propane MEPC245 (66) Regulation (EU) 2015/757	TBM	TBM	-
	H2 (natural gas)	0,12	132 JEC Study GPLHx	Fuel Cells	0	0	-	~~**N/A**~~
				ICE	0	0	TBM	
	NH3 (natural gas)	0,0186	121	No engine	0	0	TBM	-
	Methanol (natural gas)	0,0199	31,3	All ICEs	1,375 MEPC245 (66) Regulation (EU) 2015/757	TBM	TBM	-
Liquid biofuels	Ethanol ~~E100~~ sugar beet ethanol (no biogas from slop.	0,0268 Ref. to Directive (EU) 2018/2001 Annex III	**-33.2 Calculated as** $E - C_{fCO_2}LCV$ $E - Cf\ CO_2 LCV$ (	All ICEs	1,913 MEPC245 (66) Regulation (EU) 2015/757	TBM	TBM	-

	natural gas as process fuel in conventional boiler)		E_E **from Directive (EU) 2018/2001** minus **(Value Column 6) / (Value Column 3))**					
	Bio-diesel ~~Main products / wastes / Feedstock mix~~ rape seed biodiesel	0,0372 Ref. to Directive (EU) 2018/2001 Annex III	**-26.1 Calculated as** $E - C_f CO_2 LCV E - C_f CO_2 LCV$ (E_E **from Directive (EU) 2018/2001** minus **(Value Column 6) / (Value Column 3))**	ALL ICEs	2,834 (calculated)	0,00005 TBM	0,00018 TBM	-
	HVO ~~Main products / wastes / Feedstock mix~~ hydrotreated vegetable oil from rape seed	0,044 Ref. to Directive (EU) 2018/2001 Annex III	**-20.7 Calculated as** $E - C_f CO_2 LCV E - C_f CO_2 LCV$ (E_E **from Directive (EU) 2018/2001** minus **(Value Column 6) / (Value Column 3))**	ALL ICEs	3,115 (calculated)	0,00005	0,00018	-
	Bio-LNG ~~Main products / wastes / Feedstock mix~~ Manure – Maize 60 % - 40 % Case 3 Close digestate (12 to 18)	0,05 Ref. to Directive (EU) 2018/2001 Annex III	**-38.9 Calculated as** $E - C_f CO_2 LCV E - C_f CO_2 LCV$ (E_E **from Directive (EU) 2018/2001** minus **(Value Column 6) / (Value Column 3))**	LNG Otto (dual fuel medium speed)	2,75~~5~~ MEPC245 (66), Regulation (EU) 2015/757	0	0,00011	3,1
				LNG Otto (dual fuel slow speed)				1,7
				LNG Diesel (dual fuels)				0.2
				LBSI				N/A
Gas biofuels	Bio-H2 Main products / wastes / Feedstock mix	0,12	N/A	Fuel Cells	0	0	~~0~~	-
				ICE	0	0	TBM	
Renewable Fuels of non-Biological Origin	e-diesel	0,0427	**0.9** (Ref. to JEC Study RESD1) (footnote)	ALL ICEs	3,206 MEPC245 (66) Regulation (EU) 2015/757	0,00005	0,00018	-
	e-methanol	0,0199	**1.78**	All ICEs	1,375 MEPC245 (66)	0,00005	0,00018	-

(RFNBO) - (e-fuels)			(Ref. to JEC Study REME1a) (footnote)		Regulation (EU) 2015/757			
	e-LNG	0,0491	**6.7** (Ref. to JEC Study RELG1a) (footnote)	LNG Otto (dual fuel medium speed)	2,75~~5~~ MEPC245 (66) Regulation (EU) 2015/757	0	0,00011	3.1
				LNG Otto (dual fuel slow speed)				1,7
				LNG Diesel (dual fuels)				0.2
				LBSI				N/A
	e-H2	0,12	**4.3** (Ref. to JEC Study EMEL1/LH1) (footnote)	Fuel Cells	0	0	~~0~~	-
				ICE	0	0	TBM	
	e-NH3	0,0186	0	No engine	0	N/A	TBM	N/A
	e-LPG	To be done	To be done		To be done	To be done	To be done	-
	E-DME	To be done	To be done		To be done	To be done	To be done	-
Others	Electricity	-	106,3 EU **ENERGY** MIX 2020 72 EU **ENERGY** MIX 2030 JED Study [to be further discussed]	OPS	-	-	-	-

Annex II: ESSF SAPS (MARIN PORTAL)

LNG

	GWP100			GWP20		
Solution name	**WtT**	**TtW**	**WtW**	**WtT**	**TtW**	**WtW**
Diesel (HFO) ICE 2-stroke	110,3	611,1	**721,4**	110,3	611,1	**721,4**
LNG ICE 4-stroke	144,8	573,4	**718,3**	212,3	793,9	**1006,1**
LNG ICE 2-stroke	129,7	529,8	**659,5**	190,1	756,6	**946,7**
LNG (organic waste) ICE 4-stroke	-216,5	464,9	**248,4**	-144,2	496,4	**352,2**
eLNG ICE 4-stroke high speed	-497,1	671,6	**174,6**	-497,1	855,9	**358,9**
eLNG ICE 4-stroke	-389,7	464,9	**75,2**	-389,7	496,4	**106,7**

