WATERBORNE

STRATEGIC RESEARCH
AND INNOVATION AGENDA
FOR THE PARTNERSHIP ON

ZERO-EMISSION WATERBORNE TRANSPORT

Updated - January 2024

Realizing zero-emission waterborne transport to the benefit of future generations

Amid growing global and European societal pressure to resolve issues related to climate change, air pollution and the degradation of the world's oceans, political and regulatory attention has been increasingly directed towards waterborne transport, due to its high environmental and climate impact.

The European Green Deal, the Paris Agreement Objectives, the revised 2023 IMO Strategy on the reduction of GHG emissions from ships and its related measures, Sustainable and Smart Mobility Strategy, the Zero Pollution Action Plan, the Fit for 55 Package, the CCNR Ministerial Mannheim Declaration and NAIADES3 are a number of key policy developments which provide a clear objective towards zero-emission waterborne transport.

The waterborne transport sector is committed to develop and demonstrate disruptive solutions to address the aforementioned challenges. Research, development, and innovation are key to develop commercially viable and environmentally sustainable solutions to eliminate GHG emissions, air and water pollution (including underwater noise). These solutions should be applicable for both new build and existing main maritime and inland navigation ship types and services. Furthermore, the Partnership will develop solutions which will facilitate the modal shift of cargo from road to waterborne transport and, in doing so, will contribute to the achievement of the carbon neutrality and zero pollution goals envisaged by the European Green Deal.

The Partnership's objective is to

provide and demonstrate zero-emission solutions for all main ship types and services before 2030, which will enable zero-emission waterborne transport before 2050.

The Strategic Research and Innovation Agenda (SRIA) builds upon the final draft proposal for the Partnership, as published in May 2020. This version contains an update of the initial SRIA, as adopted by the Partnership Board in September 2021, in order to include the developments in the sector between June 2021 and December 2023, as well as recent regulatory changes within the EU and economic developments such as unstable fuel prices. It has been approved by the Partnership Board in January 2024.

In order to achieve the objectives, the technical content of this SRIA is divided into six parallel activities. These activities are:

- use of sustainable alternative fuels,
- electrification,
- energy efficiency,
- design and retrofitting,
- digital green and
- ports.

In addition, the SRIA includes the monitoring and governance of the Partnership, as well as cooperation at EU and international level.

This version contains an update compared to the version adopted in 2021. The main items updated concern the relevant policy and legislative developments (part 1) and the RD&I activities (state-of-play) and future research priorities (orientations).

PART 1: VISION 2050 AND OBJECTIVES 2030

The Strategic Research and Innovation Agenda (SRIA) is based on the Final Draft Proposal for a Co-Programmed Partnership Zero-Emission Waterborne Transport. Part 1 of the SRIA contains a summary of the [Final Draft Proposal including an update where necessary](#).

This chapter describes the vision of the waterborne transport sector for 2050 and the objectives of the Co-Programmed Partnership for 2030. Part 1 describes the policies, new regulations and challenges the waterborne transport sector is facing. It also sets out the vision and objectives of the Partnership, including the commitment of the industrial stakeholders.

The COVID-19 pandemic, the war in Ukraine and Gaza, and unstable fossil fuel energy costs has dramatically shown both the vulnerability of the global economic system and the continued relevance of waterborne transport. As a result of the COVID-19 pandemic, the market for cruising at sea and on inland waterways has collapsed, whilst other crucial waterborne transport segments, in particular inland waterway transport and maritime freight transport, have continued to provide their services as vital parts of the supply chains in Europe. For the maritime technology sector, the passenger vessel market and related activities has been one of Europe's most important waterborne transport sectors within both EU and global markets. However, the COVID-19 crisis has halted most activities, with the exception of some orders placed before the pandemic. From 2022 the severe impacts from the pandemic are receding with consequent rapid grow pressures within sectors which previously had to release staff members, causing difficulty to regrow output to pre pandemic levels. In addition, the inflation is putting pressure on the waterborne transport sector.

The socioeconomic impact of the COVID-19 crisis, the war in Ukraine and Gaza and related economic impacts are, however, vast and continues to grow as a result of the negative effects on the waterborne transport sector. On the other hand, changing trade patterns have until recently driven higher freight rates, in particular for container traffic, with higher profits and consequent increased capacity to invest in accelerating the take up of new sustainable alternative fuels.

The current geopolitical situation, its related economic impacts, challenges, the EU's reactions, combined with the Repower EU initiative, might offer the EU opportunities in terms of strategic autonomy.

As one of the essential and vital sectors for society and industry, waterborne transport has to remain safe and in operation. The transition to zero-emission waterborne transport offers the opportunity to grow markets in the longer term.

To ensure preparedness in line with the European Green Deal's objective to become climate neutral by 2050 (an economy with net-zero GHG emissions) and cut emissions by 55% by 2030 and its related legislative proposals requires the sector to increase flexibility, innovation, creativity and financial efforts, as well as taking full advantage of any opportunities for financial support regarding the transition to zero-emission waterborne transport.

The sector is committed to realize zero-emission waterborne transport by 2050 to the benefit of present and future generations.

Policies and regulations

Amid growing global and European societal pressure to resolve issues related to climate change, air pollution and the degradation of the world's oceans, political and regulatory attention has been increasingly directed towards waterborne transport, due to this mode of transport's high environmental and climate impact.

The most relevant recent developments are:

- The Sustainable and Smart Mobility Strategy, which includes the target of zero-emission vessels to be ready for the market by 2030[1];
- The European Climate Law (Regulation 2021/1119/EU) which sets a legally binding target of net zero greenhouse gas emissions by 2050 and includes measures to keep track of progress and adjust EU and Member States' actions accordingly.

- Launched on 14th of July 2021, the Fit for 55 Package is a package of European Commission proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels[2]. This package is now largely adopted and includes several relevant initiatives, including the extension of the EU Emission Trading System to shipping (entering into force in January 2024), the revision of the Effort Sharing Regulation (ESR), the Renewable Energy Directive (in force since 20 November 2023), the Revised Alternative Fuel Infrastructure Regulation (AFIR) and the Fuel EU Maritime Regulation (FuelEU). Both AFIR and FuelEU will enter into force in January 2025;
- Introduction of new measures at the level of the IMO, such as the Carbon Intensity Indicator, focusing on greening of operations of existing vessels. For the Partnership and the sector as a whole, this will first mean more focus on retrofitting, energy efficiency and digital green measures. Furthermore, the IMO Initial Strategy on the reduction of greenhouse gas (GHG) emissions from shipping, as launched in 2018, has been revised in 2023;
- In 2023 the IMO approved the revision of the GHG Strategy and is now focused on the design of the "basket of measures" to implement it. It envisages 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. The 2023 IMO GHG Strategy also includes a new level of ambition relating to the uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources which are to represent at least 5%, striving for 10% of the energy used by international shipping by 2030.
- The European Commission tabled in June 2021 a 35-point action plan, in its communication NAIADES III: Boosting future-proof European inland waterway transport, 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[3]

Whilst the threats and risks of climate change and the harm from air, water and soil pollution are known, policy actions have often failed to keep pace, despite increasing societal demand. To address this, the European Commission presented the European Green Deal in December 2019 with the objective for Europe to become the world's first climate-neutral continent by 2050, through the provision of a package of measures, to enable European citizens and businesses to benefit from a sustainable green transition. The Green Deal sets out the Commission's commitment to tackle climate and environmental challenges. To achieve climate neutrality, the European Green Deal envisages cutting transport emissions by 90% by 2050 at the latest. In addition, it sets out the ambition to reduce GHG emissions by at least 55% by 2030 compared to 1990, as part of the Fit for 55 package[4]. The EU's 2021 "Smart and Sustainable Mobility Strategy, together with its related action plan, includes gradual reduction of greenhouse gas emissions and it sets out the pathway for EU transport to achieve the 2050 target of cutting transport GHG emissions by at least 90% with the intermediate waterborne objective of the first zero-emission vessels being market ready by 2030.

On 12 May 2021, the European Commission adopted the EU Action Plan: "Towards a Zero Pollution for Air, Water and Soil", setting out objectives for 2030 and 2050, with the ultimate objective to create a toxic free environment.

For inland waterway transport, the Council of Transport Ministers in December 2018, and the European Parliament in February 2019, called upon the inland waterway transport sector to improve the sector's sustainability with a view to contributing to the Paris agreement objectives (COP21[5]). In the Ministerial Mannheim declaration of October 2018, the CCNR stated its commitment to largely eliminate GHG and other pollutants by 2050 and, based on it, developed a roadmap for doing so. The roadmap has contributed to the work of the EU in establishing the subsequent NAIDES action plans.

Problems

The main environmental challenges faced by waterborne transport sector, are:

- Impact on climate change;
- Air pollution from ships;
- Degradations of waters and oceans.
- Underwater noise pollution

Climate change

European CO_2 emissions from waterborne transport are a major challenge. In total, the monitored maritime fleet emitted 124 million tonnes of CO_2 emissions in 2021. International and domestic shipping dominates CO_2 emissions, whilst inland waterway transport cannot be ignored. The EU project PROMINENT calculated that inland waterway transport in the EU results in roughly 3.8 million tons of CO_2 emissions per year. In addition, the CCNR estimated the CO_2 emissions of the fleet of its Member States at 4,1 million tons of CO_2 per year[9].

The world is not on course to achieve a temperature increase limited to well below 2°C and therefore urgent action is needed[6]. In BAU scenarios, the emissions of shipping are projected to increase from 1,000 Mt CO_2 in 2018 to 1,000 to 1,500 Mt CO_2 in 2050. This represents an increase of 0 to 50% over 2018 levels and is equal to 90-130% of 2008 levels[7].

Increasing the energy efficiency of ships alone would not be sufficient to meet either the 2050 commitment inscribed in the EU Climate Law or the 2023 IMO GHG Strategy. Only a combination of low and zero-emission innovative solutions, including renewable and low-carbon fuels, sustainable energy systems and technologies and operational approaches and technologies, initiated by ambitious regulations, can bring about the change needed.

Air pollution

Emissions of sulphur oxides (SOx) from maritime transport affect air quality in the EU and globally, with remarkable impact on coastal cities and densely populated areas nearby ports. SOx emissions result from the onboard combustion of oil-based fuel products and are directly linked to the sulphur content in marine fuels used in maritime transport. SOx emissions are a precursor of PM2.5 and a major cause of acid rain. According to the European Environment Agency, shipping is responsible for 24% of EU NO_x emissions and 24% of SO_x emissions[8]. Nitrogen Oxides (NO_x) form smog, acid rain and eutrophication and are central to the formtion of fine particles (PM2.5) and ground level ozone, both of which are associated with adverse health effect. Air pollution from all sources causes 400,000 premature deaths each year (2016). Concentrations of air pollutants from shipping can be much higher in coastal and port areas, where it can be the dominant source of air pollution, however as air pollution travels large distances it can contribute to concentrations up to 400km from the coastlines.

While current IMO and EU legislation will reduce SOx emissions from international maritime shipping from 2020, emissions remain, however, much higher than other transport modes. After 2030, NO_x emissions from maritime shipping are set to exceed those from all EU land-based sources[9].

The stricter requirements on sulphur content of marine fuels that have been agreed by the IMO will cut SOx emissions 50-80 percent up to 2030, but in the absence of additional regulations, emissions will rebound afterwards. Without introducing additional measures, CO_2, Sox, PM and NO_x emissions are expected to further increase the latter emissions becoming significantly higher than those emitted by land sources. SOx Emission Control Areas (ECAs) have been established in the Baltic and North Sea in early 2000 following the request of the bordering states. Since 2015 ships sailing in these areas require an even higher level of SOx reduction. A further example is the establishment of an ECA in the Mediterranean Sea for SO_x under IMO rules, from 1st May 2025 onwards[10]. Finally, preparations are ongoing by the littoral states of the Northeast Atlantic, with the support of the European Commission, in view of requesting the IMO to establish an ECA for SOx and NOx in relevant sea waters. This would deliver on the Sustainable and Smart Mobility Strategy objective to creating ECAs in all EU waters.

The IMO has designated the North Sea and the

Baltic Sea also as a NOx Emission Control Area (NECA) starting from January 1, 2021 which applies only to new ships. A period of at least 5 years for the fleet renewal is needed before the regulation will show its full effect, according to HELCOM (Baltic Marine Environment Protection Commission)[11]. This illustrated the need at the time for sustainable retrofittable technologies and alternative fuels as an essential tool to meet policy objectives. In 2023 studies and emission monitoring shared with the IMO have shown that NECA engines are not compliant at low engine loads. This raises the need for more research both from the propulsion side, the optimal functioning of NOx abatement systems as well as monitoring of emissions on board and in ports and coastlines through remote sensing technologies in support of enforcement also in view of upcoming regulatory developments at the IMO from 2024 onward.

Inland waterway transport is not in the remit of the IMO and is covered by EU and regional legislation with different governance and legislation. It is a significant contributor to air pollution in cities along rivers. Passing through the centre of towns and cities, a large inland waterway vessel may produce approximately 11,000 kg of NO_x per year. Other transport modes are becoming cleaner and inland waterway transport faces the risk of falling behind, e.g. a modern EURO VI truck emits approximately 10 times less NO_x per t/km than an inland waterway vessel. However, inland waterway transport has great potential both for long distance and urban logistics, free capacities can be mobilised, and in some regions new markets can be identified. This process shall go hand-in-hand with further greening the IWT vessel engines. The NRMM regulation[12] addresses this topic and cuts these emissions significantly. The regulation has entered into force for new engines in inland vessels. However, these engines are not yet widely available and retrofittable technologies for the existing fleet are an essential tool to meet the policy objectives given the long lifetime of vessels and their engines.

Water pollution

Today's fuel options are drivers of water pollution, but there must be science-driven assessment of the environmental risks of the forthcoming fuel portfolio.

As an alternative to using cleaner low Sulphur fuels to reduce SO_x emissions, IMO and EU Sulphur rules allow ships to be fitted with an after treatment device as an alternative compliance method, a so-called scrubber or exhaust gas cleaning systems. A scrubber effectively captures the SO_x from the emissions and either stores the residue in a tank (closed loop) or dilutes and discharges them into the sea (open loop). The use of open-loop scrubbers is far less expensive compared to fuel-based compliance and the ship owner is less reliant on port reception facilities to dispose of the scrubber residues. But scrubber discharge waters into the sea have harmful impacts on the marine environment according to state-of-the-art studies. With the introduction of lower Sulphur limits applicable to fuels from 2020, more than 4,000 mainly open loop systems have been fitted to date, which is a source of serious environmental concern. This is why the IMO started to work in 2017 on the evaluation and harmonization of rules and guidance on the scrubber discharge waters into the aquatic environment including conditions and areas. This led to the adoption of 2022 Impact and risk assessment guidelines which set the basis for the development of a possible regulatory framework to prohibit or restrict discharge waters planned at the IMO in 2024.

Ballast water is essential for the safe operation of ships, ensuring stability and structural integrity, as well as safe manoeuvring. However, ballast water can become a vector for the transfer of invasive organisms from one part of the world to another, causing damage and impacting natural ecosystems and the economy.

Ship hulls and marine structures attract sea life which attaches itself to the ship, thereby increasing friction, slowing down the ship and increasing fuel consumption. The fuel savings made by limiting the adhesion of marine organisms using hull coatings has been estimated to reduce GHG emissions by 384 million and SO_2 by 3.6 million tons[13]. However, the antifouling compounds used may leach harmful substances into the sea, damaging the environment and possibly entering the food chain.

Underwater noise pollution

Underwater noise from maritime and inland shipping has a negative impact on the marine environment, in particular on marine biodiversity, including marine mammals. As such, levels of underwater noise are indicators of good environmental status within the scope of the European marine strategy framework directive[14]

To deliver on the Zero Pollution Action Plan, in 2022 the EU has adopted threshold value for under water noise under the MSFD to be achieved by the EU MS by adopting their marine strategies to that end. Underwater radiated noise is also addressed at the global level within the non-mandatory guidelines on ship-quieting measures issued by the IMO in 2014 and revised in 2023 accompanied by an ambition work plan including an experience building phase, sharing of best practice, incentivization and exploiting synergies with energy efficiency development.

The characteristics of the underwater radiated noise from a vessel depend on multiple factors such as size, speed, horsepower, propeller depth, etc. Levels of noise vary within a ship class due to variability in design, maintenance and operational parameters, such as speed and displacement.

Problem drivers

The contribution of shipping to the problems of climate change, air pollution and degradation of waters is difficult to tackle. Several factors contribute to a lack of change.

- Waterborne transport is an international sector by nature and solutions will have to be supported internationally.
- Large ships traveling over long distances require large amounts of energy;
- Alternative fuels have to be available and affordable in large amounts, and be available in ports around the world;
- The diversity of the sector and the long lifetime of vessels do not allow for standardised technologies and slows down the uptake of newsolutions.

International sector

The maritime transport sector is an international sector. 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[15]. Not only do ships sail in international waters, but the entire maritime shipping sector is international. Maritime transport is therefore regulated on many different levels: international, European, regional, national and local. This complex landscape of policies, rules and regulations complicates the transition to zero-emission waterborne transport.

Agreements on new rules or on permission for using new technology has to be reached at these different levels. This contributes to the sector being cautious and aiming for incremental changes.

Inland waterway transport also plays a role within this international trade and holds an international character, as shown in particular by Rhine or Danube navigation. In addition, for inland waterway transport, large European maritime ports play a key role as an open door to trade outside the European hinterland, therefore offering a large and international transport market for inland waterway transport.

High energy need

Waterborne transport is the most energy-efficient mode of transport per ton-kilometre. This efficiency is partly achieved by the economy of scale compared to other transport means: ships are much larger and, as there are fewer size constraints compared to ground transport, are getting bigger and therefore increasingly efficient per ton- kilometre. For

> Example of the international character of the maritime transport sector
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> A container ship, built in China, equipped with European engines, might be sailing from Shanghai to Rotterdam. The ship is flagged in Panama, insured in London and sails with crew from the Philippines and officers from Russia. The ship is managed from Liberia, chartered from France, owned by a German shipowner and fuelled in Singapore.

example, the largest maritime container vessel now carries more than 24,000 TEU, whereas in the late 2010s this was still less than 20,000 TEU. One single large container vessel represents the equivalent of 10,000 to 12,000 trailer trucks. The largest inland container vessels also carry more than 600 TEU. Cruise ships have doubled the maximum number of passengers over the last 20 years, along with a steady growth of average ship capacity (+64%) in the same time-line. However, with this growth in vessel size, the total power needed to propel the ship inevitably increases. For the largest ships, engines of up to 70 MW are used. Given the long sailing distance from China to Europe, a ship may be at sea for 4 weeks before entering a port again. The total energy needed for such a trip would add up to almost 50 GWh. This very high energy need places requirements on the fuel that can be stored onboard the vessel.

The transition of the entire waterborne transport fleet to a zero-emission mode of transport is even more challenging. The energy need per ship is very high, but taking all vessels in the world's fleet into account would require the generation of a huge amount of energy from alternative fuels. This energy need has hindered initiatives to enable the transition of the sector, as many feared that the renewable energy available would not be sufficient to sustain the waterborne transport mode on top of the societal need for green onshore power.

However, the introduction of a Life Cycle GHG emissions assessment from use of marine fuels brought a disruptive change to this. High energy content fuels can now be used, which have an overall LCA GHG WtW minimum impact, and can de-facto get to net-zero GHG emissions.

Demand for alternative energy sources to be used in the waterborne transport sector are projected to be high. However, this should not hinder the decarbonization of other sectors. Moreover, additionality and avoided displacement of emissions on land would be relevant aspects to consider.

Lack of sustainable alternative fuels

Although the regulatory framework has just been published to support the economic viability of sustainable alternative fuels, there is no cost effective and widely available sustainable alternative for the fossil fuels used in waterborne transport for the short term. Possible sustainable alternative fuels include advanced biofuels (either bioliquids or biogases), as well as green synthetic fuels (ammonia, methanol) based on hydrogen produced from renewable electricity and either captured carbon dioxide (to produce fuels such as synthesized forms of diesel, methane or methanol) or atmospheric nitrogen (to produce ammonia).

Different fuels have different pros and cons: bio and synthetic carbon containing fuels have a higher energy density and are compatible with current bunkering infrastructure and safety rules, but can have sustainability issues and generate carbon dioxide when used, although due to using non fossil carbon their full lifecycle emissions can be low. Methane based gases, even from renewable sources, in the case of "methane slip" still contribute to climate change. Green Hydrogen and Green ammonia produce zero carbon dioxide emission but have a much lower energy density than hydrocarbon fuels. Both hydrogen and ammonia also need new safety approaches and rules as well as a new bunkering infrastructure. None of these fuels are currently available in large quantities around the world.

Furthermore, for synthesized fuels (hydrogen, ammonia, methanol, diesel etc.) there are large differences in the energy conversion of efficiency for the different fuel options and these are likely to be reflected in cost. Substantial investment in renewable energy production infrastructure is needed to support manufacturing at scale.

Another complicating factor is that fuel preference will likely be regional. Some countries, like Norway, are promoting hydrogen (and potentially it's derivatives) as fuel for short-sea shipping. In part, this is due to the large availability of renewable electricity in Norway. Other regions have better access to sustainable biomass and favour biofuels or biomass derived fuels, such as bio-methanol. Having different fuels in different regions might require ships to be capable of sailing on several fuels depending on the expected area of operation of thevessel. Certain fuels require different fuel containment systems, which affects the ships internal lay-out. This has hindered the transition to alternative fuels.

It is therefore likely that the ultimate choice of one or more sustainable alternative fuels in waterborne transport will boil down to the particular social, economic, technical and environmental implications linked to each fuel option.

Lack of infrastructure

Port facilities are essential in the operations of vessels. Dedicated bunker vessels supply new fuel to ships in ports or at anchor. With the transition to alternative fuels and electrification, new bunker vessels have to be developed for ports and new bunkering and energy infrastructure is needed alongside European rivers and ports. The bunkering technology has to be adapted to each specific alternative fuel. Cryogenic fuels such as liquefied hydrogen (-260degC) or LNG (-162decC) require specialised technologies and safety procedures. Other alternative fuels, other than ammonia, may be bunkered in similar processes to fossil fuels.

With the electrification of vessels, the need arises for high-power charging facilities and auxiliary power supply systems, including possible battery swapping technology. At this moment, ports offer limited facilities which are not widely used for cold ironing: using shore-supplied electricity for operating the vessel while at quay. However, obligations for infrastructure development are now included in the Alternative Fuels Infrastructure Regulation, matched by requirements for ships to connect in the FuelEU Maritime regulation.

But charging of increasingly large onboard batteries for operations at sea will require much larger electricity supplies. Technologies for this fast-charging at high power is being developed. Problems still exist with the safe and reliable integration of high power charging with the electric grid in a port region.

Diversity of the sector

The diversity of the sector for waterborne transport is hindering the change towards zero-emission transport. The sector comprises shipyards, ship owners, maritime equipment manufacturers, flag states, waterway and port authorities and operators, river commissions, classification societies, energy companies, infrastructure companies, environmental non-profit organisations, research institutes, universities, citizens' associations, as well as various competent authorities, banks, insurance companies, international and regional organizations and initiatives, etc. Many initiatives are currently being taken, but the solution found for one ship does not necessarily match the requirements for another ship. There is a lack of a common innovation agenda that takes into account the differentiated needs and possibilities of the waterborne transport sector.

Variations exist within each segment of the waterborne transport sector. Business models also show a wide variety both within and between segments. These need to be taken into account as drivers or inhibitors of the application and adoption of new technologies and concepts, sharing both the (investment) burden and the economic benefit of the adaptation of green technologies throughout the value chain. The most widely used business model in shipping, chartering ships, can be an impediment to implementing new technical solutions due to split incentives between the shipowner and operator (user).

Age of vessels

Considering the average age of 21 years of a seagoing ship, the first radically changed new-build vessels need to be deployed within 10 years, with technology developed during the period of Horizon Europe. In addition, the relatively low turnover of the fleet requires zero-emission retrofit solutions to be deployed as soon as possible.

This need is even more urgent for inland navigation, where there has been a low level of reinvestment since the average lifetime of inland vessels is even longer (40-60 years), leading to the existence of a large number of outdated vessels with lower energy efficiency and larger environmental impact. Indeed, for inland waterway vessels, the western European market is characterized by a relatively old fleet, often family-owned. 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[16].

Overall vision 2050 for the waterborne transport sector

For Europe to lead and accelerate the transformation of the global waterborne transport sector into a zero-emission mode of transport which has eliminated all harmful environmental emissions (including greenhouse gas emissions, as well as air and water pollutants, including (underwater) noise through innovative ship technologies and operations which underpin European growth and employment.

Objectives of the Partnership

General objective of the Partnership on zero-emission waterborne transport is:

To provide and demonstrate zero-emission solutions for all main ship types and services before 2030, which will enable zero-emission waterborne transport before 2050.

Against this background, the specific scientific objective of the Partnership to be achieved before 2030, is:

To develop and demonstrate deployable technological solutions which will be applicable for the decarbonisation and the elimination of other harmfull emissions of main ship types and services.

The specific economic objective:

By 2030, implementation of economically viable European new technologies and concepts regarding zero-emission waterborne transport, to strengthen thecompetitiveness of European industries in growing green ship technology markets and provide the capability to re-enter markets presently dominated by Europe's competitors.

And the specific societal objectives are:

To facilitate the development and implementation of regulations and policies at national and international level, including the development of standards to enable the implementation of technological solutions for zero-emission waterborne transport by 2030 at the latest.

To facilitate the uptake of innovative zero-emission waterborne transport technologies and solutions within the European waterborne sector, supporting economic growth and European employment.

Operational objectives of the Partnership

The objectives has been broken down into a series of operational objectives that are dedicated to the operation of the Partnership. These operational objectives are organised with a view to the elimination of GHG emissions, air pollution and water pollution.

Elimination of GHG emissions

- To develop and demonstrate solutions for the use of climate-neutral, sustainable alternative fuels applicable to ships with high energy demand (e.g. long distance shipping) before 2030;
- To develop and demonstrate before 2030 solutions for the integration of high-capacity batteries solutions as single energy source for short- distance shipping (up to 150 to 200 nautical miles), as an additional energy source for all main ship types in environ-mentally sensitive areas, and to increase operational efficiency;
- To develop and demonstrate solutions to be able to reduce the fuel consumption of waterborne transport, including by the use of non-fuel based propulsion (such as wind), by at least 55% before 2030, compared to 2008;
- To develop and demonstrate solutions for port based supply infrastructure (i.e. infrastructure for bunkering of alternative fuels and electricity) needed to enable zero-emission waterborne transport, to be implemented by 2030 at the latest;
- To develop solutions for clean and climate-neutral, climate-resilient inland waterway vessels before 2030.

Elimination of air pollution

- To develop and demonstrate solutions to cut coastal and inland pollution to air from inland waterway transport and maritime shipping by at least 50% by 2030, compared to current levels

Elimination of water pollution

- To develop and demonstrate solutions to eliminate pollution to water (including harmful underwater noise) from ships, by 2030.

