UNIVERSITY OF PIRAEUS

DEPARTMENT OF MARITIME STUDIES

M.Sc. in SHIPPING

THE EUROPEAN GREEN DEAL: CHALLENGES FOR THE MARITIME INDUSTRY

Alexandra K.S. Itani

Master Thesis
submitted to the Department of Maritime Studies of the
University of Piraeus as part of the requirements for the acquisition of
Postgraduate Diploma in Shipping

Piraeus

November 2023

Authentication Statement / Copyright issues

The person performing this Master's Thesis is fully responsible for determining the fair use of material, which is determined by the following factors: the purpose and nature of the use (commercial, non-profit or educational), the nature of the material used (part of the text, tables, figures, images or maps), the percentage and significance of the portion that is used in relation to the full copyrighted text, as well as the potential consequences of such use on the market or the overall value of the copyrighted material.

Three-Member Examination Committee

This Master's Thesis was unanimously approved by the Three-Member Examination Committee appointed by the Special General Assembly of the Department of Maritime Studies of the University of Piraeus, in accordance with the Regulations of the Postgraduate Program in Shipping.

The members of the committee were:

- Maria Boile, Professor (Supervisor)
- Alexander Artikis, Associate Professor
- Stefanos Chatzinikolaou, Assistant Professor

The approval of the Master's Thesis by the Department of Maritime Studies of the University of Piraeus does not imply acceptance of the author's opinions.

ACKNOWLEDGEMENTS

At this point, I would like to express my sincere gratitude to my thesis supervisor Professor Maria Boile, for her guidance, support and patience through the entire process of conducting this master thesis, as well as for providing me with valuable assistance in locating relevant sources and generously offered me her time and shared her insights with me. Moreover, I would like to thank Associate Professor Alexander Artikis and Assistant Professor Stefanos Chatzinikolaou for the apt remarks and feedback. Last but not least, my warmest appreciation to those closest to me, who provided encouragement, support and a much-needed distraction from my work.

CONTENTS

LIST OF FIGURES AND TABLES

LIST OF ABBREVIATIONS

CCS	Carbon Capture and Storage
CIP	Competitiveness and Innovation Framework Programme
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide (Chemical Compound)
COST	Cooperation in Science and Technology
cPP	co-Programmed Partnership
CSA	Coordination and Support Actions
DC	Direct Current
EC	European Commission
ECAs	Emissions Control Areas
EEDI	Energy Efficiency Design Index
EGD	European Green Deal
EIC	European Innovation Council
EIT	European Institute of Innovation and Technology
ERA	European Research Area

ERC	European Research Council
ESIF	European Structural and Investment Funds
ETS	Emissions Trading System
EU	European Union
FP	Framework Programme
FP7	Seventh Framework Programme
GHG	Greenhouse Gas
H2020	Horizon 2020
HEU	Horizon Europe
ICS	International Chamber of Shipping
IMO	International Maritime Organization
IoT	Internet of Things
ISO	International Organization for Standardization
JRC	Joint Research Center
KERS	Kinetic Energy Recovery Systems
LCA	Life Cycle Assessment
LNG	Liquefied Natural Gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MCP	Maritime Connectivity Platform
MEPC75	Marine Environment Protection Committee
MRV	Monitoring, Reporting, Verification
MSP	Maritime Spatial Planning
NO_X	Nitrogen Oxide (Chemical Compound)
PBR	Passive Bistatic Radar
PPP	Public-Private Partnerships

R&I	Research and Innovation
RD&I	Research, Development and Innovation
ROV	Remotely Operated Vehicle
SAF	Sustainable Alternative Fuels
SEEMP	Ship Energy Efficiency Management Plan
SO_x	Sulfur Oxide (Chemical Compound)
SRIA	Strategic Research and Innovation Agenda
TFEU	Treaty on the Functioning of the European Union
TRL	Technology Readiness Level
TZAWI	Towards Zero-Accident Waterborne Industry
VOC	Volatile Organic Compounds
ZEWT	Zero Emission Waterborne Transport

ΣΥΝΟΨΗ

Η παρούσα εργασία εξετάζει την Ευρωπαϊκή Πράσινη Συμφωνία (ΕΠΣ) και τις προκλήσεις που αυτή συνεπάγεται στη ναυτιλιακή βιομηχανία. Αναλυτικότερα, μέσω της παρούσας μελέτης θα αναλυθούν οι πτυχές της Ευρωπαϊκής Πράσινης Συμφωνίας και ο βαθμός στον οποίο επηρεάζουν τους διάφορους κλάδους της ναυτιλιακής βιομηχανίας. Η μελέτη εστιάζει στις ερευνητικές προτεραιότητες και τις δράσεις έρευνας και καινοτομίας που απαιτούνται για την επίτευξη των στόχων της ΕΠΣ με έμφαση στη ναυτιλία. Στο πλαίσιο αυτό θα αναλυθούν τα επιμέρους ερευνητικά έργα που έχουν χρηματοδοτηθεί από την Ευρωπαϊκή Ένωση μέσω των προγραμμάτων πλαισίων «Ορίζων 2020» και «Ορίζων Ευρώπη», τόσο από άποψη χρηματοδότησης όσο και από τη σκοπιά της συμβολής των προσδοκώμενων αποτελεσμάτων τους στον εκσυγχρονισμό των θαλάσσιων μεταφορών και την επίτευξη των στόχων της Ευρωπαϊκής Πράσινης Συμφωνίας. Παράλληλα, θα γίνει διερεύνηση των προκλήσεων που αντιμετωπίζει η ναυτιλιακή βιομηχανία στην ενσωμάτωση των νέων ερευνητικών και τεχνολογικών ευρημάτων, καθώς και των κενών που εντοπίζονται μέχρι στιγμής στα πλαίσια έρευνας και τεχνολογικής ανάπτυξης.

Λέξεις κλειδιά: Ευρωπαϊκή Πράσινη Συμφωνία, Ναυτιλιακή Βιομηχανία, Βιωσιμότητα, Ορίζων Ευρώπη, Μηδενικές Εκπομπές Άνθρακα, Έρευνα, Ανάπτυξη και Καινοτομία

ABSTRACT

This thesis examines the challenges facing the maritime industry as a result of the policy objectives and priorities of the European Green Deal (EGD). The study analyzes the aspects of the European Green Deal related to the maritime industry and the extent to which these affect the various maritime sectors. Special emphasis is placed on the research priorities and the research and innovation actions that are needed to achieve the objectives of the EGD. Within this context, the thesis reviews individual research projects that have been supported by the European Commission under the «Horizon 2020» and the «Horizon Europe» work programmes. The projects are assessed on the basis of the funding received, as well as from the point of view of their anticipated outcomes and their contribution to the modernization of waterborne transport and the achievement of the main objectives of the EGD. Furthermore, reference will be made on the gaps that have been identified so far in the context of research and technological development, as well as the challenges faced by the maritime industry in the integration of these research and technological discoveries.

Keywords: European Green Deal, Maritime Industry, Sustainability, Horizon Europe, Zero Emission, Research, Development and Innovation

CHAPTER 1: INTRODUCTION

The maritime industry plays a crucial role in global trade and transportation, connecting nations and facilitating economic growth, as it is estimated to deliver over 80% of the world trade[1]. However, the industry's environmental impact, particularly its contribution to Greenhouse Gas (GHG) emissions and marine pollution, has raised concerns about its sustainability and the need for transformative measures. By the year 2021, ships were considered responsible for 13,5% of the total GHG emissions produced from the transport sector in the European region[2].

The European Union (EU) has identified Research, Development and Innovation (RD&I) as a key instrument in response to these challenges and as a measure to maintain its global competitiveness over the years. As stated in the Treaty on the Functioning of the European Union (TFEU), fostering a European Research Area (ERA) in which knowledge and technology flow freely may enhance competitiveness across various sectors and support necessary research endeavors[3].

In this context, the European Commission (EC) introduced the Europe 2020 Strategy, aiming to improve framework conditions and access to financing for research and innovation, ultimately transforming innovative concepts into products and services that stimulate economic growth. The Innovation Union was the flagship initiative of the Europe 2020 Strategy, using the Horizon 2020 Framework Programme (H2020) as its fundamental financial instrument[4].

---

[1] UNCTAD (United Nations Conference on Trade and Development). (2022). Review of Maritime Transport 2022

[2] European Environment Agency, (2021). "EU maritime transport: first environmental impact report acknowledges good progress towards sustainability and confirms that more effort is needed to prepare for rising demand"

[3] European Union Law EUR-Lex, (2014). "Framework for State aid for research and development and innovation"

[4] European Commission, Directorate-General for Research and Innovation, (2011). "Europe 2020 flagship initiative Innovation Union: SEC(2010) 1161, communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions"

Significantly, H2020 had already recognized the pressing needs to address environmental concerns within the maritime industry. It laid the foundation for addressing the ecological footprint of waterborne transport and ports, with the understanding that environmental sustainability was a prerequisite for securing Europe's global competitiveness[5].

The enactment of the European Green Deal (EGD) in 2019 ushered in a new era of dedication to environmental sustainability, not only in the maritime industry but across all sectors of the European economy. Within this comprehensive framework, the green transformation of the waterborne sector was highly prioritized. The EGD stands as a testament to the EU's unwavering commitment to tackle climate change, to protect and restore the environment and to promote sustainable development. The maritime industry, being a crucial artery of the European economy, plays a pivotal role in the EGD's vision[6] and will be using the Horizon Europe (HEU) Framework Programme as its key financial instrument.