Methanol

	GWP100			GWP20		
Solution name	**WtT**	**TtW**	**WtW**	**WtT**	**TtW**	**WtW**
Diesel (HFO) ICE 2-stroke	110,3	611,1	**721,4**	110,3	611,1	**721,4**
CH3OH ICE SI 4-stroke	248,1	539,3	**787,4**	314,8	539,3	**854,1**
eCH3OH 65% ICE DF 4-stroke	-168,9	590,8	**421,9**	-168,9	590,8	**421,9**
CH3OH (glycerin) ICE SI 4-stroke	-248	539,3	**291,3**	-248	539,3	**291,3**
CH3OH (black liquor) ICE SI 4-stroke	-256,3	539,3	**283**	-256,3	539,3	**283**
eCH3OH 95% ICE CI 2-stroke	-432,3	549,4	**117,1**	-432,3	549,4	**117,1**
eCH3OH 95% ICE DF 4-stroke	-459,8	576,8	**117**	-459,8	576,8	**117**
eCH3OH (flue gas CO2) LT PEM FC	-631,7	709,7	**77,9**	-631,7	709,7	**77,9**
eCH3OH (flue gas CO2) HT PEM FC	-579,8	651,4	**71,5**	-579,8	651,4	**71,5**
eCH3OH (flue gas CO2) ICE SI 4-stroke	-480,1	539,3	**59,2**	-480,1	539,3	**59,2**
eCH3OH (DAC CO2) ICE SI 4-stroke	-522,6	539,3	**16,7**	-522,6	539,3	**16,7**

Hydrogen

	GWP100			GWP20		
Solution name	**WtT**	**TtW**	**WtW**	**WtT**	**TtW**	**WtW**
Diesel (HFO) ICE 2-stroke	110,3	611,1	**721,4**	110,3	611,1	**721,4**
cH2 (natural gas) LT PEM FC	846,1	0	**846,1**	1254,4	0	**1254,4**
cH2 (natural gas + CCS) LT PEM FC	602	0	**602**	1105,5	0	**1105,5**
ecH2 96% ICE DF 4-stroke	25,2	131,2	**156,4**	25,2	131,2	**156,4**
eLH2 96% ICE DF 4-stroke	21,4	111,2	**132,7**	21,4	111,2	**132,7**
eLH2 LT PEM FC	0	0	**0**	0	0	**0**
ecH2 LT PEM FC	0	0	**0**	0	0	**0**

Ammonia

	GWP100			GWP20		
Solution name	**WtT**	**TtW**	**WtW**	**WtT**	**TtW**	**WtW**
Diesel (HFO) ICE 2-stroke	110,3	611,1	**721,4**	110,3	611,1	**721,4**
NH3 (natural gas) LT PEMFC	2630,1	0	**2630,1**	2630,1	0	**2630,1**
NH3 95% ICE DF 4-stroke	1286,2	89	**1375,2**	1286,2	89	**1375,2**
NH3 95% ICE CI 2-stroke	1209,3	90,8	**1300**	1209,3	90,8	**1300**
NH3 (natural gas) SOFC	1221,8	0	**1221,8**	1221,8	0	**1221,8**
eNH3 95% ICE CI 2-stroke	17,8	90,8	**108,6**	17,8	90,8	**108,6**
eNH3 95% ICE DF 4-stroke	19	89	**107,9**	19	89	**107,9**
eNH3 LT PEMFC	0	0	**0**	0	0	**0**
eNH3 SOFC	0	0	**0**	0	0	**0**

Annex III: SWOT Analysis

Introduction

This document presents a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of the recommended actions to achieve Zero Emission Waterborne Transport (ZEWT).

These actions have been defined for each intervention area earlier on in Deliverable 2.3[39] of STEERER. The SWOT analysis lists the results and findings for the key actions, and provides a clear insight in the internal and external factors that can have an impact on the different actions contributing to zero-emission pathways for the waterborne transport sector. This concerns actions in the field of RD&I and beyond (supporting measures). The outcome of this task 2.4. will be used as input for Tasks 2.5[40] and 2.6[41] of STEERER.

The methodology consists of a thorough analysis based on desk research, internal consultation meetings with STEERER partners, an open consultation with a survey as well as technical interaction with experts from the Scientific Committee (SC) and the Green Shipping Expert Group (GSEG). Especially the GSEG meeting of 12 January 2022 was of importance, since input was retrieved and results were validated during that session. This resulted in a SWOT overview in which the commonalities were identified and aggregated. The results are incorporated into the three following chapters of this document:

- Chapter 2 provides an overview of the SWOT findings at a general and abstract level as presented and discussed/validated with the SC and GSEG.
- Chapter 3 includes the SWOT analysis that applies to key actions relevant to all six intervention areas, which are identified in Deliverable 2.3 “Areas of intervention and related actions (implementation plan)”.
- Chapter 4 includes a number of selected specific actions in individual intervention areas from the D2.3 deliverable. The topics for these key actions have been selected by the Scientific Committee members and given priority to discuss in the 3rd GSEG meeting 12 January 2022.