Commitment of the Waterborne Transport Sector

In January 2019 the Waterborne Technology Platform launched its vision regarding zero-emission waterborne transport in 2050[17], whilst – in addition – , an emerging number of maritime and inland shipowners have set net-zero CO2 emissions in 2050 or earlier[18] as their target[19]. The European waterborne transport sector welcomes the European Green Deal and is committed to reaching its objectives[20]. An initial group of shipowners have indicated that their fleet will be emission free in 2050, stating that RD&I will be key to reaching this objective[21]. The European maritime technology sector annually invests 8-9% of its turnover in RD&I[22] and is fully committed to develop the solutions needed and to invest accordingly[23].

Whilst putting forward clear environmental and climate-neutral targets, at the same time Europe needs to guarantee the waterborne transport sector's long-term economic resilience as global competition intensifies[24]. Seizing opportunities to boost Europe's global competitiveness, as well as developments at home to become frontrunners in low-carbon and climate-proof technologies and embracing digitalisation, whilst also implementing market mechanisms to promote their take up, is key.

Scale of resources

The waterborne transport sector is fully committed to the objectives of the Partnership: zero-emission waterborne transport is a necessity for society, crucial for the sector to remain leading as a mode of transport, and an important driver for innovation and market opportunities.

The assessment of the Partnership is that the achievement of the Partnership's objectives is estimated to require an overall mobilisation of resources of approximately € 3.8 Billion (including 530 Million Horizon Europe co-financing) towards research, innovation and other activities to achieve the objectives of the Partnership. This goal will be achieved by leveraging the additional in kind contributions from the industry side of six to seven times.

Budgeted Horizon Europe co financing allocated towards the activities of the partnership to date has been €189.5 M for years 2021/22 and €153.2 M for 2023/24. Consequently the budget remaining from the foreseen €530 M of EU co funding is €187.3M for the years 2025 to 2027.

Resources contributed by the private side will include:

- Contributions from the members participating in projects funded by the Union contributions (on the basis of the non-reimbursed eligible costs);
- In-kind contributions to Additional Activities in the scope of the SRIA not covered by Union funding;
- Investments in operational activities that is spent beyond the work that is foreseen in the SRIA and aligned with the objectives of the Partnership.

Scope of Additional Activities

Additional in-kind contributions are envisaged to include:

a) Upscaling of prototypical low emission systems in new-built ships or retrofitting of existing ones;

b) Providing ships, test facilities, port and inland waterway facilities, GHG neutral fuels etc. necessary for the demonstration and development of the innovative technologies as referred to within the actions foreseen in the SRIA.

c) Industrial RD&I programs of the members contributing to the objectives of the Partnership;

d) Demonstrating that the results are achievable in a repetitive manner and thus qualifying the new solution;

e) Implementing these new solutions in larger operational environments to prove their robustness;

f) Developing proof of concept, novelty and feasibility studies and potential customer interviews to add value on the potential business case to ensure uptake of results from projects supported by the Partnership into products. Including for example: design, on-board configuration and integration of prototypical

g) low emission systems aiming at developing economies of scale;

h) Training, education and other activities outside of the projects which support the uptake of the solutions developed;

i) Development and execution of the communication and dissemination plan (including social media, press releases, scientific publications, maritime pitching days, one-to-onemeetings, fairs, workshops etc.);

j) Contribute to development of standards to ensure that they will be in line with the technological developments and to ensure Intellectual Property Rights protection;

k) Contributions to the development of new classification rules and regulations for design, constructions and operation necessary for the innovative technologies and actions referred towithin the SRIA.

l) Ensuring synergies with relevant initiatives, such as for example the Innovation Fund, Connecting Europe Facility, Pact for Skills and the Erasmus+ programme.

Investments in operational activities

Investments in operational activities may include:

a) Designing new training programs for amongst others crew managing new high tech zero- emission ships using new fuels/technologies and workers manufacturing the new technologies required for zero-emission ships;

b) Assessment of the market size dimension of innovative technologies for different operations;

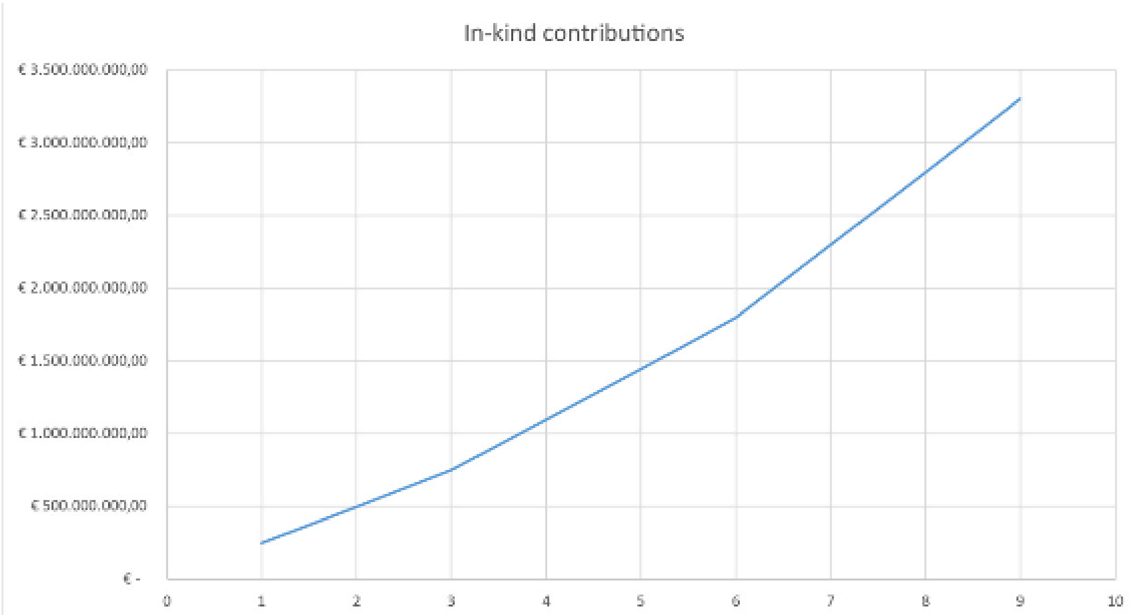
c) Commercial operations utilising solutions developed by the Partnership.

Contribution from industry partners

In total, the value of additional in-kind contributions committed from the Partners other than the union is up to €3.3. Billion for the period 2021- 2030, as laid down in the Memorandum of Understand between the European Commission and the Waterborne Technology Platform.

These activities often include more than one additional activity as identified in aforementioned scope of activities, and range from: operational measures, exploratory research addressing ship concepts, propulsion systems, greening of engines,electrification, the development of rules and regulations, testing, upscaling, deployment, as well as the execution of internal RD&I programmes that are aligned with the objectives of the Partnership.

During the lifetime of the Partnership, these additional activities will be defined as an integral part of the SRIA within its regular updates. Currently, the Additionl Activities executed by the private side amount to 1 Billion from the start until the end of 2022, well above the investments foreseen when launching the Partnership.



In-kind contributions
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TYPE OF COST	INDICATIVE ESTIMATE
Contributions from partners to projects not funded by the EU	5%
Upscaling of prototypical low emission systems in new-built ships or retrofitting of existing ones	15%
Providing ships, test facilities, port and inland waterway facilities, GHG neutral fuels etc.	5%
Industrial RD&I programs of the members contributing to the objectives of the Partnership	20%
Demonstrating that the results are achievable in a repetitive manner and thus qualifying the new solution	20%
Implementing these new solutions in larger operational environments to prove their robustness	10%
Developing proof of concept, novelty and feasibility studies and potential customer interviews to add value on the potential business case to ensure uptake of results from projects supported by the Partnership into products	9%
Training, education and other activities outside of the projects which support the uptake of the solutions developed	5%
Development and execution of the communication and dissemination plan	1%
Contribute to the development of standards to ensure that the standards will be in line with the technological developments and to ensure IPR protection	5%
Contribute to the development of new classification rules and regulations for design, construction and operation	5%
TOTAL	€3,300 M: 100%

Additional investment

The Partnership also aims to mobilise additional investments through the use of finance investment mechanisms including, for example, any emerging climate change investment banks, innovation investment guarantees and performance based schemes where innovative technology is leased on the basis of assured performance guarantees.

In addition to this, the Partnership's activities will mobilise further resources within the Member States, several of which have indicated that they expect to orientate their national RD&I programmes to ensure complementarity with the Partnership and further increase leverage. Also, mechanisms supporting first of a kind deployment to provide market reassurance will be implemented to complement the outcomes from the Partnership. These include those available from private foundations, as well as European instruments such as CEF, EU Innovation Fund, Regional Funds, etc.

Furthermore, members of the Partnership will provide resources to ensure a proper staffing of the Secretariat of the Partnership, as well as other bodies needed to execute the Partnership's tasks (contribution in kind or in cash).

Finally, the deployment of technologies and concepts requires a patchwork of regulatory and financial incentives in order to stimulate first movers. For this reason, it is vital that the Partnership establishes close links with competent administrations to ensure that the necessary rules and regulations are developed in order to ensure market introduction is facilitated. The partners in the Partnership will have an active role in providing support for the development of the required policies and regulations. In addition, synergies with regional, national and European funding schemes for first movers should be ensured.

PART 2: RESEARCH AND INNOVATION STRATEGY

This chapter describes how the objectives of the Partnership on Zero-Emission Waterborne Transport can be achieved. After outlining the overall strategy, a vision of what the future fleet could look like and the zero-emission technologies which are most likely to achieve this vision for the relevant ship types are described. Finally, the objectives described in Part 1 are linked to the research Activities being proposed in this SRIA, followed by a more detailed description of the Activities.

R&I strategy

Strategic implementation approach

Europe's waterborne transport value chain is a frontrunner in the development of innovative technological solutions and is engaged in implementing technologies to reduce and ultimately eliminate GHG and air and water pollutant emissions from waterborne transport. New-build short-sea vessels and high-end complex ships (such as cruises, ferry passenger ships and other complex special ships), as well as retrofitting with energy efficiency solutions, offer Europe the most suitable and practical opportunity to develop, test and demonstrate the new emission reduction technologies which can also be applied to other market segments such as container ships, bulkers, tankers etc. Therefore, the Partnership is creating a critical mass for the development and demonstration of innovative solutions and a win-win scenario in which emissions are substantially reduced in European and global waterborne transport services, whilst reinforcing the competitiveness of the European technological industrial base in its competition on a global scale and helping to achieve the ambition of zero- emission waterborne transport by 2050.

Within the first two years of the Partnership, a combination of lower TRL activities set the foundation for later development, as well as potential "quick wins" with high short-term environmental impact, reinforcing Europe's competitiveness as it emerged from the consequence of the COVID-19 pandemic has been undertaken. Examples of lower TRL include proving the feasibility and safety of emerging, less market ready, alternative fuels such as ammonia, whilst higher TRL "quick wins" include solutions for electrification and reducing emissions to air. As it was originally planned, now that the Partnership is approaching its 3rd year, the research will focus on higher TRL developments which will enable demonstrations from 2025 onwards. An overview of the topics included in the work programme of Horizon Europe for the period 2021 – 2024 as well as priorities for 2025 and beyond is included in the relevant part of the chapter Activities.

The Strategic RD&I programme provides scientifically founded orientations to enable informed choices concerning the optimal pathway to achieve zero-emission solutions that are climate neutral and which eliminate harmful pollution to air and water. These will be appropriate for the main ship types and services which have the largest impacts on pollution and GHG emissions, including large intercontinental merchant ships, short sea vessels, inland waterway transport and passenger vessels.

Building upon the activities of the first four years, some technologies can and will already be demonstrated in the programming period 2025 as well as 2026 and 2027. The developments starting of at lower TRL have been more developed within the first calls and have been consolidated into smaller scale demonstrations within the 2023/2024 work programme. This included smaller scale applications such as towards inland waterway vessels, however demonstrations on other ship types are currently being conducted as well.

The programme will aim to conclude in 2027 with demonstrators in the final two years, which will prove the viability of the developed solutions for all main ship types and services, meeting the Partnerships overall objective. Whilst some solutions may, for example, be applicable to large merchant ships such as container vessels, demonstrations could take place in the context of a different, but similarly relevant, ship type. For example, cruise ships have a long range and employ energy systems of similar scale to the large merchant ships.

In line with this strategy, detailed RD&I activities are developed in this SRIA on a rolling two-year basis and are reviewed annually. The SRIA is developed in the Partnership jointly between the Partnership and the European Commission, in consultation with EU Member States and Horizon Europe Associated Countries. A transparent process has been followed to update the strategy of the partnership to match the current policy goals and technological state-of-the-art, including an opportunity for the general public to express their views, as well as stakeholders, industry, Member States and societal interests. Throughout this process, the Member States, Associated Countries and several European Commission services have been and will be involved. This ensures avoiding unnecessary duplication with national programmes and enables synergies between national programmes, policy developments and Horizon Europe.

Implementation pathways

Greening the fleet has two aspects: while a certain part of the operational fleet will be converted more quickly through retrofitting, it is highly likely that another segment of the service provided by the industry will be replaced by new-builds. 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[25].

At the same time, new-builds will need to be ready to become zero emission as soon as possible, meaning that they need to be compatible or adaptable so as to be used with a range of potential sustainable alternative fuels, be optimised for efficiency (including digital), potentially deploy electric and/or battery drives, as well as renewable energy assistance. 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.

The most relevant solution will need to be chosen according to ship size, the type of traffic it is in, its energy demand, required operating range, the regional energy carriers available and bunkering infrastructure, potentially emerging legislation, policies and governance. Integrated lighthouse projects will show best practice examples to be copied by early adopters.

An important factor in the selection and uptake of technologies in waterborne transport, (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: 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 more easily adapt to each other; for instance, fuel choices, bunkering and recharging infrastructure can be aligned. With tramp services, a ship calls at many ports, often at short notice, meaning that the ship’s next destination can change overnight and alignment within every port is not possible. If ports worldwide cannot ensure the availability of their fuels, these ships either have to be able to carry relatively large amounts of fuel or electricity or have to be equipped with multi-fuel flexible energy systems.

At the same time, there are many other types of vessels, such as passenger vessels or high complex work vessels (e.g. dredging vessels, offshore construction vessels, windfarm service operation vessels). These vessel types often have a high energy demand while, in some cases, operating worldwide.

In the following sections, examples of potential pathways for the adoption of zero-emission technologies per ship category are provided.

High-end complex ships offer Europe, given its expertise, the most suitable fit to develop, test and demonstrate new emission reduction technologies. Europe has a competitive advantage in these ship types over those built by other continents. Cruise ships, for example, are a large segment for Europe and are early adopters of green technologies, as well as having market forces for its adoption. Ferries are also important for Europe and they are more suited to 100% electrification technology between fixed points. Offshore vessels built in Europe facilitate the development of offshore renewable energy. They often need a larger amount of power, but for a shorter duration than long-distance shipping.

Short-sea ships need less endurance than the intercontinental services where the volume and fuel capacity is more important. In addition, it is easier to provide specialist infrastructure.

For the majority of the existing long-distance, intercontinental cargo fleet, which typically bunker 1,000 of tons of fuel with several weeks of autonomy, future green propulsion is expected to be initially based on internal combustion engines operating on sustainable fuels, possibly assisted by wind-propulsion support, with a potential ultimate transition to fuel cells utilizing green hydrogen-based fuels. These ships are delivering the biggest part of the world's transport provision and regardless of the fact that they are the most energy efficient in terms of ton kilometres, the sheer amount of cargo they transport and the fuel they burn makes them by far the largest waterborne transport CO_2 producer and polluter and therefore the first target for greening.

The obvious solution for these existing ships is sustainable e-fuels and bio-fuels, in combination and separately, together with substantial operational and technical efficiency improvement and cleaner energy converters, as well as possibly renewable energies such as wind propulsion or solar electricity generated on board. The industry has already started to test the different options to be applied. Europe's supply industry is key to provide the technology for retrofitting, while the yards are preparing for the system integration and conversion work to come. This approach makes it possible to gradually grow into the green future by modifying existing engines and allowing for the co- combusting of existing fossil fuels with sustainable bio, hydrogen-based or e-fuels depending on availability, cost and performance, while reducing the proportions of fossil fuel. The experience from retrofits to dual-fuel systems will enable the industry to further improve the performance of dual-fuel engines. Newbuilds will benefit from these developments, considering multi-fuel tank systems, dual fuel engines, electric/hybrid drives and gen sets with hybridised energy storage, rather than large monolithic engines with direct mechanical drives which are typical today. In addition, more advanced efficiency measures are expected to find their place in long distance cargo fleets, e.g. waste heat recovery, smart energy grids/energy management, speed-adapted hydrodynamics, renewable energies such as wind and solar, as well as innovative solutions for reduction in hydrodynamic friction.

Inland Waterway Transport is characterised by vessels with modest power demands compared to maritime shipping, as well as being close to land-based infrastructures and operating within a regulatory regime which is less complex than international shipping. As a consequence, inland waterway transport offers valuable opportunities to more easily demonstrate innovative technologies.

The expected immediate focus will be on retrofitting to improve efficiency and electrification and usage of drop-in bio-fuels such as HVO and Bio- LNG. Due to the age of the fleet and the comparable modest conversion costs the feasible options range from changing of fuel storage and engine modifications to enable the use of sustainable alternative fuels, to the replacement of the entire propulsion system to battery electric or fuel cells. Inland waterway transport could also benefit from containerised solutions for fuels and batteries.

The new builds do have similar options and in addition they will benefit from energy efficiency measures such as large diameter propellers, optimised hull design, air lubrication and arrangement of tank and cargo holds. IWT is also one of the candidates for the direct use of hydrogen in combination with a dedicated network of fueling stations, which could be shared with the road fleet. The high variety of meaningful solutions, combined with the moderate cost of conversion using new innovations, make inland waterway transport implementations good examples for "marinizing" solutions from land or other modes of transport prior to later upscaling to, for example, short-sea-shipping and ferries. Cruise ships are a high technology, high added value product which is key for the European waterborne manufacturing industry. They have been technology leaders for the industry, in particular for green waterborne transport, since their customers demand sustainable transport beyond the standards required by authorities and the vessels operate within the world's most environmentally sensitive regions.

Furthermore, cruise ships are characterised by requiring high amounts of energy, including large hotel loads which are present at all times and can be larger than the propulsive load. In the shorter term, retrofitting - to enable the use of a range of potential sustainable alternative fuels, in combination and ultimately as a single fuel - as well as electrical supplies from shore, is a logical choice. Due to their electric drive system, the extension to electric energy storage, as well as energy harvesting for their hotel load, will need to be integrated into their energy grids. For the next generation of cruisers, the most complex combinations are on the agenda; fuel cells in combination with batteries and combustion engines, energy harvesting, electricity storage and propulsion support with wind assistance are the topics which will provide manifold input for innovation transfer into other ship-types. The development of smart interaction with ports for cold ironing and alternative fuel supply, for example, will deliver sustainable solutions as well as harmonisation among the ports of call for cruise ships. Ferries operate between fixed points and are the most suitable application to become fully electric with completely zero emissions. In this respect, they play a leading role when it comes to greening. Ferries operating in Europe covering a wide range of services, from urban/harbour passenger ferries with a range of a few miles, to large inter island RoPax ferries with ranges of 50 to 200 nautical miles with the longest ferry routes being as much as 500 nautical miles. For retrofitting, as well as newbuilds and ferries with a range of up to 200 nautical miles the challenge will be between full battery electric, fuel cells and ICE powered with alternative fuels, with the regional conditions and their policy priorities pushing one or the other type of solution to the forefront. Ferries with significant hotel loads will be candidates to be early adopters of fuel cells. The requirements regarding zero emissions during approach and harbour stay will push hybrid solutions with battery capacities to allow full battery electric transit for reduced noise and emissions. For the long-distance ferries, ICEs with alternative fuels will be the most competitive solution, supported by energy efficiency measures and smart power supply/buffer in port facilities. The Short Sea Shipping fleet comprises all types of cargo vessels that operate coastal and shorter distance services which are typically up to two or three days .

Compared to long distance shipping, much less fuel is needed between port calls and the quantity of fuel which can be held on board is large compared to the needs for the voyage. As a consequence, the energy density of fuels is a secondary consideration and a wider range of sustainable alternative fuels can be more easily deployed. Many of these ships have been, and will be, built in Europe, making this segment particularly important for both the development of tailored innovative solutions, as well as the introduction of fully fledged implementations from well to propeller. Upscaling of solutions from inland waterway transport to Short Sea Shipping (SSS) is an opportunity for European expertise to lead in design, production and operation and this has the potential to extend Europe's market share by technology leadership. SSS contains all of the ingredients for an entire European recipe, a zero- emission solution involving design, engineering, equipment production, shipbuilding, operation, ports and authorities to enable green shipping to grow from vision to fact. In this context, the retrofitting solutions with the lowest OPEX, due to the initial investment, and highest environmental impact will also enable the use of alternative fuels. Ships which are being ordered now should consider readiness for a range of sustainable fuel options, both individual and in combination, electrification, energy storage, shore electric connections and efficiency. For some services, a combination of ICE/electric drive, fuel cells, battery packs and renewable energies can be more quickly deployed than others.

Offshore vessels are a wide category of vessels that facilitate offshore installations, operations and maintenance. Historically, this segment has focussed on oil and gas installations. But with the onset of offshore renewable energies and other Blue Growth activities, this fleet has transformed into an enabler of sustainable growth.

Many of the offshore vessels are complex work vessels, such as installation vessels, dredgers and cable-laying vessels, which are capable of executing very accurate work. These types of vessels typically have high power needs, and a high energy consumption at peak moments. The technologies used for power generation are the same as those listed for transport vessels. As the offshore vessels are predominantly built in Europe,they are a suitable category for demonstration purposes.

The variety of operating profiles, as well as the size of ships, make offshore vessels ideal candidates for innovative solutions. Their close shore activities allow for more frequent fueling and thus low density energy carriers can be applied. Operating close to shore also means that it is necessary to reduce SOx and PM emissions to the maximum extent possible.

Designs from full electric to hydrogen powered fuel cell hybrid solutions will make sense in this context. Today, hybrid battery systems are already being cost effectively deployed and some of the newest vessels can perform their operations at sea with zero- emission technologies, while transit is still covered with conventional diesel-electric systems using low-sulfur marine diesel oil. The latest announcements on new ship designs for offshore vessels show an extended zero emission target range of up to two weeks operation time basedon a hybrid concept with 2MW hydrogen powered PEM fuel cells combined with 5,5MW diesel ICE.

Achieving the operational objectives

In the following paragraphs, the three main objectives, i.e. the elimination of GHG emissions, air pollutants and water pollutants, are presented with their underlying specific operational objectives addressed by a combination of activities in the Partnership.

Elimination of GHG emissions

The first operational objective relating to the elimination of GHG emissions concerns the use of sustainable alternative fuels on board. The fuel transition is paramount to the elimination of GHG emissions. Using fuels other than fossil fuels, applying a Life-Cycle framework for assessment of GHG emission from use of marine fuels, will make shipping a (net) zero-emission mode of transport.

One of our Activities is therefore fully dedicated to enabling the use of these new fuels on board. This includes special consideration for alternative fuels, including safe storage and usage on board ships and the conversion of the fuel into usable power through fuel cells, turbines or advanced internal combustion engines.

1. OPERATIONAL OBJECTIVE

To develop and demonstrate solutions for the use of climate-neutral, sustainable alternative fuels applicable to ships with high energy demand (e.g. long distance shipping)

Activities

- Use of sustainable alternative fuels
- Design & retrofitting
- Energy Efficiency
- Ports

- Use of alternative fuels on board
- Application to new and existing ships
- Range extension for new fuels
- Bunkering technologies

A crucial step for the fuel transition is the integration of all new technologies on board new and existing vessels. Especially for existing vessels, it is a challenge to integrate new fuels safely without completely overhauling the vessel and causing too much downtime. Modular approaches will be developed. These developments take place in the Activity on Design & Retrofitting.

The Activity on Energy Efficiency will facilitate the uptake of alternative fuels. It is expected that new alternative fuels will be (much) more expensive than the existing fossil fuels. Furthermore, storage of these new fuels on board will take up more space. Consequently, if the Energy Efficiency activity does not provide major breakthrough reduction steps in fuel consumption, either cargo load would have to be much decreased, or sailing range would be greatly limited. The need for energy from these fuels should therefore be limited as much as possible to facilitate the market uptake of alternative fuels.

The Activity on Ports is closely linked to reaching this objective. The safe bunkering of sustainable alternative fuels (and the development of standards) is, of course, crucial in developing and demonstrating these fuels on board.

The Electrification of ships is the second operational objective relating to the elimination of GHG emissions. Using electricity directly from a renewable source is more energy efficient than transferring the electricity into a fuel and carrying the fuel on board. But given the total amount of power needed on ships, it is envisaged that using batteries or other electricity storage cannot be the main power source for long-distance shipping. This will, however, be a solution for shorter ranges, from 150 to 200 nautical miles, for example. For longer ranges, it is envisaged that electrification will be used as an auxiliary power source, increasing the efficiency of the use of alternative fuels, for example, by supplying a portion of the electrical loads on board.

As with use of alternative fuels, a crucial step for the electrification of shipping is the integration of new technologies on board new and existing vessels. In new builds, the vessel's power train will be transformed into an electrical drive, instead of the conventional direct mechanical drive systems, to allow hybrid power architecture integrating different power production systems (ICE, fuel cell, battery). The electric drive systems will lead to higher controllability and higher dynamic performance, as well as higher efficiency. New internal layouts will mitigate the possible safety repercussions of using high-density batteries next to flammable alternative fuels. For existing vessels, modular set-ups will be developed to retrofit with electrical auxiliary power.

2. OPERATIONAL OBJECTIVE

To develop and demonstrate solutions for the integration of high-capacity batteries solutions as single energy source for short-distance shipping, as an additional energy source for all main ship types in environmentally sensitive areas

Activities

- Electrification
- Design & retrofitting
- Energy Efficiency
- Ports

- Use of batteries on board
- Application to new and existing ships
- Range extension for new fuels
- Fast recharging

The Activity on Energy Efficiency will facilitate the uptake of electrification by increasing the sailing range of electric vessels. The Activity on Ports is closely linked to achieving this objective. For smaller vessels or for auxiliary power, containerised battery solutions will be applied. The safe recharging of large amounts of electricity in a short time period is, of course, crucial in developing and demonstrating electrification of ships.

Increasing Energy Efficiency is the third operational objective relating to the elimination of GHG emissions. As explained above, the reduction of a ship's energy need is crucial in the implementation of alternative fuels or electrification. After all, the greenest form of energy is the energy that is not needed. Energy efficiency of ships will be improved by utilising renewable energy sources, such as wind and solar. We will also deliver solutions for the reduction of all energy needs (i.e. propulsion, equipment and hotel load) by means, for example, of optimisation of energy distribution, air lubrication, improved hydrodynamics, resistance-reducing coatings, recovering waste heat or thermal insulation. The new technologies will be integrated into designs of new vessels and by reftrofitting in the Activity on Design & Retrofitting.

The energy efficiency of ships in a fleet will be optimized in Digital Green. By applying big-data analysis to new data coming from increased digitisation, energy performance predictions will guide crew and on-shore fleet managers in making operational decisions to cut emissions.

