Strategic Research and Innovation Agenda for the Partnership on

Zero-emission waterborne transport

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Executive Summary
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 Initial IMO Strategy on the reduction of GHG emissions from ships, and the CCNR Ministerial Mannheim Declaration 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 for the aforementioned challenges. Research, development and innovation are key to develop commercially viable solutions to eliminate GHG emissions, air and water pollution. 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 by doing so, contributing to the achievement of carbon neutrality 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. In order to achieve the objectives, the technical content of this SRIA is divided into six parallel activities. These activities are:

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

In addition, the SRIA includes the foreseen monitoring and governance of the Partnership, as well as cooperation at EU and international level.
Part 1: Vision 2050 and objectives 2030


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

The COVID-19 pandemic has drastically shown both the vulnerability of the global economic system and the 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 crisis has halted most activities, with the exception of some orders placed before the pandemic.

The socioeconomic impact of the COVID-19 crisis however is vast and continues to grow as a result of the effects on the waterborne transport sector, impacting crews, workers and the communities that benefit from waterborne tourism. 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 following the COVID-19 crisis. To ensure preparedness in line with the European Green Deal flexibility, creativity and financial effort from the sector will be required, backed by suitable policies and financial support.

The sector is committed to realize zero-emission waterborne transport to the benefit of 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 European Green Deal” to ensure that Europe will be the first climate-neutral continent, thereby making Europe a prosperous, modern, competitive and climate-neutral economy, as envisaged in the Commission Communication “A Clean Planet for All: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy”;

- The International Maritime Organisation’s (IMO) Initial IMO Strategy on the reduction of GHG emissions from ships;

Whilst the threats and risks of climate change and the harm from air 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, which should enable European citizens and businesses to benefit from a sustainable green transition. The Green Deal sets out pathways for the transition to a net-zero GHG economy and strategic priorities. Seven main strategic building blocks to achieve the objectives of this vision have been defined by the European Commission and “clean, safe and connected mobility” is one of these. In March 2020, the European Commission adopted a proposal to enshrine in legislation the EU's political commitment to be climate neutral by 2050, to protect the planet and EU citizens. This European Climate Law establishes a framework for the irreversible and gradual reduction of greenhouse gas emissions and it addresses the pathway to achieve the 2050 target.


5 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’
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as early as possible this century. When the strategy will be reviewed in 2023, the level of ambition is expected to be considerably increased, not at least in light of recent scientific reports like the IPPC “Global warming of 1.5°C” report. In October 2016, the IMO MEPC also adopted the decision to reduce the sulphur content of marine fuels down to 0.50% as of 1 January 2020 in order to address the negative effects of related air pollution on health and the 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). In the Ministerial Mannheim declaration of October 2018, the CCNR stated its commitment to largely eliminate GHG and other pollutants by 2050 and to develop a roadmap for doing so and this was taken up by the Inland Waterway Agenda for Europe of the Naiades II implementation EC expert group in December 2019.

Problems

The main environmental challenges the waterborne transport sector is facing, are:

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

Climate change

European CO₂ emissions from waterborne shipping are a major challenge. In 2018, more than 130 million tons of CO₂, or around 13% of total EU transport emissions, were emitted from maritime ships over 5,000 gross tonnage visiting European ports. International and domestic shipping dominates CO₂ emissions, whilst inland waterway transport cannot be ignored. The EU project PROMINENT calculated that inland waterway transport in the EU results in 3.8 million tons of CO₂ emissions per year.

CO₂ emissions from the world fleet and seaborne trade (UNCTAD, 2018) from 2013 to 2018

The world is not on course to achieve a temperature increase of well below 2°C and therefore urgent action is needed. Even if the energy mix used for waterborne transport is changed in accordance with the objectives of limiting the temperature increase and the economic developments are commensurate with this goal, shipping

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6 [https://www.ipcc.ch/sr15/](https://www.ipcc.ch/sr15/)
7 [https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement](https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement)
9 Source PROMINENT Deliverable D6.3&D6.5
emissions are projected to increase by 20-50% between 2008 and 2050\(^9\) (or by between 50%-250% according to the third IMO GHG study, to be updated in 2021).

Increasing the energy efficiency of ships has its limits and would not be sufficient to meet either the 2050 level of ambition of the European Green Deal or the targets of the Initial IMO Strategy on Reduction of GHG Emissions from Ships. Only a combination of low and zero-emission innovative solutions, fuels, operational approaches and technologies, triggered by ambitious regulations, can bring about the change needed.

**Air pollution**

Emissions of sulphur oxides (SO\(_x\)) from maritime transport affect air quality in the EU and globally. SO\(_x\) 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. SO\(_x\) emissions are a precursor of PM\(_{2.5}\) and a major cause of acid rain. According to the European Environment Agency, shipping is responsible for 11.05% of EU NO\(_x\) emissions and 11.05% of SO\(_x\) emissions\(^{11}\). Nitrogen Oxides (NO\(_x\)) form smog, acid rain and eutrophication and are central to the formation of fine particles (PM\(_{2.5}\)) and ground level ozone, both of which are associated with adverse health effects, including 400,000\(^{12}\) premature deaths (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.

While current IMO and EU regulations will reduce SO\(_x\) emissions from international maritime shipping from 2020, emissions remain much higher than other transport modes. After 2030, NO\(_x\) emissions from maritime shipping are set to exceed all EU land-based sources\(^{13}\).

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\(^{10}\) CE Delft, Update of Maritime Greenhouse Gas Emission Projections, 2019


\(^{13}\) [https://www.iiasa.ac.at/web/home/research/researchPrograms/air/Shipping_emissions_reductions_main.pdf](https://www.iiasa.ac.at/web/home/research/researchPrograms/air/Shipping_emissions_reductions_main.pdf)

\(^{14}\) [https://iiasa.ac.at/web/home/research/researchPrograms/air/Shipping_emissions_reductions_main.pdf](https://iiasa.ac.at/web/home/research/researchPrograms/air/Shipping_emissions_reductions_main.pdf)
The sulphur in fuel requirements that have been agreed by the IMO will cut SO₂ emissions by 50-80 percent up to 2030, but in the absence of additional regulations, emissions will rebound afterwards. Without introducing additional measures, CO₂ and NOₓ emissions are expected to further increase\textsuperscript{15}. SO₂ emission control areas have been established in the Baltic and North Sea since 2015, and require higher levels of SO₂ reduction.

The IMO has designated the North Sea and the Baltic Sea as a NOₓ Emission Control Area (NECA) starting from January 1, 2021. A lengthy period of fleet renewal is needed before the regulation will show full effect, according to HELCOM (Baltic Marine Environment Protection Commission)\textsuperscript{16}. Thus, illustrating the need for retrofittable technologies as an essential tool to meet policy objectives. Another example is the establishment of an Emission Control Area in the Mediterranean Sea for sulphur oxides under IMO rules has been agreed in the Barcelona Convention framework\textsuperscript{17} by the relevant riparian states.

Inland waterway transport is not in scope of IMO and has 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 NOₓ 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 NOₓ per t/km than an inland waterway vessel. The NRMM regulation\textsuperscript{18} addresses this topic and tremendously cuts these emissions. The regulation entered into force for new engines in inland vessels. However, these engines are not fully widely available yet and retrofittable technologies for the existing fleet are an essential tool to meet the policy objectives seen the long lifetime of vessels and their engines.

**Water pollution**

*Underwater noise from maritime shipping* has a negative impact on the marine environment, in particular on marine life, 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\textsuperscript{19} and are also addressed within the non-mandatory guidelines on ship-quieting measures issued by the IMO in 2014. 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.

As an alternative to using cleaner low sulphur fuels to reduce SOₓ emissions, regulations allow ships to be fitted with an *exhaust treatment device*, a so-called scrubber. A scrubber effectively reduces the Mediterranean Sea. \url{http://web.unep.org/uneppmap/barcelona-convention-cop21-naples-2-5-december-2019}.

\textsuperscript{15}\url{https://www.iiasa.ac.at/web/home/research/researchPrograms/air/Shipping_emissions_reductions_main.pdf}


\textsuperscript{17} The contracting parties to the Barcelona Convention have agreed in December 2019 to finalise a joint and coordinated proposal to the IMO in 2022 requesting the possible designation of an ECA for sulphur oxides in the Mediterranean Sea. \url{http://web.unep.org/uneppmap/barcelona-convention-cop21-naples-2-5-december-2019}

\textsuperscript{18}\url{https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupMeetingDoc&docid=9732}

extracts the sulphur from the emission and either stores the residue in a wash-water tank (closed loop) or dilutes and discharges this mixture into the sea (open loop). These open-loop scrubbers are less expensive, and the ship owner is less reliant on port reception facilities to absorb the scrubber residue. But the discharge into the sea leads to secondary waste streams which may have harmful environmental impacts. 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 environmental concern.

**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 will attract sea life attaching themselves, thereby increasing friction, slowing down the ship and increasing fuel consumption. The fuel savings made by limiting the adhesion of marine organisms by **hull coatings** has been estimated to reduce GHG emissions by 384 million and SO\(_2\) by 3.6 million tons\(^{20}\). However, the antifouling compounds used may leach harmful substances into the sea, damaging the environment and possibly entering the food chain.

**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.

- **Shipping is an international sector** by nature, and solutions will have to be supported internationally;
- **Large ships traveling over long distances** require **large amount 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 new solutions.

**International sector**

The maritime transport sector is an international sector. Maritime shipping transports nearly 90% of international trade and is therefore of crucial importance to the world economy. Not only do ships sail in international waters, but the whole maritime shipping

\(^{20}\) [https://www.researchgate.net/publication/271179593_Marine_Fouling_An_Overview/link/54bf69850cf28ce68e6b4e8d/download](https://www.researchgate.net/publication/271179593_Marine_Fouling_An_Overview/link/54bf69850cf28ce68e6b4e8d/download)
sector is international. Maritime transport is therefore regulated on many different levels: international, European, regional and national. This incoherent landscape of policies, rules and regulations complicates the transition to zero-emission waterborne transport. Agreements on new rules or on the 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.