The drivers of the scenarios identified in deliverable 2.2 “Scenarios with quantified targets for 2025, 2030 and 2050” are directly linked to the opportunities and threats of the actions identified in deliverable 2.3. In general, it has been found that a high regulatory pressure is an opportunity, whereas a low regulatory pressure can be seen as a threat to the transition towards a zero-emission waterborne transport sector. In addition, public and private initiatives and global cooperation between companies is positive and enhances the quality of the projects under the SRIA, as funded in Horizon Europe.

[39] Task 2.3 Areas of intervention and relevant actions to achieve the targets, incl. prioritisation of actions
[40] Task 2.5 Public policy instruments and interventions and other appropriate mechanisms, incentives and business models to increase the take-up and deployment from R&I activities arising from the ZEWT candidate Partnership.
[41] Task 2.6 Recommendations towards the SRIA and Implementation Plan of ZEWT

General SWOT Findings

There are a number of general SWOT findings given all the identified actions, both key and specific actions (see chapters 3 and 4), that need to be taken by the EU waterborne transport sector to comply with the emission reduction objectives. These general SWOT findings are summarised below per SWOT category.

Strengths (internal factors):

- There is a strong network, good position thanks to the ZEWT partnership with the EU, high level of knowledge and great possibilities of cooperation available in the waterborne transport sector through the Waterborne Technology Platform.
- There are sustainable alternative technologies being developed which are absolute zero-emission at the tailpipe as well as already available solutions which are considered as near or net-zero emission seen from the full well-to-tank perspective assuming certain methodologies (e.g. IPCC).
- Some sustainable alternative technologies and fuels are already feasible for short term implementation.
- There is a growing support among partners and customers to invest in sustainable alternative technologies.

Weaknesses (internal factors):

- Most currently available alternative technologies are not absolute zero-emission at tailpipe nor from well-to-tank.
- Additional space and weight for sustainable alternative fuels and energy storage on board of vessels which limits the practical feasibility as well as the economic feasibility.
- There is in general a poor business case and concerns about the availability of funding to support the transition towards zero-emission, especially for large-scale deployment of sustainable alternative technologies, resulting in concerns about the uptake of sustainable alternative fuels and zero-emission powertrains.
- There are sometimes long lead-times of processes between preparation of project calls and the actual implementation. This hampers short term impact.
- There is a lack of agreement on the methodology and thus also the outcomes of Life Cycle Assessments for different solutions, which makes it difficult to compare sustainable alternative technologies.
- There is a lack of a clear baseline for vessels to base improvement paths on and assess technological solutions.
- There is still a lot of focus on (early stage) research, but demonstrations in operational conditions are needed to convince the market, for which funding may not always be sufficient.

Opportunities (external factors):

- There is increasing societal and legal pressure (e.g. Fit for 55) to move away from fossil energy sources and to reduce emissions. This pressure combined with well-fitted and aligned legal

initiatives could create more incentives, encourage the further deployment and uptake of sustainable alternative fuels and technologies and create a better business case for zero emission waterborne transport.

- There are plans for the production of green hydrogen(-based) fuel(s) and imports from other continents (e.g. solar power H_2 Africa).
- There are opportunities for joint projects and development with other transport modes and industrial sectors which can create synergies, reduce risks and lowers costs due to economies of scale.
- EU instruments[42] do provide opportunities for co-financing and blended finance which can help the demonstration of sustainable alternative technologies.
- The market roll-out of sustainable alternative technologies will results in new jobs and economic advantage for front runners as well as export opportunities of EU technologies and expertise.
- Use of digital technologies can sharpen business cases and enable involvement of multiple chain partners into improvement and zero emission paths, and create long term commitment between partners in the value chain or working area.

Threats (external factors):

- There is still considerable uncertainty and a long winding policy development reduces the appetite to make investments. There is a risk of stranded assets in case technologies are now selected by ship-owners which are not supported anymore in near future, depending on the policy choices and the targets set. For example, LNG may not be supported anymore if policy makers believe that the risks of methane slip are too high and the pathway to bio-LNG or sustainable synthetic methane is not sufficiently credible. Another example may be ammonia for which the external risk profile is still a pending issue whether or not to support it from the wider policy perspective. In general, there are many requirements and pre-requisites which are valid for different types of fuels and technologies which are not completely sure and reliable at this stage.
- Regional differences and the risk of no adoption of the Fit for 55 package as well as lack of global maritime climate policy actions create competitive disadvantages. This will negatively affect the business incentives and support of chain partners in sharing costs and risks as result of the energy and digital transition.
- Regional differences in financing requirements also have an impact on competitiveness. European banks fall under much stricter regulations due to the updated Basel Accords resulting in higher interest rates.
- There is a risk of unrealistic policy targets and expectations on emission reductions to be achieved by waterborne transport sector as regards the economic and technical feasibility.
- There are concerns about the global competitive finance in Europe (e.g. Taxonomy).

[42] e.g. CEF, Innovation Fund, Horizon Europe, etc.