3. OPERATIONAL OBJECTIVE

To develop and demonstrate solutions to be able to reduce the (alternative) fuel consumption of waterborne transport, including by the use of renewable energy, by al least 55%

Activities

- Energy Efficiency
- Design & retrofitting
- Digital green

- Reduce energy need for operations
- Integrating onboard
- Optimize operations

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The transition of waterborne transport into a net zero-emission mode of transport needs to be facilitated by ports and their infrastructure. The fourth operational objective is therefore related to the development and demonstration of port-based supply infrastructure.

In the Ports Activity we will develop and demonstrate standardized solutions for safe and efficient bunkering of new alternative fuels and for fast charging of high-power batteries. This is linked to the work in the Activity on the use of Sustainable Alternative Fuels on safe onboard storage of the fuels and to the work in the Activity on Electrification on the electrical grid and battery capacities on board.

4. OPERATIONAL OBJECTIVE

To develop and demonstrate solutions to be able to reduce the (alternative) fuel consumption of waterborne transport, including by the use of renewable energy, by al least 55%

Activities

- Energy Efficiency
- Design & retrofitting
- Digital green

▼

- Reduce energy need for operations
- Integrating on board
- Optimize operations

The fifth and final operational objective for the reduction of GHG emissions relates to the development of solutions for clean and climate resilient inland waterway vessels.

Many technologies that will be applicable to sea- going vessels are also applicable to inland vessels. However, the long lifetime of these vessels and the small fleet-size per owner mean that special attention must be given to the retrofitting of economically viable solutions. Given the relatively short range of many inland vessels, the electrification of the fleet is considered to be the most promising solution. The work in the Activity on Electrification will therefore pay special attention to the applicability of the solutions to this vessel type, e.g. containerised, exchangeable battery packs.

The Activity on Energy Efficiency will deliver solutions that are applicable to inland vessels similar to sea-going vessels. But the specific characteristics of inland navigation, such as extremely shallow water, continuous manoeuvring and lock operations, require special solutions.

Once again, retrofitting of new technologies into existing vessels is key in order to deliver this operational objective. The lengthy life span of inland vessels makes this an even greater challenge. Old ship designs and the integration of family living quarters require dedicated solutions with respect to safety and modularity.

5. OPERATIONAL OBJECTIVE

To develop solutions for clean and climate-neutral, climate-resilient inland waterway vessels.

Activities

- Use of sustainable alternative fuels
- Electrification
- Energy Efficiency
- Design and retrofitting

- Reduced emissions
- Zero emissions
- Reduced energy demand
- Retrofitting of existing fleet

Elimination of air pollution

The operational objective regarding the elimination of waterborne transport air polluting emissions is particularly important in coastal seas, in ports and on inland waterways, and especially in fragile ecosystems, such as arctic regions affected by black carbon.

The Activity on the use of Sustainable Alternative Fuels will develop hydrogen-based solutions which will eliminate air pollution. The Activity on Electrification will deliver solutions to enable coastal ships to sail fully electrically, thereby eliminating all air pollution. For larger vessels, batteries as auxiliary power or fuel cells will allow electrical sailing into ports or around pristine areas and will allow for considerable energy savings by optimal use of hybrid power generation systems. Inland vessels will be battery electrified or will sail on hydrogen-based fuel cells to completely eliminate their negative affect on air quality in cities along rivers.

The Activity on Energy Efficiency will deliver solutions to reduce the energy required for operating a vessel, thereby directly reducing potential air pollution and extending the range of electric sailing. New solutions will be developed for emission reduction on existing vessels still operating on fossil fuels by using clean combustion engines and after- treatment systems. The possibilities of retrofitting will be demonstrated in the Activity on Design & Retrofitting.

6. OPERATIONAL OBJECTIVE

To develop solutions for clean and climate-neutral, climate-resilient inland waterway vessels.

Activities

- Use of sustainable alternative fuels
- Electrification
- Energy Efficiency
- Design and retrofitting

- Reduced emissions
- Zero emissions
- Reduced energy demand
- Retrofitting of existing fleet

Elimination of water pollution

The operational objective to eliminate pollution to water from ships (including harmful underwater noise) is addressed by the Activities on the use of Sustainable Alternative Fuels, Electrification, Energy Efficiency and Design & Retrofitting.

Within Alternative Fuels, fuel cells will be demonstrated which use no lubricants and therefore eliminate the emissions of these chemicals.

Electrification contributes to the reduction of underwater noise by eliminating the engine noise. When smaller ships are fully electrified, the noisy internal combustion engine is removed from the noise sources. For larger vessels using electricity for auxiliary power, the internal combustion engine can be operated at lower power demand, or shut-down completely in sensitive marine environments, while still maintaining operational sailing speeds.

The Activity on Energy Efficiency will deliver solutions for new propulsion systems that will not only increase energy efficiency but also reduce noise. New solutions for air lubrication will be developed based on noise criteria. New coatings will not only lower the resistance but will also minimize the chemical release into water.

As with all new technologies being developed, it is crucial to integrate them into the design of new build vessels and into existing vessels by retrofitting. Solutions for the reduction of noise and for air lubrication will need to be applied to the existing fleet. Furthermore, new solutions could be developed to substantially remove pollution from scrubbers.

7. OPERATIONAL OBJECTIVE

To develop solutions for clean and climate-neutral, climate-resilient inland waterway vessels.

Activities

- Use of sustainable alternative fuels
- Electrification
- Energy Efficiency
- Design and retrofitting

- Reduced emissions
- Zero emissions
- Reduced energy demand
- Retrofitting of existing fleet

Activities

The technical content of this strategic research and innovation agenda is divided into six parallel activities. These activities are:

- Use of Sustainable Alternative Fuels[26]
- Electrification
- Energy Efficiency
- Design and Retrofitting
- Digital green
- Ports

The relationship between the Partnership's objectives and these Activities has been explained in the previous sections. In the next section, a brief presentation of each of the 6 activities and related sub activities will be given, with a description including the relevance concerning the Partnership's operational objectives and the innovative aspects with respect to the current state-of-the-art. Moreover, an overview of the topics for the first 4 years of Horizon Europe (short-term) as well as the priorities for 2025 and beyond, is provided.

USE OF SUSTAINABLE ALTERNATIVEFUELS

This activity concerns the development of ships with power generation systems that use Sustainable Alternative Fuels to reduce GHG and other emissions. These include dual/multi-fuel internal combustion engines, turbines and fuels cells and their seamless integration on board.

Introduction

While significant GHG emission reductions can be enabled by increased energy efficiency, electrification, renewable energy and operational improvements, the aim of achieving zero-emission waterborne operation for the entire fleet can only be met by the large-scale adoption of sustainable alternative fuels, allowing for net-zero Well-to-Wake emissions. Depending on the fuel type, many external constraints exist, from fuel availability to distribution network and adequate bunkering capacity in ports. Overcoming some of these constraints requires developments outside of the domain of waterborne transport, as well as a market which is driven by demand for the sustainable fuel by the waterborne fleet.

Currently, a limited set of technologies exist to store, distribute and convert some sustainable alternative fuels into useful work. Sustainable bio diesel, biomethane or biogas can be blended into LNG systems. and can be easily deployed in existing vessels depending on the configuration of their ICE setup. options such as the use of low flash point fuels and gaseous alternatives fuels (ammonia, methanol, hydrogen etc.) remain in development stages and pose integration challenges especially concerning safety. For implementation of these fuels in practice, a regulatory framework needs to be developed. The output of this activity will be threefold:

- An overall sustainable alternative fuel scenario for waterborne transport applications (including currently considered fuels based either on sustainable biomass or renewable electricity), monitoring the continuous ongoing developments in sustainable fuel supply and manufacture, taking into account the results of RD&I undertaken by the Partnership and allowing waterborne transport and other stakeholders to identify, compare and anticipate fuel availability, cost and benefits per waterborne transport segment and geographical area;
- the technical capabilities needed to integrate the use of sustainable alternative fuels on board;
- technologies for power conversion of these fuels in high-efficiency fuel flexible prime movers, including Internal Combustion Engines (reciprocal or continuous) and Fuel Cells.

Relevance

The introduction of the use of Sustainable Alternative Fuels in the waterborne transport domain will enable the final step towards zero-emission operation. In particular, this is true for ships that cannot be fully battery electrified, either because of their operational profile and the much lower energy density of batteries compared to liquid fuels combined with ICE, or of the legacy fleet and will therefore need retrofitting to meet the zero- emission target. Nevertheless, existing ships will have options to start the gradual phase-in "roadmap" for decarbonization, such as initially blending in of biofuels, use of OPS and possibly wind assisted propulsion. Although sustainable alternative fuels are associated with a high cost per avoided ton of CO2, they form an instrumental and unavoidable part of decarbonizing the waterborne transport domain. Since the waterborne transport sector has committed itself to decarbonize fully, a transition towards the use of sustainable alternative fuels is clearly required. At the same time, this opportunity should be taken to drastically reduce, or fully eradicate, air quality-related pollutant emissions (which are dominated by NOx, SOx and particulate matters), potential for reduction of Black Carbon emissions, and fuel-use related water pollution.

Fuels which need no exhaust gas after-treatment equipment such as scrubbers and SCR would be beneficial to achieve this goal. This is related to the fact that they reduce the (additional) cost of their implementation, thereby leading to a possible faster transition towards zero-emission operation, due to possibly lower investment risks and complexity, which could be potentially offset by lower fuel costs and increased availability.

In this respect, it is also imperative that we not only focus on carbon-free fuels, but also carbon-neutral fuels, agreeing on a life-cycle analysis framework that is able to assess different fuels on a Well-to-Wake basis regarding GHG emissions. Fuel pathways will be checked for regulatory acceptance in close dialogue with IMO and CESNI members, as well as be aligned with EU policies that have been set out in the Fit for 55 package concerning both maritime transport and inland waterway transport. We will develop the solutions with the overall lowest systemic cost for a healthier society with a green- skilled waterborne workforce, while keeping in mind the need to decrease specific barriers for their implementation. One example is a cross-link with Ports and their infrastructure for bunkering alternative fuels, as described in the activity dedicated to Ports.

Innovative aspect

In recent years, a large volume of research has been performed on development of sustainable alternative fuels. This includes research under the Horizon 2020 and the Partnership program calls in Horizon Europe, but also from national programs by Member States and research and pilots by the sector. Significant progress has been made on power conversion and safe storage on board for sustainable alternative fuels, such as, liquified biogas, bio diesel, methanol, ammonia and hydrogen. Hundreds of orders for vessels on methanol have been placed in different market segments but mainly for large vessels built in East Asia and less challenging to design with the safety requirements such as safety zones etc., which form a major challenge in smaller vessels or big passenger vessels such as ferries and cruise ships. Currently, there is no consensus on a single fuel to address all requirements and concerns. There is a need to develop better simulation tools to analyse the different sustainable energy options and the impact on the ship design with respect to safety, performance, capex and opex.

Fuel scenario

This line of activities includes developing a range of potential overall fuel scenarios for waterborne transport applications based on trends per waterborne transport segment and geographical area. Economic and safety requirements for onboard fuel storage, as well as handling and utilization technologies, will be based on this fuel scenario, taking into account the likely worldwide differences in fuel availability today and possibilities for the future, potential costs, their potential evolution and level of decarbonization. Given the complexity of the overall implementation of new fuel supply chains, which also implies infrastructure works in ports, roads, etc., it is of vital importance that collaboration with other Partnerships is established. This will enable us to take advantage of sectoral integration opportunities and satisfy common requirements.

During the past years, several dedicated scenario studies have been published or are ongoing. Under Horizon 2020 and the ZEWT Partnership program in Horizon Europe, the STEERER and NEEDS project were initiated, aimed at developing scenarios and strategies for the waterborne transport energy transition. Furthermore, in the port projects Magpie and Pioneers roadmaps are currently being developed, expected to finish by 2026. Several other scenario studies were performed by (amongst others) the waterborne transport sector itself. In addition, an economic assessment of greening technologies was performed for the inland waterway transport sector which resulted in transition pathways towards zero-emission in 2050. These results have been taken up by the CCNR and a roadmap has been developed. In the aforementioned studies, there is a general consensus on the types of candidate sustainable alternative fuels considered (bio/e-drop-in fuels, methane, methanol, ammonia and hydrogen). However, the studies come to different conclusions regarding the development and uptake of these fuels in the longer term. Main considerations are the speed of the technical development on the waterborne transport side (on-board storage and propulsion), the development of regulations and standards (at IMO, EC and CESNI) and development of availability (production, capacity, bunkering infrastructure), comparative price level and market factors (e.g. market stability, carbon pricing, etc.) of sustainable alternative fuels (both bio-fuel options and e-fuels). Due to the fast nature of developments within the sector, a frequent update of scenarios is foreseen as a continuous activity throughout the Partnership. Especially, this involves the cost and availability of different sustainable alternative fuels. For this, a link is needed to the other pillars (such as ports), other Partnerships (such as Clean Hydrogen Europe) and initiatives such as the Renewable and Low Carbon Fuel Alliance.

Fuel on board

We develop the technical capabilities and safety requirements to store large quantities of sustainable Alternative Fuels on board ships, taking into account the flexibility required due to the evolution of fuel types, local availability differences and cost scenarios. For this field several European projects have been initiated focusing on safe storage of a specific sustainable alternative fuel, including methanol (Fastwater) and ammonia (Engimmonia). Dedicated calls have been developed also for methanol and hydrogen (RH2IWER) in the Work Programme 2021 / 2022. This has been complemented by several national research programs and ship designs developed in industrial research. For methanol and drop-in-fuels, fast progress has been made and the technology is maturing. For (different forms of) hydrogen and ammonia additional RD&I is needed for safe storage and handling. Furthermore, measures for storing sustainable alternative fuels on board under development are often technically advanced and coming with high cost being in the pilot phase. R&D activities might be needed on cost saving technologies in order to further develop cost efficient measures. This needs to be done in cooperation with the design and retrofitting pillar.

Power conversion

A third stream in this pillar addresses on-board power conversion, which develops the most efficient way to transform the chemical energy of the Sustainable Alternative Fuel into propulsion power or into electrical energy to feed propellers and other ship equipment. Developments will be based on multiple technology paths, including Internal Combustion Engines (ICE), Fuel Cells and possibly Turbines or other technologies like small modular nuclear reactors. Several European and national programmes, combined with industrial research, have made steps in development of ICE-concepts for sustainable alternative fuels such as methanol, hydrogen and ammonia, as well as in the development of fuel cells (both dedicated for waterborne transport purposes as well as for other applications). It is foreseen that in the coming years a wide set of initial solutions will come available that can serve different segments of the waterborne transport fleet. For upscale of sustainable alternative fuels in ICEs in the transition period, there is a need for flexible solutions. This includes the development of new injection systems and mixing of sustainable alternative fuels with currently used methane and MGO or HFO. Another field where there is need for development is aftertreatment of specific issues for different fuel types (ammonia slip and possibly N_2O for ammonia and formaldehyde for methanol). For fuel cells, research is still needed on different types of fuel cells and the application of different hydrogen carriers (LOHC, ammonia, methanol, etc.) is needed for both ICE's and fuel cells.

Nuclear power may play an important role onboard commercial ships. Despite having been already applied in military ships and submarines, the application of nuclear power technology in maritime transport has close to negligible expression. It may however represent a possible solution for zero-emissions shipping provided that all other aspects of its application are addressed and all safety and environmental risks adequately mitigated. To this end, as a priority, it is considered important to further develop the understanding on relevant available technology solutions, formal safety assessment, full life-cycle safety and environmental assessment and identification of cost-effective risk control options.

Short-term

For the Work Programme Horizon Europe 2021-2024, in order to pave the way for the overall development of the use of Sustainable Alternative Fuels (illustrated in the chart below), the focus has been on the following issues:

- HORIZON-CL5-2021-D5-01-07: Enabling the safe and efficient onboard storage and integration within ships of large quantities of ammonia and hydrogen fuels (2021);
- HORIZON-CL5-2021-D5-01-08: Enabling the full integration of very high- power fuel cells in ship design using co- generation and combined cycle solutions for increased efficiency with multiple fuels (2021);
- HORIZON-CL5-2021-D5-01-14: Proving the feasibility of a large clean ammonia marine engine (2021);
- HORIZON-CL5-2021-D5-01-09: CSA Identifying waterborne sustainable fuel deployment scenarios (2021);
- HORIZON-CL5-2023-D5-01-11: Developing the next generation of power conversion technologies for sustainable alternative carbon neutral fuels in waterborne applications (2023);
- HORIZON-CL5-2023-D5-01-12: Demonstrations to accelerate the switch to safe use of new sustainable climate neutral fuels in waterborne transport (2023);
- HORIZON-CL5-2024-D5-01-13: Demonstration of Technologies to minimise underwater noise generated by waterborne transport (2024);
- HORIZON-CL5-2024-D5-01-16: Structuring the Waterborne transport sector, including through changed business and industrial models in order to achieve commercial zero-emission waterborne transport (2024).
- HORIZON-CL5-2024-D5-01-17: Coordinating and supporting the combined activities of member and associated states towards the objectives of the Zero Emission Waterborne Transport partnership so as to increase synergies and impact (2023)
- HORIZON-CL5-2023-D5-01-14: Developing a flexible offshore supply of zero emission auxiliary power for ships moored or anchored at sea deployable before 2030 (2023)

Medium -term

In the forthcoming Work Programs under Horizon Europe 2025- 2027, strategic orientations are anticipated to offer deeper insights into the practical applications of sustainable alternative fuels. Additionally, they are expected to facilitate the launch of demonstrator projects.

One pivotal area of focus involves the comprehensive investigation and demonstration of various hydrogen carriers, including types of storage systems, operability and safety considerations. Coordinating closely with the Clean Hydrogen Partnership, the research aims to provide design guidelines and retrofitting strategies to seamlessly integrate hydrogen-based solutions into both existing and new waterborne transportation systems.

In particular, the advancement of ship systems capable of achieving overall efficiencies exceeding 60+% range either with fuel cells or ICE's integrated with other solutions is a research priority. Another critical topic for research and demonstration is the maintenance requirements and storage systems for methanol and ammonia, particularly concerning their integration into shipboard systems and the increased safety requirements.

This is highly relevant given the rising prominence of methanol as a promising sustainable fuel for maritime applications. Taking this into account, the research for methanol as fuel are expected to focus on:

•Integration onboard of state-of-the-art energy conversion technologies.

•Gaining experience in the application of the IMO interim guidelines for the safe use of methanol as fuel.

•Development of optimized solutions for storage of methanol onboard, including the possibility of "easy-retrofit" solutions.

Numerous installations are expected for operational roll-out in the near future (for instance for Maersk, van Oord and CMA CGM just to mention a few). Regarding exhaust after-treatment, there is a need for further research on NOx abatement since this is a type of pollutant emission that relates more to the energy converter than with the fuel.

This is especially needed for liquid fuel systems injecting methanol, ammonia, or hydrogen. The focus should also extend safety protocols and risk mitigation strategies particularly when employing liquid fuels like green methanol, ammonia, or hydrogen.

Simulation projects of the different new systems and their integration into real vessels warrant attention. In the shipbuilding industry prototypes represent significant capital investments. To mitigate design risks and optimize performance, considerable emphasis on employing simulation models and digital twins.

The development of new technologies must be holistic, encompassing not just storage tanks, engines, or injection mechanisms. Their impact on factors like load-steps, load acceptance, and vibration behavior must be thoroughly understood to facilitate the design of high-performing, maintainable, and safe vessels.

The assessment of safety and feasibility on the integration of advance nuclear technologies on-board of ships should address R&I and legal and licensing challenges and opportunities for nuclear-powered vessels build and operated in the EU, together with an assessment of appropriate reactor technologies and environmental and economic impact.

In summary the following orientations are preliminary recommended for further actions:

- Demonstration of various hydrogen carriers (excluding MeOH and NH3) that go beyond the State of Play, considering the hydrogen-based fuel as the prime energy carrier for large vessels (going from currently 1 MW for auxiliary to main power drive solution) including types of storage systems, safety, maintenance, and environmental considerations as well as analysis of the use of hydrogen carriers onboard the ship. This solution should target priority operational profiles that can be built and/or retrofitted in the EU, such as short sea shipping, roro and large ferries.

- Demonstration of integrated storage systems for methanol and ammonia into shipboard systems including maintenance, safety considerations as well as employment of simulation models and digital twins.

- Conceptual design of multi-fueled

ship based with novel design methodologies, like simulation and MBSE. Strong preparation focused on safe ship integration of alternative fuels is required.

Being demonstrated for one of the ship types mentioned in ZEWT, i.e. inland waterway, short sea, long distance, cruise, ferries, or offshore work vessels, and including at least two of the following criteria:

a) Development, and demonstration of sustainable fuel injection and exhaust after-treatment systems as well as possible integration with carbon capture technologies to ensure zero emission operation. Research on exhaust after-treatment should be focused on NOx, and do not focus on EGCS. It should also follow an assessment of potential residual air pollution in 2050 depending on the energy mix of the fleet by then. CCS should be considered to the extent that this solution is linked to zero emission technologies such as High-Temperature Fuel Cells, not traditional oil fuel installations.

b) Establishment of robust certification processes, regulations, and testing protocols for alternative fuels.

c) Demonstration as well as establishment of simulation models of ship systems capable to achieve overall efficiencies exceeding 60+% range with FC's or ICE's integrated to other solutions.

d) Utilization of big data and data science technologies in order to determine real-world reference regarding ship performance and maintenance needs.

Use of Sus. Alt. Fuels | Electrification | Energy Efficiency | Design and Retrofitting | Digital Green | Ports

OPERATIONAL OBJECTIVES

Eliminating GHG emissions

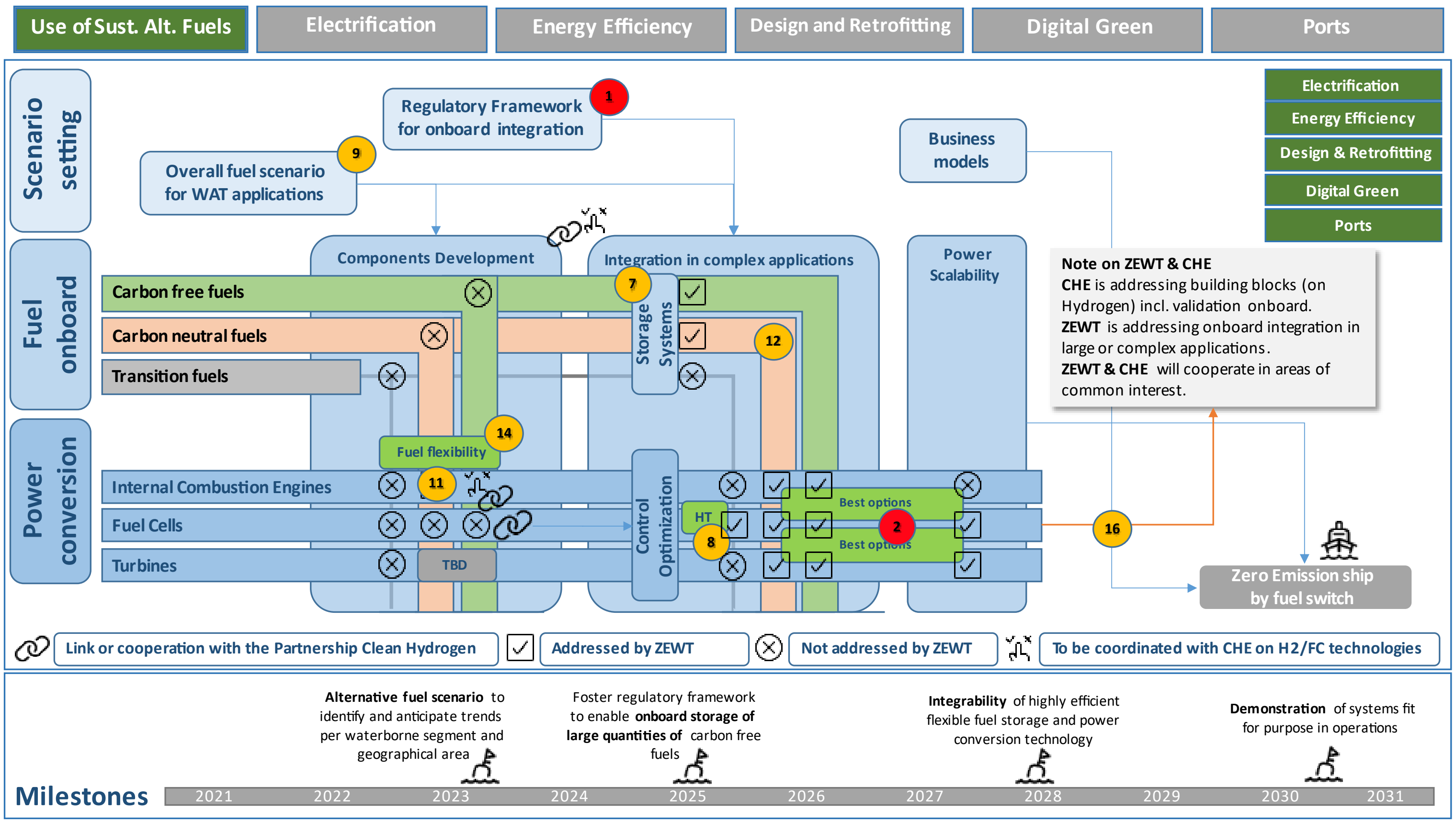
✓	To develop and demonstrate solutions for the **use of climate-natural, sustainable alternative fuels applicable to ships with high energy demand (e.g. long distance shipping)** before 2030;
	To develop and demonstrate **before 2030** solutions for the **integration of high-capacity batteries** solutions as single energy source for short distance shipping **(up to 150 to 200 nautical miles)**;
	To develop and demonstrate solutions to be able to reduce the fuel consumption of waterborne transport, including by the use of non-fuel based propulsion (such as wind), **by at least 55% before 2030, compared to 2008;**
	To develop and demonstrate **solutions for port based supply infrastruture** (i.e. infrastructure for bunkering of alternative fuels and electricity) **needed to enable zero-emission waterborn transport**, to be implemented **by 2030 at the latest;**
✓	To develop solutions for clean and climate-neutral, climate-resilient **inland waterway vessels before 2030.**

Eliminating air pollution

✓	To develop and demonstrate solutions to **cut coastal and inland pollution to air** from inland waterway transport and maritime shipping by **at least 50% by 2030, compared to current levels.**

Eliminating water pollution

✓	To develop and demonstrate solutions to **eliminate pollution to water** (including harmful underwater noise) from ships, by 2030.