This master thesis aims to an in-depth analysis of the multifaceted challenges and opportunities that the waterborne sector encounters as it seeks to align with the EGD's overarching environmental goals. In the following chapters, an attempt will be made to thoroughly present the European research policy framework and its individual instruments under the EGD. Moreover, this thesis will demonstrate an overview of the H2020 topics and projects related to the waterborne transport sector in order to identify their research outcomes and perform a gap analysis upon which the operational objectives of the HEU were build. In addition, a review will be conducted of the open topics and funded projects of the HEU until January 2023, in order to identify potential gaps in the existing state of research statements in correlation to the EGD's objectives.

[5] CINEA. (n.d.). "H2020 Programme"
[6] European Commission, (n.d.). "A European Green Deal Striving to be the first climate-neutral continent"

CHAPTER 2: BACKGROUND CONTEXT OF THE EUROPEAN GREEN DEAL

In this chapter, key concepts will be analyzed in order to better understand the European Green Deal and the relevant European research policy framework. In particular, the aspects related to the maritime industry will be examined, as well as the individual goals and tools to achieve them.

2.1. WHAT IS THE EUROPEAN GREEN DEAL

The EGD consists of a set of policies that aim to address issues concerning climate change, air pollution and the degradation of waters[7]. In an attempt to resolve these issues, attention has been placed on waterborne transport, among other sectors, as it has been proven to be a sector with significant environmental and climate impacts.

The main objective of the EGD initiative is to make Europe the first climate-neutral continent by 2050, using a set of policies for the period 2021-2027[8]. These policies aim to make Europe a more competitive and smart continent and at the same time more connected, by enhancing mobility. In addition, they aim to promote the sustainable and integrated development of all territories, bringing it closer to its citizens, with a more social character and without exclusions. Last but not least, they anticipate and greatly emphasize a greener transition[9] with low GHG emissions towards a clean zero-carbon economy.

Although climate change and air pollution cause tremendous impacts on societies, policy actions so far have often failed to address these issues, despite the increasing awareness of the population in recent years. Consequently, in December 2019, the EC presented the EGD, whose main concern is to make Europe the first climate-neutral

[7] European Council. (2019). "What is the European Green Deal?"
[8] Waterborne TP, (2021). Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport
[9] European Council. (n.d.). "European Green Deal"

continent by the year 2050. One of its fundamental goals is a sustainable green transition through a set of measures, by which both European citizens and businesses will profit from. The EGD embarks the EC's engagement to work on climate and environmental challenges. In order to accomplish that climate neutrality, the EGD contemplates to reduce transport emissions by 90% by 2050 and GHG emissions by at least 50% by 2030. The EC's "A Clean Planet for All" vision[10] contemplates a climate-neutral economy through a long-term strategic plan which will result to net-zero GHGs by 2050.

2.2. POLICY INITIATIVES AT INTERNATIONAL LEVEL

At an international level, the IMO adopted an Initial Strategy on the reduction of GHG emissions from ships with a target to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008[11]. The strategy includes a list on short, medium and long term objectives and a number of other measures to reduce emissions, such as operational efficiency measures, further speed reductions, measures to address methane and Volatile Organic Compounds (VOCs) emissions, alternative low-carbon and zero-carbon fuels, as well as market-based measures.

Regarding the short term from 2018 to 2023, the regulations focus on broader implementation and possible enhancement of the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP), two measures introduced by IMO in 2011 aiming at improving technical and operational ship efficiency[12]. For the medium term from 2023 to 2030, additional measures including effective uptake of alternative low and zero-carbon fuels as well as possible opportunity provided by market-based measures will be included. In the IMO Marine Environment Protection Committee (MEPC75) held in November 2020[13], a further step has been

[10] European Commission, (n.d.). 2050 long-term strategy
[11] International Maritime Organization, (n.d.). Initial IMO GHG Strategy
[12] International Maritime Organization, (n.d.). Improving the energy efficiency of ships
[13] International Maritime Organization, (2020). Marine Environment Protection Committee (MEPC) 75, 16-20 November (virtual session)

taken towards the preliminary approval of a new package of technical and operational measures covering GHG emissions in the short run aiming at achieving IMO targets.

Accordingly, in July 2023 the MEPC80 retracted the initial 2018 IMO GHG Strategy and introduced the 2023 IMO Strategy on Reduction of GHG Emissions from Ships which aims to lower CO_2 emissions by at least 40% by 2030 in comparison to 2008 levels and to adopt new technologies and the use of alternative fuels and energy resources in order to eliminate GHG emissions by 2050[14]. This readjustment to the IMO's strategic agenda sets quite ambitious targets, but not to the extent that the EU has already set her own back in 2019.

2.3. POLICY INITIATIVES UNDER THE EUROPEAN GREEN DEAL

At European level and in order to achieve the above-mentioned overall goals, the EGD has proposed and established numerous initiatives, including certain strategies, action plans and proposal packages. The figure 2-1 demonstrates the structure of the EGD in terms of initiatives, aspiring to pave the path for a green transition of the continent in an economically viable and competitive way.

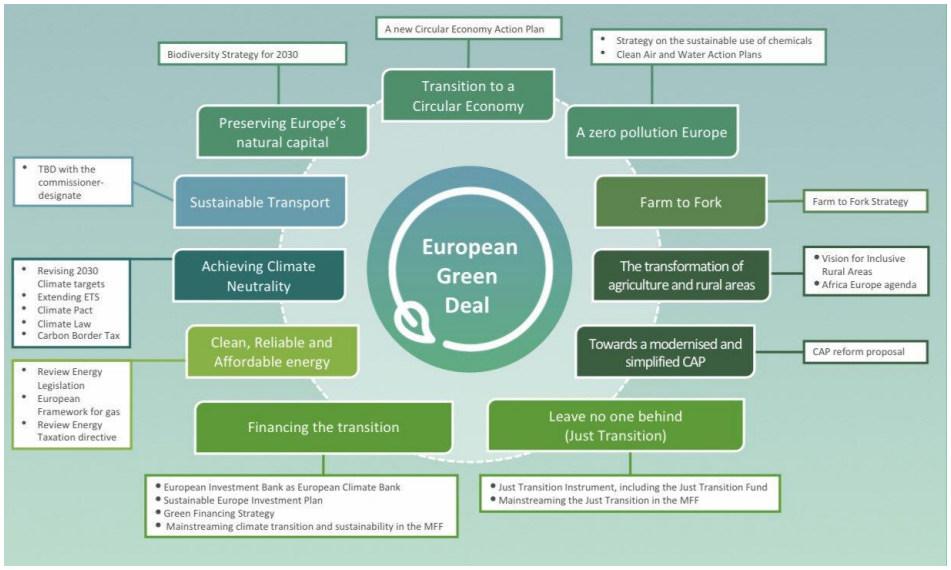

Figure 2-1: The European Green Deal Policy Initiatives (European Compost Network, 2019)

By analyzing the above figure, the maritime industry and in particular the waterborne

[14] International Maritime Organization, (2023). "2023 IMO STRATEGY ON REDUCTION OF GHG EMISSIONS FROM SHIPS"

transport sector can benefit from several European strategies and action plans, all aiming to address the ambitious objectives set by the EC under the EGD.

Initially, the European Hydrogen Strategy holds particular significance to the maritime industry, as it seeks to establish a resilient and sustainable ecosystem for the use of hydrogen across Europe. In particular, it aims to facilitate the industry's efforts in decarbonizing waterborne transport by integrating green and renewable hydrogen in various applications for promoting cleaner and more sustainable energy solutions. In addition, it aspires to introduce new pathways for the adoption of hydrogen-based solutions and synthetic fuels, aligning with the sector's objective of reducing emissions and embracing cleaner energy alternatives[15].

Moreover, the EC has issued in December 2020 the "Sustainable and Smart Mobility Strategy" which envisions a sustainable, interconnected and digitalized transport system that benefits all citizens and regions by reducing the transport sector's emissions by 90% by the year 2050 through ambitious policies and actions[16]. The greatest ambition of this strategy regarding the waterborne transport sector is to develop state-of-the-art prototypes and demonstrate ready for market zero-emission vessels, as well as infrastructures capable of accommodating such transition through proper R&DI financed channels.

Regarding the maritime industry, the greatest initiative towards achieving climate neutrality relies on the "Fit for 55" package of legislation which is a set of policies and update proposals for EU legislation, primarily aiming to reduce GHG emissions by at least 55% by the year 2030[17].

[15] Sustainable Development Solutions Network Europe. (n.d.). "The Policy Framework for Implementing the European Green Deal"
[16] European Union Law EUR-Lex, (2020). "Sustainable and Smart Mobility Strategy – putting European transport on track for the future"
[17] European Council. (2023). "Fit for 55"

One of the key policy regulations used to promote green shipping is the EU's Emissions Trading System (EU ETS). This system sets a cap on GHG emissions from ships operating in EU waters and requires ship owners to purchase allowances for their emissions. The system was designed to incentivize emissions reductions by making it more expensive to emit GHG[18]. As part of the 'Fit for 55' initiative, the reform of this system is a component of a comprehensive set of proposals designed to amend and modernize EU climate, energy and transportation regulations. These changes are aimed at helping the EU achieve its climate objectives, including reducing net GHG emissions by a minimum of 55% by 2030 and attaining climate neutrality by 2050[19].