- There is a risk of high prices and lack of supply of feedstock for renewable fuels (e.g. green electricity, hydrogen), also because of competition between different sectors and industries in the economy, causing high costs of transport and reduction of trade and transport demand.
- Negative geo-economic and geopolitical/global developments creating a low transport demand, shrinking market with overcapacity of vessels, lack of financial resources, other policy priorities, etc. (e.g. war in Ukraine which could further escalate, inflation to cause economic downturn, COVID-19 to persist, nature disasters and other wars).
- Policies and incentives that could facilitate the production, distribution and supply of alternative fuels differ among EU Member States. For instance, not all Member States have tax exemptions in place for alternative fuels and/or reduces fees for using the electricity grid to produce those fuels on land, even when the electricity is produced from windmills at sea. While some of these concerns could be tackled through e.g. the revision of the Energy Taxation Directive, the needed unanimity is expected to complicate any agreement on the matter.

SWOT Analysis – Key Actions

The paragraphs below contain the SWOT analyses, per action, for the key actions that apply to all six intervention areas in the Strategic Research Innovation Agenda (SRIA) for ZEWT. The ten key actions in D2.3 have been taken as a starting point and after reduced to seven actions by merging those actions that were rather similar in nature[43].

Key action 1 – knowledge platform

There is an enormous amount of technological knowledge available but unfortunately, it's scattered. By further developing and refining the Waterborne TP website in close collaboration with the waterborne members, the website can serve as a knowledge platform by better collecting, assessing and diffusing information. Concrete examples are providing a clear overview of the waterborne research projects, including potential challenges, opportunities and conclusions. The platform can serve as a means to find information faster and connect people which are working on similar technologies, and it can also benefit possible future research projects that aim to further decarbonize the entire waterborne supply chain. Besides having a knowledge platform, it's also recommended to regularly set up knowledge sharing sessions related to the projects on the knowledge platform and physically bringing together different consortia and experts that have been working on similar topics. This could also help to increase awareness on topics such as safety concerning sustainable alternative fuels that come with different risks.

The **strength** of this key action is that already a lot of knowledge has been generated and collected in the waterborne transport sector throughout the years in various projects and research programmes which can be used for this purpose. Waterborne TP is also a very suited platform to facilitate this.

[43] Actions 2 and 6 were merged due to the similarity. Actions 5 and 7 were merged, both are about long term contracts. Actions 8 and 9 are also merged due to the complementarity.

A **weakness** is that the information and expertise is extremely dispersed in the broader waterborne transport sector. It will be challenging and time-consuming to bring everything together, while new innovations are going on continuously and collected information will be quickly outdated. Furthermore, organisations within the Waterborne TP could be reluctant in sharing potentially sensitive information because of the competitive advantage of pioneers and intellectual property rights.

There is a lot of uncertainty and a lack of knowledge regarding all the challenges and opportunities related to the transition towards a zero-emission waterborne transport sector, this can create a strong demand for the dissemination of information from such a platform, and can be seen as a key **opportunity**.

There might be a lack of priority and hence no funding and capacity available, either from the EU or members from the waterborne transport sector itself, to support such a platform and its continuation on the long term which can be seen as an important **threat**. External partners outside Waterborne TP could be reluctant to share information for the benefit of the knowledge platform.

Key action 2 – technical and safety regulations and class guidelines

With new technologies (i.e., sustainable alternative fuels and hardware) technical/safety regulations and class guidelines are often missing, making it difficult to actually use these new technologies and fuels due to lacking licenses/permits. There are possibilities for getting exceptions on the short term and adjustments to regulations on the longer term to enable the deployment of new technologies on a larger scale. However, such processes take a long time and eventual guidelines of individual classification societies are not always aligned. New initiatives in the waterborne transport sector such as RD&I programmes and projects should always address the (foreseen) challenges and gaps as regards class guidelines, technical regulations, standards and safety and environment guidelines.

Experts within the waterborne transport sector have a clear view on what the gaps are and what needs to be provided and updated in terms of guidelines, regulations and standards to enable the adaptation of alternative fuels and technologies, which can be regarded as a **strength**.

Adjusting technical/safety regulations, class guidelines and standards are time-consuming processes, which is a known **weakness**.

Public bodies have an interest though in adapting technical regulations to accelerate the deployment of alternative technologies and fuels, and there is currently a strong momentum for this with the whole FF55 package following the EU Green Deal. This can be seen as a strong **opportunity**.

Addressing class, technical regulations and standards will require the involvement of classification societies and regulatory bodies such as the IMO, CESNI, national inspections, etc. Involving such bodies in waterborne transport RD&I projects has been proved relatively difficult in practice as compared to involving shipping companies, technology providers, etc.). Furthermore, if the individual measures in the FF55 package relevant for the Waterborne Transport sector will not be adopted, then there will be less pressure for these organisations to come up with adapted guidelines and technical regulations. These are two important **threats**.

Key action 3 – earmarked fund

New fuels come with high investment as well as operational costs, as long as there is no international price on carbon for waterborne transport, there will be a need to incentivise the use of sustainable alternative fuels. Therefore, a dedicated waterborne fund such as the Ocean Fund proposed by MEP Peter Liese, rapporteur on the EU ETS in the European Parliament, would be warmly welcomed. A dedicated waterborne transport fund will accelerate the fuel transition by for example bridging the price gap between conventional and sustainable alternative fuels. Frameworks such as the "First movers in shipping's decarbonisation", published by Lloyd's Register 9 December 2021, can be used to identify which key ports and vessel types to target per sustainable alternative fuel initially.