Use of Sust. Alt. Fuels
Electrification
Energy Efficiency
Design and Retrofitting
Digital Green
Ports
Scenario setting
Fuel onboard
Power conversion
Regulatory Framework for onboard integration
Overall fuel scenario for WAT applications
Business models
Components Development
Integration in complex applications
Power Scalability
Carbon free fuels
Carbon neutral fuels
Transition fuels
Storage Systems
Fuel flexibility
Internal Combustion Engines
Fuel Cells
Turbines
TBD
Control Optimization
HT
Best options
Best options
Electrification
Energy Efficiency
Design & Retrofitting
Digital Green
Ports
Note on ZEWT & CHE
CHE is addressing building blocks (on Hydrogen) incl. validation onboard.
ZEWT is addressing onboard integration in large or complex applications.
ZEWT & CHE will cooperate in areas of common interest.
Zero Emission ship by fuel switch
Link or cooperation with the Partnership Clean Hydrogen
Addressed by ZEWT
Not addressed by ZEWT
To be coordinated with CHE on H2/FC technologies
Alternative fuel scenario to identify and anticipate trends per waterborne segment and geographical area
Foster regulatory framework to enable onboard storage of large quantities of carbon free fuels
Integrability of highly efficient flexible fuel storage and power conversion technology
Demonstration of systems fit for purpose in operations
Milestones
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031

ELECTRIFICATION

This activity concerns the development of ships with high-power energy storage systems and new DC/AC distribution grids optimized for efficiency, safety and operational profiles, new high performances, high efficiency variable energy generators and fully digitalized twin power trains.

Introduction

Electrification using renewable alternative sources is the most energy efficient way to power a ship. For many waterborne transport applications, battery electrification is not a feasible solution due to the size, weight and costs of batteries. Nevertheless, vessel electrification will play an important role in all applications – with battery electrification feasible for short-range transport applications, and with hybrid electrification used in larger applications.

The application of Sustainable Alternative Fuels may not be sufficient to meet with the ship's power demand. Electrification using renewable alternative sources may represent a necessary complement to increase energy-efficiency together with power generation based on Sustainable Alternative Fuels for long-range waterborne transport, as well as the single energy source for short-range, port calls and entry into environmentally sensitive or nature protected zones. Solutions must ensure a high level of environmental protection and lower emissions, meet public policy objectives, providing competitive economic performance compared to the conventional vessels. This activity will be developed through three forward steps related to the state of the art: Energy Models, Energy Storage Systems (ESS), Electric Generators, Propulsion Drive Control and Grid Architecture and Control.

First, Energy Models, including static and dynamic power optimization and management systems, will be developed to allow a best optimized management of the energy resources available (Sustainable Alternative Fuels, batteries, renewables, fuel cells), taking into consideration different ship types and operational profiles. Secondly, in parallel with the development of the new energy models, the most appropriate and effective Energy Storage System technologies (e.g. lithium batteries, metal-hydride, liquid metal, liquid, solid- state lithium batteries, etc.), for example utilising battery swapping including innovative digital powertrain management or other configurations, will be chosen and modelled. Ground-breaking applications for batteries on board will be implemented since they offer a form of power which can be immediately transformed into ship's power and motion. Moreover, studies on the feasibility of other options will be provided, including alternative energy storage systems and hybrid systems, as well as fast recharging systems at the port. The application of swappable batteries (which can be replaced by recharged batteries or energy storage systems during the journey or when loading/unloading) will also be addressed. Finally, the development of Innovative Grid Architecture and Control will allow a smooth electrical integration of energy storage systems and renewables, together with traditional and non-conventional power generation plants (also allowing a switch to hybrid power architectures).The objective is to optimize the size of sources and switchboards (installed power, volume, safety, weight and cost) and to be able to operate simultaneously with a different kind of electric sources (DC or AC, having different dynamic responses) and power storage devices, acting either as an energy buffer or back-up supply (battery, solid or liquid state power storage, ultra-capacitors and others). The onboard micro-grid should be integrated with a suitable control system, capable of regulating the electric variables of the micro-grid itself (voltage, frequency, active and reactive powers) with the desired dynamic performance, guaranteeing the overall stability. The onboard micro-grid should be further integrated with an energy management system (EMS), which is able to manage the power flows inside the micro-grid, suitably designed in order to pursue specific target functions (minimum fuel consumption, minimum polluting emissions, maximum efficiency of the energy conversion, minimum cost, etc.). A significant part of the electric system to be modelled is constituted by Power Generators and by Propulsion Drives, whose proper design and control present a significant impact on the dynamic performance, manoeuvrability, efficiency, fuel consumption and pollution of the entire ship.

By developing all these sub-activities that integrate design, operative and controlling issues, a technology demonstrator of a large storage system installed on board a ship will be produced, taking into consideration the necessity of achieving the highest standards of safety in design, operation and material lifecycle

Relevance

Electrification is one of the most promising options with a view to achieving Europe's aim of becoming the first continent with zero net emissions of greenhouse gases in 2050.

Electrification and electrical energy storage systems onboard are critical to meet the requirements for zero-emissions at berth included in FuelEU, AFIR and the ETS. In addition, the requirement for containerships and passenger ships to connect to OPS in EU ports brings a clear vector for increased electrification of shipping, at least for zero-emission operations at berth. The focus of public R&D efforts will be mainly around cost-efficient approaches for integration of different shore-power and onboard electrical energy storage systems, where possible and feasible, with a view to respond immediately to regulatory obligations already published.

New renewable low carbon power sources (i.e. green H2, H2 FC, solid/liquid batteries) will reduce greenhouse gas emissions and pollutants from the transport of goods and passengers by ship (emissions of CO_2, SO_x and NO_x compounds and marine noise, for instance), for both short sea and long distance waterborne transport. The extensive Electrification of transportation systems (e.g. cars, trains, airplanes and ships) has today become a game changer, which offers a fast-evolving efficient energy conversion in comparison to conventional concepts. In this perspective, a fully electric ship provides more flexible, efficient and sustainable design and digital twin management of ships, geared towards GHG emissions and other pollutants (e.g. air, water, marine noise) reductions from waterborne transport in line with the EU 2050 Green Deal targets.

In this regard, it must be noted that high Energy Density Storage Systems fed by renewable resources are one of the best solutions to achieve zero GHG emission for many kinds of vessels, such as smaller in-land or near coastal vessels, ferries and platform supply vessels and even for long-distance shipping. The development of safe high energy density large-scale storage systems can also be useful to reduce both the GHG and pollutant emissions caused by modern passenger ships.

Approaching the port in a "zero emissions condition" will be made possible through a green-power unit which can be fast-recharged while ships are at berth and connected to onshore power supply facilities or battery chargers. Furthermore, considering the promising improvements by the emerging next generation of solid-state battery technology, new prospects of a further reduction of GHG emissions are also expected for long-distance energy-intensive vessels. Finally, the development of Innovative Digitalized Grid Architecture and Control systems will enable the reduction of overall emissions linked to low efficiency utilizing digital twin management and control optimization of electric energy on board, by both the generation and demand side, leveraging energy modelling able to provide optimized operating conditions of the vessel aiming to achieve zero-emission target.

It is worth pointing out that a suitable grid architecture, partially or fully reliant on DC/AC hybrid distribution, will make it possible to optimize the needed power conversion stages onboard and, therefore, the related electrical power losses, with an increase in the overall system efficiency.

Innovative aspect

For an electric system to be considered as the main power system, one crucial, challenging aspect which is highly dependent on ship power and operational profile constraints has to be overcome: high-power and compact electric storage solution on board (i.e. solid/liquid-metal and other battery types). Moreover, the ports will need to have suitable high-capacity charging infrastructures and power network. This aspect is already a challenge on shore-side electricity since, for instance, cruise ships need high electric power continuously for their hotel operations when at berth (in the 1-20 MW range). To address this issue, innovative new Energy Models and renewable sources to predict the required power load and devise high-capacity onshore Energy Storage Systems (e.g., on site green H2 production facilities, storage and conversion system). Furthermore, innovative intelligent Grid Architectures and Control Strategies including grid interaction will be implemented and integrated into the Port ecosystem to achieve a more efficient, safe, flexible and sustainable waterborne transport sector.

Energy Models

It must be highlighted that a critical aspect of all these technologies will be the development of the ability to simulate the required power through operational power needs assessment and energy optimization modelling methodologies per ship type. The traditional methods used to calculate a ship's power demand and select the size of the generation system have become suboptimal addressing the technological needs of the new generation low carbon / zero emission innovative naval design requirements. Models will simulate electric load power demanded along the full ship operation time profile (anchor, manoeuvring, navigation, etc.) and the power generated by each power generation system, such as modern energy storage systems (H2 FC, H2 Solid/liquid and other type of batteries etc.). New electric grid architectures (allowing comparison, for example, between AC/DC hybridisation configurations) and environmental footprint abatement (lifecycle assessment, GHG and pollutant emissions) will be integrated into the ship design process.

These models can subsequently be used in the optimisation of the operation of the energy systems on board, and of the operations of the vessel. This links to the activity on Digital Green, where operational decision support systems are foreseen using these energy models. To implement advanced energy management models a framework for aligning data from all providers, open to further development, is needed.

Energy Storage Systems (ESS)

For a full electric-drive ship power system, where both propulsion and other service loads are powered by electricity, the high variation in power demand typical of ships is even more significant than for traditional onshore power systems. In fact, in those conditions, power generation systems in most cases work far from their optimal point, resulting in an undesirable increase in costs, fuel consumption and emissions. Therefore, as happens in many land applications, characterized by uncertainties related to the power generation profile (e.g. wind and solar power generation plants), it may be advantageous to also install Energy Storage Systems on board many vessels. Such systems can be used to cover the fluctuating load variations and increase the efficiency, reliability and flexibility of the entire power system. In particular, they can be exploited by the vessel's Energy Management System to pursue specific objectives, and to reduce the impact of fast load variation on the main generator set. They can be further used to cover voltage fast variation and to cover power quality issues. They can even be devised to supply the energy needed by either the load or the propulsion system (if electric), in case of sudden failure of one of the main or auxiliary generators. Nowadays, Energy Storage Systems are becoming common in most new-builds. The full electrification of ships for longer ranges will become feasible thanks to new generation power storage banks and batteries and other emerging innovative Energy Storage Systems such as metal-hybrid solid low-pressure applications. Further, existing vessels of different sizes will be retrofitted with batteries, either for increased electric range, better onboard load balancing, or zero-emissions operation at berth. Among the solutions available, new generation batteries and new emerging power storages will be developed. Innovative approaches to ensure the safety of large Energy Storage Systems will be tested.

Grid Architecture and Control

Electrification will bring about another significant change and challenges. Today's standard for power system Grid Architectures is currently characterized by Alternating Current (AC) and radial configuration. However, priority has recently been given to the need for more complex power systems relying on Direct Current (DC), as well as adial/ring/decentralized configurations offering higher survivability, reliability and efficiency. Power conversion from DC-AC-DC should be considered in line with the high safety requirements.

With the advent of alternative forms of power, such as Energy Storage Systems (or fuel cells, see use of Sustainable Alternative Fuels), connected directly to the grid or via converters, both AC and DC configurations will be possible (DC or hybrid AC-DC). The improvement of energy efficiency requires the development of grid models, the implementation of control strategies and smart energy management systems, optimizing energy flows and ensuring safe operations. Another critical issue to be tackled is improvement of power electronic converters for interfacing electrical generators, storage systems and loads to the power grid. Such converters should comply with criteria required by the onboard application, i.e., modularity, high power density, redundancy, reliability and safety. When used in a storage system, they must provide bidirectional flow of power.

Moreover, specific control strategies of rotating electrical generators can be devised, according to a variable speed paradigm, to pursue the target of minimizing fuel consumption and related polluting emissions.

These innovations will result in weight and space savings, lower transmission losses, a faster and simpler connection of generators, enabling, overall, a more functional vessel layout and innovative operational principles.

Short-term

For the Horizon Europe Working Programme 2021-2024, in order to pave the way for the overall development of Electrification (illustrated in the chart below), the focus has been on the following issues:

- HORIZON-CL5-2022-D5-01-01: exploiting electrical energy storage systemsand better optimising large battery electric power within fully battery electric and hybrid ships (2022);
- HORIZON-CL5-2022-D5-01-02: Innovative energy storage systems on-board(2022);
- HORIZON-CL5-2021-D5-01-11: Hyper powered vessel battery chargingsystem (2021).
- HORIZON-CL5-2024-D5-01-11: Achieving high voltage, low weight, efficient electric powertrains for sustainable waterborne transport (2024);
- HORIZON-CL5-2024-D5-01-14: Demonstrating efficient fully DC electric grids within waterborne transport for large ship applications (2024)

Medium -term

For the Work Programs Horizon Europe 2025-2027, the following orientations are preliminary recommended for further actions:

Electrification in Short-sea Shipping. One of the objectives of the partnership is to demonstrate technologies for full electrification up to 150 to 200 nautical miles. Therefore, a topic on the design, optimisation and demonstration of battery-electric vessels is foreseen. Various profiles of ships, including short-sea cargo vessels, must be tested. The scope will not only include newbuilds but also retrofitting solutions – with integrated or swappable battery systems – in ferries and small vessels. This topic will cover different geographical areas, also with a focus on the Mediterranean Sea. To extend the range of the vessels, hybrid solutions with zero-emission systems like wind propulsion or hydrogen fuel cells, or SAF – each with zero emission pollution- are foreseen. A decision support tool is needed to help ship-owners decide on the optimal hybrid balance between electrification and SAFs.

Zero-emission operation at harbours and sensitive areas: Electrification solutions need to be implemented to demonstrate zero-emission operation of large vessels, particularly container ships and passenger ships, at harbours as well as other sensitive areas. This includes the use of onshore power supply (OPS) and onboard battery systems. In addition to newbuilds supporting battery/OPS-based harbour operation, the retrofit of OPS and/or battery solutions on existing large vessels should be prioritized. Battery swapping could be considered as a possible solution, wherein battery groups could be used to compensate low-utilization periods in-between peak demand periods. This orientation aims to link to AFIR including possible co-funding from CEF for the infrastructure side of the project. Emission-free operation may also be extended to manoeuvring in harbours, requiring the retrofit of the propulsion system to be powered electrically by onboard zero-emission sources.

Optimization of shore-to-ship power transfer: There remains potential to further optimize high-power shore-to-ship power transfer, while remaining within the realms of IEC/IEEE 80005 standards. This orientation particularly focuses on advancements in onboard components such as HV transformers, OPS switchboard, safety monitoring and blackout prevention/mitigation systems, and automated connection systems. New battery- and charger-side technologies and solutions enabling fast charging for onboard batteries should be prioritized. The shore-to-ship interface should also be capable of supporting vessel-to-grid operation, wherein onboard batteries can be used for peak shaving and other ancillary services on the port microgrid.

Alternative energy storage systems and hybrid systems, including hydrogen fuel cells should be considered, to give sufficient flexibility in storing enough energy on board vessels.

Energy models for optimal operations The use of new hybrid power systems requires decision support tools for vessel crew and vessel management for reduction of total emissions, optimisation of energy use and minimisation of the use of expensive SAFs. The modelling should include possibilities for multi power generator systems, multiple SAFs, and be on a WtW basis. The latest EC and IMO regulations and proposals should be taken into consideration.

OPERATIONAL OBJECTIVES

Eliminating GHG emissions

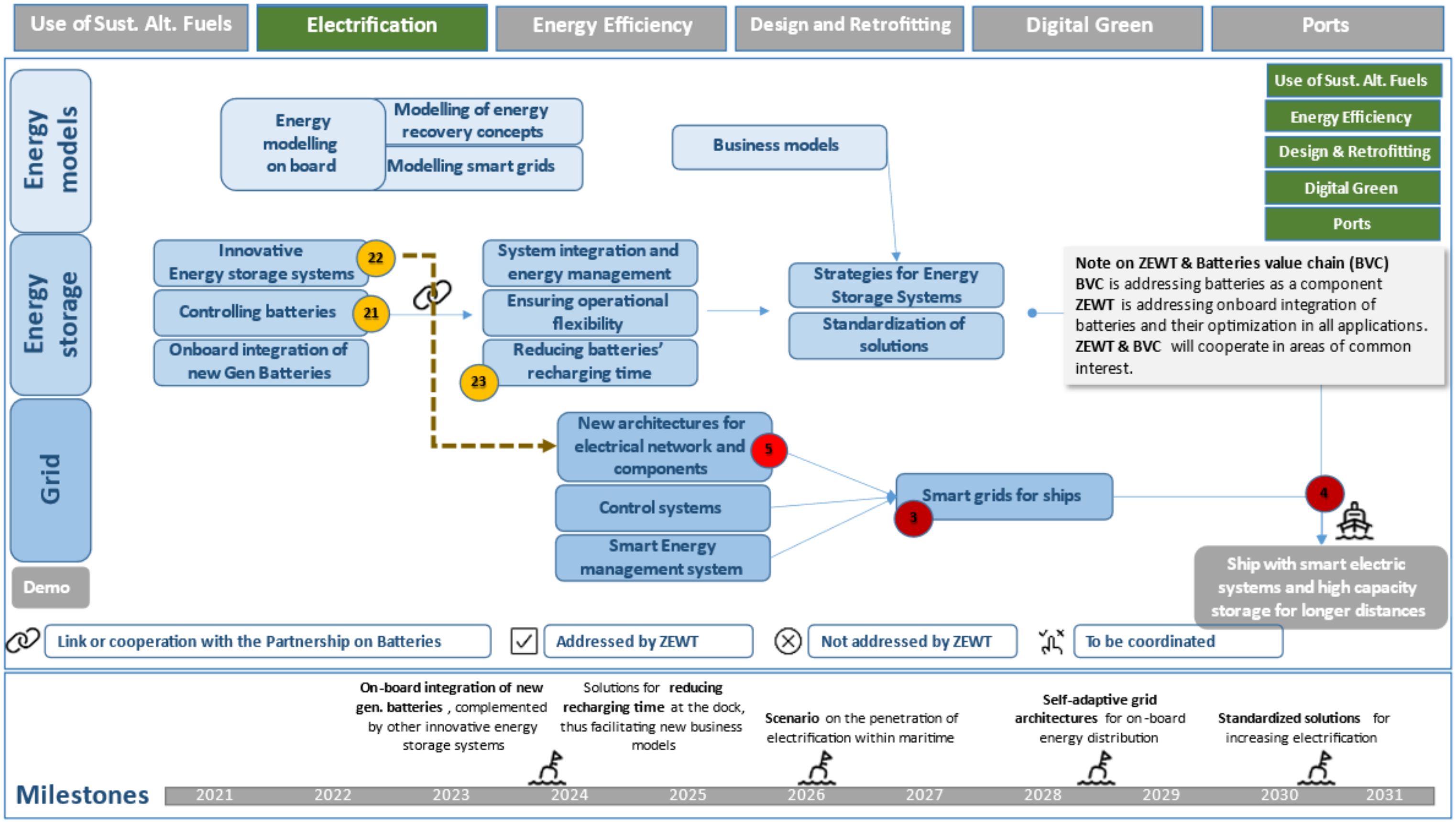
	To develop and demonstrate solutions for the **use of climate-natural, sustainable alternative fuels applicavle to ships with high energy demand (e.g. long distance shipping) before 2030;**
✓	To develop and demonstrate **before 2030** solutions for the **integration of high-capacity batteries** solutions as single energy source for short distance shipping **(up to 150 to 200 nautical miles);**
	To develop and demonstrate solutions to be able to reduce the fuel consumption of waterborne transport, including by the use of non-fuel based propulsion (such as wind), **by at least 55% before 2030, compared to 2008;**
✓	To develop and demonstrate **solutions for port based supply infrastruture** (i.e. infrastructure for bunkering of alternative fuels and electricity) **needed to enable zero-emission waterborn transport**, to be implemented **by 2030 at the latest;**
✓	To develop and demonstrate solutions for clean and climate-neutral, climate-resilient **inland waterway vessels before 2030.**

Eliminating air pollution

✓	To develop and demonstrate solutions to **cut coastal and inland pollution to air** from inland waterway transport and maritime shipping by **at least 50% by 2030, compared to current levels.**

Eliminating water pollution

✓	To develop and demonstrate solutions to **eliminate pollution to water** (including harmful underwater noise) from ships, by 2030.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Onboard integration of new Gen Batteries
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Note on ZEWT & Batteries value chain (BVC)
BVC is addressing batteries as a component
ZEWT is addressing onboard integration of batteries and their optimization in all applications.
ZEWT & BVC will cooperate in areas of common interest.
New architectures for electrical network and components
5
Control systems
Smart Energy management system
Smart grids for ships
3
4
Ship with smart electric systems and high capacity storage for longer distances
Link or cooperation with the Partnership on Batteries
Addressed by ZEWT
Not addressed by ZEWT
To be coordinated
On-board integration of new gen. batteries, complemented by other innovative energy storage systems
Solutions for reducing recharging time at the dock, thus facilitating new business models
Scenario on the penetration of electrification within maritime
Self-adaptive grid architectures for on-board energy distribution
Standardized solutions for increasing electrification
Milestones
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031

ENERGY EFFICIENCY

This activity concerns the development of ships requiring significantly less power for operation thanks to power efficient solutions, the exploitation of renewable systems such as wind assisted propulsion and the reconfiguration of the ship's architecture and operation. It is strongly connected to digital green and electrification activities, as well as ports and alternative fuels, since optimization of solutions in the aforementioned activities or their integration into a holistic approach are targeting energy efficiency. This activity has been identified as more important for long distance shipping, followed by short-sea shipping, cruise ships and ferries.

Introduction

The most environmental-friendly and cost-effective energy is energy that we do not need to produce, store and use. In this respect, the Energy Efficiency activity will contribute mainly to one major operational objective, which is reducing the fuel consumption, and therefore GHG emissions of waterborne transport by at least 55 % before 2030. A systemic and holistic approach for managing energy onboard, in combination with innovative energy efficiency technologies and renewable and free energy solutions, can achieve such a breakthrough. Energy efficiency optimization schemes need to be further developed, beyond the current state-of-the-art with regards to single or limited design and operation points. This approach considers the full spectrum of ship energy needs and consumers, as well as operating profiles, to develop, demonstrate, assess, optimize and select the most efficient technologies, ship design and operation solutions. As a result, the ship's energy needs will be reduced drastically. The IMO's Carbon Intensity Indicator (CII) will primarily support this objective, as well as the Energy Efficiency Existing Ship Index (EEXI) framework and Ship Energy Efficiency Management Plan (SEEMP).

Such an innovative approach and related solutions can be deployed along 3 main lines:

- Ship design and operation optimization, integrating all solutions optimally and taking into account the variability of ship operation profiles and corresponding dynamic energy needs,
- Energy-efficient technologies, to optimize the energy needs for all consumers (technology bricks)
- Renewable and free energy solutions, often contributing highly to the vessel's needs (i.e., propulsion), to offer free additional energy sources, thereby further reducing the overall ship energy need either for nowadays conventional fuels or emerging sustainable alternative fuels,

while taking full advantages of the new opportunities offered by new configurations, for instance electric power ship architecture, smart operations, digital twin and technologies presented in the Electrification and Digital Green activities.

Energy efficiency technologies are identified as more promising among these three pillars (e.g., waste heat recovery) in an industry context, followed by design and operation optimization and integrations (e.g., holistic ship design). For the third pillar, the renewable and free-energy solutions, the relatively mature wind-assisted propulsion solutions have the potential of dominating the industry, but is in need of further optimization and investment.

Relevance

Improving ship Energy Efficiency offers multi-dimensional advantages for this new paradigm of zero- emission waterborne transport, through reduction of fuel need and fuel storage volume on board, as well as down-sizing of ship power production systems. Those developments should also combine digital green ports, transiting towards net-carbon waterborne transport. The roadmap towards zero-emission waterborne transport is also aligned with UN Goals regarding air quality as improved energy efficiency results to fuel reduction which in turn leads to significant reduction of harmful air pollutants such as PMs, SOx, NOx. Improving ship Energy Efficiency offers multidimensional advantages for this new paradigm of zero-emission waterborne transport, through reduction. Therefore, the following benefits can be achieved:

- Direct reduction of the ship OPEX (fuel bill) and CAPEX (fuel tank and power system down-sizing) for the shipowner;
- Opening new grounds to develop innovative zero- emission ship architecture designs, for designers;
- Improve energy efficiency indices following the EU Taxonomy Climate DA, which has been updated and includes EEDI revised criteria, EEXI/GHG Intensity for both complying with new regulatory restrictions and leading to

better business decisions through sustainable driven financing schemes;

- Counter-balancing of higher alternative fuel prices, lower alternative fuel energy density, or lower compactness of new fuel power conversion systems such as fuel cells (see "Sustainable Alternative Fuels" activity), for the market;
- And even limitation of new infrastructures and operating constraints to supply alternative fuels to the ships safely and in the appropriate quantities, for the ports (see "Ports" activity).

Since Energy Efficiency is aiming to reduce the fuel consumption, and therefore GHG emissions of waterborne transport dramatically (by at least 55 % before 2030), the abovementioned gains will be tremendous, offering key leverage for zero-emission waterborne transport. In this regard, among renewables, wind propulsion can serve as a complementary and transformational energy source and ultimately a primary propulsion solution, thanks to the more advanced technology already available, with respect to the use of sustainable alternative fuels. Moreover, reducing the energy need will directly impact the ship's GHG and air and water pollutant emissions by the similar amount (through the ship's power production system exhausts and underwater noise), contributing 55% of the overall emission reduction objectives.

The efforts should first focus on retrofitting, despite the difficulties, since the current fleet will be running up until the reference year of 2030, while newbuilds will gradually offer the modernization of the fleet in a European and global scale, with the efficient design efforts being optimized continuously. For both cases, optimization is extremely important, as the maritime industry relies and will rely on certain technologies (e.g., ICE) for a long time ahead. Finally, standardization is crucial for all aspects of energy efficiency activities since it may significantly assist regarding the feasibility of integration.

Innovative aspect

Currently, ship energy efficiency optimization primarily focuses on specific scenarios, such as the EPL (Energy Power Limitation) on a ship's maximum power. However, these scenarios represent only a fraction of the broader spectrum of ship operations. Furthermore, existing solutions predominantly rely on passive technologies. For instance, they might involve tailoring a ship's propellers with a duct for optimal performance within a specific speed range. Unfortunately, these passive technologies tend to exhibit suboptimal performance when confronted with different operational conditions. The adoption of renewable energy in the waterborne transport sector is limited, primarily due to the lack of mature high-power options and insufficient incentives in the light of low fuel prices.

To achieve the ambitious goal of zero-emission waterborne transport and a 55% reduction in energy consumption, and thus, emissions reductions, we propose three critical paradigm shifts:

- Embracing a systemic and holistic approach to ship energy efficiency, now fully determined by the operational context,
- Transition from passive, single-scenario technologies to active and adaptive, ship design for operation solutions,
- Promote large-scale implementation of efficient energy solutions, including the upscaling of wind-assisted propulsion, to enhance vessel sustainability.

Design and operation integrations

This pioneering approach to enhancing ship energy efficiency, characterised by its systemic, comprehensive, and transformative characteristics, holds the potential for a profound revolution in the supervision, forecasting, and real-time control of the full spectrum and complexity of ship energy needs, flows and operating profiles (ship energy dynamics). By employing this method, energy efficiency optimisation, even during the ship's design phase, can be achieved by considering various parameters that influence ship performance under diverse operational conditions (e.g., wave characteristics, wind strength, hull biofouling growth rate). Additionally, this approach streamlines the process of selecting and fine-tuning advanced energy power systems such as fuel cells, batteries, fast charging, efficient energy transformation, and renewable energy sources. Moreover, it paves the way for the development of adaptable real-time optimization strategies to accommodate expected and unforeseen operational conditions.