In addition, the FuelEU Maritime initiative aims to promote the use of sustainable alternative fuels and the uptake of low-carbon technologies in the shipping industry. It

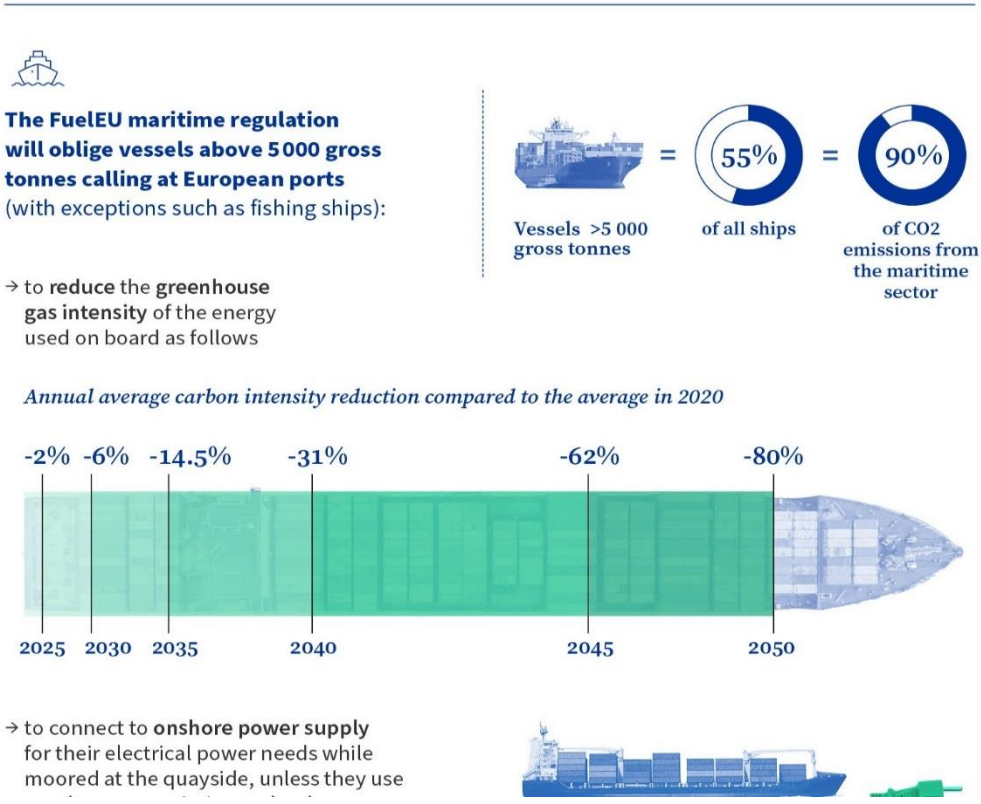

Figure 2-2: The FuelEU maritime regulation (European Council, 2023)

[18] European Commission, (2021). EU Emissions Trading System (EU ETS)
[19] European Council. (2023). "Fit for 55: reform of the EU emissions trading system"

includes a proposal to introduce mandatory targets for the use of renewable and low-carbon fuels in the maritime sector[20].

Moreover, the "Fit for 55" package also consists of the Alternative Fuels Infrastructure Regulation (AFIR) which contemplates to facilitate the transition from the use of fossil fuels to greener and less pollutant fuels for vessels. The main objective of this initiative is to reinforce the current level of infrastructures, in accordance to the sustainable alternative fuels' development to be used by ships and the electrification of vessels. Ports, at this point, seem inadequate and cannot respond to the emerging needs of such transition, as alternative fuel refueling and specific recharging points are requested[21].

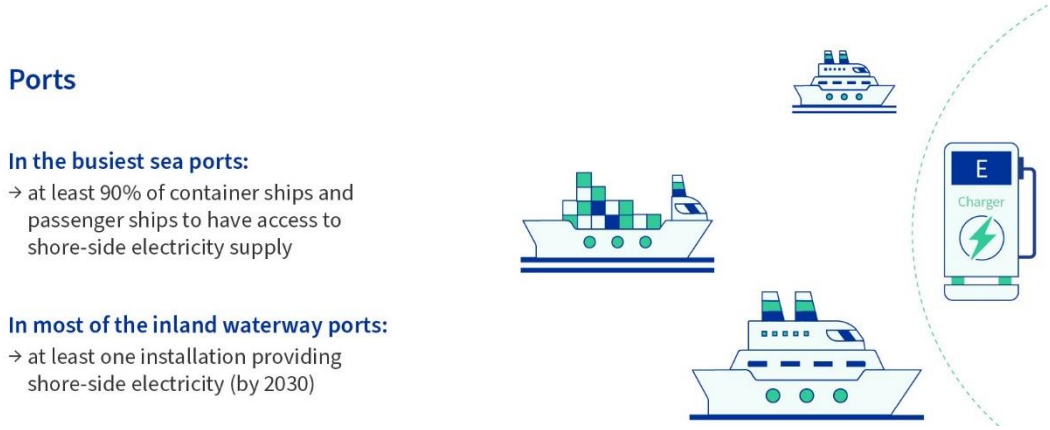

Figure 2-3: Objectives for Ports under the AFIR (European Council, 2023)

Another part of the "Fit for 55" package is the recently revised Energy Efficiency Directive which has set the extremely ambitious energy efficiency target of 11,7% to be achieved by the year 2030 by the EU Member States[22]. As the Commissioner of Energy Ms. K. Simson stated on September 2023, Energy Efficiency is the key instrument in implementing the climate goals set by the EC under the EGD and can

[20] European Council, (2023). FuelEU Maritime initiative: Provisional agreement to decarbonise the maritime sector
[21] European Council. (2023). "Fit for 55: towards more sustainable transport"
[22] European Commission. (2023). "European Green Deal: EU agrees stronger rules to boost energy efficiency"

facilitate the full decarbonization of the European economy, including the maritime industry[23].

Other notable policy initiatives regarding the maritime industry include the European Climate Law, which sets the legally binding target of achieving climate neutrality by 2050[24], the European Green Deal Investment Plan, which aims to mobilize at least € 1 trillion in public and private investment over the next decade to finance the transition to a sustainable, carbon-neutral economy[25] and the Circular Economy Action Plan, which aims to increase the use of recycled materials and promote circular business models[26].

2.4. IMPLEMENTATION OF POLICY INITIATIVES

These strategies and action plans, as well as the priorities outlined in the EGD, are illustrated through EU-funded research projects in the waterborne transport sector via financial instruments known as Framework Programmes (FP). These FPs are the main European instrument for funding research. They are a fundamental collaboration key between academia and industry, they have a specific duration of time which is defined by the EC and they receive funding according to the individual objectives set each time at their strategic agenda[27].

EU's key funding programme for supporting research and innovation in achieving the ambitious goals set under the EGD is the Horizon Europe (HEU), the 9th EU's FP for Research and Innovation for the period 2021-2027, with a budget of approximately €

[23] European Commission. (n.d.). "Energy efficiency directive"
[24] European Commission, (n.d.), European Climate Law
[25] European Commission, (2020), The European Green Deal Investment Plan and Just Transition Mechanism explained
[26] European Commission, (2020). A European Green Deal Striving to be the first climate-neutral continent
[27] European Commission. (n.d.). "Research framework programme"

95,5 billion and the successor to the 8th Horizon 2020 Framework Programme (2014 - 2020)[28].

HEU was designed in order to assist in strengthening the EU's scientific and technological base, reform the ERA and improve the EU's capacity to innovate. Moreover, it is expected to link research and innovation with six key European priorities. Those priorities include the digital transformation of societies and the economy, the well-being and security of citizens, in addition to the protection of European democracy. Last but not least, HEU aims to address climate change, primarily by changing the main energy resources into clean and renewable energy.

2.4.1. STRUCTURE OF HORIZON EUROPE

HEU consists of three pillars, regarding "Excellent Science", "Global Challenges and European Industrial Competitiveness" and "Innovative Europe". The programme's structure is complemented by a fourth Horizontal Priority under the name "Strengthening the European Research Arena", which aims to fill in and interconnect the three pillars of the Programme.

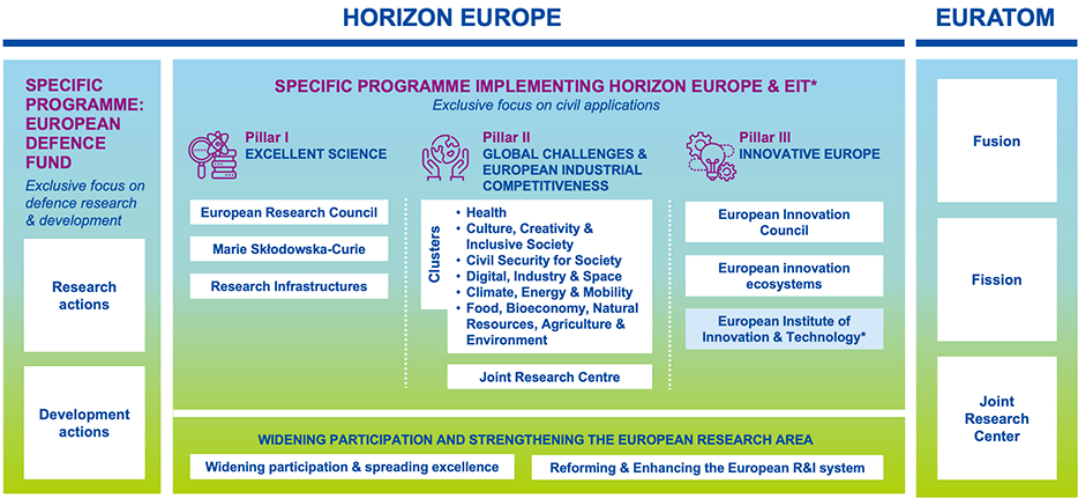

Figure 2-4 - Structure of the HE Programme (European Commission, 2023)

[28] European Commission. (2020). Horizon Europe

2.4.1.1. PILLAR I – OPEN SCIENCE

As far as Pillar I is concerned, the fundamental differences compared to H2020 can be observed in the supplemental actions of Future and Emerging Technologies.