Example of the international character of the maritime transport sector
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.

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 is less size constraints compared to ground transport, are getting larger and larger, and so more and more efficient per ton-kilometre. For example, the largest maritime container vessel now carries almost 24,000 TEU, whereas five years ago this was still less than 20,000 TEU. One single large container vessel representing the equivalent of 10,000 to 12,000 trailer trucks. The largest inland container vessels are also carrying more than 600 TEU. Cruise ships have doubled maximum number of passengers over the last 20 years, along with a steadily growth of ship average capacity (+64%) in the same time-line. However, with this growth in vessel size, inevitably the total power needed to propel the ship increases. For the largest ships, engines are used of up to 70 MW. 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 that is needed for such a trip would add up to almost 50 GWh. This very high energy need puts 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 leads to huge amount of energy needs from alternative fuels. This energy need has hindered initiatives for the transition of the sector, as many feared that the renewable energy available would not be enough to sustain the waterborne transport mode on top of the societal need for green onshore power.

Lack of alternative fuel
At the moment there is no cost effective and widely available alternative for the fossil fuels used in waterborne transport. Possible alternative fuels include biofuels (either bioliquids or biogases) as well as synthetic fuels based on hydrogen produced from renewable electricity and either captured carbon dioxide (to produce fuels such as synthetic diesel, synthetic methane or synthetic methanol), or captured 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 generate carbon dioxide when used, even if their full lifecycle carbon emissions can be zero. Green Hydrogen and ammonia are
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zero carbon dioxide emission, but have a much lower energy density and will therefore require more space on board ships. Both hydrogen and ammonia also need new safety approaches and rules plus a new bunkering infrastructure.

None of these fuels are yet available in large quantities around the world.

Another complicating factor is that fuel preference will likely be regional. Some countries, like Norway, are promoting hydrogen 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 fuels derived from it. Having different fuels in different regions might require ships to be capable to sail on several fuels depending on the expected area of operation of the vessel. Certain fuels require different fuel tanks which impacts the ships internal lay-out. This has hindered the transition to alternative fuels.

The ultimate choice of one or more alternative fuels in waterborne transport will therefore likely 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, new bunker vessels have to be developed for ports, and new bunkering infrastructure is needed alongside the European rivers. The bunkering technology has to be adapted to each specific alternative fuel. Cryogenic fuels like hydrogen require specialised technologies and safety procedures, similarly to LNG. Other alternative fuels may be bunkered in similar processes to fossil fuels.

With the electrification of vessels, the need arises for high-power charging facilities, including battery swapping technology. At this moment, port offer facilities for cold ironing: using shore-supplied electricity for operating the vessel while at quay. But charging onboard batteries for operations at sea will require a much large throughput of electricity. Technologies for this fast-charging of large power is being developed. Problems still exist with the safe and reliable integration of large 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, etc. Many initiatives are taken now, but solutions for one ship do not match the requirements for another ship. A common innovation agenda has been missing taking 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 ship owner 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, since the average lifetime of inland vessels is even longer (40-60 years) thus inducing outdated and lower energy & environmental efficiencies on such old vessels. Indeed, for inland waterway vessels, the western European market is characterised by a relatively old fleet. Half of the active fleet in Germany, the Netherlands and Belgium and 80% of the French fleet were 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\textsuperscript{21}.

\textsuperscript{21} [https://inland-navigation-market.org/](https://inland-navigation-market.org/)
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 underpins 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 emissions of relevant ships and services.**

The specific economic objective

**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.**
And the specific societal objectives are:

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.

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 specific objectives have been broken down into a series of operational objectives that are dedicated to the operation of the Partnership. These operational objectives are organised along 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 environmentally sensitive areas, and to increase operational efficiency;

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 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.
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 on how 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 cruise/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 will create a critical mass for the development and demonstration of innovative solutions and create a win-win scenario in which emissions are substantially reduced in European and global waterborne transport services whilst reinforcing the European technological industrial base in its competition on a global scale and enabling the ambition of zero-emission waterborne transport by 2050.

Within the first two years of the Partnership it is foreseen to undertake a combination of lower TRL activities setting the foundation for later development, as well as potential “quick wins” with high short-term environmental impact and which will reinforce Europe’s competitiveness as it emerges from the consequence of the COVID-19 pandemic. These will be elaborated within the SRIA. 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” could include solutions which substantially improve energy efficiency. These are elaborated within this SRIA and will be chosen according to the capability to trigger the transformation of the sector in the short and long term.

The Strategic RD&I programme will provide scientific knowledge 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 towards the large intercontinental merchant ships, short sea vessels, inland waterway transport, and passenger vessels.

As the programme starts off with a mix of low and high TRL RD&I, some technologies can already be demonstrated during the mid-years of the programme. The developments starting off at a lower TRL, will be developed and consolidated into smaller scale demonstrations in these mid-years. This could include smaller scale applications such as inland waterway vessels and other ship types, providing that the solutions can be a basis for a technology pathway for large scale deployment.

The programme will aim to conclude with demonstrators in the final two years, which will prove the viability of the developed solutions towards all main ship types and services. Whilst some solutions may for example be applicable to large merchant ships such as container
vessels, demonstration could take place in the context of a different but similarly relevant ship type. For example cruise ships have long autonomy 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 which will be reviewed annually. The SRIA is developed in the Partnership jointly between the Partnership and the European Commission, in consultation with EU Member States, Horizon Europe Associated Countries. A transparent process will be deployed, including an opportunity for public comments as well as from stakeholders, industry member states and societal interests. Throughout this process, the Member States, Associated Countries and several European Commission services will be involved. This ensures avoiding unnecessary duplication with national programmes and it 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 through retrofitting, it is highly likely that another segment of the service provided by the industry will be replaced by new-builds. About 50,000 maritime ships and approx. 12,000 inland vessels are in operation, and will need to be transformed towards zero emissions, through retrofitting as well as replacement. At the same time, new-builds will need to be ready to become zero emission asap, meaning they need to be compatible or adaptable to be used with a range of potential sustainable 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 founded upon modular principals to facilitate conversion to full electric or hybrid powered units.

Depending on 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, the best qualified solution will need be chosen. Integrated lighthouse projects will show best practise 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 on many ports, often on short term notice, meaning that the ships 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.
Examples of liner (left) and tramper (right) services: recent 3-month AIS data for two different vessels

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, they are more suited for 100% electrification technology between fixed points. Offshore vessels built in Europe facilitate the development of offshore renewable energy. Often they need larger 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 1000 of tons of fuel with several weeks of autonomy, the future green propulsion is expected to be initially based on internal combustion engines operating on sustainable fuels, possibly assisted with 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 and regardless 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 CO₂ producer and polluter and thus the first target for greening.
The obvious shorter term solution for these existing ships is sustainable e-fuels and bio-fuels, in combination and separately, together with substantial operational and technical efficiency improvement, cleaner energy converters as well as possibly renewable energies. 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 allows to gradually grow into the green future by modifying existing engines and 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 empower the industry to improve the performance of dual-fuel engines further. Newbuilds will benefit from these developments considering multi-fuel tank systems, dual fuel engines, electric / hybrid drives and gen sets with hybridised energy storage instead of large monolithic engines with direct mechanical drives which are typical today. Also, 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 infrastructure 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 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 cost the range of feasible options goes 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 profit from energy efficiency measures like large diameter propellers, optimised hull design, air lubrication and arrangement of tank and cargo holds. IWT is also one of the candidates for direct use of hydrogen in combination with a dedicated net of fuelling stations which could be shared with the road fleet. The high variety of meaningful solutions combined with moderate cost for conversion with 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 instance, 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 to green waterborne transport since their customers demand sustainable transport beyond what is required by authorities and the vessels operate within the world’s most environmentally sensitive regions.

Furthermore, cruise ships are characterised by requiring high energies, 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 fuels, in combination and ultimately as 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 e.g. cold ironing and alternative fuel supply 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 are covering the 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 both retrofitting as well as newbuilds and up to 200 nautical miles range 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 front. Those ferries with significant hotel loads will be candidates for early adopters of fuel cells. The requirements on 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 seconded 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, this makes this segment particularly important for both development of tailored innovative solutions as well as implementing 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 which holds the potential to extend Europe’s market share by technology leadership. SSS contains all ingredients for an entire European recipe, a zero-emission solution involving design, engineering, equipment production, shipbuilding, operation, ports, and authorities to enable green shipping growing from vision to fact. The retrofitting solutions with the lowest CAPEX and highest environmental impact will be also here enabling the use of alternative fuels. Ships which are now ordered should consider readiness for a range of sustainable fuel options, 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 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, allowing for executing very accurate work. These type of vessels typically have a high energy consumption at peak moments. The technologies used for power generation are the same as for the above listed transport
vessels. As the offshore vessels are predominantly build in Europe, they are a suitable category for demonstration purposes.

The variety of operating profiles as well as size of ships make Offshore vessels ideal candidates for innovative solutions. Their close shore activities allow for more frequent fuelling and thus low density energy carriers can be applied. Operating close to shore also requires to reduce SO\textsubscript{x} and PM emissions to the maximum extent possible. Designs from full electric to hydrogen powered fuel cell hybrid solutions will make sense. Already today, hybrid battery systems are cost effectively deployed and some of the newest vessels can perform their operation at sea with zero-emission technologies, while transit is still covered with conventional diesel-electric systems using low-sulfur marine diesel oil. Latest announcements on new ship designs show an extended zero emission target range of up to two weeks operation time based on 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 other fuels than fossil fuels will make shipping a (net) zero-emission mode of transport. One of our Activities is therefore fully dedicated to enabling these new fuels on board. This include 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. As a safeguard for the transitional period, Carbon Capture and Storage (CCS) systems are part of the portfolio.