In pursuit of this objective, harnessing the capabilities of state-of-the-art technologies such as digitalization, Digital Twin models, Big Data analysis, Artificial Intelligence, hybrid energy power systems and intelligent onboard energy storage systems (ESS), as illustrated by the Digital Green and Electrification initiatives and activities, signifies a fundamental shift in ship energy management.

With respect to port activities, the energy efficiency performance for ships could be enhanced by taking advantage of ports as energy hubs or by introducing an intermodal battery infrastructure approach. Ports should also serve ships towards higher energy efficiency, by supporting mixed fuel types, and respective business models, or by preparing their interfaces with autonomous shipping, or other leading energy efficiency technologies. In the context of holistic approaches, autonomous ships can drastically reduce emissions, in terms of more energy efficient operation and sailing.

Small case applications on cruise ships and bulk carriers that operate on relatively short distances (Short Sea Shipping) have already showcased significant energy savings. However, a full scale adoption of this approach and its associated methodologies could significantly contribute to achieving the ambitious target of reducing overall energy consumption, to result in the 55% GHG emission reduction.

Energy-efficient technologies

The mastery of comprehensive ship energy systems and their operational profiles signifies a new era of research and development for energy-efficient technologies. This paradigm shift is poised to accomplish onboard efficiency, propulsion efficiency and increased power generation efficiency, through the following:

- Pioneering assessments and optimized integration of groundbreaking power conversion and storage systems, including innovations like waste heat recovery (WHR) solutions, machinery prognostics and system simulations, variable speed electric motors, and both centralized and modular energy architectures. As a concrete example of developing technologies, there is a wide variety of solutions that aims in waste heat recovery (e.g., integrated control for waste heat recovery, thermal energy storage, etc.), where the reduction potential can meet up to 8% of the main engine fuel consumption. Furthermore, these advances encompass more energy-efficient consumers such as novel HVAC design and technology architectures, enhanced thermal insulation, and other related solutions.

- Facilitating a transformative shift away from the prevailing reliance on passive technologies to embrace active and adaptive ship design and solutions. This transition empowers vessels to operate efficiently under diverse conditions continually. This encompasses innovations under the umbrella of active, adaptive and hull improved performance solutions like active deadweight and trim controls, bio-mimetic appendages, groundbreaking hull coatings, and dynamically predictive engine maintenance. Especially novel propulsion solutions, defying the traditional propellers, are continuously gaining ground and are promising for even a 20% more efficient propulsion system. Air lubrication technology has also been identified as a promising solution for drastically increasing energy efficiency of propulsion in overall. In addition, a better and integrated hull management system, including new methodologies for fouling levels assessment, robot hull preventive cleaning at sea, new nonpolluting coatings, hull digital twins and others innovative technologies would help shipping to achieve it mandatory CO2 emissions targets.

- The incorporation of technologies like fuel cells, hybrid solutions and advanced engine systems, along with combined cycles, promises substantial reductions in sustainable fuel consumption. Coupled with the utilization of alternative fuels and electrification, these developments will contribute significantly to optimizing energy requirements across various technology components and thereby substantially reduce both fuel consumption and emissions. For the long-term, and still under a lot of debating, small modular reactors (SMR) are examined as an increased energy efficiency solution.

All these domains are explored and comprehensively demonstrated as part of our overarching endeavor.

Renewable and free energy solutions

Either integration solutions or energy efficiency technologies cannot answer alone the challenge of the energy transition, without considering either alternative fuel options, or, in the case of energy efficiency activities, renewable and free energy solutions, which are currently attracting a great deal of interest, either in terms of research or innovation efforts. In more detail, the wind-assisted propulsion systems (e.g., rotor sails, rigid wing sails, soft wing sails, ventilated foil system) have gained significant attention as a means of reducing ship fuel consumption and emissions. This solution has already delivered yearly fuel savings of between 5% and 9% for certain ships, and is claimed to have the potential to reach 25%. It may have also the potential to be the primary propulsion solution (50% and higher) in the case of newbuild vessels. Other renewable solutions may include solar energy systems, which can mainly support inland and smaller-scale vessels, and still need to be developed. Additionally, harnessing wave energy, as a renewable energy source, is proven to increase energy efficiency through bio-mimetic or other more groundbreaking solutions, which however are encountering significant technological limitations, and should be further examined.

These can effectively support the greening of larger and/or higher energy demand ships, in terms of renewable and energy-free solutions. Wind-assisted propulsion is widely adopted in the industry, where optimisation is necessary, while other renewable solutions need more concrete results in terms of research and innovation outcomes, considering also business cases.

Short-term

For the short-term Work Programme period of 2021-2024, in order to pave the way for the overall development of Energy Efficiency (illustrated- in the chart below), the focus has been on the following issues:

- HORIZON-CL5-2022-D5-01-03: Exploiting renewable energy for shipping,in particular focusing on the potential of windenergy(2022);
- HORIZON-CL5-2021-D5-01-10: Innovative onboard energy saving solutions (2021).
- HORIZON-CL5-2024-D5-01-12: Combining state of the art emission reduction and efficiency improvement technologies in ship design and retrofitting for contributing to the “Fit for 55” package objective by 2030 (2024)
- HORIZON-CL5-2022-D5-01-04: Transformation of the existing fleet towards greener operations through retrofitting (2022)

Medium -term

For the Work Programs Horizon Europe 2025-2027, strategic orientations are expected to boost further research and innovation aspect regarding Energy Efficiency, the following orientations are preliminary recommended for further actions, in order of priority:

• Optimal integrated onboard renewable energy solutions, by considering wind-powered and hull performance technologies.

• Real-time monitoring and adaptive EMS for advanced supervision, forecasting, optimization and control, for the full spectrum and complexity of ship energy needs and operating profiles.

• Development and technology validation for disruptive, active and adaptive propulsion solutions.

OPERATIONAL OBJECTIVES

Eliminating GHG emissions

✓	To develop and demonstrate solutions for the **use of climate-natural, sustainable alternative fuels applicavle to ships with high energy demand (e.g. long distance shipping) before 2030;**
✓	To develop and demonstrate **before 2030** solutions for the **integration of high-capacity batteries** solutions as single energy source for short distance shipping **(up to 150 to 200 nautical miles);**
✓	To develop and demonstrate solutions to be able to reduce the fuel consumption of waterborne transport, including by the use of non-fuel based propulsion (such as wind), **by at least 55% before 2030, compared to 2008;**
	To develop and demonstrate **solutions for port based supply infrastruture** (i.e. infrastructure for bunkering of alternative fuels and electricity) **needed to enable zero-emission waterborn transport**, to be implemented **by 2030 at the latest;**
✓	To develop and demonstrate solutions for clean and climate-neutral, climate-resilient **inland waterway vessels before 2030.**

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✓	To develop and demonstrate solutions to **cut coastal and inland pollution to air** from inland waterway transport and maritime shipping by **at least 50% by 2030, compared to current levels.**

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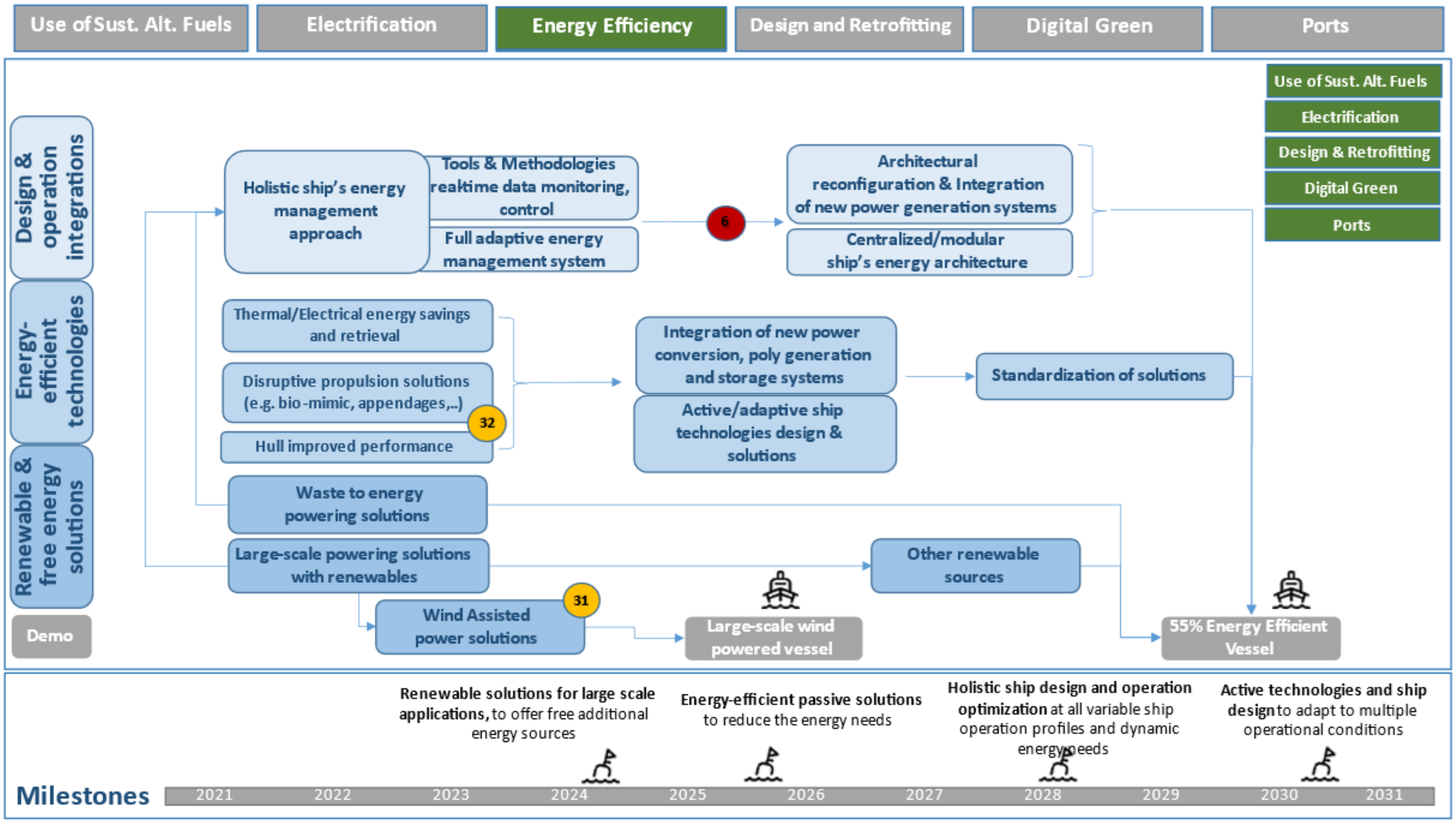
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Digital Green
Ports
Design & operation integrations
Energy-efficient technologies
Renewable & free energy solutions
Demo
Holistic ship's energy management approach
Tools & Methodologies realtime data monitoring, control
Full adaptive energy management system
6
Architectural reconfiguration & Integration of new power generation systems
Centralized/modular ship's energy architecture
Thermal/Electrical energy savings and retrieval
Disruptive propulsion solutions (e.g. bio-mimic, appendages,..)
32
Hull improved performance
Integration of new power conversion, poly generation and storage systems
Active/adaptive ship technologies design & solutions
Standardization of solutions
Waste to energy powering solutions
Large-scale powering solutions with renewables
Other renewable sources
Wind Assisted power solutions
31
Large-scale wind powered vessel
55% Energy Efficient Vessel
Renewable solutions for large scale applications, to offer free additional energy sources
Energy-efficient passive solutions to reduce the energy needs
Holistic ship design and operation optimization at all variable ship operation profiles and dynamic energy needs
Active technologies and ship design to adapt to multiple operational conditions
Milestones
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031

DESIGN AND RETROFITTING

This activity concerns the development of methodologies for green design, sustainable manufacturing and zero-emission retrofitting for all type of waterborne vessels.

Introduction

To provide and demonstrate zero-emission solutions for all main ship types and services before 2030, which will enable zero-emission waterborne transport before 2050, requires dealing with many technologies and solutions for both the existing fleet and newbuilds. Different technologies need to be developed and adapted to the specific operational needs and business models of different ship types, and these technologies also need to anticipate the continuous evolution of transport needs, the technical evolution in ports and infrastructures and the variability of regulations. All of these aspects require new methodologies in Design, Manufacturing and Retrofitting.

New design approaches will integrate the latest and disruptive technologies in light, safe, clean and cost-effective ship solutions. Design methodologies will anticipate future needs to replace existing ship systems with new green systems, which will be demonstrated before 2030. Modular ship and system architectures will assure cost-effective retrofitting of low emission solutions throughout the ship's lifetime.

For ships-in-service, high priority will be given to the integration and demonstration of easy-to-integrate green retrofitting solutions, in particular those being addressed and developed in the pillars "*use of sustainable alternative fuels*", "*electrification*" and "*energy-efficiency*", but also in the area of exploiting zero- (or low-) emission energy sources. New digital and AI technologies are also suggesting to work on the development of new types of intelligent Decision Support Systems (DSS) to provide a synthesis of the different technologies accounting for safety aspects, cost-effectiveness and life-cycle costs, including the decommissioning phase.

Advanced assessment methodologies, full twinning of ship design and manufacturing processes will be developed to attain a high level of confidence regarding the environmental performance of ship designs, of ships in service before/after-retrofitting and the environmental impact of manufacturing processes. It is very clear however, that the more we go toward digitalization of systems and services, the more cybersecurity defense systems and physical countermeasures (e.g. redundancy, off-line fundamental systems) have to be embedded into the design process and retrofitting.

Relevance

A new business model is needed to achieve a reduction in GHG and other polluting emissions (NOx, SOx, PM, methane slip) towards zero values in 2050. At the same time, it is in the public interest to maintain the leading role of Europe's shipyards and maritime equipment suppliers: fostering clean, safe and competitive European waterborne transport in a period of lower economic prosperity, also offers a way to meet both future market and societal needs.

The environmental performance of a ship is determined by her initial business model, her operational requirements, the energy management on board and the embedded technologies, which usually corresponds to the state of the art at the time of ship delivery.

However, recent fossil fuel price volatility with some fuels increasing in price 3 times is driving moves for new orders to be constructed with a vision of fuel flexibility and retrofit as market conditions change. Since the average life span of a ship is 30-40 years, and only 2% of the worldwide fleet is replaced yearly by newbuilds, specific measures for abating emissions on ships in service are needed. The maintenance of ships must evolve from the current preservation of the initially designed environmental and operating performances towards a process of minimizing them by retrofitting. While retrofitting ships in use is bound by architectural constraints, newbuilds replacing the older part of the fleet must anticipate future retrofitting options and employ appropriate measures in design and manufacturing. Despite the differences between newly designed and in- service ships, a common strategy to greening, for GHG-elimination and pollution mitigation to air and water, can be applied in three consecutive steps.

- minimise the ship energy needs,
- minimise the share of onboard ICEs in power systems and
- install alternative ship power systems and apply clean fuels on ICEs (fuel cells, alternative fuels, Energy Storage Systems, etc).

Innovative aspect Design

Current ship design methods benefit from past experiences, either by copying or scaling of ship designs with comparable requirements or by creating a digital model based on pre-programmed rules derived from the analysis of existing designs (parametric design). Over the past decades, diesel engines and fuels have been more-or-less stable factors in ship design, production and CAPEX and OPEX. Once the ship powering demand was determined, power train and fuel weights, volumes and general layouts followed well-established practices with the final details being set by the chosen brands.

Nowadays, new elements have to be considered in designing a ship. Examples are the transition to other energy conversion technologies and fuels, which will need different tradeoffs for weight, volumes and layouts. Potential future retrofitting of the ship with newer green technologies and systems (new systems expected to come in a near future) leads to different needs for the ship architecture, foreseeing the necessity to accommodate new abatement systems. Additionally, recycling and circular economy must be accounted here as well. Introducing high strength and lightweight materials such as composites or intelligent materials with self-healing or self-cleaning properties to improve energy efficiency cannot rely on current design, manufacture and end of life practices. Disruptive changes in power systems are envisaged and therefore new fuel storage systems, new materials and components will require ship design solutions to adapt to changed operational and environmental requirements, including legislation. Moreover, cost-effective technology upgrades for greening will have to be foreseen throughout the life cycle with a view to maximizing value, including end-of-life, supporting sustainability, and ensuring that the ships remain competitive under varying market and mission requirements. Changes and uncertainties mean that future ship design methods will have use probabilistic approaches to identify design solutions that will exhibit the smallest effects of random variability, e.g. those that are the most *robust*. A new probabilistic design for greening will make it possible to address uncertainties linked to totally new parameters, such as thrust from wind propulsion, use of different sustainable alternative fuels, etc., as well as operating and/or environmental conditions. Wind propulsion in addition to other propulsion systems also requires innovative design solutions. There is also a foreseen increase of average sea states and frequency of extreme events to be taken into account, according to naval registers, due to storms of increasing energy (as an effect of global warming and worldwide increased temperatures).

Fast design assessment methodologies capable of dealing with new technologies, their mutual impact, the overall impact on the ship, along with design robustness, flexibility and resilience over the entire life cycle, will be developed and validated. The traceability of systems and components, as well as operational data obtained from remote monitoring and validated by the ship digital twin, will support the outlined greening strategy.

Advanced simulation-based design tools will be used more frequently, due to a general reduction of the computational costs: new opportunities will be offered by digital twins, and technologies presented in the Digital Green activities will be fully leveraged to ensure a dual exploitation of results, both for the design of new vessels and their operational management. One relevant obstacle to overcome in applying Digital Twins technologies, is the requirement of data standardization and how to overcome proprietary limitations to data use and sharing imposed by the companies producers of single systems components.

Finally, it has to be highlighted here the need for the shipbuilding industry to become a *digital design authority*, which will implement digitalization, automation and autonomy in ships and maritime industrial processes through the utilization of AI and data analytics-based systems, to support the business. It is of crucial importance to highlight the role of shipyards in integrating complex systems, developing innovation and after-sales services through advanced digitalization, to reach a full circularity in the Life Cycle Management of ships and maritime infrastructure, and at the same time control the entire supply chain. As a market leader at the EU level, the shipbuilding industry needs to become a cross-sectoral integrator among different ship types.

Innovative Aspect in Manufacturing

European shipbuilding and its highly relevant supply chain will continue to compete on a global level, with new business models employing the most advanced market leading green technologies which contribute to the 2050 zero-emission targets.

The state-of-the-art manufacturing technology of European shipyards contains advanced CAD/CAE/CAM platforms with various levels of automation in parts of manufacturing, assembly and outfitting processes.

Modular ship architectures are now applied only on a limited scale, with closer integration of the suppliers throughout the value chain, i.e. during design, engineering and assembly phases. To build green-to-zero emission ships, European shipyards will deal with new technologies, new supply chain partners, harmonization of new technical rules andstandards and new materials processed in shop floor processes. Furthermore, the manufacturing of a zero-emission ship will fundamentally differ from current practices, thanks to high reconfigurability for modular shipbuilding.

Manufacturing is the "enabler" for building and retrofitting green ships at competitive costs in the global shipbuilding and ship repair, maintenance and retrofitting industry. The research will address – in an LCPA context – new, low-polluting floor processes related to the building and retrofitting of green ships, e.g. with light alternative materials.

Innovative Aspect in Retrofitting

Today, capturing and twinning an existing ship's architectural data by reverse engineering is not effective in lead time and cost, further reducing the efficiency of the retrofitting process. The increased complexity of green technologies requires a better understanding of the ship systems' re-design and integration of old and new technologies and components. A practical example is the electrification of the ship, including the installation of battery sets and relevant auxiliaries. Assessing the impact of retrofitting alternatives in terms of sustainability requires efficient methods and life cycle-oriented business models.

Among the different approaches for the achievements of the targets, activities seem to be focused (and have to) on solutions to:

- **improve the ship efficiency**, such as air lubrication systems, smart energy management, holistic hydrodynamic and operational optimization, aux engine retrofit via thermoelectric elements and use of excess heat, carbon capture using CCM technology and membranes and finally air cleaning and reuse to reduce HVAC energy use. CCS systems should be strongly considered for ship's retrofitting solutions as well as other capturing systems for other pollutants (SOx, NOx, and PM).

- **exploit renewables or zero- and low-emission energy sources**, such as wind assisted propulsion, fuel cells, solar energy and hybridization of the propulsion system. Wind assisted propulsion need a special mention, since research and innovation proved these devices as actually useful and effective. Further investments will be necessary for a better integration with other propulsion systems, for optimal routing trade-off, lightweight elastic and durable materials for rigid sails, etc.

- **emissions reduction not linked to energy sources**, such as better on-board treatment of solid or liquid waste from ship exploitation (black / grey waters, food), processes of waste on-board, energy recoverery, storing space reduction, etc.) and reduction of noise. Other examples are oil emissions from commercial shipping propulsion systems and bearings, that discharge over 240 million liters of oil annually into our oceans, and that can be eliminated by introducing seawater lubricated propeller shafts.

Two parallel retrofit tracks have been identified. First of all, the existing fleet and in particular the relatively younger fleet segments (< 10 years), thanks to more recent technologies, will allow for a fast assessment of retrofit options following the strategy of minimizing energy needs, ICE's share and polluting emissions.

Retrofit candidates are the ship systems for energy conversion, distribution and management, waste recovery, emissions reduction and capture, energy- saving devices (ESVs), ships' speed profiles review, propulsion train re-design and wind thrust-generating. Retrofit solutions have to be standardized, modularized and easy to operate and maintain, to make the business case acceptable and therefore to lower the threshold for introduction to the existing fleet.

The second track concerns fleet replacement and in particular the relatively older (> 25 years) fleet segments in Europe. New builds will be designed for operational flexibility and robustness with structural measures for future retrofitting with progressively maturing green technologies, aligned with evolving port infrastructures (fueling, waste disposal and shore supply). Modular design for green retrofit as a new sub-discipline in ship design will address all energy and emissions issues, enable efficient retrofit processes and provide LCA-tools for the assessmentof retrofit scenarios. A wide variety of retrofit strategies and assessment methodologies for the entire waterborne sector will be developed.

Short-term

For the short-term Work Programme period of 2021-2024, in order to pave the way for the overall development of Design & Retrofitting (illustrated- in the chart below), the focus has been on the following issues:

- HORIZON-CL5-2022-D5-2022-D5-01-04: transformation of the existing fleet towards greener operations through retrofitting (2022);
- HORIZON-CL5-2021-D5-01-12: assessing and preventing methane slip from LNG engines in all conditions within both existing and new vessels (2021).

In the final years of the Partnership, the design and assessment models for future greening have to be developed and demonstrated. Furthermore, the modularization, standardization and integration of various state-of-the-art retrofit solutions, such as developed in the other pillars of the SRIA, has to be realized and demonstrated on system and ship level.

Medium -term

For the Work Program Horizon Europe 2025-2027, priority areas and roadmaps in relation to Design & Retrofitting cover: electrification, alternative fuels, vehicle design and manufacturing, connected and automated transport, more efficient design with a greener footprint, Carbon Capture System and Life Cycle program.

The following orientations and challenges are preliminary recommended:

- Developing standardized approaches per type of vessel & type of retrofit, considering that new vessels will need retrofitting in the future.
- Developing new advanced digital-based robust (i.e. probabilistic) ship design methods including (i) modular design principles, (ii) optimal volume and mass redistribution for wind assisted propulsion and (iii) CCS systems. The HE Project DT4GS is currently working on such issues, and expected to end by May 2025. The launch of this new topic should start 1 year before the end of the project.
- Developing solutions for smart on-board degassing, vapor recovery, treatment of solid or liquid waste, potentially heat recover, new bearings capable of avoiding oil emissions from commercial shipping propulsion systems and bearings.
- Developing techniques for improved NOx abatement systems operations for optimal functioning especially at low engine loads where 2023 studies shared with IMO have shown NECA engines are not currently compliant.
- Developing technologies and techniques to reduce fugitive emissions from shipping cargoes, e.g., leakage of methane, VOCs.

Use of Sus. Alt. Fuels | Electrification | Energy Efficiency | **Design and Retrofitting** | Digital Green | Ports

OPERATIONAL OBJECTIVES

Eliminating GHG emissions

✓	To develop and demonstrate solutions for the **use of climate-natural, sustainable alternative fuels applicavle to ships with high energy demand (e.g. long distance shipping) before 2030;**
✓	To develop and demonstrate **before 2030** solutions for the **integration of high-capacity batteries** solutions as single energy source for short distance shipping **(up to 150 to 200 nautical miles);**
	To develop and demonstrate solutions to be able to reduce the fuel consumption of waterborne transport, including by the use of non-fuel based propulsion **(such as wind), by at least 55% before 2030, compared to 2008;**
✓	To develop and demonstrate **solutions for port based supply infrastruture** (i.e. infrastructure for bunkering of alternative fuels and electricity) **needed to enable zero-emission waterborn transport**, to be implemented **by 2030 at the latest;**
✓	To develop and demonstrate solutions for clean and climate-neutral, climate-resilient **inland waterway vessels before 2030.**

Eliminating air pollution

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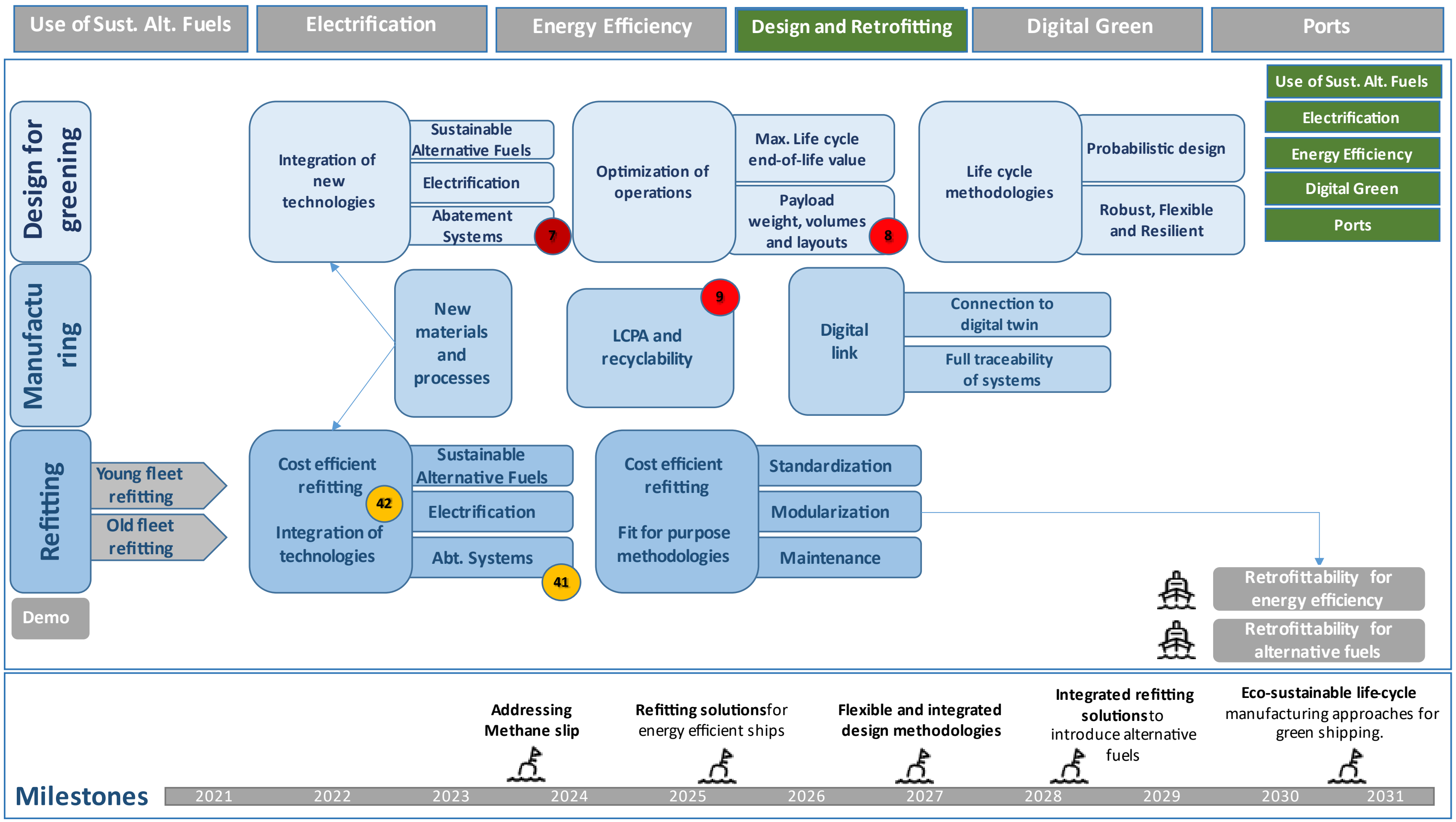
Eliminating water pollution

	To develop and demonstrate solutions to **eliminate pollution to water** (including harmful underwater noise) from ships, by 2030.