Similar to H2020, Pillar I follows a bottom-up approach and is not based on pre-defined thematic priorities. It deals, for the most part, with issues related to cutting-edge research and consists of the following agencies:

European Research Council (ERC)

- Frontier research by the best researchers and their teams

Marie Sklodowska-Curie Actions

- Equipping researches with new knowledge and skills through mobility and training

Research Infrastructures

- Integrated and inter-connected world-class research infrastructures

2.4.1.2. PILLAR II – GLOBAL CHALLENGES AND INDUSTRIAL COMPETITIVENESS

Pillar II is characterized by a thematic approach and it engages with issues concerning social challenges and industrial technologies. It is divided into six Clusters as demonstrated below:

1. Health
2. Civil Security for Society

3. Culture, Creativity and Inclusive Societies
4. Digital, Industry and Space
5. Climate, Energy and Mobility
6. Food, Bioeconomy, Natural Resources, Agriculture & Environment

The Joint Research Center (JRC) adds up scientific documentation and technical support for policies through its various activities. Furthermore, Pillar II has been enriched with the addition of two new EU Initiatives, the European Partnerships and the Missions.

Missions

The following five Missions have been selected through the Strategic Planning Process striving to achieve specific, ambitious and achievable goals.

- Adaptation to climate change, including societal transformation
- Cancer
- Soil health and food
- Climate-neutral and smart cities
- Healthy oceans, seas, coastal and inland waters

Missions will be actions that draw resources and funds from the various clusters mentioned above or from other aspects of the Programme. Their fundamental goal is to develop synergies with national initiatives. Each mission is expected to have a maximum budget of up to € 600 million with a maximum funding period of no more than 10 years.

2.4.1.3. PILLAR III – OPEN INNOVATION

The European Innovation Council (EIC)

- Support innovations with breakthrough and market creating potential
- "Pathfinder" – advanced research, supporting emerging technology
- "Accelerator" – innovation and early market deployment up to pre-mass commercialization

Strengthening the European innovation ecosystems

- Connecting with regional and national innovation actors (EIC Forum, Enterprise Europe Network and Startup Europe).

European Institute of Innovation and Technology (EIT)

- Bringing key actors (research, education and business) together around a common goal for nurturing innovation

2.4.1.4. HORIZONTAL PRIORITY – STRENGTHENING THE EUROPEAN RESEARCH ARENA

The Priority includes two distinct components:

Sharing Excellence

- The continuation of H2020 Widening Actions such as Teaming, Twinning and ERA Chairs as well as the Cooperation in Science and Technology (COST) Programme with the ambition to increase the participation of low-performing R&I countries.

Reforming the R&I Systems

- Instruments to support reforms at a national level, such as Policy Support Facility, and actions to promote cross-cutting issues, for instance open science, international cooperation, empowering human capital, linking with the European Higher Education etc.

2.4.2. PRIORITES OF HORIZON EUROPE FOR THE MARITIME INDUSTRY

The HEU prioritizes projects that focus on developing and implementing low-carbon and zero-emission technologies in the maritime industry. This includes funding research on alternative fuels, energy-efficient ship designs and propulsion systems that reduce GHG emissions. The programme also supports projects that explore innovative solutions for decarbonizing waterborne transport and increasing energy efficiency in ports and logistics.

The HEU additionally supports projects that aim to reduce pollution from shipping activities. This includes funding research on cleaner technologies for emissions control, such as exhaust gas cleaning systems and advanced air pollution monitoring systems. The programme also promotes projects that address wastewater management, waste reduction and the prevention of marine litter, fostering the development and adoption of sustainable practices throughout the maritime sector.

Moreover, HEU emphasizes on projects that contribute to the transition to a circular economy in the maritime industry. This involves funding research on sustainable shipbuilding practices, recycling and reusing ship components and developing environmentally friendly materials. It also supports initiatives that promote resource efficiency in vessel operations, such as optimizing energy consumption and reducing water usage.

The HEU will fund research projects focused on marine biodiversity conservation and sustainable fisheries, hence supporting initiatives that aim to protect and restore marine

ecosystems, develop sustainable fisheries management practices and reduce the impact of human activities on sensitive marine habitats. The funding enables the implementation of innovative approaches to biodiversity conservation and promotes the sustainable use of marine resources.

Under the HEU, the importance of digitalization and innovation in driving sustainability in the maritime sector is recognized. It will provide funding for projects that leverage digital technologies, data analytics and automation to optimize operations, enhance safety and reduce environmental impacts. This includes supporting research on smart ports, autonomous vessels, intelligent logistics and digital platforms for enhancing efficiency and sustainability in maritime activities.

Through its funding and support mechanisms, HEU actively contributes to advancing the priorities of the EGD in the maritime industry. It enables collaboration between stakeholders, facilitates knowledge transfer and accelerates the development and deployment of innovative solutions that address the environmental challenges and promote sustainability in the waterborne sector.

At a great extent, the role of the maritime industry in achieving the goals of the EGD is significant and will require the industry to adopt a range of measures to reduce its environmental impact. By working with stakeholders across the sector and with the support of policymakers and regulators, the maritime industry can play a vital role in assisting the EU achieve its climate objectives.

In conclusion, the EU's research policy under the EGD is a comprehensive and ambitious framework aimed at promoting sustainability in the waterborne transport sector. Implemented through policy instruments, such as HEU, this research policy incorporates strategies and action plans for decarbonization, pollution prevention and control, resource efficiency and biodiversity conservation. Through EU-funded

research projects, these strategies are translated into practical solutions that contribute to a more sustainable and environmentally friendly maritime industry.

2.5. POLICY PRIORITY SHIFT AND THE cPP ZEWT

The EU's framework programmes have witnessed a notable shift in policy priority and orientation within the waterborne transport sector, transitioning from a focus on digital advancements to a more prominent emphasis on green technologies and sustainability. This shift reflects the evolving priorities and objectives of the EU towards achieving a greener and more environmentally friendly transport sector[29].

In earlier framework programmes, such as the Seventh Framework Programme (FP7), there was a strong emphasis on digital technologies and innovations within the waterborne transport sector. The objective was to enhance efficiency, safety and connectivity through the integration of digital solutions. The emphasis was primarily on leveraging digital advancements to optimize operations, streamline logistics and enhance connectivity among stakeholders[30].

However, with the advent of the EGD and the increasing urgency to combat climate change and environmental degradation, the focus has shifted towards green technologies and sustainability in the maritime industry. This shift is evident in the more recent framework programmes, such as H2020 and HEU.

H2020, the eighth framework programme, placed a greater emphasis on research and innovation initiatives related to sustainability, including the development of cleaner and more energy-efficient technologies for waterborne transport. Projects funded under H2020, although they weren't funded by the EC within the context of the EGD,

[29] European Commission. (2020). "Sustainable and Smart Mobility Strategy – putting European transport on track for the future"
[30] European Commission. (2016). "Commission presents its evaluation of the 7th Framework Programme for Research"

addressed several environmental challenges, provided reducing emissions solutions and promoted the use of renewable energy sources in the maritime sector[31].

Building upon the achievements of H2020, HEU, the current framework programme funded by the EC specifically within the context of the EGD, prioritizes the green transition within the waterborne transport sector. The programme focuses on fostering sustainable and zero-emission solutions, supporting research and innovation in areas such as alternative fuels, decarbonization technologies, energy efficiency and circular economy principles. It aims to accelerate the deployment of green technologies and contribute to the overall objectives of the EGD[32].

This shift in policy priority and orientation from digital to green within the framework programmes highlights the recognition of the urgent need to address environmental challenges and promote sustainability in the waterborne transport sector. The EU's commitment to prioritizing green technologies aligns with its broader objectives of achieving carbon neutrality, reducing GHG emissions and ensuring a more sustainable future for the maritime industry.

By shifting the policy focus towards green technologies, the EU aims to drive the development and adoption of environmentally friendly solutions, promoting a more sustainable and resilient waterborne transport sector. This transition not only helps to mitigate the industry's environmental impact but also contributes to the overall goals of the EGD, ensuring a greener and more sustainable future for the maritime industry and the planet as a whole.

The shift in policy priority and orientation within the EU’s framework programme towards green technologies and sustainability in the waterborne transport sector can be

[31] CINEA. (2021). “Waterborne Transport Projects. Horizon 2020 projects managed by CINEA and opportunities for synergies”
[32] Waterborne TP, (2021). “Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport”

further exemplified by the establishment of the Co-Programmed Partnership on Zero-Emission Waterborne Transport (cPP-ZEWT). This partnership represents a significant step towards achieving the objectives of the EGD and accelerating the transition to a zero-emission maritime industry.