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 range of sailing would be much limited. The need for energy from these fuels should thus 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 is of course crucial in developing and demonstrating these fuels on board.

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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 the fuel on board. But due to the total power needed on ships, it is foreseen that using batteries or other electricity storage cannot be the main power source for long-distance shipping. But, this will be a solution for shorter ranges, say up to 150 to 200 nautical miles. For longer ranges, it is foreseen 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 alternative fuels, a crucial step for 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 classical 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, higher dynamic performance as well as higher efficiency. New internal lay-outs will mitigate possible safety repercussions of using high-density batteries next to inflamable alternative fuels. For existing vessels, modular set-ups will be developed to retrofit with electrical auxiliary power.

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 reaching this objective. For smaller vessels or for auxiliary power, containerised battery solutions will be applied. The safe recharging of large amount 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 the energy need of a ship is crucial in the implementation of alternative fuels or electrification. After all, the greenest form of energy is the energy that you do not need. Energy efficiency of ships will be improved by utilising renewable energy sources, such as wind and solar. We will also deliver solutions for reduction of all energy needs (i.e. propulsion, equipment and hotel load) by means of for example 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 retrofitting in the Activity on Design & Retrofitting.

### 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 at least 55%.

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

### 4. Operational objective

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.

#### Activities

- Ports
- Alternative fuels
- Electrification
- Safe technologies
- On-board storage
- On-board grid

In the Activity Ports 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 Alternative Fuels on safe onboard storage of the fuels, and to the work in the Activity Electrification on the electrical grid and battery capacities on board.

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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**.

Once again, retrofitting of new technologies into existing vessels is key to deliver on this operational objective. This is extra challenging with the large life-time of inland vessels. Old ship designs and the integration of family living quarters require dedicated solutions with respect to safety and modularity.

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, require special attention to retrofitting of economically viable solutions. Given the relatively short range of many inland vessels, electrification of the fleet is envisaged to be the most promising solution. The work in the Activity Electrification will therefore have special attention to 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 particularities of inland navigation, like extreme shallow water, continuous manoeuvring, and lock operations require special solutions.
Elimination of air pollution
The operational objective on elimination of non-GHG air pollution is particularly important in coastal seas, in ports and on inland waterways.

6. Operational objective
To develop and demonstrate solutions to cut coastal and inland pollution to air from inland waterway transport and maritime shipping by at least 50%.

The Activity on Alternative Fuels will develop hydrogen-based solutions which will eliminate air pollution. The Activity on Electrification will deliver solutions for coastal ships to sail fully electrically, thus 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, thus directly reduction 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.

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Elimination of water pollution

The operational objective to eliminate pollution to water from ships (including harmful underwater noise) is tackled by the Activities on 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 this 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. Solutions for air lubrication will be challenged to 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 vessel by retrofitting. Solutions for the reduction of noise and for air lubrication will need to be applied to the existing fleet. Furthermore, new solutions will be developed to remove pollution from open-loop scrubbers.

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

- Sustainable alternative fuels
- Electrification
- Energy Efficiency
- Design and Retrofitting
- Digital green
- Ports

The relation between the Partnership’s objectives and these Activities has been explained in the previous sections. In the next section, a brief presentation regarding 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 proposed topics for the first 2 years of Horizon Europe (short-term) is provided.

Sustainable alternative fuels
This activity concerns the development of ships with power generation systems based on Sustainable Alternative Fuels that allow for reducing GHG and other emissions coupled with engines, turbines and fuels cells and their integration on board.

Introduction
While significant GHG emission reductions can be enabled by increased energy efficiency, electrification, renewable energy and operational improvements, achieving zero-emission waterborne operation for the entire fleet can only be met by large-scale adoption of sustainable alternative Fuels. 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 require 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 and in this respect more challenging are the low flash

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22 Wherever Alternative Fuels are mentioned in the following (e.g. charts, etc.), please note that reference is made addressing sustainable Alternative Fuels.
Strategic research & innovation agenda for Zero-emission waterborne transport

point fuels and gases (ammonia, methanol, hydrogen etc.), whilst for example sustainable bio diesel fuels can be more easily deployed. Besides this, a regulatory framework needs to be developed. The output of this activity will be threefold:

1) An overall **sustainable alternative fuel scenario** for waterborne transport applications (incl. 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 R&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;

2) **the technical capabilities needed to integrate sustainable alternative fuels on board**

3) **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 **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 electrified, because of either their mission profile or of the legacy fleet, which will need retrofitting to meet the zero-emission target. So, though 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**. Given the fact that the **waterborne transport sector has committed itself to decarbonize** fully, a transition towards sustainable alternative fuels is thus required. This opportunity should be taken to, at the same time, drastically reduce, or fully eradicate, air quality-related pollutant emissions (which are dominated by NOₓ, SO₂ and particulates) and fuel-use related water pollution. **Fuels which need no exhaust gas after-treatment equipment such as scrubbers and SCR would be beneficial for this goal.** This is related to the fact that they reduce the (additional) cost of their implementation, thus leading to a possible faster transition towards zero-emission operation, due to possibly lower investment risks and complexity, but 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. **Fuel pathways will be checked for regulatory acceptance in close dialogue with IMO and CESNI members**, as well as EU policies, both concerning **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**

Today, **very few sustainable alternative fuels are in use in significant quantities in the waterborne transport domain**. Small amounts of renewable diesel fuels are used. These are mostly waste cooking oil-based products that are limited in availability. Besides

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23 Including National Maritime and Inland waterways Authorities
this, the use of Liquefied Bio Gas is increasing but is also extremely low. Trials with many other sustainable alternative fuels such as ammonia and methanol are emerging throughout the industry, but no single fuel has yet emerged to address all requirements and concerns.

Fuel scenario
We will follow an approach that starts from 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, 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. The need for and value of fuel flexibility of vessels will be quantified. Given the complexity of the overall implementation of new fuels, that 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. The move of the waterborne transport sector away from the utilization of waste products as fuel (HFO) to tailor-made fuels (either Bio- or renewable electricity-based) which are available at large scale, means that a paradigm shift in the relationship between fuel producers and the waterborne transport sector will occur. We will also take into account potential competition for similar sustainable alternative fuels from other sectors such as aviation or domestic gas supplies. This will be addressed as a rolling scenario assessment which continues to monitor the evolution of potential sustainable fuels, their supply and manufacture as well as the solutions needed to enable their end use on board, including those developed within the context of this Partnership.

Fuel on board
We will develop the technical capabilities and safety requirements to store on board ships large quantities of sustainable Alternative Fuels, taking into account the required flexibility due to the evolution of fuel types, local availability differences and cost scenarios. Most sustainable alternative fuels require additional storage space (i.e. low environmental impact liquid and gaseous fuels, such as hydrogen, etc.) thus necessitating the operational profile requirements to be an integral part of these developments. And all of this will be subjected to the highest standards of safety in design and operation. Integration of the full alternative fuel-value chain through ports will be addressed to ensure appropriate development of bunkering and emergency response procedures. As a safeguard for a transitional period, on-board carbon capture and storage (CCS) systems may potentially be part of the portfolio.

Power conversion
A third stream will address on-board power conversion, which will develop 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, Fuel Cells and Turbines. The technology upgrade will take into account the efficiency of energy conversion and the scalability in size and power of the propulsion system, as well as system cost, power density, complexity, operability and maintainability by the crew. Moreover, the robustness of the system, its loading capabilities (i.e. the possibilities to react quickly to changing energy demand) and operational safety (including, but not limited, to fire safety and bad
weather condition response) will be considered. Given the very diverse makeup of the waterborne transport fleet and the technologies powering it today, we will need a broad palette of technologies and solutions to be developed. Not only these will differ in power output and fuel compatibility, but they will in integration level, acceptable complexity and cost. To make an example, the most favourable combination of solutions for an inland vessel will not likely be the most favourable one for a large container carrier or cruise vessel.

Besides the developments in these three areas, the action on Alternative Fuels will also support the further development of the regulatory framework that, at the moment, is either missing at all or incomplete.

**Short-term**

For the Work Programme Horizon Europe 2021-2022, to pave the way for the whole development of Alternative Fuels (shown by the logic depicted in the chart below), we will focus on the following issues:

- 11 enabling the safe, efficient onboard storage and integration within ships of **large quantities of ammonia and hydrogen fuels** (2021);
- 12 enabling deployment in shipping of **low flash point GHG neutral fuels** by ensuring safety underpinned by the necessary norms and regulations (2022);
- 13 Enabling the full integration of **very high power fuel cells** in ship design using combined cycles for increased efficiency with multiple fuels (2021);
- 14 ensuring **clean, efficient engines using new carbon neutral fuels** separately and in combination (2022)

- 15 proving the feasibility, safety and environmental acceptability of a **large green ammonia engine** (2022).
## Operational Objectives

### Eliminating 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);
- 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 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.

### 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.
Strategic research & innovation agenda for Zero-emission waterborne transport

Alternative Fuels | Electrification | Energy Efficiency | Design and Retrofitting | Digital Green | Ports

Scenario setting
- Overall fuel scenario for WAT applications

Fuel onboard
- Carbon free fuels
  - Carbon neutral fuels
  - Transition fuels

Power conversion
- Internal Combustion Engines
- Fuel Cells
- Turbines

Components Development
- Intergration in complex applications
- Power scalability

Regulatory framework for onboard integration

Business models

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.

Link or cooperation with the Partnership Clean Hydrogen
- Addressed by ZEWT
- Not addressed by ZEWT
- To be coordinated with CHE on H2/FC technologies

Milestones

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- 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
Electrification

This activity concerns the development of ships with high-power energy storage systems and new DC distribution grids optimized for efficiency and operational profiles, new high performances, high efficiency variable speed electric generators and power trains.