The **strength** of such an earmarked waterborne transport fund is that it could generate sufficient revenues to provide financial support to vessel owner/operators to use alternative fuels and invest in sustainable solutions and hence contribute to the zero-emission objective.

A **weakness** is the necessary support and decision-making to agree upon the contents of the fund, i.e. its governance structure, conditions for funding, etc. This will require a complex and lengthy process given the need for alignment between countries and market segments.

It is an **opportunity** though that the waterborne transport sector is regarded as one of the hardest to decarbonise sectors, though stringent objectives have been announced (FF55 and European Green Deal) for some segments within the waterborne transport sector. Hence, such an earmarked fund could be a major step in contributing towards timely reaching the zero-emission objective. The existing political support for the idea is a strong boost.

The waterborne transport sector is an internationally operating sector consisting of many diverse public and private stakeholders. There is a **threat** of insufficient support for the concept, e.g. as a result of geopolitical issues such as the war in Ukraine, or disturbing the level plaiying field due to the fund if its biased to EU member states only.

Key action 4 – ecolabels

The development of international standards or eco-labels for vessels translated into product labels could impact consumer choices on the one hand and might also incentivise cargo-owners to choose the more sustainable vessels on the other hand.

It is a **strength** that already many initiatives in this field are launched like "CountEmissions EU" and the Global Logistics Emission Council (GLEC) Framework.

It will be difficult to have an accepted and supported standard(s) for eco-labels for all types of waterborne vessels that can easily be adopted by consumer goods manufacturers in their own eco-labels for consumer products, this can be regarded as a **weakness**.

It is an **opportunity** though that eco-labels for consumer products are becoming more widely used and consumer awareness is increasing in this respect. We can add to this the fact that consumers are also more and more interested about the carbon footprint of goods that they purchase.

Deteriorating geo-economical and geopolitical developments area a **threat** and may have a negative impact on the value attached to eco-labels by consumers. Another problem can be the lack of clarity and/or information between the ecolabel of the product itself and that of the transport, which can have a negative effect for all 3 stakeholder groups concerned – waterborne transport, consumer goods manufacturers and the end-customers.

Key action 5 – long term engagement

Ships are substantial financial assets that have a life span of 20 years and more. Bringing new frontrunner technologies into the market and onboard ships therefore comes with considerable financial risks for certain stakeholders and in the first place the owner of the ship. Long term engagement from other stakeholders involved, such as charterers, cargo-owners and fuel suppliers through for example long-term chartering contracts could provide more certainty to the market and facilitate further investments in these new technologies.

Ship owners may feel the increased need (**strength**) to try to conclude long-term contracts with their clients and suppliers to create financial certainty which is highly welcomed given the needed future investments in sustainable technologies for their vessels.

A fairly large part of vessel owners/operators are active on the spot market and long-term contracts with shippers and charterers do not fit into their business model and entrepreneurial culture which is a **weakness** for having long term contracts.

Large shippers are willing to support the transition in the waterborne transport sector and in that way contribute to realising their own corporate social responsibility. Furthermore, suppliers of sustainable alternative fuels may be willing to engage in long term contracts to gain an early market share in this new market. These are **opportunities** for ensuring long term contracts between different parties in the waterborne transport sector.

The main **threats are** the economic downturn and the uncertainty on transport demand and trade patterns, which will lead to reluctancy by shippers to make long term contacts, in order to ensure flexibility.

Key action 6 – business case and new business models

There is a need for new initiatives and projects that address the business case for sustainable innovations in all intervention areas, taking into account the different waterborne transport segments, and come up with new business models to finance these innovations.

Possible solutions in this respect are pay-per-use, data ownership models, leasing options, joint procurement for construction and refit of sustainable vessels, etc. It can be regarded as a **strength** that there are already initiatives investigating and companies providing new business models to create a positive business case for investments in sustainable technologies by vessel owners. An example is containerised battery solutions that are being leased by vessel owners.

A lack of reliable information and uncertainties (e.g. related to costs and benefits of certain propulsion techniques and fuels) will make it difficult to provide reliable financial insights and develop accompanying new business models, which is a **weakness**. Another aspect here is the unwillingness to share data by numerous stakeholders.

Other sectors cope with the same challenges though. Cooperation with other sectors and other modes of transport can be an **opportunity** in creating economies of scale and new business models (e.g. energy as a service, modular multi-purpose energy boxes).

A **threat** is the insufficient funding for RD&I or other projects, either dedicated projects or where these subjects are integrated into projects, that focus on or include to a larger extent business case and business model studies for the techniques that are being studied and developed within the project.

Key action 7 – policy implementation FF55

An initiative could be launched on policy implementation of the Fit-For-55 package for the whole waterborne transport sector, from a business/economic viewpoint in relation to policies. This needs to provide insights into the business/economic impact of the Fit-For-55 package on the waterborne transport segments, to raise stakeholder acceptance and support for detailed implementation plans.