Use of Sust. Alt. Fuels
Electrification
Energy Efficiency
Design and Retrofitting
Digital Green
Ports
Use of Sust. Alt. Fuels
Electrification
Energy Efficiency
Digital Green
Ports
Design for greening
Integration of new technologies
Sustainable Alternative Fuels
Electrification
Abatement Systems
7
Optimization of operations
Max. Life cycle end-of-life value
Payload weight, volumes and layouts
8
Life cycle methodologies
Probabilistic design
Robust, Flexible and Resilient
Manufacturing
New materials and processes
LCPA and recyclability
9
Digital link
Connection to digital twin
Full traceability of systems
Refitting
Young fleet refitting
Old fleet refitting
Cost efficient refitting
42
Integration of technologies
Sustainable Alternative Fuels
Electrification
Abt. Systems
41
Cost efficient refitting
Fit for purpose methodologies
Standardization
Modularization
Maintenance
Retrofittability for energy efficiency
Retrofittability for alternative fuels
Demo
Addressing Methane slip
Refitting solutions for energy efficient ships
Flexible and integrated design methodologies
Integrated refitting solutions to introduce alternative fuels
Eco-sustainable life-cycle manufacturing approaches for green shipping.
Milestones
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031

DIGITAL GREEN

This activity concerns the use of digitalisation to improve the environmental performance of the waterborne transport sector. Connectivity, the gathering of big sets of data, combined with data science can provide a deeper understanding of operations and enable effective support tools for decision-making. Digital twins can be used as a basis for comparison and decision support systems to achieve operational optimisation resulting in reduced energy needs and less emissions.

This can be applied to the production process of ships as well as to the ship's operations and port logistics.

Introduction

Reducing GHG, air and water pollutions requires not only the integration of new digital technology in vessels, but also the effective use of these technologies in an operational context. The optimisation of fleets, traffic, port operations and individual ship operations as part of its function requires the availability of data, data fusion capabilities, their analysis, AI and decision support. For effective implementation a new way of working needs to be developed and accountability and governance issues need to be resolved.

Managing and organising digitalisation towards the goals of this programme requires the development of three activities. These can be seen as the three steps progressively leading to reduced emissions:

Connectivity, mining data and Big Data analytics: gathering big sets of data, combining this with data science for a deeper understanding of operations and enable effective support tools for diagnostic and predictive analysis.

Digital Twin system: to enable mutually and real-time interacting physical assets and digital representations. Digital Twin systems may be used by organisations to provide value to their core corporate offerings through services (servitization).

Zero-Emission Decision Support Systems: insights from the digital twin system will translate into business or organizational decision-making activities, Decision support systems can be either fully computerized or human-powered, or a combination of both.

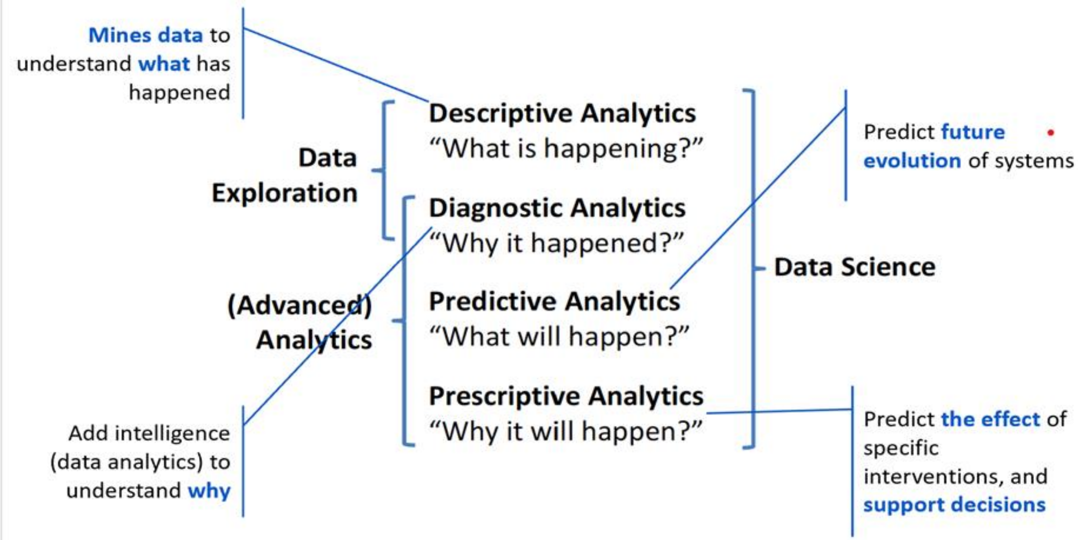


Figure x: Data science as a tool for understanding, predicting, operating with knowledge extracted from data

These activities aim to make use of digital capabilities to reduce emission by means of decision support for the operational condition and ship health monitoring necessary to reduce emissions through a combination of increase vessel utilization, fleet efficiency, optimized traffic and port logistics, as well as to enable compliancy with rules and regulations, such as.

Connectivity, Mining Data and Big Data Analytics cover sensing, sensors carriers, data acquisition and storage, including big data sourcing, connectivity, data management and sovereignty, data analytics and reporting. Some of the fundamental requirements to enable this are the availability of data standards, compliance, Intellectual property rights (IPR),) and data sharing agreements, configuration management and security management. Essential steps are data management (cleaning, labelling, traceability, pre-processing) and the analysis of data uncertainties remain key steps.

The essence of the Digital Twin is a virtual representation of the ship and its performance and its relevant systems' performance connected to the physical representation, the ship as it is built and operated. Providing predictive capabilities in addition to the historical and real-time data-based insights coming from Monitoring and Big Data Collection is not only an essential enabler for Zero-Emission Decision Support Systems, but also a prerequisite for a manageable and safe digitalized vessel. Nowadays, systems and subsystems increasingly come with advanced automation and software, including their own digital twin. Digital integration onboard (onboard digital architecture, digital twin open architecture, interface with measured data, interface with onboard applications such as decision support system) has therefore become a challenge in itself, with necessary verification and validation through hardware in the loop testing and continuous software upgrades.

Additionally, consistent configuration management is required throughout the lifecycle of the ship. In terms of energy consumption reduction, managing digital integration through a Digital Twin is crucial for zero-emission ships. The combined outcomes of the Monitoring and Big Data Collection and Digital Twin sub-activities, act as a basis for development of Zero-Emission Decision Support Systems. In order to develop a reliable and effective decision support system or in extremis a smart automation system to improve operational performance and reduce emissions, a reliable, verified and validated digital twin is required as well as reliable real-time data and fast-time computing on board.

Creating a digital twin can allow the quantification of vessel performance, enhancement of strategic technological trends, the prevention of costly failure.

By combining data such as fuel consumption, hull state, sea and current conditions and emissions relative to speed, transit time or transfer of cargo or passengers, it may calculate multiple scenarios indicating the room for improvement to the captain, fleet manager, traffic controller or any other stakeholder. The combination of historical and real-time data with predictions based on alternative scenarios, including human collaboration with the crew or the ship's captain, allows for the optimization of the condition of ship systems, the vessel performance (for emissions) and optimization of the vessel, traffic, and port and fleet operations.

A Zero Emission Decision Support System may convert these insights into real-life results by translating operator guidance into actions which, depending on the autonomy level, are executed by a Decision Support System and supervised by the captain, cargo handler, traffic controller and any other operator.

Relevance

Fleet optimisation in the context of a single operator operating a fleet of ships, or multiple operators serving a single market or linked in a logistic chain, requires accurate and real-time information regarding vessels, ship conditions, environmental conditions and operational plans. Digitalisation though Monitoring, Big Data Collection and Data sharing enables concepts to improve fleet utilization through collaboration and as a result, lowers energy need on a fleet or logistic chain level.

Measurements through appropriate sensors & carriers, analysis of data, control optimisation through predictive capabilities (the Digital Twin) and operator support or automated actions (autonomy) will contribute to reduce energy consumption, air pollution and underwater radiated noise. The organisation of ship operations is also dependent on the availability of accurate and real-time information regarding the ship, the onboard energy converters and consumers and environmental data, such as weather and sea state data, as well as water conditions on inland rivers (water depths and currents) and waiting times at inland locks and bridges and port terminals.

Ship condition optimisation allows for the continuous monitoring of ship systems data concerning energy conversion and use. This enables those activities described in Energy Efficiency pillar can be fully utilised. Increased energy demands caused by, for example, hull fouling, propellor damage or control deviations, can be monitored and analysed for deviations that require corrective action. Underwater radiated noise can be measured and monitored to allow for operator guidance depending on local rules and regulations or practices within particularly sensitive areas and Maritime Protected Areas.

Monitoring data and automation of reporting can furthermore be used for compliance with rules and regulations by individual ships and allows for measured data-driven policies and enforcement of rules and regulation. Data obtained in EU-MRV is a first good example of such an application.

Innovative aspect

The innovative approach represented by monitoring and big data collection, digital twin and the subsequent implementation of Zero-emission Decision Support Systems, will be fully leveraged not only for the operational management of the new zero-emission vessels, but also for the related Design & Retrofitting activities (newbuilds & retrofits).

In recent years, several research activities have been performed under the Horizon 2020 and the Partnership program calls in Horizon Europe:

- The Horizon Europe project CRISTAL develops solutions for monitoring, data analytics and decision support for several inland shipping cases.
- Development of data sharing and decision support solutions are also included in projects that develop concepts on autonomous shipping such as MOSES.
- The Horizon Europe project DT4GS is developing an open framework for digital twins that covers the full ship life cycle.

Digitalisation is also covered in national programs, such as the development of a Joint Maritime Digital Platform in the Dutch Maritime masterplan. Furthermore, several companies are working on digital twin development, including hardware in the loop models, edge computing and automated reporting tools. Coordination of these different activities is key to ensure that developed standards are aligned.

Connectivity

State-of-the-art digitalisation and connectivity solutions are characterised by proprietary and (sets of) subsystem specific solutions. As such, the functionality to monitor the condition of the vessel in terms of emissions requires a combination of connectivity solutions both for newly designed and for existing vessels. Data standards to facilitate the reusability of connectivity solutions for other ship types or system designs are currently non-existent. Data platforms to exchange and share acquired data are emerging but offer partial and often proprietary solutions. Meeting the requirements concerning data sovereignty, IPR and security requirements on the one hand, and allowing access to stakeholders (equipment suppliers, shipyards, shipowners, cargo owners, classification societies, software application developers, flag states) on the other hand, is yet to be achieved. The DT4GS project will develop first results in this field, but further efforts will be needed.

Furthermore, quantification of uncertainties in data is still lacking. The Partnership delivers the necessary standards for zero-emission relevant data exchange, including a platform design for the monitoring, analysis and compliance of ship-related data and required data from sources other than the vessel. The data platform will allow interoperability with traffic, port and logistic operations. This requires interaction with other data sharing standards such as the DTLF.

Digital Twin system

True digital twin systems, consisting of mutually and real-time interacting physical assets and digital representations, are in an infant stage of development. Combinations of simulation capabilities and operations do exist, most often in a semi- disconnected way, but these are still hampered by a lack of accuracy, and adequate configuration management of control systems applied in the physical vessel. Besides, for an on board Digital Twin, it could be necessary to simplify the on-shore Digital Twin in order to be able to execute computation on-board within an expected delay with reduced CPU. The addition of predictive capabilities in the operations of vessels to improve efficiency and eliminate emissions, therefore, requires modelling standards, Verification, Validation and Accreditation (VV&A) procedural standards, configuration management, systems in the loop testing and distributed simulation architectural standards. Furthermore, there is a need to investigate, determine and implement regulations on server capacity onboard of vessels as well as the connectivity requirements for connectivity to shore.

The quantification of uncertainties in the digital twin model and their comparison with real-time measured data is required, possibly with AI, so that digital twin predictions can be continuously improved. A topic here is to ensure that connectivity and data models are made available for the whole European fleet. This requires the development of datasets for a wide range of vessels. Furthermore, research is needed how segment specific benchmarks relate to individual vessels (since every vessel is considered unique).

Multiple linked twins are required to accurately and reliably monitor and forecast all aspects of the vessel. This system must be flexible and adaptive in order to deal with changes in the IT landscape, the physical twin (possibly modifications to the ship), and the needs of the end users. Digital Twin Lifecycle management and validation must ensure that the ship's Digital Twin system can be used for multiple different applications and remains reliable in the long term for decision support and automation. Since these systems can come from different suppliers non-technical aspects such as organization, governance, IP rights and business models need to be taken into account. By providing regulations and standards on these topics digital twin data can be transferred into services for the different stakeholders (servitization).

Zero-Emission Decision Support Systems

Zero-emission Decision Support Systems will subsequently be developed, combining sensor information, analytic and predictive capabilities and higher levels of automation, including AI. Ship condition and hull monitoring, environment data, traffic data, port operations data and logistic chain data are to be combined in Decision Support Systems or autonomous systems, while bearing in mind, the limitations of autonomous systems, as well as those of humans interacting with autonomous systems, which may require specific actions for stronger cooperation between the operator and decision support system.

Special attention should be given to decision support solution for the sip's power train system. The need for automatization of the ship's engine room is mainly driven by the introduction of new power train systems. These systems can consist of combinations of different component (for instance an ICE methanol engine with a battery electric auxiliary engine or fuel cell configurations), resulting in increasingly complex systems. This needs to be met by increasing skills for personnel on board of the vessel. Part of this needs to be met by training and improved work procedures on board. This can however be complemented by automatization of parts of the power train and digital or on shore support. Automatization and digitisation can furthermore enhance the safety of working with complex systems or with energy carriers that require additional requirements. Digitisation can improve the ship's health monitoring and reduce the changes of human errors.

Short-term

For the Horizon Europe Work Programme 2021-2024, in order to pave the way for the overall development of Digital Green (as illustrated in the chart below), the focus has been on the following issues:

- HORIZON-CL5-2021-D5-01-1 Digital Twin models to enable green ship operations(2021).
- HORIZON-CL5-2023-D5-01-13:Integrated real-time digital solutions to optimise navigation and port calls to reduce emissions from shipping (2023)
- HORIZON-CL5-2024-D5-01-15: Advanced digitalisation and modelling utilizing operational and other data to support zero emission waterborne transport

Medium -term

For the Work Programs Horizon Europe 2025-2027, strategic orientations are expected to boost further research and innovation aspect regarding Digital Green, the following orientations are preliminary recommended for further actions:

- ➢ Develop digital prerequisites for sharing Waterborne data
    - o Development of data sharing Standards (industry, class or vessel owner/operator input)
    - o Data Integration (Standards, guidelines or regulation)
    - o IPR, Security data sharing models (TPS, TCP, AMQP)
- ➢ Develop Decision support systems in combination with Digital Twin
    - o Open-Source modelling (Guidelines, standards, investigation)
    - o Developing solutions for fast-time onboard computing power/ fast data connectivity to shore
    - o Verification (verification of input, verification of connectivity, verification of data format)
- Interaction between DSS with the human operator.
- Develop, design and demonstrate solutions for digital support and automatization of the power train of a vessel, enabling crew support that face more complex power train configurations and improve the safety onboard.
- Assessment of calibration and certification of remote-sensing technologies in support of enforcement of IMO emissions requirements.
- A digital solution for IWT for monitoring and reporting which does not require any verification.

OPERATIONAL OBJECTIVES

Eliminating GHG emissions

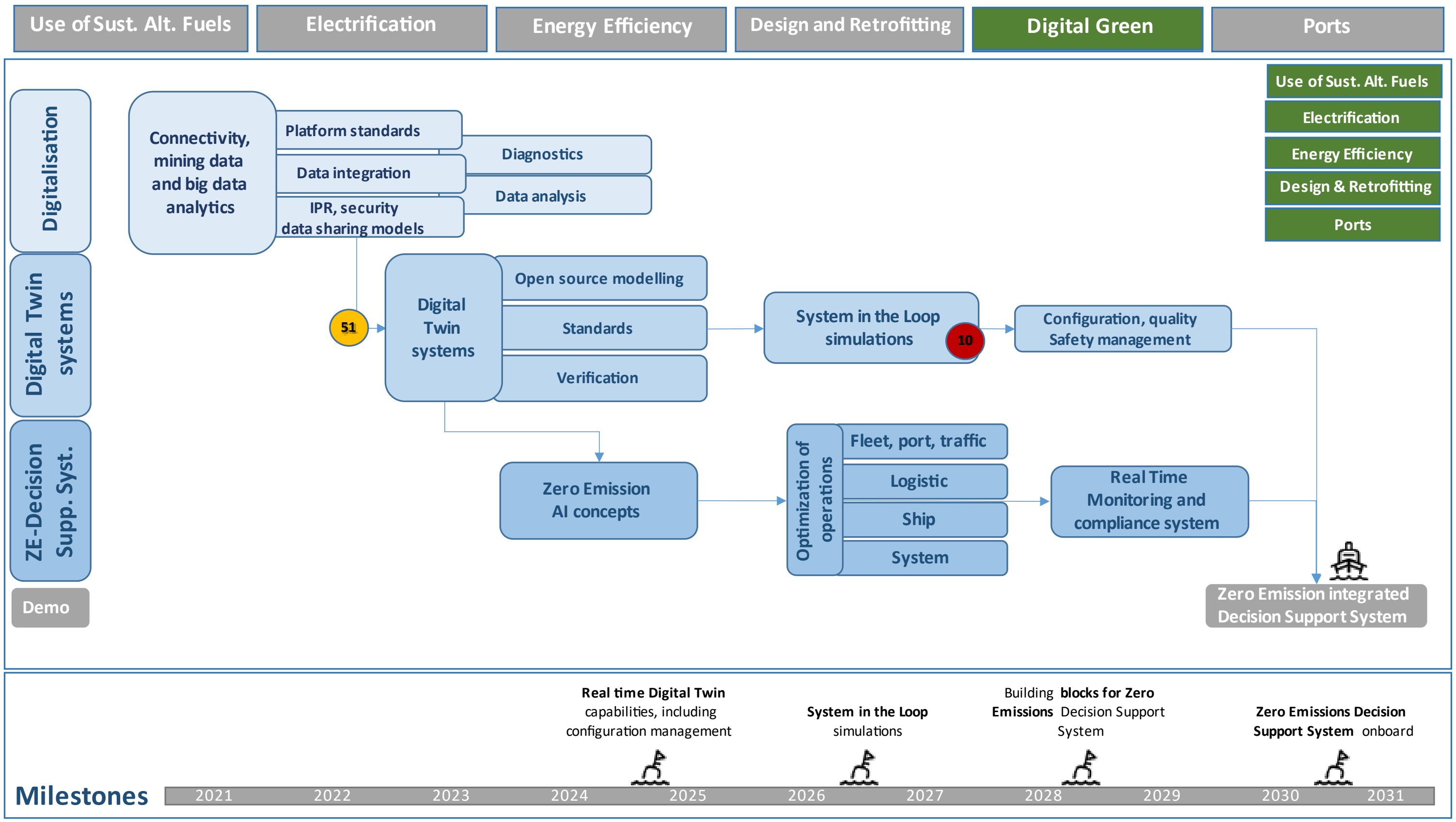
	To develop and demonstrate solutions for the **use of climate-natural, sustainable alternative fuels applicavle to ships with high energy demand (e.g. long distance shipping) before 2030;**
	To develop and demonstrate **before 2030** solutions for the **integration of high-capacity batteries** solutions as single energy source for short distance shipping **(up to 150 to 200 nautical miles);**
✓	To develop and demonstrate solutions to be able to reduce the fuel consumption of waterborne transport, including by the use of non-fuel based propulsion (such as wind), **by at least 55% before 2030, compared to 2008;**
✓	To develop and demonstrate **solutions for port based supply infrastruture** (i.e. infrastructure for bunkering of alternative fuels and electricity) **needed to enable zero-emission waterborn transport**, to be implemented **by 2030 at the latest;**
	To develop and demonstrate solutions for clean and climate-neutral, climate-resilient **inland waterway vessels before 2030.**

Eliminating air pollution

	To develop and demonstrate solutions to **cut coastal and inland pollution to air** from inland waterway transport and maritime shipping by **at least 50% by 2030, compared to current levels.**

Eliminating water pollution

	To develop and demonstrate solutions to **eliminate pollution to water** (including harmful underwater noise) from ships, by 2030.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Use of Sust. Alt. Fuels
Electrification
Energy Efficiency
Design & Retrofitting
Ports
Digitalisation
Digital Twin systems
ZE-Decision Supp. Syst.
Demo
Connectivity, mining data and big data analytics
Platform standards
Data integration
IPR, security data sharing models
Diagnostics
Data analysis
51
Digital Twin systems
Open source modelling
Standards
Verification
System in the Loop simulations
10
Configuration, quality Safety management
Zero Emission AI concepts
Optimization of operations
Fleet, port, traffic
Logistic
Ship
System
Real Time Monitoring and compliance system
Zero Emission integrated Decision Support System
Real time Digital Twin capabilities, including configuration management
System in the Loop simulations
Building blocks for Zero Emissions Decision Support System
Zero Emissions Decision Support System onboard
Milestones
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031

PORTS

This activity concerns the development of safe technologies and procedures for the bunkering of sustainable alternative fuels at inland and maritime ports and the use of Onshore Power Supply (OPS) when calling at ports. Furthermore, new necessary systems and infrastructures for alternative energy solutions (i.e., multi-fuel bunkering, recharging and transhipment points for batteries) and systems for monitoring and reducing emissions from waterborne transport within ports are developed.

Introduction

Achieving net-zero emission waterborne transport, as well as broadly facilitating zero emission for the wider logistics network, is one of the most critical challenges for port areas. Ports represent crucial hubs in the logistics network, linking maritime transport to the hinterland, including inland waterway transport, and finally to customers. Therefore, ports have to develop a strategy to facilitate net-zero-emissions for the different transport modalities entering the port and for port services such as towage, bunkering and pilotage. Besides reaching the emission targets, ports and waterways should also adapt to climate change effects by developing feasible and resilient solutions to minimize the impact on operations.

Ports and infrastructure solutions, including those located along inland waterways, for flexible bunkering of sustainable alternative fuel will be developed within this activity to enable the transition of waterborne transport. A reduction of port emissions will be ensured by a higher level of electrification and by increasing the abatement of the main water and air pollutants.

Relevance

Our proposed solutions in the Ports activity are designed to enable the energy transition of maritime shipping and inland navigation in relation to activities in ports. These include bunkering solutions, which are a precondition for vessels to be able to switch to alternative low carbon energy sources and thus reduce GHG and other pollutants. By taking actions to make the waterborne transport sector zero emission, it reinforces its position with respect to increasingly electrified road transport and reduces the risk of reverse modal shift towards road transport for both inland navigation and Short-Sea maritime shipping. This approach is essential to ensure that European maritime and inland shipping meets the strategic objectives of zero emission, as expressed in the EU Green Deal communication, making it clean and underpinning its position as the most energy-efficient mode of transport. It is therefore necessary to provide solutions to support the implementation of the Green Deal directives and regulations (such as AFIR, FuelEU Maritime, NewBatteries regulation, EED or EU-ETS) in ports in a pragmatic and targeted manner. Air pollution from waterborne transport has a considerable impact on the environment of ports, but also to coastal and surrounding city areas. The activities of the Partnership will tackle these emissions and will address the issue of eliminating accidental environmental damage, for example during bunkering operations.

Innovative aspect

Ideally, there should be an integrated vision and approach to the development of sustainable alternative energy solutions for ship propulsion. However, a range of candidate fuels are listed, and it is likely that these will be deployed differently, depending on the service and availability.

There is a lack of technical standards for bunkering some of these fuels, leading to a fragmentation of bunkering options throughout European ports and the emergence of early-stage cooperation agreements between ports concerning bunkering for particular routes.

Finally, there is still much uncertainty on safe storage and bunkering for several alternative fuel options as well as questions how new storage facilities can be integrated at acceptable costs with current infrastructure. By developing standards, creating flexible fuel storage and supply options for different energy suppliers, and integrating them into the overall port energy grid, the fast adoption of bunkering different alternative fuels in European ports (maritime and inland ports) can be guaranteed.

This is also the case for onshore power supply (or Shore Side Electricity). For inland waterway vessels and some smaller seagoing vessels, OPS has already been developed. For larger vessels, there is a lack of standards and there are no flexible solutions for providing enough power when vessels are calling.

Bunkering alternative energy solutions

The lack of an established distribution and bunkering network in ports and along inland waterways across is an issue but also the incipient implementation of green corridors. Europe is considered to be a major constraint for a large-scale roll-out of new sustainable alternative energy solutions to provide a feasible service to both maritime shipping and inland navigation. In this respect, special attention should be paid to hydrogen and their carriers, whose bunkering and supply would be addressed by the Clean Hydrogen Horizon Europe Partnership.

By learning from the recent challenges related to the introduction of LNG as a fuel in ports, the Partnership will develop flexible and adaptive solutions as well as innovative operational procedures with marine renewable energies and alternative fuels. In recent years, much attention has been given to the development of safe bunkering solutions of methanol, hydrogen and the supply of electricity both for Onshore Power Supply (OPS) and batteries charging. There is a need for cost-effective and modular solutions, especially for small and remote ports. Furthermore, developments are ongoing in the definition of proper and consistent rules, regulations, standards, and procedures, which will support the introduction of sustainable alternative shipping fuels in ports in the safest way possible.