Introduction

In some waterborne transport applications, the adoption of Alternative Fuels is not sufficient to guarantee the ship's power demand. Electrification may represent a necessary complement to a power generation based on Alternative Fuels for long-range waterborne transport as well as the unique solution for short-range, port calls and entry to environmental protected zones. Solutions must ensure the same performances of conventional vessels. This activity will be developed through three steps forward concerning the state of the art: Energy Models, Energy Storage Systems (ESS), Electric Generators and Propulsion Drive Control, and Grid Architecture and Control.

First of all Energy Models will be developed, both static or dynamic if needed, to allow a correct design and optimal management of the energy resources available (Alternative Fuels, batteries, renewables, fuel cells) taking in consideration different ship's types and operational profiles. Secondly, in parallel with the development of the new energy models, the most appropriate and effective Energy Storage Systems technologies (e.g. lithium batteries, solid-state lithium batteries, super-/ultra-capacitors, etc.), for example utilising battery swapping 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 fast recharging systems at the port. Also, the application of exchangeable batteries (which can replaced by recharged ones during the journey or when loading/unloading) will 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, 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 electric storage devices, acting either as energy buffer or back-up supply (battery, ultra-capacitors, and others). The onboard micro-grid should be integrated with a suitable control system, able to regulate 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), 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 the one constituted by the Electric Generators and 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 of a ship, will be realized, taking into consideration the necessity of realizing the highest standards of safety both in design and operation.

Relevance
With the perspective to be the first continent with zero net emissions of greenhouse gases in 2050, Electrification is one of the most promising options. New electrical power sources (i.e. batteries) will reduce greenhouse gas emissions from the transport of goods and passengers by ship (emissions of CO\textsubscript{x}, SO\textsubscript{x} and NO\textsubscript{x} compounds and acoustic signature of the engine room, for instance), for both short sea and long route waterborne transport. The extensive Electrification of transportation systems (e.g. cars, trains, aeroplanes and ships) has become today an appealing technology, which offers the most efficient energy conversion in comparison to conventional concepts, even for waterborne transport applications. In this perspective, a fully electric ship could lead to more flexible, efficient and sustainable design and management of ships, oriented to the abatement of GHG emissions and the substantial decrease of the contribution to air/water pollution from ships.

In this regard, it has to be noted that Energy Storage Systems are one of the best solutions to achieve zero GHG emission for several kinds of vessels, such as smaller in-land or near coastal vessels, ferries and platform supply vessels. The development of large scale Energy Storage Systems can be useful also to reduce both the GHG and pollutant emissions due to modern passenger ships.

Approaching the port with a “zero emissions condition” will be made possible, through a power unit fast-recharged while ships are at berth and connected to the onshore power facility (i.e. in “cold ironing”). Furthermore, considering the improvements promised by the next generation of solid-state battery technology that should be commercially available within the next 5 years, new prospects of a further reduction of GHG emissions are also expected for energy-intensive vessels. Finally, the development of Innovative Grid Architecture and Control systems will allow reducing overall emissions linked to waste of energy, utilizing optimal management and control of electric energy on board, by both the generation and demand side, leveraging on energy models able to provide the real operating conditions of the ship.

It is worth pointing out that a suitable grid architecture, partially or fully relying on DC distribution, will allow reducing the needed power conversion stages onboard and, therefore, the related electrical losses, with an increase of the overall system efficiency.

Innovative aspect
For an electric drive system to be “worthwhile” as the main power system, one crucial, challenging aspect has to be overcome, which highly depends on ship power and operational profile constraints: high-power and compact electric storage solution on board (i.e. batteries). Moreover, ports need of suitable charging infrastructures. This aspect is already an issue with shore-side electricity since, for instance, passenger ships need high electric power continuously for their hotel operations when at berth (in the 1-20 MW range). With this respect, we will develop entirely new Energy Models to predict the required power load and more powerful Energy Storage Systems. Moreover, innovative Grid Architectures and Control Strategies will be implemented and integrated into the Port ecosystem, to achieve a more efficient, flexible and sustainable waterborne transport sector.
Energy Models
It has to be highlighted that a critical aspect of all these technologies will be the development of the ability to predict the required power through energy models. The traditional methods used to calculate ship’s power demand and select the size of the generation system have become inadequate since they are based on very dated assumptions and do not take in account the possibility of innovative or alternative energy sources. 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 ESS (batteries, super capacitors, etc.). New electric grid architectures (allowing comparison, for example, between AC/DC configurations) and environmental footprint abatement (GHG and pollutant emissions), will be integrated into the ship design process.

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 shore 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 it happens in many land applications, characterized by uncertainties related to the power generation profile (e.g. wind and solar power generation plants), also on board of many vessels it may be advantageous to install Energy Storage Systems. Such systems can be used to cover the fluctuating load variations and increase the whole power system efficiency, reliability and flexibility. In particular, they can be exploited by the Energy Management System of the vessel to pursue specific objectives, from one side, and to decrease the impact of fast load variation on the main generator set from another side. They can be further used to cover voltage fast variation and to cover power quality issues. They can even be devised in order to furnish the energy needed by either the load or the propulsion system (if electric), in case of sudden failure of one of the main generators during the start-up of the auxiliary generators. Nowadays Energy Storage Systems are not widespread, mostly limited to Lead-acid batteries used for UPS in emergency conditions. Full Electrification of ships will be feasible, also for longer ranges, thanks to new generation batteries and other innovative Energy Storage Systems. Among the solutions at disposal, new generation batteries, Super-/ultra-capacitors, or SMES (Superconductivity Magnetic Energy Storage) will be developed. Innovative approaches to ensure safety of large Energy Storage Systems will be tested.

Grid Architecture and Control
Electrification will bring another significant change. Today’s standard for power system Grid Architectures is currently characterized by Alternative Current (AC) and radial configuration. In contrast, the need for more complex power systems relying on Direct Current (DC) as well as radial/ring/decentralized configurations, offering higher survivability, reliability and efficiency, have recently gained priority. With the advent of alternative forms of power such as Energy Storage Systems (or fuel cells, see 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, implementation of control strategies and smart energy management systems, optimizing energy flows and ensuring safe operations. Another critical issue to be dealt with to properly address electrification and energy efficiency is the
design and development of appropriate 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 (conceived according to Power Electronic Building Blocks or PEBBs concept), high power density, redundancy, reliability and safety. When used in 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 the 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 2021-2022, to pave the way for the whole development of *Electrification* (shown by the logic depicted in the chart below), we will focus on the following issues:

- **21** exploiting the potential of **innovative electrical energy storage systems** and how to better optimise **large battery electric power** within fully battery electric and hybrid ships (2022);
- **22** onboard integration of innovative **energy storage systems including control systems and connection to onboard electrical grid** (2022);
- **23** **hyper powered fast charging** of battery for vessels, possibly with consideration of battery swapping technology (2021).
Operational Objectives

Eliminating 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);
- 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 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.

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.
Strategic research & innovation agenda for Zero-emission waterborne transport

Energy models
- Energy modelling on board
- Modelling of energy recovery concepts
- Modelling smart grids

Energy storage
- Innovative Energy storage systems
- Controlling batteries
- Onboard integration of new Gen Batteries

Grid
- New architectures for electrical network and components
- Control systems
- Smart Energy management system

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

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.

Milestones
- 2021
- 2022
- 2023
- 2024
- 2025
- 2026
- 2027
- 2028
- 2029
- 2030
- 2031

Link or cooperation with the Partnership on Batteries
- Addressed by ZEWT
- Not addressed by ZEWT
- To be coordinated

Ship with smart electric systems and high capacity storage for longer distances
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 and the reconfiguration of the ship's architecture.

Introduction

The most environmental-friendly and cost-effective energy is the one that we do not need to produce, store and use. With this respect, the Energy Efficiency activity will contribute mainly to one major operational objective, which is reducing the fuel consumption of waterborne transport by at least 55 % before 2030. A new systemic and holistic approach can achieve such a breakthrough. Energy efficiency optimization schemes need to be developed beyond actual state-of-the-art with regards to single or limited design and operation points. This approach will tackle the full spectrum of ship energy needs and consumers as well as operating profiles, to develop, demonstrate and select the most efficient technologies, ship design and operation solutions. As a result, the ship's energy needs will be reduced dramatically.

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

- 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 need for all consumers (technology bricks),
- Renewable and free energy solutions, to offer free additional energy sources, therefore reducing further the overall ship energy need from (alternative) fuels,

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

Relevance

Improving the 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. Therefore the following benefits can be achieved:

- Direct reduction of the ship OPEX (fuel bill) and CAPEX (fuel tank and power system down-sizing) at the shipowner's side;
- Opening new grounds to develop innovative zero-emission ship architecture designs (through the free volume generated), for designers;
- 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 “Alternative Fuels” activity), for the market;
- And even limitation of new infrastructures and operating constraints to supply quantity-wise and safety-wise the alternative fuels to the ships, concerning ports (see "Ports" activity).

As Energy Efficiency is aiming to reduce the fuel consumption of waterborne transport dramatically (by at least 55 % before 2030),
the above gains will be tremendous, offering key leverage for zero-emission waterborne transport. Moreover, reducing the energy need by at least 55% before 2030 will directly impact by the same amount the GHG and air and water pollutant emissions of the ship (through the ship’s power production system exhausts and underwater noise), contributing by 55% of the overall emission reduction objectives.