There is a strong desire in the waterborne transport sector and on the level of the (waterborne transport) authorities to get clear insights into the economic/business impact of the FF55 package, which is a **strength**.

The lack of reliable information and the uncertainties (e.g. related to costs and benefits of certain propulsion techniques and fuels) are **weaknesses,** and will make it difficult to provide reliable insights into possible economic impacts. This will result in a lack of decision on investments or in unsuitable investments.

There is a strong political will to adopt FF55 which can be regarded as an **opportunity**.

The lacking motivation and consensus among governments and the private sector due to lacking consensus to follow the recommendations and adopt FF55 is a **threat** though. On the other hand, if FF55 will be adapted but the availability of technologies and innovative solutions will not follow in a timely manner, and the differences on international level remain, then it may lead to decreasing competitiveness of the European waterborne transport sector and generate a large obstacle for the production and exploitation of vessels in Europe. It is important to timely deliver the required technologies, fuels, systems and strategies. At the moment there is uncertainty in this regard.

SWOT Analysis – Selected Specific Actions

The paragraphs below provide the SWOT analyses for a selected number of specific actions in individual intervention areas that have been selected by the Scientific Committee members for further discussion during the 3rd GSEG meeting.

Specific action 1 – Green hydrogen as fuel for ships

RD&I activity on green hydrogen as fuel for ships, addressing:

- Technical development:
  - Fuel Cells, Internal Combustion Engines (including emission abatement)
  - Most efficient energy carriers and conversion on board (LOHC options, compressed, liquified)
  - Technical regulations and safety standards
  - Modular and exchangeable solutions enabling new business concepts
- Fuel availability[44]
- Comparison with other solutions
- Applicability (fleet/routes/markets), market potential and deployment plan
- Impact on GHG saving and other pollutants savings
- Demonstrations and pilots

Strengths of green hydrogen as fuel for ships is that it can be a net zero-emission solution from well-to-wake viewpoint if applied in a Fuel Cell configuration. It can also be (near) zero-emission with ICE's including aftertreatment. Furthermore, there can also be synergy with transporting H2 in ships and using it for the propulsion.

Weakness of H2 in compressed or liquified form is the additional storage capacity needed, due to the low energy density of hydrogen compared to the energy density of fossil fuels or even other sustainable alternative fuels, that have a higher energy density, such as e-ammonia and bio/e-methanol. Using H2 on board also has its safety concerns. Perhaps the most important weakness from a vessel owner's perspective is the high price for the required hardware as H2 cannot be used as a drop in fuel[45]. Furthermore, for the production and storage of H2, a lot of energy is needed, which makes the overall energy efficiency relatively low compared to direct use of electricity from grid for battery electric propulsions.

Opportunities: possible increasing fossil fuel prices could lower the price gap with the more expensive sustainable alternative fuels, which could facilitate an increase in production facilities for green hydrogen and the strong European and national political support for green hydrogen (e.g. in FF55). Another set of opportunities comes from the continuous investments in H2 production and H2-related technologies, both within and outside the EU, that are applicable in various transport segments. Consequently, (parts of) the waterborne transport sector can benefit from these developments, both directly and indirectly.

[44] Fuel production itself is beyond the scope of this deliverable, however, sensitivity and risks of fuel prices and their availability should be taken into account for the decision making process in the waterborne transport sector.
[45] It is assumed here that drop-in fuels are fuels that can be blended with conventional fuels and used without modifications of engines or fuel systems on board of vessels.

Despite the strong policy support, vague policy developments with regard to the deployment of hydrogen in vessels can be a **threat**. Furthermore, lack of support from the wider waterborne transport sector for climate goals are a threat though, as well as a low future availability of green hydrogen and possible accidents with hydrogen in pilots. Moreover, it shall be guaranteed that indeed the hydrogen is green and not from fossil sources like natural gas, as the latter is resulting in more greenhouse gas emissions compared to the use of gasoil or heavy fuel oil. Another threat is the fact that many other countries and regions outside the EU may decide not to opt for hydrogen as one of the main fuels for waterborne transport, thus making it a relevant fuel for transport only in-between European ports and with a limited number of non-European ones.

Specific action 2 – Green methanol as fuel for ships

RD&I activity on green methanol as fuel for ships, addressing:

- Technical development
  - Fuel Cells, Internal Combustion Engines (including emission abatement)
  - Technical regulations and safety standards
  - Modular and exchangeable solutions enabling new business concepts
- Fuel availability
- Comparison with other solutions
- Applicability (fleet/routes/markets), market potential and deployment plan
- Impact on GHG savings and other pollutants savings
- Demonstrations and pilots

The strengths of green methanol as fuel for ships start with the fact that it can be regarded as a net zero-emission solution, from well-to-wake, when applied in a Fuel Cell configuration, and (near) zero-emission with ICE's including aftertreatment. In comparison to the other two fuels considered (H2 and ammonia), methanol is relatively safe to store on board and to bunker, which makes it easier and more efficient in storage and bunkering operations. Furthermore, its gravimetric and volumetric density makes it also a more attractive sustainable alternative compared to compressed or liquified H2 and ammonia– which makes it a key candidate to decarbonize long-distance shipping. Finally, the methanol-based technologies can become mature on relatively short--medium term and some of them are being demonstrated today, which can ensure market availability and economies of scale for both technology and fuel production

A key **weakness** is the carbon content (CH3OH) in methanol fuel, hence it will result in GHG emissions (tank-to-wake). This can only be compensated if the methanol comes from sustainable feedstocks or through direct air capture (Carbon capture), which needs to be regulated. There is also a risk of NOx and formaldehyde emissions when burned in internal combustion engines (still NOx is lower and there are no SOx and sooth emissions). Furthermore, using methanol in existing vessels requires adjustments to e.g. the fuel tank (coating is needed) and the engine, which needs either to be equipped with a retrofit package or to be replaced with a new engine that can run on methanol.