The Partnership also addresses solutions to support and facilitate transfer of Ship Based Carbon Capture. The Partnership will develop solutions and strategies to link local energy streams (electricity, hydrogen, waste, ...) with the supply of alternative fuels for shipping, with a focus on the ship, whilst taking the overall value chains into consideration (smart fuel management systems solutions).

The development of business models that on the production of sufficient quantities of sustainable fuels at the points where they are supplied will help to achieve wider implementation. The reskilling and upskilling of the operators should also be considered.

Reducing port area emissions

Once it is possible to move beyond the current state- of-the-art, innovative on-board emission monitoring, the use of (automated) drones, vessels and other remote compliance monitoring and detection methods will be used to monitor and enforce emission limits applicable to waterborne transport. However, these systems require research *on calibration/certification of remote sensing systems to support the enforcement of SOx and NOx European (Sulphur Directive) and international emission rules (MARPOL Annex VI)* leading towards common operational procedures to test and agree upon methodologies, operational and reporting procedures, thresholds, and data-processing for MARPOL Annex VI surveillance and compliance strategy. As an innovative solution, different monitoring data may be combined and used to ensure compliance and enforcement of (new and emerging) environmental rules and regulations, ensuring a level playing field for ship owners. In this context, the interoperability of data and systems has to be ensured. Supporting the Waterborne activities on the electrification of vessels and ship-port operations, we shall develop technical standards for recharging equipment and power supply solutions, such as integration with smart grids and mobile solutions. Aiming an interoperable charging standard for vessels will support automated charging processes for such vessels.

Short term

For the Horizon Europe Work Programme 2021-2024, in order to pave the way for the overall development of Digital Green (as illustrated in the chart below), the focus has been on the following issues:

HORIZON-CL5-2023-D5-01-13 Integrated real-time digital solutions to optimize navigation and port calls to reduce emissions from shipping (WP 2023).

Medium -term

For the Work Programs Horizon Europe 2025-2027, the following orientations are preliminary recommended for further actions:

- Developing alternative fuel bunkering infrastructure standards and safe and cost-efficient multi-fuel bunkering at EU ports, going beyond the state-of-play of the different available solutions.
- Flexible, modular and mobile solutions for Onshore Power Supply and the provision of fast charging batteries using renewable energies during simultaneous cargo and supply operations. There is a need in R&I in
    - Solutions for adaptive mobile sockets for containership terminals
    - Automated cable management systems and connections systems for Ro-

Pax
- OPS solutions for Tankers and Chemicals carriers (solutions for connectivity in Explosive Atmospheres/Dangerous zones)
- Blackout mitigation
- Grounding monitoring

These solutions should be aligned with the onboard systems and the:

- Optimized onboard HV transformers
- Automation of onboard connection systems
- Optimization of onboard OPS switchboard operation
- Onboard safety monitoring systems and blackout prevention/mitigation systems.

Finally, these solutions will not incentivize the development of microgeneration in ports based on anything other than zero-emission technologies. Moreover, barges of shore-mobile base ICE generators will not be accepted

- Solutions supporting and facilitating debunker of Ship Based Carbon Capture

- Collection and interpretation in real time of data in regard to emissions to enforce emission limits based on interoperable data systems

- Safety and environmental sustainable impact of alternative fuels, such as ammonia, methanol and hydrogen and smart fuel management solutions at ports

1. Identify different hazardous scenarios for different alternative fuels (key fuels to cover – methanol and ammonia)
2. Formal Safety Assessments / Risk Assessment. Qualitative Assessment
3. Quantitative Assessment (Dispersion analysis following accidental release – urgent to address ammonia) – 1st: Computational Analysis + 2nd: Validation with experimental procedures
4. Develop Risk Control Options (including as a matter of priority the development/setting of Safety Distances for bunkering of methanol and, as a priority, of ammonia.

Use of Sus. Alt. Fuels | Electrification | Energy Efficiency | Design and Retrofitting | Digital Green | **Ports**

OPERATIONAL OBJECTIVES

Eliminating GHG emissions

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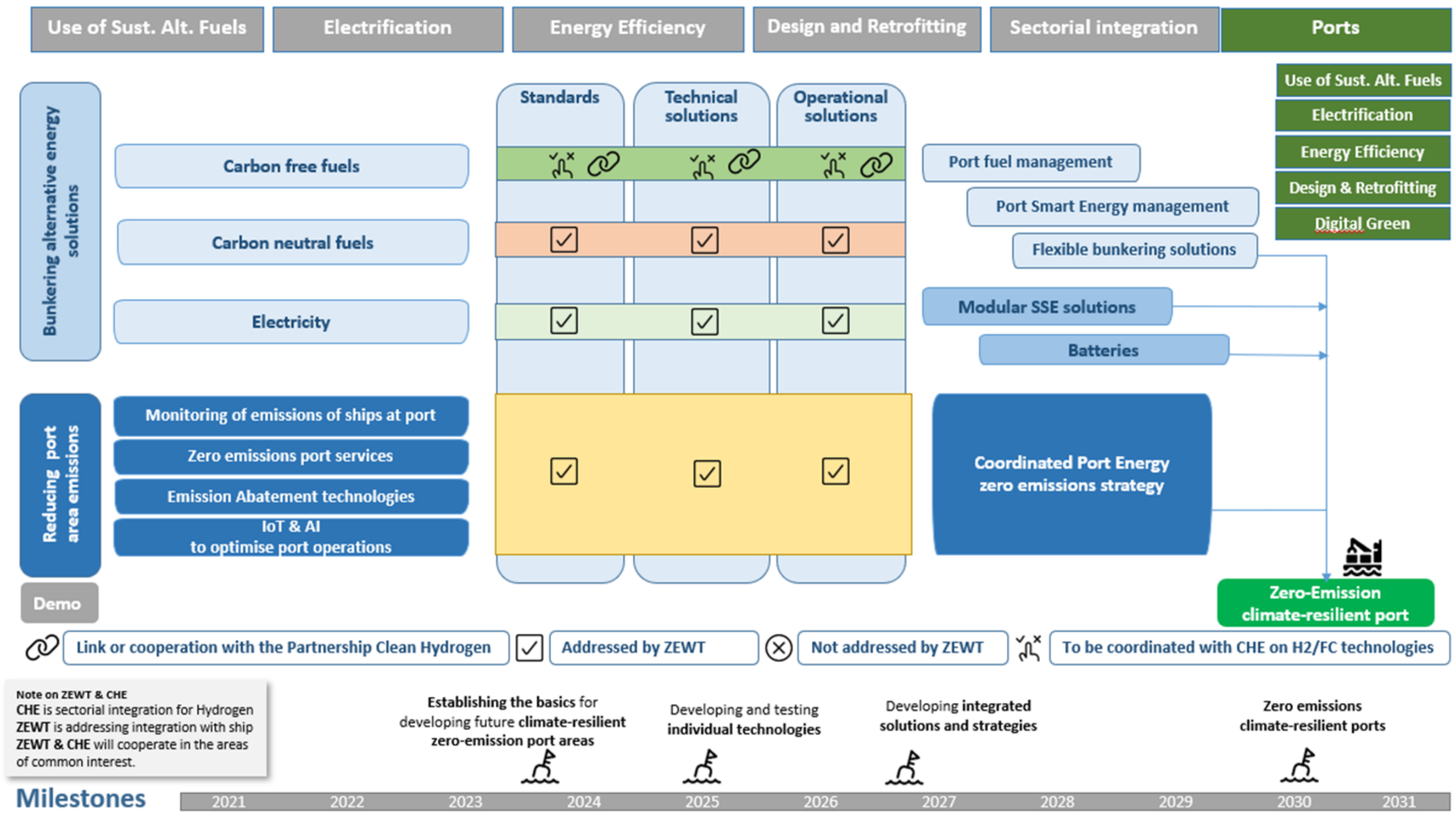
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Energy Efficiency
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Digital Green
Bunkering alternative energy solutions
Carbon free fuels
Carbon neutral fuels
Electricity
Standards
Technical solutions
Operational solutions
Port fuel management
Port Smart Energy management
Flexible bunkering solutions
Modular SSE solutions
Batteries
Reducing port area emissions
Monitoring of emissions of ships at port
Zero emissions port services
Emission Abatement technologies
IoT & AI to optimise port operations
Coordinated Port Energy zero emissions strategy
Zero-Emission climate-resilient port
Demo
Link or cooperation with the Partnership Clean Hydrogen
Addressed by ZEWT
Not addressed by ZEWT
To be coordinated with CHE on H2/FC technologies
Note on ZEWT & CHE
CHE is sectorial integration for Hydrogen
ZEWT is addressing integration with ship
ZEWT & CHE will cooperate in the areas of common interest.
Establishing the basics for developing future climate-resilient zero-emission port areas
Developing and testing individual technologies
Developing integrated solutions and strategies
Zero emissions climate-resilient ports
Milestones
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031

PART 3: EXPECTED IMPACTS

Achieving zero-emission waterborne transport to the benefit of future generations

The Partnership on Zero-Emission Waterborne Transport is built upon the following vision:

"For Europe to lead and accelerate the transformation of the global waterborne transport sector into a zero- emission mode of transport which has eliminated all harmful environmental emissions (including greenhouse gas emissions, as well as air and water pollutants, including (underwater) noise) through innovative ship technologies and operations which underpin European growth and employment."

The Partnership will therefore contribute to the three main impacts:

- the significant reduction of GHG emissions from waterborne transport, in line with the EU's commitment to cut GHG emission by at least 55% in 2030 compared to 1990 levels and to achieve a 90% reduction in transport emissions by 2050. In addition, the deployment of solutions will stimulate the modal shift to waterborne transport;

- cutting pollution, significantly improving the quality of the (European) environment and human health. The external costs of the impact on human health from maritime transport in the EU28 has been estimated to be €98 billion in 2016 and were €3 billion for inland waterway transport;

- it will enable Europe's waterborne transport sector to enhance its global competitiveness in terms of innovative solutions, as well as its global technological leadership in green ship technologies and solutions over foreign competitors (in particular South Korea and China) which, in turn, will create higher added value and economic wealth, as well as innovative jobs. The Partnership has a number of objectives and the impact per objective is elaborated upon in this chapter.

Impact of the specific objectives

The Partnership is built upon specific scientific, economic and societal objectives. These objectives will have a major impact on European society and the waterborne transport sector, as well as EU and international policies. These impacts will be described in the following sections.

Specific scientific objective

To develop and demonstrate deployable technological solutions which will be applicable for the decarbonisation and the elimination of other emissions of relevant ships and services.

GHG emissions - European Green Deal

The European Green Deal aims to ensure that Europe will be the first climate-neutral continent, thereby making Europe a prosperous, modern, competitive and climate-neutral economy. Becoming the world's first climate-neutral continent is a great challenge and opportunity. The Partnership will ensure that the waterborne transport sector assumes its responsibility to contribute to this ambitious policy objective.

The Waterborne community is committed to provide and demonstrate technologies and solutions for all main ship types and services before 2030, which will enable zero-emission waterborne transport before 2050.

If no actions were to be taken, the GHG emissions from waterborne transport would be at least 5 to 10% of the world emissions in 2050. Therefore, the solutions developed in this Partnership will contribute significantly to the policy objectives of the European Green Deal to tackle climate and environmental-related challenges, thereby contributing to the preservation of human and animal life, as well as forests and oceans.

In addition, the Partnership will facilitate the achievement of the targets foreseen within the Fit for 55 legislation, including the FuelEU Maritime regulation, the inclusion of maritime shipping in the EU ETS, the revision of the AFIR etc.

Finally, the Partnership's solutions will contribute to the Green Recovery, as a key element to mitigate the economic effects of the COVID-19 Pandemic. Since the European waterborne transport sector is world leading in complex technologies, Europe can lead the world in the transformation of the waterborne transport sector.

The United Nations has formulated 17 Sustainable Development Goals (SDGs) which are at the heart of the 2030 Agenda for Sustainable Development, adopted by all UN Member States. Climate action is SDG13 and is fully in line with the European Green Deal. Therefore, achieving the objectives of the Partnership will significantly contribute to SDG13.

SDG 13 – Climate Action

- ZeroEmission Waterborne Transport solutions (Sustainable Alternative Fuels, Electrification, Renewables, Abatement Systems)
- Zero Emission Decision Support System
- Climate resilient port strategies & contingency plans

Air pollution

Another Sustainable Development Goal defined by the United Nations is the Good health and well-being of citizens, SGD3.

The Partnership will develop and demonstrate solutions for the elimination of air pollution in port cities, coastal areas and along inland waterways. Waterborne transport into ports will be fully electrified; shipping along coastlines will be either electrified or based on clean, sustainable alternative fuels. Inland shipping will make use of batteries or hydrogen-based fuel cells, completely eliminating harmful effects.

SDG3 - Good health and wellbeing

- Reduction of air pollution in port cities and along inland waterways (Use of alternative fuels, electrification, emission abatement systems)

Annual premature European deaths caused by air pollution are estimated at 430,000-800,000. A major cause of these deaths is nitrogen dioxide and other nitrogen oxides (NOx) emitted by transport. By switching to sustainable alternative fuels, the waterborne sector is contributing significantly to the reduction of these premature deaths.

Water pollution

Another Sustainable Development Goal defined by the United Nations is the protection of Life below water.

SDG14 - Life Below Water

- Abatement systems for ship pollution
- New hull coatings with no release of chemicals
- Minimizing underwater noise of ships

The Partnership will contribute to the protection of the Ocean and Life below Water by developing and demonstrating technologies for the reduction of pollution from shipping. The use of open systems, such as scrubbers, will be drastically reduced. New hull coatings will be developed to reduce resistance of ships, whilst at the same time reducing the release of harmful chemicals into water. Furthermore, underwater noise will be mitigated by the development of quiet engines and quiet propulsion systems. Noise levels of individual ships will be significantly decreased.

Specific economic objectives

By 2030, implementation of economically viable European new technologies and concepts regarding zero-emission waterborne transport, to strengthen the competitiveness of European industries in growing green ship technology markets and provide the capability to re-enter markets presently dominated by Europe's competitors.

The European (EU 28+Norway+Turkey) waterborne technology industries, including shipbuilders, boatbuilders and 1st and 2nd tier equipment suppliers, are world leading in terms of aggregated production value of shipbuilding and ship-systems production, even though its physical level of shipbuilding production (in terms of gross tons (GT) and deadweight tons (dwt)) has decreased. With a calculated value of EUR 147 billion, the EU 28+2 countries represent 30,5% of the global production value for maritime technology of EUR 482,5 billion[27] (annual average for 2010-2014) and are securing more than 750.000 jobs in more than 40.000 enterprises in Europe[28].

Consolidating and further strengthening the EU's frontrunner role in RD&I and the implementation of greening technologies and concepts will be essential to ensure the transition to a clean and competitive European waterborne transport sector and to enhance the competitiveness of the European waterborne transport sector across all market segments.

The Partnership is a centre-piece of the European waterborne technology sector, underpinning the development of new ship concepts and system technologies and demonstrating radical onboard technologies. Innovation is seen as essential for gaining access to new markets, accessing high value niches (e.g. specialised vessels for offshore), or re-entering markets lost to competing continents.

Specific societal objective

To facilitate the development of regulations and policies at national and international level, including the development of standards to enable the implementation of technological solutions for zero- emission waterborne transport by 2030 at the latest.

The International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. IMO's work supports the UN SDGs and its work is therefore essential for the achievement of the policy objectives of the European Green Deal. The EU and its Member States discuss future regulations for the maritime transport sector at the IMO. The Partnership will provide the scientific and technical basis for discussion at the level of the IMO.

For inland waterway transport, the Partnership will present the progress and results of the Partnership during meetings of CESNI, as well as the relevant NAIADES working groups.

The Partnership will therefore be a key instrument to provide the necessary input for the development of policies, rules and regulations to accelerate the transition towards zero-emission waterborne transport.

To facilitate the uptake of innovative zero-emission waterborne transport technologies and solutions within the European waterborne transport sector supporting economic growth and European employment.

The waterborne transport sector will benefit from the Partnership by developing new technologies, while boosting circularity and creating new markets. Therefore, the European waterborne transport sector will take a leading role in the transformation of the worldwide sector and will enhance its competitiveness at the same time, ensuring long- term employment, often in remote areas.

People, skills and knowledge are the backbone of the European waterborne transport sector. The waterborne transport sector is one of the most diversified sectors in terms of types of jobs and required skills, ranging from jobs in ports, forwarders, stevedores, designers, builders of thousands of systems to crew on board vessels, as well as office staff. Managing such a wide and diversified set of skills and tasks requires a coordinated approach in order to adapt skills along the entire value chain during the transformation. The waterborne transport sector will ensure that skills which are needed for deploying and using innovative technologies are embedded in education and training activities. In this context, a particular emphasis will be placed on nurturing Small and Medium-sized Enterprises which are an essential part of the European ecosystem. The waterborne transport sector will pay specific attention to the use of long term skills development strategies and innovative educational and training methods to address the increasing diversity of the European workforce (which is comprised of people of all genders and ages, local and/or migrant origin) and also to attract more talented women and young people to the waterborne transport sector. Through the creation of the foundation to facilitate the shift to zero-emission waterborne transport, the Partnership will play a key role in the economic recovery following the COVID-19 pandemic through the creation of highly skilled jobs.

Enablers and requirements to reach the full impact of the Partnership

For the Partnership to reach its maximal impact, it is important that enablers are sufficiently developed and that requirements are met. Some examples are:

- Market demand for green and sustainable products
- Infrastructure and fuel availability
- Regulations and international long-term governance
- Rules of classification societies

Market demand for green and sustainable products

The most crucial factor to reach the full impact of the Partnership is the uptake of zero-emission technology by the sector. This can not only be achieved by technology push; there has to be a strong demand for green products and services. We are already seeing the first signs of shippers requesting green transport; or shippers awarding long-term contracts based on a transition to greener shipping. This is followed by some ship-owners pledging that, from 2030 onwards, they will only order zero-emission vessels. But this demand for green transport has to grow in the coming decade to stimulate the uptake of technologies. By developing and demonstrating deployable solutions and by supporting the development of rules and standards for green products, the Partnership will have an indirect impact on stimulating deployment, e.g. by ensuring synergies with deployment programmes like CEF, Innovation fund etc.

Infrastructure and fuel availability

Another important enabler or requirement to achieve the full impact of the Partnership is the availability of fuel and the necessary bunkering infrastructure. Here we are facing a Catch-22 situation: without demand for alternative fuels, availability of these fuels will be very limited and without availability of fuels along a route or in a sea region, the uptake of new technologies using these fuels will stop. Local, small scale cooperation may lead to small breakthroughs, but also to local solutions which limit wider applications. The international standardization of fuel availability and of bunkering technologies is necessary. This requires a coordinated approach outside the scope of the Partnership.

Regulations and international long-term governance

For ship owners making large investments or assuming long-term financial obligations, it is very important that their assets are future proof. On the one hand, this requires flexible ship designs and possibilities for retrofitting to adapt to new upcoming innovations. But a long-term perspective in international governance of the waterborne transport sector is also an important enabler of the transition. Regulations need to be known well in advance and should preferably be applicable world-wide. Given the lifetime of vessels of close to 30 years, a reliable framework of regulations has to be put in place to facilitate the transition to a zero-emission mode of transport. The Partnership will provide input to the European Commission and the Member States regarding their position in regulatory discussions, with a special focus placed on long-term governance.

Rules of classification societies

Ships are being designed and built according to the rules of classification societies. Following these rules is necessary for guaranteeing a safe investment for financing institutions and for obtaining insurance of the vessel in operation. Classification rules are developed to establish standards for the structural strength of the ship's hull and its appendages and the safety of the propulsion and steering systems, power generation and those other features and auxiliary systems which have been built into the ship to assist in its operation. A vessel built in accordance with the applicable rules of a classification society may be assigned a class designation by that society upon satisfactory completion of the relevant surveys. For ships in service, classification societies carry out surveys to verify that the ship remains in compliance with those rules.

With the development of new technologies for propulsion, design, retrofitting and operations, the uptake of these innovations has to be facilitated with associated classification guidelines and rules. It is crucial that these guidelines and rules are developed alongside the development of the technology and in alignment with the IMO, to avoid their being a gap between demonstration and possible deployment. Timely development of rules will enable the Partnership to reach its full impact, but the Partnership will also have a role in supporting the development of these rules.

Proposed monitoring arrangements

An Objective oriented approach

The Partnership takes an objective driven approach, founded upon the ambition to achieve climate neutrality and eliminate harmful pollutants. From this general objective, specific and operational objectives follow and these objectives drive the Partnerships Intervention Logic.

The operational objectives are most closely linked to the implementation of the Partnership and are foundation for a set of KPI's (key performance indicators) which can be used to monitor the effectiveness of the action. In summary:

- General or overall objectives are the goals set at the EU level to which the initiative aims to contribute:

(To) provide and demonstrate zero-emission solutions for all main ship types and services before 2030, which will enable zero-emission waterborne transport before 2050.

- Specific objectives are those setting out what the initiative aims at achieving at the scientific, economic and societal level. In this respect the Partnership aims at developing and demonstrating new technological solutions, strengthening the competitiveness of the EU industries and facilitating the uptake of innovative technologies and the development of new policies and regulations.
- Operational objectives are the specific focuses of the activities of the initiative.

From objectives to Results

As a research and innovation action the final impacts towards the widespread implementation of zero-emission waterborne transport will only be achieved in the long term. However, the direct activities of the partnership will achieve 3 types of Results:

- Outputs are the solutions directly developed within the Partnerships activities in the short term, which will contribute to meeting the Operational objectives;
- Outcomes are the medium term results of the actions of the initiative, meeting Specific objectives;
- Impacts are the long term indirect result of the action, i.e. General objectives, expected to be achieved in the social, economic and scientific spheres.

DATA COLLECTION

The primary means of collecting information for some of the reporting elements will be through European Commission's reporting systems for management of the Horizon Europe programme. For the private side, the necessary data needed to monitor the implementation of the Partnership will be compiled by means of a questionnaire circulatedby the Secretariat every second year to the membership. The questionnaire will obtain:

- Details of the value of the additional in kind resources mobilised, broken down by broad category;
- The outcomes, solutions, commercialisations and patents arising out of the Partnership activities;
- Any scientific publications and participation within policy and regulatory forums linked to the Partnership;
- Any other relevant data necessary for the monitoring framework

Similarly Member States and Associated States within the cooperation group will be asked to provide information on any alignment between their programs and the Partnership.

The Partnership will also formulate a framework to enable the projects supported to report towards the Secretariat on their activities without substantial additional efforts.

Reporting data will be aggregated so as to maintain the reasonable commercial confidentialities of the members.

The Partnership expects that the European Commission will provide reasonable support to provide the necessary quantified statistical data needed for annual reporting whilst respecting its confidentiality obligation.

Key Performance Indicators (KPIs)

The following KPI's will be used to support the monitoring of partnership implementation

Key Performance Indicators (KPIs)

European Partnership on Zero-Emission Waterborne Transport		Monitoring and evaluation framework		
General objectives	Measure of success	Data source and methodology	Responsible for monitoring and timing	Baseline and targets
G01 To provide and demonstrate zero-emission solutions for all main ship types and services before 2030, which will enable zero-emission waterborne transport before 2050.	a) Value of contribution (EU and additional resources) mobilised towards the achievement of the European Green Deal objectives (total in 2030, monitored every year) b) Total value of the private contribution and EU contribution and its percentage of the EU contribution mobilised to date, dedicated to decarbonisation (total in 2030, monitored every 2 years) c) Total value of private contribution and its percentage of EU contribution mobilised to date, dedicated to reducing air pollution (total in 2030, monitored every 2 years) d) Total value of private contribution and its percentage of EU contribution mobilised to date, dedicated to water pollution(total in 2030, monitored every 2 years)	a) HE budget, and information from the Partnership secretariat on in-kind contribution following questionnaire to members b, c and d budget for the partnership and for total value including additional activities (biannual WPs)	a) b) c) and d) RTD, INEA, Partnership Secretariat (monitored and reported every 2 years, target measured at the end of the program)	Baseline: start of the Partnership a) Total resources deployed in the context of the the partnership (EU contribution defined in MoU +3.3 bn Eur private additional in kind resources) by 2030 b) Target: billion €2.3 of private contribution (additional resources) & 70% of EU contribution c) Target: 660 million € of private contribution (additional resources) & 20% of EU contribution d) Target: 330 million € of private contribution (additional resources) & 10% of EU contribution

Key Performance Indicators (KPIs)

European Partnership on Zero-Emission Waterborne Transport	Monitoring and evaluation framework			
Program level objectives	Measure of success	Data source and methodology	Responsible for monitoring and timing	Baseline and targets
Partnership leveraging the EU's investment	e) Commitment deployed compared to planning, % of value of additional resources mobilised compared to EU contribution to date.	e) Partnership secretariat (response to questionnaire to partners), Cordis data (funding per project), INEA.	e) To be monitored on yearly basis compared to planning at start of partnership and additional activities described within MoU. Target measured at the end of the program	Final target 600% (by 2030) 3Bn€/500€M
Achieving a critical mass to increase impact.	f) Number of MSs and Horizon Europe associated states who have adapted R&I programs to increase synergies with ZEWT. g) Number of companies, research bodies and universities who have adapted R&I programs to increase synergies with ZEWT.	f) Partnership's States Representative Group, questionnaire, Partnership secretariat, g) Partnership secretariat (response to members questionnaire),	f, g) To be measured every second year. Targets: intermediate (y+3) and final - end of the program (2030)	f) Intermediate (after Y+3) at least 3 states, 2030 at least 5 states g) Intermediate (after y+3) 30 members, 2030 50 members.

Key Performance Indicators (KPIs)

European Partnership on Zero-Emission Waterborne Transport		Monitoring and evaluation framework		
Program level objectives	Measure of success	Data source and methodology	Responsible for monitoring and timing	Baseline and targets
Broadening Participation in European Research Programmes.	h) Number of different MSs and Horizon Europe associated states industries represented within the membership of ZEWT. i) Percentage of projects including participants from the MSs and Horizon Europe associated states who are within the lower quartile of Horizon 2020 activity. j) Percentage of projects including SME participation	h, i, j) CORDIS, INEA, Partnership secretariat.	h, i, j) To be calculated on yearly basis	h) 20 states i) 30% j) 80%

Key Performance Indicators (KPIs)

European Partnership on Zero-Emission Waterborne Transport	Monitoring and evaluation framework			
Specific objectives	Measure of success	Data source and methodology	Responsible for monitoring and timing	Baseline and targets
S01 (scientific) To develop and demonstrate deployable technological solutions which will be applicable for the decarbonisation and the elimination of other harmfull emissions of main ship types and services.	a) Number of scientific papers and journal citations arising from the partnership including projects (from year +3) b) Number of patents and solutions placed on the market for outcomes resulting from ZEWT supported activities, projects (from y+3). c) Impact studies, examples that provide evidence for significant impacts from the partnership.	a) Project questionnaire, citation index, Monitoring mechanisms of the industry b) Projects, Monitoring mechanisms of the industry etc. c) Secretariat, membership questionnaire, INEA, feedback from the projects, expert interviews.	a) Projects, Partnership secretariat and members; Every second year b) Projects, partnership secretariat; Every second year, starting y+3 c) Case studies included within reporting every second year, illustrating contribution to specific objectives and added value from partnership. Every second year	Baseline: start of the Partnership a) Target: min 50 after y+3, min. 300, in 2027, min. 450 in 2030 b) Baseline: by 2030 minimum 50 patents and/or solutions commercialised c) At least four successful impact studies included in reporting every second year (except for the first biennial report).