Innovative aspect

Today ship’s energy efficiency optimization is conducted with regards to single or limited design and operation points (e.g. maximum ship speed required). On the other hand, these specific conditions represent a limited part of the full spectrum of ship operation profiles and corresponding energy needs. Furthermore, the technology solutions used to optimize these single or limited operation cases are mainly passive technologies (e.g. duct tail optimized to a specific ship speed) that can even offer lower performances in other ship operation conditions. Also, use of renewable energy is very scarce, mainly due to non-mature solutions (or lack of solutions compatible for high power/large-scale applications (e.g. wind powering, solar panels), beyond a low fuel price and no specific incentive to develop such solutions. In the context of zero-emission waterborne transport and to achieve such objective, and especially the 55% reduction in energy consumption, the current situation needs to change dramatically. A new paradigm will be developed here, based on 3 breakthroughs:

- A systemic and holistic approach of ship energy efficiency,
- A switch from passive technologies and single or limited design/operation point approach to active and adaptive, multi-parameter ship design and solutions,
- Large-scale, energy-efficient applications of renewable energies.

Design and operation integrations

This **systemic, holistic and disruptive ship energy efficiency approach** will allow much better understanding, monitoring, prediction and real-time control of the full spectrum and complexity of ship energy needs, flows and operating profiles. So, it will enable, at the design stage, to conduct a full-scale multi-parameter optimization of ship energy efficiency for overall ship operation conditions. Selection and optimization for the integration of new energy power systems (i.e. fuel cells, batteries and renewable energies) and energy-efficient technologies will also be supported. Moreover, it will open new opportunities to develop **real-time adaptive optimization to take into account foreseen operating conditions as well as new operating conditions under ship operation**. This approach will make full use of new capabilities offered by **breakthrough energy and ship data monitoring, analysis and prediction** (digitalization, Digital Twin, Big Data, Artificial Intelligence), and **hybrid energy power systems**, as presented in the **Digital Green** and **Electrification** activities. Small case applications of this complex approach on cruise ships have already shown considerably high energy savings and a full market up-take of such approach and methodologies should maximize these gains, so contributing largely to the overall 55% reduction of energy consumption objective.

Energy-efficient technologies

The **mastering of the full ship energy systems and operating profile** opens a new paradigm for research and development of energy-efficient technologies, by:

- **breakthrough assessment and optimized integration** of new innovative power conversion and storage systems (e.g. heat/steam energy recovery solutions, variable speed electric motors, centralized or modular energy architecture), and innovative and more energy-efficient consumers (e.g. HVAC
new design/technology architecture/solutions, thermal insulation, ...). Solutions like fuel cell technologies and advanced engine technology and combined cycles are expected to significantly reduce fuel consumption. This, in combination with alternative fuels and electrification, will strongly contribute to optimize the energy need for all consumers (technology bricks) and significantly reduce fuel consumption as well as emissions.

- enabling a disruptive switch from today mostly passive technologies to active/adaptive ship design and solutions, for energy-efficient operation conditions at all-times (e.g. active deadweight and trim controls, active and bio-mimic appendages, innovative hull coatings...).

Both axes will be developed here and fully demonstrated.

**Renewable and free energy solutions**

Renewable and free energy solutions are rising now much more interest in the dramatic climate change context. Wind powering (e.g. multi-MW wind turbines, automatic-controlled kites, large sails made of hinged composite panels,...), or waste to energy solutions (e.g. Hydrothermal Oxidation and alternatives), as breakthrough solutions for larger ships propulsion are also emerging. Most solutions are still under development at small scale and may not apply to all ships types. Ship design and integration and full-scale demonstrators will be conducted to assess and select the most effective solutions, depending on ship types and operations. Great potential market uptake is expected now by 2030, with progressively increasing energy savings depending on the ship application and operating profiles. Combination of renewable and free sources to power small-scale vessels (such as solar energy for an energy-autonomous drone), or provide off-shore fuel bunkering (see "Ports" activity), will enable new energy-efficient waterborne applications. Most promising applications will be assessed and demonstrated. For large-scale onboard ship applications, disruptive solutions in terms of power output and density such as for wind (or solar) energy still need to be developed.

**Short-term**

For the short-term Work Program period of 2021-2022, to pave the way for the whole development of Energy Efficiency (shown by the logic depicted in the chart below), we will focus on the following issues:

- 31 exploiting renewable energies, particularly wind assistance for ships (2022);
- 32 energy saving technology to improve efficiency (2021).
**Operational Objectives**

**Eliminating 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 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 (alternative) fuel consumption of waterborne transport, including by the use of renewable energy, 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.

**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.
Strategic research & innovation agenda for Zero-emission waterborne transport

- **Alternative Fuels**
- **Electrification**
- **Energy Efficiency**
- **Design and Retrofitting**
- **Digital Green**
- **Ports**

**Design & operation integrations**

- Holistic ship’s energy management approach
  - Tools & Methodologies: real-time data monitoring, control
  - Full adaptive energy management system

- Architectural reconfiguration & integration of new power generation systems
  - Centralized/modular ship’s energy architecture

**Energy-efficient technologies**

- Thermal/Electrical energy savings and retrieval
- Disruptive propulsion solutions (e.g., bio-mimic, appendages,..)
- Hull improved performance
- Waste to energy powering solutions
- Large-scale powering solutions with renewables

Integration of new power conversion, poly generation and storage systems

Active/adaptive ship technologies design & solutions

Standardization of solutions

**Renewable & free energy solutions**

- Large-scale wind powered vessel

55% Energy Efficient Vessel

**Demo**

- 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 energies
- 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, manufacturing and retrofitting.

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, necessitates dealing with the existing fleet and with newbuilds. The composition of the current fleet excludes a "one-size-fits-all" single zero-emission solution which may transform the sector. Different technologies need to be developed and adapted to the specific operational needs and business models of different ship types, also anticipating on the continuous evolution of transport needs, ports infrastructures, technologies and regulations. All these aspects require new methodologies in Design, Manufacturing and Retrofitting: these activities are the zero-emission target "enablers" throughout the entire life cycle of ships. A new design approach will integrate the latest and disruptive technologies in light, safe, clean and cost-effective ship solutions. At the same time, design methodologies will anticipate future needs to replace existing ship systems with new green systems, which will be demonstrated before 2030. Modular ship architectures will assure cost-effective retrofitting of low emission solutions throughout the ship lifetime. For ships-in-service, high priority will be given to the development and demonstration of easy to integrate green retrofitting solutions such as electrification (batteries) or alternative fuels and power conversion systems before 2030. Moreover, retrofitting of after-treatment systems for internal combustion engines, combined with climate-neutral drop-in fuels, will be considered.

To attain a high level of confidence regarding the environmental performance of ship designs, of ships-in-service prior and after retrofitting, and of the environmental impact of manufacturing processes, advanced assessment methodologies and full twinning of ship design and manufacturing processes will be developed.

Relevance
A new business model is needed to realise 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 lesser economic windfall, also offers a way to meeting 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, usually corresponding to state of the art at the time of ship delivery. Considering an average of 30-40 years for ship's life duration, specific measures for abating emissions on ships in-service are needed. Ship's maintenance must evolve from the current preservation of the initially designed environmental and operating performances towards a process of minimising 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:

1) minimise the ship energy needs,
2) minimise the share of onboard ICE’s in power systems and
3) install alternative ship power systems and apply clean fuels on ICE’s (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 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 layouts followed well-established practices with the final details being set by the chosen brands. The transition to other energy conversion technologies and fuels leads to different needs for weight, volumes and layouts. Moreover, potential retrofitting the ship with newer green technologies and systems leads to different needs for the ship architecture. Likewise, introducing high strength and lightweight materials like 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, thus new fuel storage systems, new materials and components will require ship design solutions adapting to changed operational and environmental requirements including legislation. Moreover, cost-effective technology upgrades for greening will have to be foreseen throughout the life cycle maximising value, including end-of-life, supporting sustainability, competitive under varying market and mission requirements. Changes and uncertainties determine that the future ship design methods will use probabilistic approaches to identify design solutions that will exhibit the smallest effects of random variability, e.g. are the most robust. A new probabilistic design for greening will enable dealing with uncertainties linked to totally new parameters like thrust from wind propulsion, use of different alternative fuels, etc., as well as operating and/or environmental conditions. Fast design assessment methodologies capable of dealing with new technologies, their mutual impact, the overall impact on the ship along with the 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 ship digital twin, will support the outlined greening strategy. The new opportunities offered by digital twin and technologies presented in the Digital Green activities will be fully leveraged, for a dual exploitation of results, both for the Design of new vessels and their operational management.

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. 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 and standards, new materials processed in shop floor processes. Not to mention that 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 a LCPA context – new, low-polluting floor processes related to the building and retrofitting of green ships, e.g. with light alternative materials.

Retrofitting

Today, capturing and twinning an existing ship's architectural data by reverse engineering is not effective in lead time and cost, thereby also reducing the retrofitting process efficiency. 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.

Two parallel retrofit tracks are identified. First, the existing fleet and in particular the relative younger fleet segments (< 10 years), thanks to more recent technologies, will allow a fast assessment of retrofit options following the strategy of minimising 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 (ESV’s), ships’ speed profiles review, propulsion train re-design and wind thrust-generating. The second track concerns the fleet replacement and in particular the relative 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 ports' infrastructures (fuelling, 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 retrofit scenarios’ assessment. A wide variety of retrofit strategies and assessment methodologies for the entire waterborne sector will be developed.

Short-term

For the short-term Work Program period of 2021–2022, to pave the way for the whole development of Design & Retrofitting (shown by the logic depicted in the chart below), we will focus on the following issues:

- 41 retrofits to cut GHG’s and pollution from existing vessels (2022);
- 42 assessing and preventing methane slip from LNG engines in all conditions within both existing and new vessels (2021).
# Operational Objectives

## Eliminating 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); ✔
- 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 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. ✔

## 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.
Digital green

This activity concerns the broadest use of digitalisation to improve efficiency and reduce emissions through monitoring and big data collection, the development of a secure and IPR-compatible Digital Twin and Zero-Emission Energy Decision Support Systems.