The cPP-ZEWT is a collaborative initiative that brings together stakeholders from industry, research institutions and public authorities. It aims to foster research and innovation in zero-emission technologies and solutions for the waterborne transport sector[33]. By combining resources and expertise, the partnership seeks to accelerate the development and deployment of sustainable and decarbonized maritime technologies.

This partnership aligns with the priorities and strategies of the EGD, which emphasizes the reduction of GHG emissions, the promotion of clean energy sources and the transition towards a carbon-neutral economy. Through collaborative research and innovation projects, the cPP-ZEWT aims to drive the adoption of zero-emission technologies, such as alternative fuels, electric propulsion systems and energy-efficient vessel designs[34].

The partnership's activities are supported by the EU's framework programme HEU, which provides the necessary funding and support for research and innovation projects focused on zero-emission waterborne transport. By integrating the goals of the cPP-ZEWT, the EU demonstrates its commitment to promoting sustainable and environmentally friendly solutions within the maritime industry.

Through the cPP-ZEWT, the EU aims to stimulate collaboration, knowledge sharing and technological advancements in the field of zero-emission maritime transport. By bringing together stakeholders and leveraging the resources of the framework

[33] Waterborne TP, (n.d.). "Zero Emission Waterborne Transport"
[34] Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport"

programmes, the partnership aims to overcome barriers and accelerate the development and commercialization of zero-emission technologies in the waterborne transport sector.

This collaborative approach not only supports the EGD's objectives but also contributes to the overall sustainability and resilience of the maritime industry. By fostering innovation in zero-emission technologies, the cPP-ZEWT plays a crucial role in driving the transition towards a greener and more sustainable future for the waterborne transport sector, ultimately leading to reduced emissions, improved air quality and a more sustainable maritime industry as a whole.

Overall, the EGD represents a significant step forward in the global effort to address climate change and environmental degradation. By promoting sustainable economic growth and reducing the environmental impacts of the maritime industry, it has the potential to create a more prosperous and sustainable future for all. However, achieving these goals will require continued commitment and cooperation from all stakeholders, including governments, industry and civil society.

CHAPTER 3: HORIZON 2020

This chapter will demonstrate an overview of the research statements under the Horizon 2020 (H2020), which is the 8th EU's research Framework Programme for Research and Innovation covering the period 2014-2020, with a budget of around € 80 billion[35]. The Programme supports the Europe 2020 strategy, which highlights research and innovation as key drivers for smart, sustainable and integrated development, while effectively addressing important societal challenges.

A core part of Europe 2020, Innovation Union and European Research Area (ERA) is, primarily, to respond to the economic crisis, by investing in future jobs and growth. Furthermore, H2020 concentrates on addressing people's concerns about their livelihoods, safety and environment and, ultimately, to strengthen the EU's global position in research, innovation and technology[36].

The overview of the research statements under the H2020 will focus on topics and projects related to the waterborne transport sector. Although H2020 projects have not been funded by the EC in the context of the EGD, they have addressed several greening objectives and have contributed in identifying certain research gaps, which were taken into consideration while structuring the next FP. These gaps will be examined in the gap assessment section, taking into consideration the Interim Evaluation of the H2020 and the outcomes that were demonstrated by the closed projects.

3.1. STRUCTURE HORIZON 2020

EU's H2020 Programme emphasizes on three major areas of expertise. Scientific excellence, competitive industry and tackling societal challenges are at the heart of

[35] European Commission, (n.d.). Horizon 2020
[36] European Commission, (n.d.). What is Horizon 2020?

H2020. Targeted funding ensures that the best ideas are transported faster to the market and used in cities, hospitals, factories, stores and households as soon as possible.

The three main Pillars of the Programme are:

- Excellent Science: World-class scientific research aimed at attracting the best scientists to the EU.
- Industrial Leadership: Strategic investment in key technologies, such as nanotechnology-microelectronics, private sector participation, creation of innovative companies.
- Societal Challenges: Addressing important societal challenges, such as population aging, depletion of energy resources, tackling climate change.[37]

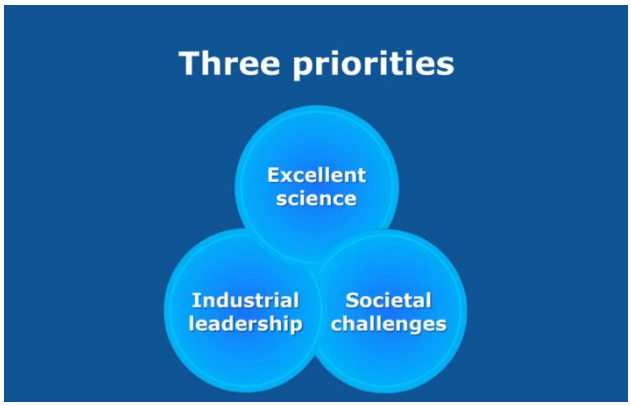

Figure 3-1: The three main Pillars of H2020 (Muntion, 2014)

In 2013, former EC's President J. M. Barroso presented H2020 as "*a means to drive economic growth and create jobs, having the political backing of Europe's leaders and the Members of the European Parliament"*. They agreed that research is an investment in citizens' future and so placed it at the core of the EU's blueprint for smart, sustainable and inclusive growth and jobs.[38]

H2020 is merging research and innovation, primarily by emphasizing on excellent science, industrial leadership and undertaking societal challenges. The objective is to ensure that Europe develops world-class science, overcomes obstacles towards

[37] European Commission. (n.d.). Horizon 2020 structure and budget
[38] European Commission. (2013). Europe 2020: A blueprint for the Post-Crisis World

innovation and facilitates the collaboration of the public and private sectors in order to deliver groundbreaking innovation.[39]

H2020 is structured in such a way as to be open to everyone and to promote public participation. By simplifying bureaucratic procedures, participants can devote themselves to conducting research and producing more immediate results based on their actual user-driven needs.

3.2. STRATEGIC PRIORITIES

Aiming at a more efficient issuance of results, the waterborne research under H2020 has been divided into three main strategic priorities.

3.2.1. SUSTAINABLE WATERBORNE TRANSPORT

The first strategic priority emphasizes on a seamless transition towards a more sustainable waterborne transport. Topics under this priority focus on the development of innovative technologies addressing shipping, shipbuilding, ports and infrastructures, equipment suppliers and service providers. The objective is to minimize the environmental impact of waterborne transport, while improving safety and security and maintaining the European waterborne sector competitive in a global scale.

a. Assuring security of supply

The waterborne transport is responsible for the European energy supply, as ships are the most efficient means of oil transportation. Although, geopolitical instability and technological threats can cause concerns in the implementation of these shipping routes, as acts of terrorism or piracy are occurring. Therefore, the need arises for new solutions

[39] CINEA. (n.d.). H2020 Programme

to address not only the European dependence on fossil fuels, but to also ensure the safety and security of the crew performing such itineraries and for ships to endure travelling under extreme circumstances.

b. Promoting safer and more environmentally friendly ships

An additional area under the priority of sustainable waterborne technology is to exploit the high technology of European's shipbuilding sector to develop more sustainable vessels. This front faces many challenges, as the shipping industry was responsible for approximately 2,7% of global CO_2 emissions for the year 2010[40] and the global trade continuously grows. With this upward trend in global trade, emissions are expected to grow as well in the upcoming years, unless the waterborne sector is equipped with high-end technology vessels, commence to use alternative fuels and develop innovative propulsion systems.

c. Competitiveness

The maritime industry is extremely competitive and relies, primarily, on high productivity and performance, innovative products and services and in the continuous implementation and promotion of such innovations. The modernization of the technology used to provide any maritime services, including shipbuilding, ports and infrastructures, the usage of alternative fuels and power resources, etc., would increase Europe's level of competitiveness worldwide, thus benefiting it economically and environmentally.

d. Technology, education and skills

R&I are the key components for developing cutting-edge technological breakthroughs. For those breakthroughs to be applicable and efficient, the need arises for a properly

[40] Olmer, N. et al., (2017)

educated workforce. The human factor is crucial in producing and promoting innovative achievements and for those to be effective, adequate education and the cultivation of special skills is required.

3.2.2. SUPPORT OF THE HARVESTING OF OFFSHORE RESOURCES

The second strategic priority revolves around the exploitation of energy and other natural resources, as well as their transportation to the end-users, aiming at reducing the environmental impact on oceans and increasing competitiveness for the maritime industry.

a. Energy

In recent years, there has been a heightened effort to minimize the use of fossil fuels. However, until there are viable alternatives, it appears necessary for vessels to be more advanced and capable of operating in extreme conditions and meeting the demands of deep-water exploration.

Another perspective is the exploration of alternative energy sources. In the maritime industry, such endeavor can be implemented by supporting offshore wind farms, thermal and osmotic energy, advanced dredging, energy conversion, specialized repair yards and ports, as well as the storage and transportation of these energy resources.

b. Food

Due to the rapidly increasing world population and a poor resources management, natural sources, such as fish, are declining. As an alternative treatment, fish farming is moving to the open sea, where waterborne technology can provide great support by using effective monitoring systems and specialized support vessels.

c. Raw materials

The seabed from the unexplored world's oceans is an emerging market consisting of valuable and necessary resources. The exploitation of these resources requires a high level of innovation regarding site investigations, deep water operations, as well as advanced simulation and validation.