Opportunities are similar to other sustainable alternative fuels and include the increasing fossil fuel prices, EU policies such as FF55 and increasing facilities to produce green methanol from sustainable feedstock and from green H2.

In line with the opportunities, the **threats** are similar as the ones for other sustainable alternative fuels and include the unclear policy development, lack of a wide support base for climate goals, the possibility that other countries and regions outside the EU may not see methanol as one of the main fuels of the future, and limited availability of sustainable feedstocks for the production of green methanol. Moreover, usage of green methanol shall be ensured to really achieve emission reductions from the well-to-wake viewpoint.

Specific action 3 – Green ammonia as fuel for ships

RD&I activity on green ammonia as fuel for ships, addressing:

- Technical development:
  - Fuel Cells, Internal Combustion Engines
  - Ammonia cracking on board
  - N20 emissions, NH3 slip abatement
  - Technical regulations and safety standards
- Fuel availability
- Comparison with other solutions
- Applicability (fleet/routes/markets), market potential and deployment plan
- Impact on GHG saving and other pollutants savings
- Demonstrations and pilots

The strengths of green ammonia as a fuel for ships are that it could be a zero-emission solution for the propulsion of vessels. There may also be a synergy with transporting ammonia in ships and using it for the propulsion. Furthermore, there will be a relatively lower loss of cargo space when storing ammonia on board of the vessel as compared to compressed and liquified hydrogen and batteries.

Weaknesses are the strong safety and environmental concerns. There is a risk of N20 as emissions which has a dramatic CO2 equivalent. Furthermore, ammonia engines require aftertreatment systems and have the risk of NH3 slip and formation of aerosols. Moreover, an ammonia spill following an accident will lead to tremendous local consequences. This adds up to the entire safety concerns along the whole value chain, as higher quantities of ammonia would need to be produced, transported and stored for the benefit of the waterborne transport sector. It is also difficult to apply it as a mono-fuel in combustion engines.

Opportunities are similar to the other sustainable alternative fuels and include the increasing fossil fuel prices and EU policies such as FF55. Production facilities of green hydrogen and ammonia as hydrogen carrier in other continents may also be an opportunity.

Threats are similar as the ones for other alternative fuels and include the unclear policy development,

lack of a wide support base for climate goals, the decision of other countries and regions not to use ammonia in the future, and limited availability of green ammonia as fuel for vessels. Given the high safety concerns, potential accidents in pilots with ammonia are also a significant threat for the development and uptake of ammonia in the waterborne transport sector. It is yet uncertain if internal combustion engines running on ammonia will be developed that are reliable, safe and clean (including the abatement of N emissions).

Specific action 4 – Electrification

RD&I activity on Electrification, addressing:

- Technical development
  - Fuel Cells
  - Batteries
  - Modular design and standardised transhipable energy containers
  - Technical regulations and safety standards
- Comparison with other solutions / ICE
- Applicability (fleet/routes/markets)
- Market potential and business plan
- Demonstrations and pilots

One of the **Strengths** of fully electrifying vessels is that it results in zero-emissions tank-to-wake and depending on the energy source zero-emission from well-to-wake. The technology is also further developing rapidly, resulting in less weight and volume needed for energy storage, and in reduction of costs in hardware. From a financial perspective, there are already leasing and pay-per-use constructions for batteries, which lower the financial threshold for a vessel owner to use batteries. Furthermore, direct usage of electricity from grid is very energy-efficient as there is only a small thermal loss. This is much more energy efficient as compared to e-fuels like green H2, (e-)methanol, e-methane or e-diesel. Moreover, synergies are possible for the stability of the electricity grid with peak shaving options to stabilise frequency and electricity supply, by buffering abundant electricity generated from solar, wind or water power at favourable weather conditions.

Weaknesses of in particular batteries are the severe space occupation and weight which will be at the expense of cargo space or passengers. In some cases it will even be not possible to fit the necessary batteries on certain ship types to be used as main source of energy for example for large long distance ocean-going vessels and inland push boats. Furthermore, both for batteries and fuel cell systems, there will be high investments costs. There is a need for specific infrastructure to make use of electricity as main energy source for the propulsion of a vessel. Furthermore, diesel-electric propulsion as a first step is not always a no-regret solution as it may result in lower efficiencies in some cases. This is due to the energy conversion loss compared to diesel-direct mechanical drive, which can result in an overall lower energy efficiency and thus higher CO2 emissions. This has to be taken into account when still a diesel generator set is needed to provide sufficient operating range for the vessel.