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 (e.g. a logistic chain, as currently discussed by the Digital Transport and Logistics Forum – DTLF with the proposed use of Corridor Information Systems) requires the availability of data, their analysis and guidance.

Managing and organising digitalisation towards the goals of this program requires three activities to be developed. These activities can be seen as the three steps to the zero-emission epiphany:

1. Monitoring and Big Data collection: to look back by measuring, connecting, complying and making a diagnosis
2. Digital Twin: to look ahead by predicting and improving predictions
3. Zero-Emission Decision Support Systems: to act and create value, in terms of emission reductions, transcending the boundaries of individual ships and ship operations.

Monitoring and Big Data Collection cover sensing, data acquisition 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, IPR agreements, configuration management and security management. These activities aim to enable operational condition- and ship health monitoring necessary to reduce emissions through a combination of increased vessel utilization, fleet efficiency, optimized traffic and port logistics, as well as to enable compliancy to rules and regulations. The essence of the Digital Twin is a virtual representation of the ship and its relevant systems connected to the physical representation, the ship as it is built. Providing predictive capabilities in addition to the historical and real-time data-based insights coming from Monitoring and Big Data Collection is an essential enabler for Zero-Emission Decision Support Systems, but also a prerequisite of a manageable and safe digitalized vessel. Nowadays, systems and subsystems increasingly come with advanced automation and software. Thus digital integration onboard has 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. On top of combined Monitoring and big data collection and Digital Twin sub-activities, a Zero-Emission Decision Support System will be developed. A digital twin can quantify vessel performances like fuel consumption 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 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. The Zero Emission Decision Support System transfers these insights into real-life results by translating operator guidance into actions which are executed, in most cases, by the 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 shackle in a logistic chain, depends on accurate and real-time information of vessels, ship conditions, environmental conditions and operational plans. Digitalisation though Monitoring and Big Data Collection on board increases fleet utilisation and as a result, lowers the energy need on a fleet or logistic chain level. Optimisation of fleet utilisation, ship operations and ship condition, based on Monitoring and Big Data Collection, offers a vast potential for the zero-emission goal of the Partnership. Measurements through appropriate sensors, analysis of data, control optimisation through predictive capabilities (the Digital Twin) and operator guidance or automated actions (autonomy) will contribute to reducing energy consumption, air pollution and underwater radiated noise on multiple levels of maritime operations. Ship operations optimisation rely equally on the availability of accurate and real-time information of the ship, the 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. In combination with data shared by other vessels, ports and logistic chain data voyage optimisation will be raised to the level of the entire logistic chain, thereby lowering the energy consumption and pollution of ship operations on a single ship level. Ship condition optimisation allows for the continuous monitoring of ship systems data concerning energy conversion and use, thereby ensuring the energy efficiency gains as described in Energy Efficiency activity. Increased energy demands caused by for example hull fouling, propeller 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. Compliance to rules and regulations by individual ships and accurate data by large numbers of ships are enabled by Monitoring and Big Data Collection for ships and shipping and allow for measured data-driven policies and enforcement of rules and regulation, as an additional societal benefit.

Innovative aspect
The innovative approach represented by monitoring and big data collection, digital twin and 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).

Monitoring and big data collection
State of the art digitalisation and connectivity solutions are characterised by proprietary and (sets of) subsystem specific solutions. As such, the functionality required to monitor the condition of the vessel concerning emissions requires a combination of connectivity solutions for each newly designed vessel. Data standards to facilitate the reusability of these solutions for other ship types or system designs are non-existent. Data platforms to
exchange and share acquired data are emerging but offering 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 Partnership delivers the necessary standards for zero-emission relevant data exchange, including a platform design for 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.

Digital Twin

True digital twins, 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 and hampered by a lack of adequate configuration management of control systems applied in the physical vessel. 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\(^{24}\), and distributed simulation architectural standards. These will be developed and demonstrated in the Partnership.

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 monitoring, environment data, traffic data, port operations data and logistic chain data are to be combined in Decision Support Systems or autonomous systems. Nevertheless, limitations of autonomous systems, as well as those of humans interacting with autonomous systems, have to be taken into account. As a result, a continuous and monitored maximum reduction of waterborne transport emissions in ship operations and an essential contribution to the 55% reduction goal of fuel consumption of Waterborne Operations will be achieved.

Short-term

For the Horizon Europe Work Program 2021-2022, to pave the way for the whole development of Digital Green (shown by the logic depicted in the chart below), we will focus on the following issue:

- 51 sensorisation, data merging and digital twin modelling to improve efficiency, and increase owner confidence in innovative green system performance (2022).

\(^{24}\) The "system-in-the-loop" approach (modern evolution of "hardware-in-the-loop"), meaning the feedback backward to design processes and the feedback forward to future operational conditions by means of a virtual framework coupled with the physical system.
## Operational Objectives

### Eliminating 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); [ ]
- 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 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. [ ]

### 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. [ ]
Strategic research & innovation agenda for Zero-emission waterborne transport

Digitalisation

- Digital prerequisites for waterborne
  - Platform standards
  - Data integration
  - Data analysis

Digital Twin

- Open source modelling
- Standards
- Verification

System in the Loop

- Simulations
- Configuration, quality management

Optimization of operations

- Fleet, port, traffic
- Logistic
- Ship
- System

Real Time Monitoring and compliance system

Zero Emission AI concepts

Demo

ZE-Decision Supp. Syst.

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

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Ports
This activity concerns the development of safe technologies and procedures for **bunkering of sustainable fuels at inland and maritime ports**, the supply of electricity to vessels, taking into account new necessary systems for alternative energy solutions (i.e. recharging and transhipment points for exchangeable battery containers, in case of electrification), and **systems for reducing emissions** from waterborne transport within ports.

**Introduction**

**Achieving net-zero emission waterborne transport as well as wider facilitating zero emission for wider logistics** is one of the most critical challenges for port facilities. Ports represent crucial hubs in the logistics network linking maritime transport to the hinterland, including inland waterway transport and finally to customers. Net-zero emission waterborne transport and including related wastes within ports are facilitated by this activity. **So, ports have to develop their net-zero-emissions strategy adapting to the evolution of the different transport modalities**, with vessels in the first place, including port vessels such as tug boats. At the same time, **ports and waterways should adapt to climate change effects** developing resilient solutions to minimise their impact on operations.

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

**Relevance**

Our proposed solutions in **Ports** activity are enabling the energy transition of maritime shipping and inland navigation and its interaction with ports and related infrastructures. These solutions are, therefore, strategic in facilitating **GHG reduction and reduction of other pollutants** for vessels. 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 inland and maritime shipping meet the strategic objective of zero emission as expressed within the EU Green Deal communication and underpins its position as the cleanest and most energy-efficient modalities of transport. **Air pollution from waterborne transport** has an important impact on the environment of ports and the surrounded city areas. The activities of the Partnership will also tackle these emissions. As well as eliminating accidental water pollution, for example during bunkering operations. Technical standards and procedures for safe storage and bunkering of sustainable alternative energy providers, including fuels and preventing their spillage will also be addressed. Hull coating management and noise reduction during maintenance phase in port areas will be also reduced.

**Innovative aspect**

At present, there is no integrated vision and approach to the development of sustainable fuel supplies for alternative energy solutions. Furthermore, technical standards for bunkering of these fuels are lacking, leading to a fragmentation of bunkering options.
throughout European ports. Lastly, there is still much uncertainty on safe storage and bunkering for several alternative fuel options. By developing standards, creating flexible fuel storage and supply options for different energy suppliers and integrating them into the overall port energy grid, fast adoption of bunkering different alternative fuels in European ports (sea ports and inland ports) can be guaranteed.

This hold also for inland waterway vessels sailing on inland waterways. Whilst cold ironing is already developed for the lower powers needed for inland navigation vessels and for some small-scale maritime vessels (such as short-distance ferries), for larger vessels, there is a lack of standards, and there are no flexible solutions for providing enough power (for instance, for large passenger vessels).

**Bunkering alternative energy solution**

Unavailability of an established distribution and bunkering network in ports and along inland waterways across Europe is considered an important constraint for a large-scale roll-out of new alternative sustainable energy solutions to provide a feasible service to both maritime shipping and inland navigation. In this respect, special attention should be paid to hydrogen whose bunkering and supply would be addressed by the Clean Hydrogen Horizon Europe Partnership. By learning from the recent challenges for the introduction of LNG as a fuel in ports, the Partnership will develop solutions and operation procedures with marine renewable energies and alternative fuels, given the varied range of fuels and a large assortment of engines technically possible. Safe, flexible bunkering solutions for different types of sustainable fuels for different waterborne transport segments, will be realized to facilitate their increased use.

The definition and development of proper and consistent rules, regulations and procedures will support the introduction of sustainable alternative shipping fuels in ports in the safest way possible for the infrastructure, the environment and the surrounding population. Furthermore, technical standards will be developed for transferring to ship, or recharging ships and the directly related facilities (i.e. nozzles and hoses) to ensure that ships can be serviced throughout Europe.

Besides, the Partnership may address solutions for transfer and storage solutions for on board Carbon Capture from ships providing these can be shown to be sufficiently energy efficient and feasible at scale. 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 but with consideration of the overall value chains.

**Reducing emissions**

When progress can be beyond the current state-of-the-art, innovative on-board monitoring, use of (automated) drones, vessels and other detection methods will be used to enforce emission limits applying to waterborne transport. 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. Supporting the Waterborne activities on electrification of vessels and shipping-port operations, we shall develop technical standards for recharging equipment and power supply solutions such as integration with smart grids and mobile solutions.
Short-term

For the Horizon Europe Work Program 2021-2022, to pave the way for the whole development of Ports (shown by the logic depicted in the chart below), we will focus on the following issue:

- development of recharging system allowing safe (port/offshore) operations (2022).
### Operational Objectives

**Eliminating 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);
- 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 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.