3.2.3. MINIMIZING IMPACT ON THE OCEANS – BLUE SEAS

Climate change and the intervention of the human factor have had tremendous impact on the oceans and seas, especially in increasingly crowded coastal areas. Certain policies and regulations should be implemented, as coastal areas, especially those located near large population centers, face challenges of sea level rise, coastal erose and other extreme events. Furthermore, ships have been noticed to transport invasive species in ballast water and cause profound changes in marine ecosystems.

3.3. WATERBORNE STRATEGIC RESEARCH AGENDA

The Waterborne Strategic Research Agenda focuses on addressing the innovation challenges, summarized under the three pillars of the Waterborne Vision 2020:

- Safe, Sustainable and Efficient Waterborne Operations
- A Competitive European Maritime Industry
- Manage and Facilitate Growth and Changing Trade Patterns

3.3.1. ACHIEVING VISION 2020

Vision 2020 is aspiring for a safer, more sustainable and efficient future for waterborne operations by the year 2020, through reducing CO_2 emissions, enlarging the offshore renewable energy market and retrofitting existing ships[41].

Research is a major factor in achieving Vision 2020, as it can develop and establish new quality standards for sustainable maritime operations, in addition to accelerating the pace of advancing maritime innovations.

3.3.2. SAFE, SUSTAINABLE AND EFFICIENT WATERBORNE OPERATIONS

As shipping is one of the most economic and efficient means of transportation globally and taking into consideration the upward trend of global trade, waterborne operations face multiple challenges regarding their evolution.

Initially, the environmental effects of the maritime industry continue to exist to a large extent despite the efforts of recent years to minimize their impact. R&I is required to emphasize on developing more efficient ships and provide retrofitting solutions for the existing fleet by researching for new and alternative fuels and power sources to operate vessels. Moreover, safety at the maritime sector is at stake, as studies have shown that the human factor is responsible for approximately 70% of accidents[42].

3.3.3. A COMPETITIVE EUROPEAN MARITIME INDUSTRY

Europe is one of the most competitive markets in the maritime industry, as it controls approximately 40% of the world tonnage[43]. But considering the rapid evolution of technology as well as the growing pace of waterborne transport demands worldwide, it needs to invest in R&I in order to preserve its competitive advantage and maintain its

[41] Waterborne TP, (2011). Strategic Research Agenda
[42] Galieriková, A. (2019)
[43] Union of Greek Shipowners, (2019). Greek Shipping A Major EU Export INDUSTRY of Strategic Importance

leadership. Therefore, the need arises for the development of new innovative vessels, the optimization of systems for waterborne operations and the adaptation of automation to a greater extent.

3.3.4. MANAGE AND FACILITATE GROWTH AND CHANGING TRADE PATTERNS

The increase in world population is proportional to the increase in world trade and the necessity for maritime transport. Consequently, in order to cope with these upward trends, H2020 ought to invest in the development of vessels that are more efficient, sustainable and with greater capacity, but also to appropriate infrastructure that can meet to their needs. Moreover, by exploiting informational technology and automation, R&I can provide solutions to facilitate the intermodality of transport, to optimize port operations and to contribute towards understanding and minimizing the environmental impact of infrastructure.

3.4. OPERATIONAL OBJECTIVES

In order to achieve Vision 2020, the R&I of the waterborne sector under H2020 has been divided into five key thematic areas, each of which presents the following operational objectives.

3.4.1. INFRASTRUCTURE

In the area of infrastructure, topics under the H2020 address challenges regarding, primarily, the technological, societal and economical evolution of Europe and the upgrade of logistics efficiency. Ports are crucial for the improvement of maritime operations and the investment in such research can provide solutions in low emission mobility through the optimization of freight or passenger flows. Last but not least, topics under this thematic area can assist on the development of alternative sustainable

fuels and other power sources, as per their storage and distribution.

3.4.2. INNOVATIVE SHIPBUILDING AND COMPLEX VALUE-ADDED SPECIALISED VESSELS

Under the thematic area of innovative shipbuilding and complex value-added specialized vessels, the key challenge that is addressed is the deployment of new advanced materials that can upgrade and modernize the level of ship construction. The development and production of innovative vessels that consume alternative fuels or operate on more sustainable power sources is vital for the implementation of Vision 2020, as it can reduce the environmental impact of waterborne transport while increasing its efficiency. In addition, under this thematic area, attempts will be made in order to deploy unique and more enduring materials for the construction of ships, which will extend the life cycle of vessels, resulting in substantial economic and sustainable benefits.

3.4.3. NEW AND IMPROVED WATERBORNE TRANSPORT CONCEPTS

In order to provide solutions for a new and improved waterborne transport sector, this thematic area addresses challenges related to the improvement of waterborne operations and inland waterway logistics. Moreover, topics focus on analyzing all the major factors for the development of autonomous ships, as well as the deployment and demonstration of autonomous vehicles for under-water services and surveillance.

3.4.4. ENERGY EFFICIENT AND ZERO EMISSION VESSELS

This thematic area focuses on providing solutions on decarbonizing the maritime industry and developing groundbreaking innovations towards achieving the construction of zero emission vessels. In order to accomplish that objective, topics address the challenges of assessing and reforming current regulations of vessels, as well as spreading worldwide the socioeconomic and environmental benefits of green

shipping. Such an undertake can conclude in improving Europe's competitive advantage while reducing the environmental impact of the shipping industry.

3.4.5. SAFER AND MORE EFFICIENT WATERBORNE OPERATIONS

The thematic area of safer and more efficient waterborne operations deals with the increase of safety and security on and offshore. In particular, it addresses challenges of preventing accidents caused by human error, such as fires at sea and oil spills, alongside with designing systems of risk assessment and evacuation strategies.

3.5. RESEARCH STATEMENTS

Having as its primary goal the achievement of the above-mentioned operational objectives, during its implementation H2020 has shown a multitude of results through a set of projects, several of which are still active. Categorized according to each operational objective, the approved projects from EC are reviewed below.

Since the beginning of H2020, seventy-nine projects have been launched related to the waterborne transport sector, with an estimated total cost of more than € 600 million, from which approximately 86% came from EU funding. By January 2023, more than half of them had been completed and the remaining are expected to be concluded by September 2026 at the latest. To illustrate, the overall cost of the projects as well as the EU's financial contribution are presented in the chart below.

Figure 3-2: Budget Allocation for H2020 projects per Operational Objective

3.5.1. INFRASTRUCTURE

In the area of Infrastructure, EC has approved ten projects during the implementation of H2020 with a total cost of € 100.513.959,88 of which € 85.195.820,78 was funded from the EU. Four of these projects addressed issues concerning the fulfillment of the vision for the ports of the future. Specifically, the context and overall objectives of these projects were the improvement of the existing infrastructures, especially ports, through the adoption of new automation technologies and the better usage of information and data selection. State-of-the-art ports are of significant importance, as they can optimize operations for freight's loading and unloading, as well as its storage during intermodal transport.

Moreover, with the upcoming advancement of technology in the fuel division and the potential use of alternative power sources, port facilities need to be modernized in order to keep up with such innovation. Therefore, EC has granted two projects with a total

cost of € 64.230.085,47 which are expected to be completed in September 2026 and intend to combine the transformation towards greener and more sustainable forms of energy consumption with the optimization of port operations and logistics.

The achievement of the above may reduce current port congestion levels, which will result in the reduction of emissions and the increase of efficiency and productivity in the supply chain, thus benefiting environmental, societal and economic aspects of the community.

The following table lists in detail all the approved topics and relevant projects related to the operational objective of Infrastructure, as well as the total funding they have received.

Table 3-1: Overview of Topics and Projects under the Operational Objective of Infrastructure

Topics	Projects	EU Funding	Total Cost	Duration
		85.195.820,78 €	100.513.959,88 €	
The Port of the Future		16.310.637,25 €	16.310.637,25 €	
	PIXEL	4.890.223,50 €	4.890.223,50 €	05/2018-09/2021
	PortForward	4.994.311,25 €	4.994.311,25 €	07/2018-06/2022
	COREALIS	5.150.540,00 €	5.150.540,00 €	05/2018-04/2021
	DocksTheFuture	1.275.562,50 €	1.275.562,50 €	01/2018-11/2020
Green airports and ports as multimodal hubs for sustainable and smart mobility		49.964.561,49 €	64.230.085,47 €	
	PIONEERS	24.999.997,26 €	33.465.726,63 €	10/2021-09/2026
	MAGPIE	24.964.564,23 €	30.764.358,84 €	10/2021-09/2026
Next generation transport infrastructure: resource efficient, smarter and safer		4.182.954,16 €	4.182.954,16 €	
	RCMS	4.182.954,16 €	4.182.954,16 €	05/2015-01/2017

Innovative applications of drones for ensuring safety in transport		4.997.133,75 €	4.997.133,75 €	
	RAPID	4.997.133,75 €	4.997.133,75 €	06/2020-11-2023
Supporting the emergence of data markets and the data economy		5.740.586,63 €	6.675.951,75 €	
	DataPorts	5.740.586,63 €	6.675.951,75 €	01/2020-03/2023
Developing Fuel Cell applications for port/harbour ecosystems		3.999.947,50 €	4.117.197,50 €	
	H2Ports	3.999.947,50 €	4.117.197,50 €	01/2019-12/2024

Regarding the outcomes of the above projects, five out of the ten approved ones were completed by January 2023 and according to their deliverables, they presented the following findings in correlation to the operational objectives initially set.