Key Performance Indicators (KPIs)

European Partnership on Zero-Emission Waterborne Transport	Monitoring and evaluation framework			
Specific objectives	Measure of success	Data source and methodology	Responsible for monitoring and timing	Baseline and targets
SO2 (economic) By 2030, implementation of economically viable European new technologies and concepts regarding zero-emission waterborne transport, to strengthen the competitiveness of European industries in growing green ship technology markets and provide the capability to re-enter markets, presently dominated by Europe's competitors.	Number of solutions arising from the outcomes of the projects supported by the partnership	Projects, monitoring mechanisms of the industry etc.	Partnership Secretariat, Industry; On yearly basis, starting y+3	Baseline: start of the Partnership Target: min. 12 after y+3, min. 50 after 2027 and 70 solutions at the end of the program (2030)

Key Performance Indicators (KPIs)

European Partnership on Zero-Emission Waterborne Transport		Monitoring and evaluation framework		
Specific objectives	Measure of success	Data source and methodology	Responsible for monitoring and timing	Baseline and targets
S03 (societal) To facilitate the development and implementation of regulations and policies at national and international level including the development of standards to enable the implementation of technological solutions for zero-emission waterborne transport by 2030 at the latest;	Number of contributions from projects forming basis towards the development of guidelines, standards and rules provided directly to the relevant standards and rule setting bodies (IMO, Member States, legislative expert groups, Classification Societies, etc.)	Projects, partnership secretariat questionnaire to members	Partnership secretariat, INEA, COM (RTD), To be monitored every second year, starting y+2 until 2030	Baseline: start of the Partnership Target: minimum 20 contributions to developments of standards from ZEWT projects by 2030
S04 (societal) To facilitate the uptake of innovative zero-emission waterborne transport technologies and solutions within the European waterborne transport sector supporting economic growth and European employment.	Number of solutions resulting from the projects supported by ZEWT, whose uptake has been facilitated by CEF, Climate Innovation Fund, Regional Funds, national deployment schemes and other relevant programs and/or private investments (commercialised)	Secretariat questionnaire to members, own industry's monitoring mechanisms, CEF yearly reports, Climate Innovation Fund reports etc.	Partnership Secretariat, INEA, RTD, CLIMA (starting from y+3 and in 2030)	Target: minimum 50 solutions by 2030

Key Performance Indicators (KPIs)

European Partnership on Zero-Emission Waterborne Transport		Monitoring and evaluation framework		
Operational objectives	Measure of success	Data source and methodology	Responsible for monitoring and timing	Baseline and targets
001 (GHG) To develop and demonstrate solutions for the use of climate-neutral, sustainable alternative fuels applicable to ships with high energy demand (e.g. long distance shipping) before 2030	Number of directly deployable solutions developed using climate-neutral, sustainable alternative fuels applicable to ships with high energy demand, e.g. long distance shipping;	Projects results	INEA, Partnership secretariat (can be monitored after first results, y+3, and then throughout the program, the final result will be known at the end of the program 2030), every second year	Target: 20 solutions by 2030
002 (GHG) To develop and demonstrate before 2030 solutions for the integration of high-capacity batteries solutions as single energy source for short distance shipping (up to 150 to 200 nautical miles)	% of target electrified autonomy (150nm-200nm) achieved for commercially scaled shipping using electrical energy storage systems		Projects, INEA, Partnership secretariat, Progress reported every second year from Y+3.	Target: of 150nm 100% electric autonomy demonstrated by 2030

Key Performance Indicators (KPIs)

European Partnership on Zero-Emission Waterborne Transport	Monitoring and evaluation framework			
Operational objectives	Measure of success	Data source and methodology	Responsible for monitoring and timing	Baseline and targets
003 (GHG) To develop and demonstrate solutions to be able to reduce the fuel consumption of waterborne transport, including by the use of non-fuel based propulsion (such as wind), by at least 55 % before 2030, compared to 2008	% of fuel consumption reduction target (55%) achieved applicable to large scale shipping as a result of innovations supported by the partnership.	Projects results	Projects, INEA, Partnership secretariat. Progress reported every second year from Y+3.	Target: 100% of target 55% reduction in fuel consumption demonstrated applicable to large scale shipping by 2030
004 (GHG) To develop and demonstrate solutions for port based supply infrastructure (i.e. infrastructure for bunkering of alternative fuels and electricity) needed to enable zero-emission waterborne transport, to be implemented by 2030 at the latest	Number of projects which demonstrates innovative solutions enabling deployable cost-effective bunkering of different sustainable alternative fuels and electricity supplied to ships.	Projects	Projects, INEA, Partnership secretariat measured at the end of the program and monitoring cycle. Reported every second year.	Target 004: 5 projects by 2030.

Key Performance Indicators (KPIs)

European Partnership on Zero-Emission Waterborne Transport		Monitoring and evaluation framework		
Operational objectives	Measure of success	Data source and methodology	Responsible for monitoring and timing	Baseline and targets
005 (GHG) To develop solutions for clean and climate-neutral, climate-resilient inland waterway vessels before 2030.	005 Number of solutions demonstrating clean and climate-neutral, climate-resilient inland waterway vessels	Projects	Projects, INEA, Partnership secretariat, measured at the end of the program and monitoring cycle. From Y+3 reported every second year.	Target 005: 15 number of solutions demonstrated by 2030.
006 (Air) To develop and demonstrate solutions to cut coastal and inland pollution to air from inland waterway transport and maritime shipping by at least 50% by 2030, compared to current levels.	006 Number of solutions demonstrated contributing to cutting coastal and inland pollution to air from inland waterway transport and maritime shipping by at least 50% by 2030.		Projects, INEA, Partnership secretariat, measured at the end of the program and monitoring cycle. From Y+3 reported every second year	Target 006: 25 solutions demonstrated by 2030.
007 (water) To develop and demonstrate solutions to eliminate pollution to water (including harmful underwater noise) from ships, by 2030.	Number of projects demonstrating solutions to eliminate pollution to water (including harmful underwater noise) from ships		Projects, INEA, Partnership secretariat, measured at the end of the program and monitoring cycle From Y+3 reported every second year.	Target: 5 number of projects

PART 4: GOVERNANCE

Description of the governance of the Partnership

The Partnership has been concluded between the European Commission and the Waterborne TP Association (hereinafter referred to as Partners), representing the entire waterborne transport community. The Waterborne TP is established as an Association under Belgian law with the role of representing its members with regards to RD&I strategies defined within its statutes. It is a membership-based organisation; it is open to newcomers, on the basis of a paid subscription (€3,000 annually as of 2020). Other parties can also participate as observers at no cost, subject to board approval; these may include civil society organisations and representatives of national administrations.

Partnership Board

The Partnership is governed by a Partnership Board. This board steers the Partnership towards achieving its SRIA, supervise the process of interaction with industry and Member States, approve the research programme as set out in the SRIA and the specific topics to be addressed in Horizon Europe calls. The actual decision on the calls to be published is taken following comitology procedure.

The Partnership Board consists of representatives of the European Commission Services, together with representatives of the Partnership. The European Commission co-chairs and may include several participants, such as from DG RTD, DG MOVE, DG CLIMA, DG GROW and DG ENV, and potentially other DG's as necessary. The Partnership's representatives are approximately 15 high-level representatives of the stakeholders in the transition to zero- emission waterborne transport. The Waterborne TP representatives are proposed by the association following a vote in its General Assembly and be appointed by the European Commission. Participation in the Partnership Board from the industry side will be on a rotating basis, every second year.

The Partnership Board have laid down its Rules of Procedure, based on a harmonised proposal provided by the European Commission, covering inter alia rules on confidentiality, transparency and avoidance of conflicts of interests.

States Representatives Group

EU Member States and Associated Countries are involved in the Partnership through the States Representatives Group. All Member States and associated countries are invited to participate. The aim is to ensure a two-way information flow between the updates of the SRIA and research proposals from industry and national priorities, policies and programmes. This is seen as a crucial step in the priority-setting process and will facilitate discussions in the Horizon Europe programme committee. In addition, it will facilitate the take- up of results and the development of necessary policies and regulations.

Secretariat

The Partnership is assisted by a Secretariat provided by the Waterborne TP association. The partners other than the EU will be organised within the Waterborne TP association. Within the Partnership's working groups, members of the Partnership discuss the technical requirements and research progress for the Partnership. Representatives of EU Member States, Association Countries and European Commission services may be invited to participate in the technical meetings of the working groups.

Managing crosscutting issues

The research requirements and associated research activities for the Partnership are a subset of the activities of the existing Waterborne TP association. There is a close link between topics in the Partnership's research agenda and topics that, although outside the scope of the Partnership, are addressed by collaborative research activities of Horizon Europe. Examples of cross cutting issues include digitalization for greening within the Partnership vs digitalization for safety, or fire/ explosion/toxity risks and passenger safety on vessels in general and the safety associated with using new sustainable alternative fuels and the required ship layouts which would be covered within the Partnership. In addition, to address the synergies described below, ensuring the coordination of needs and activities linked to these issues is important and will be ensured by the Waterborne TP Coordination Group and Board.

Furthermore, the Waterborne TP will organise activities to maintain an overview of ongoing relevant research and developments in the waterborne sector and more broadly. It will also ensure the appropriate communication and dissemination of the findings of the results of the Partnership as well as ensuring high visibility of the Partnership and its activities. For example, this might be undertaken through brochures, maintaining a website, social media activities and organising events. Such activities will also be coordinated together with the activities of the "Lasting" CSA and the related dissemination activities of the European Commission.

The Partnership has established a visual identity to stimulate participation in its activities by organising conferences, workshops, social media accounts e.g. Twitter, newsletters and press releases. As the main European branch organisations take part in the Partnership, the broader waterborne transport community will be informed through them, thereby ensuring an appropriate level of visibility for the Partnership, including its visual identity.

Openness and transparency

The waterborne transport sector is, by its very nature, a highly diversified sector and an objective of the Partnership is to bring together the sector's diverse activities and focus efforts more efficiently on zero-emission waterborne transport. As a consequence of this diversity, the Partnership has a broad composition and is open to new members. From the beginning, the Partnership has included all members of the Waterborne TP which, in turn, includes relevant European associations representing, for example, ship owners and operators, as well as industrial representatives within the maritime and inland navigation sectors.

As the Partnership is for co-programming, participation in calls for proposals is open to all by definition.

Participation

Stakeholders in the waterborne transport sector and in zero-emission transport can participate in the Partnership in two ways:

- Associations, companies, academia and research institutes can join the Waterborne TP Association. There is a low annual membership fee for this association (3,000 EUR for 2023) which allows as broad a participation in the association as possible. Benefits of being a member of the Waterborne TP Association include:
    - Direct involvement in in-depth discussions on all technical issues;
    - Participation in other relevant waterborne issues, such as safety of ships, digitization and automation, production processes, Blue Growth and logistics;
    - Automatic membership of the Partnership;
    - Networking and collaboration;
    - Direct access to the additional activities performed by the Partnership related to establishing synergies with relevant initiatives/programmes as well as information on applicable financial instruments.
- Non-members can participate in events organised by the Partnership and/or the Waterborne TP Association. Events may include conferences to present the latest RD&I results or open discussions on the technical research agenda.

Governmental and non-governmental organisations can join the Partnership at all levels as observers, without having to pay a fee. Observers will be invited to strategic and detailed programming workshops.

It is understood that many stakeholders in the waterborne transport sector are small companies and travel to and from Brussels may hinder their on site participation in the Partnership, and physical meetings with direct interaction with European Commission Services and Member State representatives which usual takes place in Brussels. Consequently, the Partnership will facilitate remote access and tele presence for most events as well as organising outreach events towards remoter maritime and inland navigation regions (such as Bulgaria, Romania, Ireland) to allow a balanced participation from all Member States.

Furthermore, meetings of the Partnership will be live-streamed and live feedback to the participants in the meeting will be possible. In addition, a number of Associations involved in the Partnership represent a broad base of SMEs. These SMEs will be involved via discussions in their relevant associations, online consultations and national outreach events and will be able to represent their umbrella organisations during meetings.

Access to information

The Partnership will launch a dedicated website which will give an overview of its research agenda and of ongoing and finished projects. For finished projects, the website will detail the main results and deliverables for everyone to use. The website will also offer the possibility to provide feedback on the Strategic Research and Innovation Agenda and the rolling detailed activity plans through surveys and will show what feedback has (or has not) been taken up and why.

The Partnership undertakes actions that increase the impact of its activities and the supported RD&I, including ensuring broad awareness within key bodies such as IMO and relevant Commission expert groups, like the European Sustainable Shipping Forum.

Recruitment policy

The Partnership actively recruits new participation by analysing the evolving waterborne transport stakeholders and the representation of relevant sectors. We will invite new members or industrial sectors through our European and national branch organisations. The Partnership is also open to direct expressions of interest and, in this respect, membership will only be rejected for exceptional reasons, such as lack of European added value or applications from non-European competitors.

Update of the SRIA

For the update of the SRIA and the input to multi- annual calls, an open, but manageable, process is applied.

The Partnership undertakes a broad assessment of the current state-of-the-art and challenges for the different ship types and services. On this basis, this SRIA was developed for 7 years, addressing the main objectives and activities. The SRIA is updated taking into consideration the results achieved (within or outside the Partnership), the technological developments available in the market and the immediate priorities of the sector;

The Partnership will maintains an overview of ongoing projects and research outcomes (including policy recommendations). This overview is not limited to EU funded research, but through its members and its contact with the Member States, the Partnership acquires information on relevant national or industrial projects, as well as assess reports within the wider press and journals;

The Partnership continuously liaise with relevant bodies and working groups and integrate the work being done in the framework of the Strategic Research Agenda for inland waterways and ports[29]. Following the execution of research projects, the policy recommendations will be discussed during dedicated meetings with EU Member States and Associated Countries (see governance) and/or during the relevant meetings of the bodies and working groups identified;

The Partnership organizes conferences on a yearly basis to present the research outcomes as mentioned above and to discuss necessary updates to the SRIA (e.g the Waterborne Days 2023). These conferences will target dedicated audiences, such as European Commission Services, MEPs, Representatives of EU Member States and Associated Countries,as well as representatives of the waterborne transport sector;

The proposed updates to the SRIA for the Partnership are put forward in an open consultation through the Partnership's website. Discussions on the topics will be facilitated on this website. EU Member States, Associated Countries, NGOs and civil-society organisations will be invited to participate in the discussions and to encourage their local stakeholders to participate in the consultation;

On the basis of the SRIA, and taking into account emerging developments, each year experts from the Partnership's members evaluate the portfolio of activities, taking into account the most recent developments and consultations for new RD&I topics, as well as types of research (e.g. TRL levels may need to be revised), actions needed to facilitate deployment, actions concerning disseminationand communication etc., in order to ensure the maximum impact of results. Following this update, the portfolio of activities for the following two years is be drawn up in order to ensure the maximum impact of results. These proposed actions will be discussed with the European Commission Services, representatives of EU Member States and Associated Countries.

The EU Member States, Associated Countries and the European Commission are involved throughout this process. This ensures avoiding unnecessary duplication and enables synergies between national programmes, policy developments and Horizon Europe.

Cooperation with Member States and Countries Associated to Horizon Europe

In order to align the developments of the Partnership with relevant national (sectoral) policies, programmes and activities, close cooperation with EU Member States and Associated Countries will be established from the start of the Partnership. For inland waterway transport, close cooperation has been established with the River Commissions which play an important role in coordination with their Member States on technical and legislative matters for inland navigation. There are a number of areas of attention which are of importance to streamline the Partnership's developments with relevant policy developments, as well as research initiatives:

- Create synergies between the Partnership and national research and implementation strategies and programmes and vice versa, discussed in the States Representatives Group;
- Coordinate between the Partnership (including research outcomes) and regulatory actions at regional, national and international level.

For this reason, the Member States and Associated Countries are involved in the governance of the Partnership through the States Representative Group and through observer status in the Waterborne TP association.

Synergies with other Partnerships

In preparation for the Partnership, the Waterborne TP has nominated interlocutors who will act on behalf of the Partnership to liaise on the developments of the Partnership with other relevant initiatives in order to avoid duplication of efforts, as well as to discuss necessary prioritization. Finally, the representatives of the Partnerships, Missions, Technology Platforms and other relevant initiatives will be invited to attend meetings with the Waterborne TP on a regular basis to discuss the issues at stake, the creation of possible synergies, to develop joint work plans and common calls (where possible) and any other issues relevant to the execution of the tasks of the Partnership.

Synergies with other Partnerships foreseen include:

- "Towards a competitive European industrial battery value chain for stationary and mobile applications", which addresses battery development, with automotive as the largest target and biggest market. The Batteries Partnership will also address development for other markets, including for waterborne transport. In this respect, it focusses on specialist battery technology, material and manufacturing, including battery safety, whilst the Zero-emission waterborne transport Partnership will address integration of a battery within the ship systems and enable pre-deployment in maritime and inland applications (addressing, for example, charging infrastructure, certification process, etc.). This is reflected in the proposal for Batteries and cooperation between the two Partnerships will be maintained to ensure relevance and to generate synergies;
- "Clean Hydrogen" Partnership focuses on green hydrogen fuel production, storage and supply, as demand side technologies and the development of high-power fuel cells. The Waterborne Partnership will address technology integration, implementation and validation, for both maritime and inland shipping. This includes safety of bunkering and integration of onboard storage of non-hydrogen alternative fuels.

The "Clean Hydrogen" Partnership will ensure close coordination with a view to exploit the role hydrogen can have as a candidate fuel towards the achievement of zero-emission waterborne transport. The Partnership will focus on onboard technology and on board standards, whilst CHE will focus on onshore and important technology building blocks such as multi MW fuel cells for ship propulsion and the related fuel technology. Whilst one or the other Partnership will lead on these linked activities, there are inevitably grey areas where close cooperation will be undertaken to ensure complementarity and to enable the possiblity of developing linked actions. An example of information sharing is Partnerships projects linked to hydrogen may be asked to contribute non confidential project data within a hydrogen projects data base;

- Connected, Cooperative and Automated Mobility Partnership "CCAM", addresses mobility and safety for automated road transport. CCAM also mentions potential interfaces with other transport modes. In this context, within a zero- emission waterborne transport Partnership, any efficiency improvements achieved through automated shipping and maritime/river traffic management may be leveraged through synergies with CCAM for the efficiency of the wider multimodal mobility system as a whole;
- "A climate neutral, sustainable and productive Blue Economy" is focused upon resilient marine ecosystems and marine resources, contributing to the realisation of a sustainable economy for maritime and inland waters. Waterborne transport is one of several influencers on the marine environment and, in this respect, cooperation between the Partnerships will be ensured. It is noted, however, that the 'Blue Economy' Partnership is not expected, as such, to develop the solutions enabling zero-emission waterborne transport itself (e.g. new technologies, fuels, or any relevant bunkering infrastructure).
- "Made in Europe", which will be the driving force for sustainable manufacturing in Europe. It will contribute to a competitive and resilient manufacturing industry in Europe and affects many value chains. Another priority is circular economy and following a circular by design approach. The Partnership will serve as a platform for aligning national and regional manufacturing technology initiatives. Synergies and cooperation with this Partnership are essential to ensure the alignment of the production process in the context of the ZEWT Partnership, in order to be able to reach its objectives.

In the area of logistics, Waterborne TP remains its strong link with the ALICE TP.

To maximise synergies and impact, memorandums of understanding have been signed with Clean Hydrogen, Batt4EU and SBEP. Further synergies will be explored with the rest of the Partnerships listed above and regular meetings will be held to share information, identify complementaritiesand potential linked actions which could maximize leverage from the EU's investment[30].

Links with missions

- The Mission "Restore our Oceans and Waters by 2030". Although the main focus of the mission is not on the greening of transport, our targets for the reduction of water pollution, including underwater radiated noise, contribute to a healthier ocean;
- The Mission on "100 Climate Neutral and Smart Cities by 2030". Although the main focus of the mission is not centred on greening of transport, our targets for reduction of harmful air pollution will contribute to a clean living environment in port cities and their surroundings;
- The Mission on "Adaptation to Climate Change: support at least 150 European regions and communities to become climate resilient by 2030". Although the mission will not focus on greening of (waterborne) transport, it may have influence on shipping through the protection of port cities from rising sea levels. The results of both the Partnership, as well as the Mission, might cross- fertilize each other.

Communications with these missions are maintained so as to ensure complementarities between the programs as well as flagging any potential overlaps. As the scope becomes clearer, cooperation agreements will be made, to ensure clarity with respect to the linked activities.

Synergies with other EU financial instruments

A number of European programmes have synergies with the implementation of the technologies developed in the framework of the Partnership, notably:

- Innovation Fund (DG CLIMA): The Innovation Fund focuses on a wide range of innovative technologies in areas such as energy-intensive industries, renewables, energy storage, net-zero mobility and buildings, hydrogen, and carbon capture, use and storage. This fund is essential to support the implementation of solutions developed by the Partnership;
- Modernisation Fund (DG CLIMA): support for modernisation of energy systems and transition in 13 beneficiary Member States. This fund is essential to support the implementation of solutions developed by the Partnership;
- Connecting Europe Facility – Transport (DG MOVE): which supports the roll-out of innovation in the transport system in order to improve the use of infrastructure, reduce the environmental impact of transport, enhance energy efficiency and increase safety;
- European Fund for Regional Development (DG REGIO): The current ERDF focuses its investments on several key priority areas. This is known as 'thematic concentration'. This fund is essential to support RD&I in line with the Partnership at the regional/national level.
- LIFE (DG ENV): the LIFE Programme has four objectives:
    - Help the move towards a resource-efficient, low carbon and climate resilient economy, improve the quality of the environment and halt and reversebiodiversity loss;
    - Improve the development, implementation and enforcement of EU environmental and climate policy and legislation, and act as a catalyst for, and promote, the mainstreaming ofenvironmental and climate objectives into other policies and practices;
    - Support better environmental and climate governance at all levels, including better involvement of civil society, NGOs and local actors;
    - Support the implementation of the 8th environmental action plan, which entered into force in May 2022.

Through close interaction with the European Commission Services, as well as the EU Member States, the Partnership will discuss the possible alignment of its activities with other relevant EU financial instruments.

This is expected to take place within the context of an annual coordination meeting held with each of the linked programmes.

International cooperation

To support identification of the most important knowledge, regulatory, standardisation and technological gaps, the Partnership monitors the discussions and developments of international organisations such as the IMO (in particular its Marine Environment Protection Committee), HELCOM, OSPAR etc. In addition, the Partnership has established links with the Department of Partnerships and Projects of the IMO, with a view to avoiding duplication of effort and to stimulate the development of necessary rules and regulations.

The members of the Partnership also actively participate within and present the results of the Partnership and projects supported to the European Sustainable Shipping Forum (ESSF). Although, the ESSF is a Commission Expert Group, which provides advice to the Commission and the Member States on matters related to sustainability of shipping, these activities are important with respect to he formulation of the EU and Member States contribution to the discussion at the IMO level.

The Partnership has also established links with governing bodies in Inland Waterway Transport, in particular the Central Commission for the Navigation on the Rhine, the Danube Commission and, if relevant, other river commissions as well as UNECE. In this context, the study regarding financing of the energy transition in inland waterway transport as conducted by the CCNR ahs been taken into account.

Cooperation with regions will also be pursued. The international nature of the waterborne transport sector requires cooperation with other non-EU research-oriented countries and flag states as well. Of course, cooperation is subject to requirements on IPR protection, as well as the fair processing of investments and public procurement

NOTES

1. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_313
2. https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541
3. https://transport.ec.europa.eu/transport-modes/inland-waterways/promotion-inland-waterway-transport/naiades-iii-action-plan_en#:~:text=The%20European%20Commission%20tabled%20in,zero%2Demission%20barges%20by%202050.
4. COM(2013) 918 final ' Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - a Clean Air Programme for Europe'
5. https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/
6. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
7. https://ec.europa.eu/clima/system/files/2021-08/swd_2021_228_en.pdf
8. https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20-%20Full%20report%20and%20annexes.pdf
9. Emissions Gap Report 2023 | UNEP - UN Environment Programme
10. https://emsa.europa.eu/emter.html https://www.eea.europa.eu/publications/maritime-transport/
11. https://www.iiasa.ac.at/web/home/research/researchPrograms/air/Shipping_emissions_reductions_main.pdf
12. https://worldmaritimenews.com/archives/205936/imo-designates-north-sea-baltic-sea-as-neca/
13. https://marine-offshore.bureauveritas.com/newsroom/sulphur-emission-control-area-seca-mediterranean-sea-2025
14. https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupMeetingDoc&docid=9732
15. https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm
16. https://www.researchgate.net/publication/271179593_Marine_Fouling_An_Overview
17. https ://unctad.org/webflyer/review-maritime-transport-2020
18. https://inland-navigation-market.org/wp-content/uploads/2021/09/CCNR_annual_report_EN_2021_WEB.pdf
19. http://www.waterborne.eu/media/35860/190121-waterborne_sra_web_final.pdf
20. https://www.maersk.com/news/2018/12/04/maersk-sets-net-zero-co2-emission-target-by-2050
21. http://www.inlandnavigation.eu/media/92406/Future-proof-shipping-presentation-191016.pdf
22. https://www.ecsa.eu/news/european-shipping-industry-welcomes-european-green-deal
23. https://worldmaritimenews.com/archives/290006/cmb-to-operate-zero-emission-fleet-by-2050/
24. SEA Europe, White Paper, Maritime Technology in Europe: A Strategic Solution Provider for Major Societal Challenges, 2019
25. http://www.seaeurope.eu/
26. https://ec.europa.eu/epsc/sites/epsc/files/epsc_clean-transport-at-sea.pdf
27. https://www.statista.com/statistics/264024/number-of-merchant-ships-worldwide-by-type/
28. Wherever Alternative Fuels are mentioned

in the following (e.g. charts, etc.), please note that reference is made to the use of Sustainable Alternative Fuels.

29. https://www.ccr-zkr.org/12090000-en.html
30. Average annual value for the period 2010-2014 acc. BALance Analytics for "Study on New Trends in Globalization in Shipbuilding and Marine Supplies", Study for EU COM 2017
31. Average annual value for the period 2012-2016 acc. BALance Analytics and "European Shipbuilding SupplyChain Statistics", Study for SeaEurope 2019
32. http://www.inlandnavigation.eu/news/policy/towards-a-strategic-research-agenda-for-inland-waterways-transport/
33. As of February 2021 an MoU has been concluded with Hydrogen Europe and Hydrogen Europe Research, the remaining are expected to be concluded over the course of 2021.

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