**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.
Strategic research & innovation agenda for Zero-emission waterborne transport

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Part 3: Expected Impacts

Realizing 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 thereby contribute to the three main impacts:

1) the significant reduction of GHG emissions from waterborne transport, in line with the EU’s commitment to cut GHG emission by at least 50% 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;

2) 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;

3) 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 by the specific objectives

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

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 takes up 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.

Without any action, 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. Finally, the solutions of the Partnership will contribute to the Green Recovery, as a key element to mitigate the economic effects of the COVID-19 Pandemic. As 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 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. Thereby, achieving the objectives of the Partnership will significantly contribute to SDG13.

**SDG13 - Climate Action**

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

**SDG3 - Good health and well-being**

- 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. An important 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, like open-loop scrubbers, will be eliminated. New hull coatings will
be developed to reduce resistance of ships, but at the same time reduce the release of harmful chemicals into water. Furthermore, the underwater noise will be mitigated by the developments of quite engines and quite 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 27+Norway) waterborne technology industries, including shipbuilders, 1st and 2nd tier equipment suppliers, presently 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 112.5 billion, the EU 27+1 countries represent 23.3% of the global production value for maritime technology of EUR 482,5 billion (annual average for 2010-2014) and are securing more than 550,000 jobs in more than 30,000 enterprises in Europe.

Consolidating and further strengthening the EU’s frontrunner role in RD&I and 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 to demonstrate 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 thereby 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 thereby 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. Thereby, 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, crew on board vessels as well as office staff. Such very large and diversified type of skills and tasks to deal with 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 given to nurturing Small Medium Enterprises which are an essential part of the European ecosystem. The waterborne transport sector will pay specific attention to utilize long term skills’ development strategies and innovative educational and training methods to address the increasing diversity of the European workforce (which is comprised from people of all genders and ages, local or/and migrating) and to also attract more talented women and young people to the waterborne transport sector. By the creation of the foundation to transform to zero-emission waterborne transport, the Partnership will play a key role in the economic recovery following the COVID-19 pandemic by creation of highly skilled jobs.

Enablers and requirements to reach 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 products
- Infrastructure and fuel availability
- Regulations and international long-term governance
- Rules of classification societies

Market demand for green products
The most crucial factor to reach the full impact of the Partnership is the uptake of zero-emission technology by the sector. And this can not only be 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. The Partnership, by developing and demonstrating deployable solutions, and by supporting development of rules and standards for green products, will have an indirect impact on stimulating deployment, e.g. by ensuring synergies with deployment programs like CEF, Climate Innovation fund etc.

Infrastructure and fuel availability
Another important enabler or requirement for 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 halt. Local, small scale cooperation may lead to small breakthroughs, but also to local solutions which limit wider applications. 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 taking up 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 an important enabler of the transition is also a long-term perspective in international governance of the waterborne transport sector. 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 for their position in regulatory discussions, with a special focus on this long-term governance.

Rules of classification societies
Ships are being designed and built according to 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 on 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 IMO, to prevent 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 development of these rules.

Proposed arrangements to monitor
Key Performance Indicators w.r.t. Operational objectives

An Objective oriented approach
The Partnership Proposal 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 service 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 ZEW T 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 shipping 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 by 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.

**Monitoring system and KPIs Indicators**

To assess progress against objectives an efficient monitoring system is required, including a set of **key performance indicators** (KPIs) combined with a performance reporting system which collects data, including KPIs, and reports the outcomes **efficiently, effectively and in a timely manner**.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Results</th>
<th>Indicators</th>
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<tr>
<td>General objective(s)</td>
<td>Impacts</td>
<td>Impact indicators</td>
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<tr>
<td>Specific objective(s)</td>
<td>Outcomes</td>
<td>Outcome indicators</td>
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<tr>
<td>Operational objective(s)</td>
<td>Outputs</td>
<td>Output indicators</td>
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Indicators are defined according to the European Commission’s “RACER” principals.

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<th>Definition</th>
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<tr>
<td><strong>Relevant</strong></td>
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<td>The indicator should have a strong correlation with the objective that the initiative aims to achieve.</td>
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<td><strong>Accepted</strong></td>
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<td>The indicator must be easily understood and should be accepted by all stakeholders (e.g. staff).</td>
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<td><strong>Credible for non-experts</strong></td>
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<td>The indicators must be accessible to non-experts, unambiguous and easy to interpret.</td>
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<td><strong>Easy to monitor</strong></td>
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<td>It should be possible to collect the data with available resources, based on the principle of ‘proportionate analysis’ (appropriate scope and depth).</td>
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<tr>
<td><strong>Robust against manipulation</strong></td>
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<tr>
<td>The indicators should be sensitive enough to monitor changes; therefore it is important to select them according to the time lag between the action and the expected change that points to current progress towards long-term or future improvements.</td>
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The methodology

Each project within the framework of the partnership, will be required to report data relevant to KPIs which will be used by the partnership for monitoring.

Reflecting the difference between immediately directly measurable outcomes, and those which must be estimated such as cost-effectiveness and potential toward wider impacts following deployment two levels of KPIs indicators have been defined:

1. KPI-LEV.1, measuring the number of a specific output from the projects
2. KPI-LEV.2, estimating the impact on new built or existing ships on specific waterborne segments towards the operational objectives.

KPI-LEV1 are a direct measure, while KPI-LEV2 will be linked to the average impact to the sector as defined by research projects (it can be declared if the project has just started, or calculated if the project is running to its conclusion)“KPIs will be depending from the execution of the projects; therefore it is expected that in the first years the parameters will be linked to declared intentions of successful proposals (i.e. achievable), while in a longer run actual achievements will be taken from research projects developed in the partnership (i.e. achieved). This approach will help proponents to align to the objective of the partnership and will also allow the partnership to verify – during the course of the project and at their end – the achievements that were reached.

The technological solutions developed with this approach will represent the building blocks for the decarbonisation of the sector. Demonstrator projects will prove the viability of the combination of different building-block technologies, thus indicating the effectiveness of the developed solutions.

Achievements reached by waterborne members with private research or funded at national/regional level will be assessed and presented describing the additionality of the intervention and proving directionality.

List of KPIs relevant to operational objectives

<table>
<thead>
<tr>
<th>Operational Objective</th>
<th>Code</th>
<th>KPI</th>
<th>TARGET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective 1 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</td>
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</tr>
<tr>
<td>Obj.1</td>
<td>OPE-KPI-1-1a</td>
<td>% reduction of GHG emissions, demonstrated by projects at technology level and applicable to ships with high energy demand (&gt;5MW)</td>
<td>% reduction demonstrated at the end of the project aiming to achieve -50%</td>
</tr>
<tr>
<td>Obj.1</td>
<td>OPE-KPI-1-1b</td>
<td>Number of formal contributions (e.g. to expert groups, formal public consultations, rule settings, standards, legislative processes, ...) related to market measures, standard and the adoption of European and/or</td>
<td>At least 30 contributions</td>
</tr>
</tbody>
</table>
### Objective 1

**Obj.1**

| OPE-KPI-1-2 | Average % reduction of GHG emissions relevant to high energy demand (>5MW), expected to be achieved by projects developing fuel switch technologies which will support the EU’s commitment to cut emissions by 50% before 2030. | At least 50% reduction |

**Objective 1**

To develop and demonstrate that international regulations for sustainable Alternative Fuels will be achieved by projects developing fuel switch technologies which will support the EU’s commitment to cut emissions by 50% before 2030.

### Objective 2

**Obj.2**

| OPE-KPI-2-1b | Number of formal contributions (e.g. to expert groups, formal public consultations, rule settings, standards, legislative processes, …) related to market measures, standard and the adoption of European and/or international regulations for ship’s electrification | At least 30 contributions |
| OPE-KPI-2-2 | Range demonstrated within projects as being feasible for fully electric navigation by 2030 | At least 150 nm |

**Objective 2**

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 environmentally sensitive areas, and to increase operational efficiency.

### Objective 3

**Obj.3**

| OPE-KPI-3-1 | % reduction of engine energy demand demonstrated from exploiting renewable energies on an average basis. | Contribution from renewables exceeds 35% of total energy required |
| OPE-KPI-3-2 | % reduction of fuel consumption, before 2030, achieved by projects on average | Average reduction from successful projects of at least 55% before 2030, compared to 2008. |

**Objective 3**

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 at least 55% before 2030, compared to 2008.
**Objective** 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.

<table>
<thead>
<tr>
<th>Objective</th>
<th>KPI</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Obj.4</strong></td>
<td>OPE-KPI-4-1a</td>
<td>Deployable cost-effective solutions for port based electricity supply to ships, to be developed for small to big capacity ports (including inland) applicable to at least 90% of ships requiring electric energy supply. At least 3 solutions</td>
</tr>
<tr>
<td><strong>Obj.4</strong></td>
<td>OPE-KPI-4-1b</td>
<td>Number of projects which demonstrate technologies which enable deployable cost-effective bunkering of different sustainable alternative fuels. At least 5 projects</td>
</tr>
</tbody>
</table>

**Objective 5** To develop solutions for clean and climate-neutral, climate-resilient inland waterway vessels before 2030.