The PIXEL project focused on developing and implementing new digital solutions to enhance the safety and security of ports, as illustrated in the diagram below[44]. The deliverables of this project fulfilled the operational objectives under the Infrastructure thematic area regarding the evolution of ports, facilitating the upgrade of logistics efficiency and laid the groundwork towards the optimization of freight and passenger flows[45].

[44] European Commission. (2021). Port IoT for Environmental Leverage
[45] PIXEL. (n.d.). Deliverables

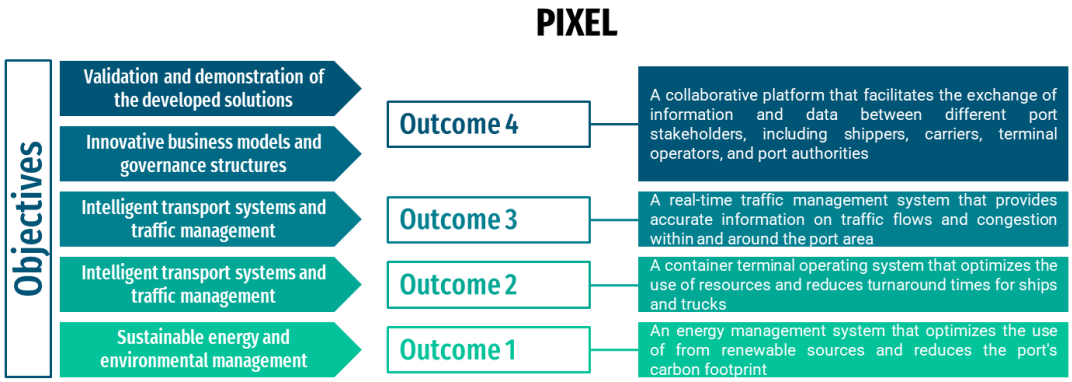

Figure 3-3: Objectives and Outcomes of the PIXEL Project

The PortForward project aimed to create a network of ports and technology providers to accelerate the adoption of new technologies in the maritime sector, thus improving and upgrading the interconnectivity within the logistics supply chain[46].

[46] PortForward. (n.d.). The Project Objectives

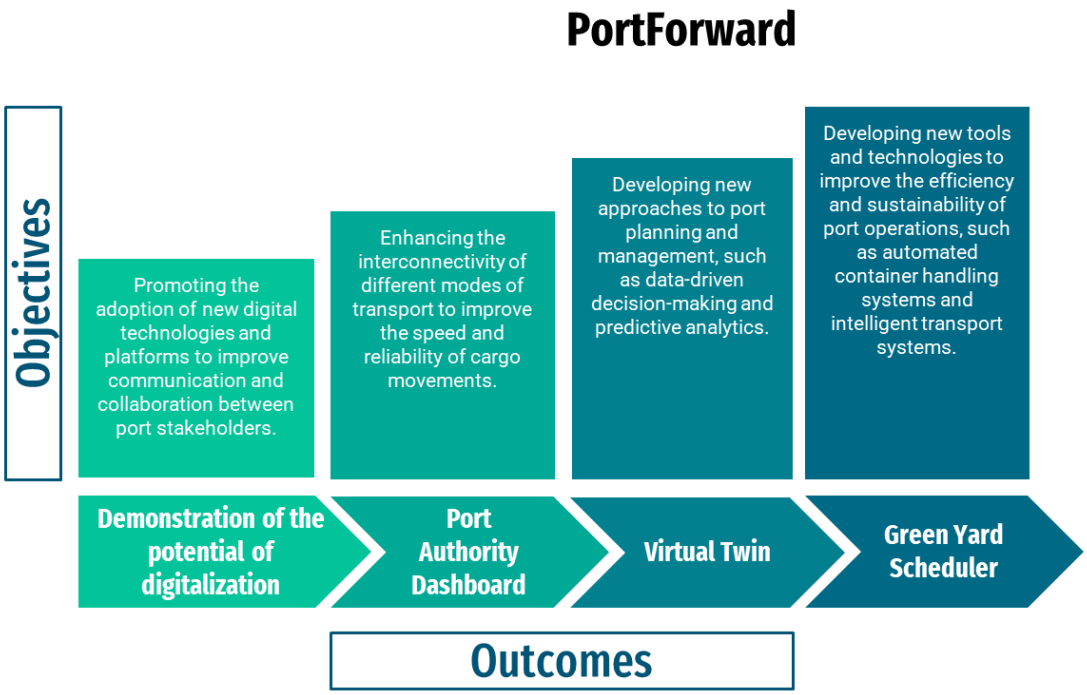

Figure 3-4: Objectives and Outcomes of the PortForward Project

The COREALIS project was funded in order to improve the coordination and collaboration between different stakeholders in port logistics[47]. The deliverables of the project contributed to optimizing port operations, hence increasing efficiency, providing

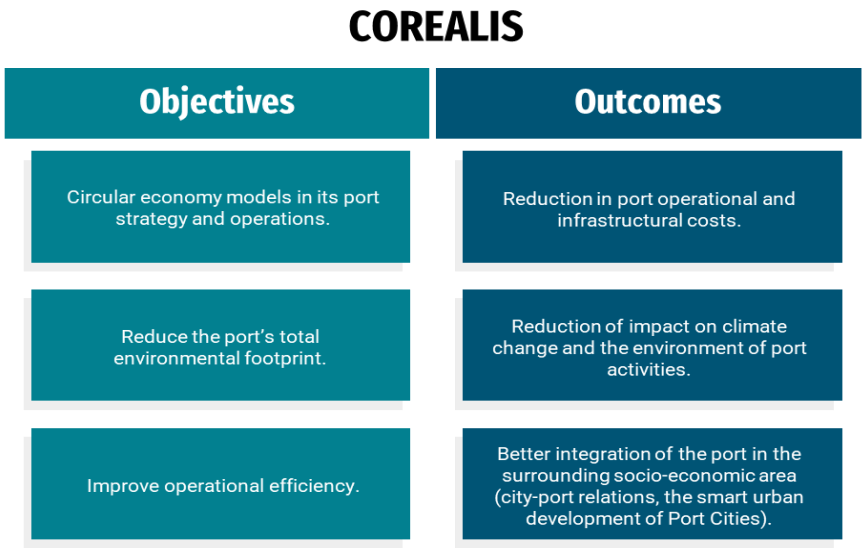

Figure 3-5: Objectives and Outcomes of the COREALIS Project

[47] COREALIS. (n.d.). The Objectives

cost-effective and environmentally friendly solutions[48].

The DocksTheFuture project aimed to develop new strategies and technologies to optimize the use of space in ports and increase their environmental and economic sustainability[49]. This project attributed to the research arm of the development of sustainable alternative fuels by providing future concepts of storage and by upgrading port infrastructure.

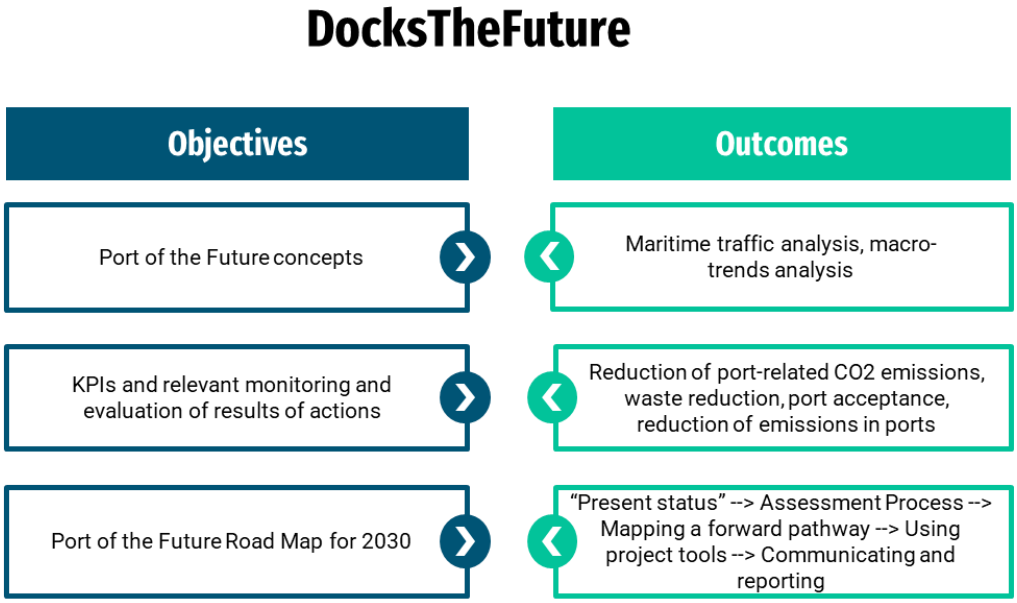

Figure 3-6: Objectives and Outcomes of the DocksTheFuture Project

The RCMS project aimed to directly address the development, evaluation and comparison of RCMS in specific terminals and ports, as well as its impact on transport network efficiency and environmental factors. In summary, the project outcomes demonstrated that RCMS offered improved efficiency, reduced handling times, decreased traffic congestion, energy savings and emissions reduction. The developed simulation model and evaluation in specific terminals and ports have laid the

[48] European Commission. (2021). Capacity with a pOsitive enviRonmEntal and societAL footprInt: portS in the future era
[49] DocksTheFuture. (n.d.). Project

foundations for further developments and implementation of RCMS in seaport container terminals worldwide[50].