Opportunities are similar to other decarbonization alternatives and include the increasing fossil fuel prices and EU policies such as FF55. The production costs for green electricity are dropping and its availability is going up. A specific opportunity is the expectation that electricity availability will overall be much higher than that of sustainable alternative fuels, both within and outside the EU, which will mean a higher possibility of technologies' roll-out and market uptake. Furthermore, electrification and the use of batteries is already widely being done in other sectors (e.g. automotive). Hence, lessons learned from other sectors can be used in the waterborne transport sector.

Threats are: the electricity grid which is not yet fully developed to meet future requirements in and around some ports, and that there is a shortage of onshore power supply points, recharging points and points to exchange containerised batteries. In line with the threats of other alternatives, an unclear policy development and availability of green electricity are threats as well. Two specific threats are: (i) the very high costs of onshore infrastructure investments; (ii) the lack of a standardized onshore power supply around the world, which will hamper the deployment of electrification solutions.

Specific action 5 – Wind assisted propulsion

RD&I activity on Wind assisted propulsion, addressing:

- Structural designs including retrofitting options
- Technical regulations
- Applicability (fleet/routes/markets)
- Market potential and business plan
- Impact on GHG saving and other pollutants savings
- Demonstration and pilot

The first **strength** of wind assisted propulsion is its compatibility with all fuel types. It is a zero-emission and "free" energy solution for the vessel. Moreover, the energy produced can be used directly at the point of production, resulting in low energy losses and a high efficiency. Storage or infrastructure requirements on board of the vessel can be reasonably low when compared to e.g. H2 or ammonia. The European industry is strongly involved in the development of these systems. Moreover, in most optimal conditions – wind availability, technologies used, size of the ship and route – the WAPS can actually provide by themselves enough energy to fully meet the power needs for the ship's propulsion.

Weaknesses are a high CAPEX when conventional financing is applied, perception of old technology, and limited investment returns when applied on unsuitable routes (i.e. with unsuitable sailing conditions for wind-assisted propulsion). Shipping is mostly a tramp sector, which means it's uncertain where the vessel will sail and therefore to calculate a ROI when making investment decisions. An additional weakness is the fact that wind assistance has its limits. While it can be used to make a vessel more energy efficient (consume less fuel = save fuel) it is highly unlikely that any commercial vessel will sail on wind only.

However, savings created by wind-assistance might generate a tipping point for the next step technologies and can be seen as an **opportunity** as it will reduce the energy needed and therefore the costs of the (more expensive) alternative fuels including storage on board. Leasing (and) modular

applications will result in limited CAPEX for the vessel owner. As with other sustainable solutions, policy support is also an opportunity for wind-assisted propulsion.

Threats are on a general level similar as the ones for alternative sustainable fuels and include the unclear policy development, and lack of a wide support base for climate goals. Specific threats are the "fuel-centric" approach by the industry instead of an energy centric one, and the failure to adapt regulation to wind-assisted propelled vessels and vessels using wind as primary energy for the propulsion.

Specific action 6 – Digital Twins

RD&I activity on Digital Twins, addressing:

- Digital solutions supporting operational strategies and remote monitoring and control contributing to higher energy efficiency.
- Innovative on-board energy saving solutions with more and advanced sensors integrated with advanced energy management
- Full life-cycle ship energy efficiency to feed into digital twin models for the ship and for its sub-systems.
- Interoperability and connections to other digital twins (e.g. ports)
- Data collection methods for feeding Digital Twin models
- Cyber security
- Demonstration and pilot
- Impact on GHG saving and other pollutants savings
- Market potential and business plan

Strengths of digital twins are numerous. Digital twins have an ability to detect irregular energy demand of vessels, to provide solutions for specific situations and scenarios which are difficult to simulate in real-life conditions Design iterations and sensitivity studies can be performed easily and extensive, which gives in a short timeframe good insight in alternative configurations. Predictive maintenance is another key advantage that can be achieved with the help of digital twins.

Weaknesses are: the lack of standardised interfaces for modular twins, the computational effort is often too high for direct simulation (e.g. CFD) and less accurate (meta-)models are required. With in-depth simulations things can become very expensive without any added benefit to get a good solution. Furthermore, there is a need for high-quality and large datasets to simulate real-world conditions as well as skilled and specialised staff to develop and operate digital twins. Last, given its complex nature, digital twins may initially only be accessible and feasible for larger companies given the high operating costs (skilled workers) and the qualified workforce that is difficult to find. In fact, the latter reasons can be counted as individual weaknesses themselves, as they may the entire industry to various degrees over a significant period of time.

Opportunities are a.o. the current momentum in the sector for developing and applying digital twins, reducing commissioning and testing time of new builds and retrofits, chances for open innovation to increase speed of innovation and optimization, modular data models which could make it more

accessible, insights in performance could generate commitment from end customer. Other opportunities come from the fact that other industry sectors are also looking at the development of digital twins, and their results and lessons learned may be beneficial for the waterborne transport sector.

The main **Threats** are the risk of cyber-attacks and the lack of qualified personnel to make complex enough digital twin models for waterborne transport applications and/or properly operate them.