<table>
<thead>
<tr>
<th>Objective</th>
<th>KPI</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Obj.5</strong></td>
<td>OPE-KPI-5-1</td>
<td>% reduction of CO2eq emissions demonstrated at technology level applicable to inland waterway vessels, which will support the EU’s commitment to cut emissions by 50% by 2030.</td>
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<tr>
<th>Objective</th>
<th>KPI</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Obj.6</strong></td>
<td>OPE-KPI-6-1</td>
<td>% reduction of air pollution (e.g. SOx, NOx, PM, etc...) emissions, demonstrated by projects at technology level and applicable to coastal and inland navigation. % reduction demonstrated at the end of the project aiming to achieve -50%</td>
</tr>
<tr>
<td><strong>Obj.6</strong></td>
<td>OPE-KPI-6-2</td>
<td>Average % reduction of air pollution (e.g. SOx, NOx, PM, etc...) emissions relevant to coastal and inland navigation to be achieved by projects which will support the At least 50% reduction</td>
</tr>
</tbody>
</table>
Strategic research & innovation agenda for Zero-emission waterborne transport

EU’s commitment to cut emissions by 50% by 2030.

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

| Obj.7 | OPE-KPI-7-1 | Number of different harmful emissions to water demonstrated at technology level as being eliminated | At least 5 solutions Single technologies contributing to achieve at least 50% reduction |

Part 4: Governance

Description of the governance of the Partnership

The governance presented below is based on the assumption that the current Waterborne TP Association can be the private partner in the Partnership. The development of the governance structure also depends on the final MoU laying down the requirements of the Partnership. The proposed governance scheme described below may have to be adjusted in light of the final legal requirements.

The Partnership will be concluded between the European Commission and the Waterborne TP Association, 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.

The Partnership will be governed by a Partnership Board. This board will steer 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 will consist of representatives of the European Commission Services, together with representatives of the Partnership. The Commission will have several representatives. Currently, the intention is to include representation from DG RTD, DG MOVE, DG CLIMA and DG ENV. If deemed necessary or depending on the topic, there might be a need to include additional representatives from DG MARE, DG ENER, DG TAXUD, DG COMP, SEC GEN and DG GROW. The Partnership’s representatives will be (a subset of) the Waterborne TP board and high-level representative of the important stakeholders in the transition to zero-emission waterborne transport. The Waterborne TP representatives will be proposed by the association following a vote in its General Assembly and appointment by the European Commission.

EU Member States and Associated Countries will be involved in the Partnership through an advisory body (States Representatives Group or similar). All Member States and associated countries are invited to participate. The aim is to ensure 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 Transport Programme Committee. In addition, it will facilitate the take-up of results and the development of necessary policies and regulations.

The Partnership will be assisted by a secretariat which will be provided by the Waterborne TP association. The private side of the Partnership will be organised within the Waterborne TP association. Within the Partnership’s working groups, members of the Partnership will discuss the technical requirements and research progress for the Partnership. Representatives of EU Member States, Association Countries and European Commission services will be invited to participate in the technical meetings of the working groups.

The actual division of the industrial research discussions in working groups will be aligned with the final subdivision of topics in this SRIA. 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 part of collaborative research. Examples of this include digitalization for greening vs digitalization for safety, or fire/explosion/toxicity risks and passenger safety on vessels using new fuels and layouts. Proper coordination of needs and activities is therefore of paramount importance 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 research in the waterborne sector and to ensure the appropriate communication and dissemination of the findings of the results of the Partnership, such as creating brochures, maintaining a website, social media activities and organising events.

Openness and transparency

The waterborne transport sector by its very nature is 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 will have a broad composition and will be open to new members. From the beginning, the Partnership will include 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. Furthermore, leading companies from all stakeholders will sign the Partnership agreement.

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 2020) 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 well understood that many stakeholders in the waterborne transport sector are small companies far away from Brussels. Whilst travel to and from Brussels may hinder participation, interaction with European Commission Services and Member State representatives is done mostly in Brussels. The Partnership will therefore organise outreach events to specific 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 will establish 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 will be taking 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.

The Partnership will undertake actions that will 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 will actively recruit new participation by analysing the evolving waterborne transport stakeholders and the representation of relevant sectors. We will invite new members or industrial sector through our European and national branch organisations. The Partnership will also be 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, we envisage applying an open but manageable process.

1. The Partnership will undertake a *broad assessment of the current state-of-the-art* and challenges for the different ship types and services. On this basis, a SRIA will be developed for 7 years, addressing the *main objectives and activities*. *Each year* the SRIA will be 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;

2. The Partnership will create and maintain an overview of *ongoing projects* and *research outcomes (including policy recommendations)*. This overview will not be limited to EU funded research, but through its members and its contact with the Member States, the Partnership will acquire information on *relevant national or industrial projects*, as well as assess reports within the wider press and journals. A summary of this overview and the main trends will be published each year;

3. The Partnership will 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. 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;

4. The Partnership will organise conferences on a yearly basis to present the research outcomes as mentioned above and to discuss necessary updates to the SRIA. 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;

5. The proposed updates to the SRIA for the Partnership will be 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;

6. On the basis of the SRIA, and taking into account emerging developments, *each year experts* from the Partnership’s members will 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 dissemination and communication etc., in order to ensure the maximum impact of results. Following this update, the portfolio of activities for the following two years will 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.

Throughout this process, the EU Member States, Associated Countries and the European Commission will be involved. This ensures avoiding unnecessary duplication and enables synergies

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strategic research & innovation agenda for zero-emission waterborne transport

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 will be 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, which will be discussed in the States Representatives Group;
- Coordinate between the Partnership (including research outcomes) and regulatory actions at regional, national and international level (see paragraph 3.1.2);

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

Cooperation at EU level

The Waterborne TP has recently established collaboration and signed a Memorandum of Understanding with counterparts from Hydrogen Europe26, as well as with ALICE27. In preparation for the Partnership, the Waterborne TP will nominate interlocutors who will act on behalf of the Partnership to liaise on the developments of the Partnership with the 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

Synergies with other Partnerships include:

- The proposed Partnership, “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

26 https://www.hydrogeneurope.eu/

27 https://www.etp-logistics.eu/
and cooperation between the two Partnerships will be maintained to ensure relevance and to generate synergies;

- The proposed “Clean Hydrogen” Partnership focuses on green hydrogen fuel production, storage and supply, as well as demand side technologies, as well as 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 bunkering and integration of onboard storage of non-hydrogen alternative fuels. The “Clean Hydrogen” Partnership can play an important role in coordinating with this Partnership with a view to develop the multi MW fuel cell required for ship propulsion and the related fuel technology. The Clean Hydrogen Partnership (CHE) will address technology transfer from land application of H2 technologies (FC, tanks or refuelling infrastructure) as a prospect of rapid deployment, initiating demonstration projects to validate technologies;

- The proposed 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;

- The proposed Partnership for “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);

Links with missions

- The Mission on Healthy Oceans, Seas, Coastal and Inland Waters. The mission’s focus is yet to be fully developed. Although the main focus of the mission is not on greening of transport, our targets for the reduction of water pollution including underwater radiated noise contribute to a healthier ocean;

- The Mission on Climate Neutral and Smart Cities. The mission’s focus is yet to be fully developed. 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 clean living environment in port cities and their surroundings;

- The Mission on Adaptation to Climate Change including Societal Transformation. The focus for this mission is also yet to be fully developed. The mission will not focus on greening of (waterborne) transport, but 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.

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: 1) innovative low-carbon technologies and processes in energy intensive industries, including products substituting
carbon intensive ones; 2) carbon capture and utilisation (CCU); 3) construction and operation of carbon capture and storage (CCS); 4) Innovative renewable energy generation; 5) Energy 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 10 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;

- **Connecting Europe Facility Transport Blending Facility (European Commission and EIB):** It is currently envisaged that, via InvestEU, the CEF Transport Blending Facility will co-finance greening of maritime and inland waterway transport fleets in the period 2021 - 2027;

- **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;

- **EIB Green Shipping Guarantee:** is a sector risk-bearing facility supported by the Connecting Europe Facility (CEF) and the European Fund for Strategic Investments (EFSI), designed for projects that will improve the environmental performance of transport vessels in terms of reducing the emission of pollutants, as well as increasing fuel efficiency;

- **LIFE (DG ENV):** the LIFE Programme has four objectives:
  o Help the move towards a resource-efficient, low carbon and climate resilient economy, improve the quality of the environment and halt and reverse biodiversity loss;
  o Improve the development, implementation and enforcement of EU environmental and climate policy and legislation, and act as a catalyst for, and promote, the mainstreaming of environmental and climate objectives into other policies and practices;
  o Support better environmental and climate governance at all levels, including better involvement of civil society, NGOs and local actors;
  o Support the implementation of the 7th environmental action plan.

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 relevant other EU financial instruments.

**International cooperation**
To support identification of the most important knowledge, regulatory, standardisation and technological gaps, the Partnership will monitor the discussions and developments of the international organisations like the IMO (in particular its Marine Environment Protection Committee), HELCOM, OSPAR etc. In addition, the Partnership will follow the process of establishment of the International Maritime Research and Development Board (IMRB), as recently proposed in the context of the IMO, with a view of avoiding duplication of efforts and to stimulate the development of necessary rules and regulations. Alignment of research investments in efficient and effective innovation are crucial to accelerate the introduction of low-carbon and zero-carbon technologies and fuels can have an impact on the strategic execution of the Partnership’s SRIA.
The members of the Partnership will also actively participate, present and discuss the developments and results of the RD&I projects supported within the framework of the Partnership, during meetings of the European Sustainable Shipping Forum (ESSF). The ESSF is a Commission Expert group, which provides advice to the Commission and the Member States on specific important, mainly technical matters related to sustainability of shipping, including preparations to the discussions at the IMO level. Europe can thereby play a leading role at international level regarding the transition to zero-emission waterborne transport.

The Partnership will equally establish links with governing bodies in Inland Waterway Transport, in particular the Central Commission for the Navigation on the Rhine, the Danube Commissions and if relevant other river commissions as well as UNECE. Cooperation with other regions than EU member states will also be pursued. The international nature of the waterborne transport sector requires cooperation with other research-oriented countries and flag states. Of course, cooperation is subject to requirements on IPR protection, as well as fair treatment of investments and public procurement.