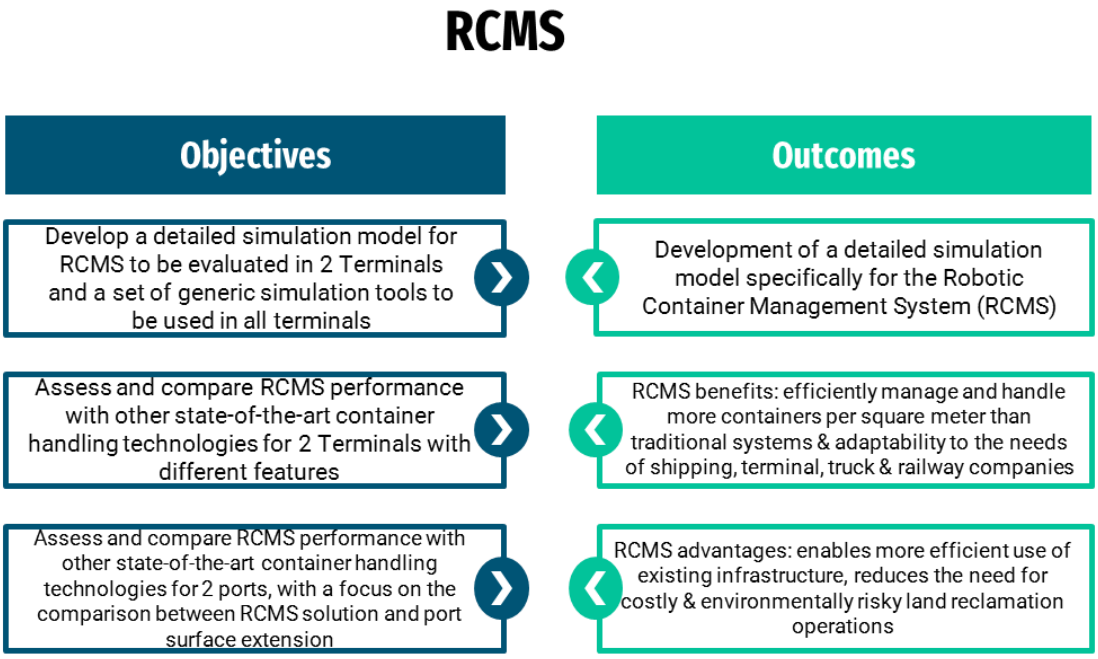

Figure 3-7: Objectives and Outcomes of the RCMS Project

The deliverables of these projects included new technological solutions, improved collaboration and coordination between stakeholders, more efficient and sustainable port operations and the establishment of networks to support the adoption of new technologies and practices in the maritime sector. Overall, the projects sought to promote the digitalization and sustainability of the maritime sector and improve the competitiveness of European ports in the global market[51].

3.5.2. INNOVATIVE SHIPBUILDING AND COMPLEX VALUE-ADDED SPECIALIZES VESSELS

[19] European Commission. (2022). Rethinking Container Management Systems
[51] European Commission. (2020). Developing the methodology for a coordinated approach to the clustering, monitoring and evaluation of results of actions under the Ports of the Future topic

In the field of Innovative Shipbuilding and Complex value-added specialized vessels, H2020 Waterborne Portfolio consists of ten closed and five active projects with a total cost of € 118.798.972,32 from which € 99.001.514,96 were EU funded. The main objective of this field is to demonstrate innovative state-of-the-art specialized vessels able to operate in the most efficient, environmentally friendly and cost-effective way. In addition, in order to maintain the high level of shipbuilding against competitors, Europe needs to optimize shipyard operations to not only obtain high-quality results in the most profitable way, but also to keep pace with emerging technological innovations.

In particular, two projects tackled with the improvement of producing superior ship concepts through virtual prototyping for optimizing Life Cycle Cost Analysis, while two other projects emphasized on developing innovative materials to produce more time resilient vessels and to strengthen shipbuilding in the long term. Similarly, five projects addressed the challenges of creating innovative and state-of-the-art vessels operating with alternative power sources, emphasizing on vessels' modular design and production. Last but not least, three active projects have been granted to improve shipyards' operations and deliver innovative production processes.

The following table lists in detail all the approved topics and projects related to the field of Innovative Shipbuilding and Complex value-added specialized vessels, as well as the total funding they have received.

Table 3-2: Overview of Topics and Projects under the Operational Objective of Innovative Shipbuilding and Complex value-added specialized vessels

Topics	Projects	EU Funding	Total Cost	Duration
		99.001.514,96 €	118.798.972,32 €	
System modelling and life-cycle cost optimisation for waterborne assets		17.575.896,00 €	17.575.896,00 €	
	SHIPLYS	6.144.150,00 €	6.144.150,00 €	09/2016-08/2019
	HOLISHIP	11.431.746,00 €	11.431.746,00 €	09/2016-12/2020

Improved Production and Maintenance processes in shipyards		15.953.130,90 €	19.609.017,50 €	
	Mari4_YARD	4.998.824,76 €	5.913.440,00 €	12/2020-11/2024
	FIBRE4YARDS	5.941.720,01 €	7.572.437,50 €	01/2021-12/2023
	RESURGAM	5.012.586,13 €	6.123.140,00 €	02/2021-01/2024
High value-added specialised vessel concepts enabling more efficient servicing of emerging coastal and offshore activities		9.680.698,88 €	12.057.281,24 €	
	LINCOLN	6.343.600,00 €	7.808.691,25 €	10/2016-09/2019
	NEXUS	3.337.098,88 €	4.248.589,99 €	11/2017-04/2021
Development, production and use of high performance and lightweight materials for vessels and equipment		19.665.763,40 €	24.535.303,75 €	
	FIBRESHIP	8.866.322,75 €	11.041.212,50 €	06/2017-05/2020
	RAMSSES	10.799.440,65 €	13.494.091,25 €	06/2017-11/2021
Complex and value-added specialised vessels		26.217.182,15 €	33.435.937,08 €	
	HYSEAS III	7.886.390,14 €	10.818.910,83 €	07/2018-06/2022
	TrAM	11.741.430,63 €	14.662.856,31 €	09/2018-02/2023
	NAVAIS	6.589.361,38 €	7.954.169,94 €	06/2018-05/2022
Integrating Activities for Starting Communities		5.996.563,75 €	5.996.565,50 €	
	ARICE	5.996.563,75 €	5.996.565,50 €	01/2018-12/2022
Small business innovation research for Transport		1.802.187,63 €	2.574.553,75 €	
	ProZero	1.802.187,63 €	2.574.553,75 €	04/2016-03/2018
Green Deal		2.110.092,25 €	3.014.417,50 €	
	SmartWings	2.110.092,25 €	3.014.417,50 €	09/2020-12/2023

Regarding the outcomes of the above projects, ten out of the fifteen approved ones were completed by January 2023 and according to their deliverables, they presented the following findings.

The SHIPLYS project aimed to develop and demonstrate lightweight and energy-efficient ship design solutions using advanced composite materials[52]. The project delivered innovative design tools, advanced compound materials and manufacturing techniques and a set of recommendations for the design and construction of composite ships, in order to upgrade ship construction and provide solutions for new materials to extend the life cycle of vessels[53].

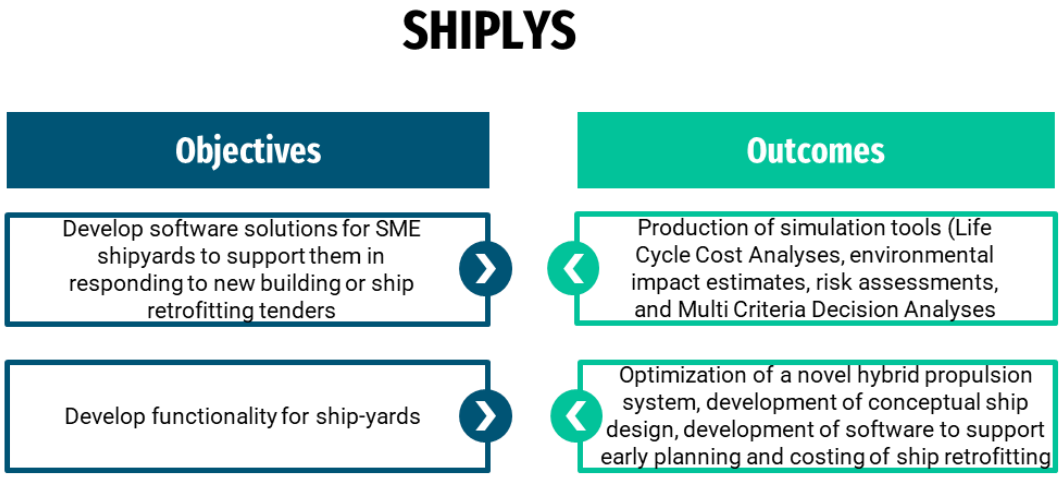

Figure 3-8: Objectives and Outcomes of the SHIPLYS Project

The HOLISHIP project aimed to develop and demonstrate a holistic design methodology for ship design and production, with a focus on reducing the

[52] SHIPLYS. (n.d.). Objectives
[53] European Commission. (2019). Ship Lifecycle Software Solutions

environmental impact and lifecycle costs of ships[54]. The project delivered a suite of digital tools and methods for ship design and production[55].

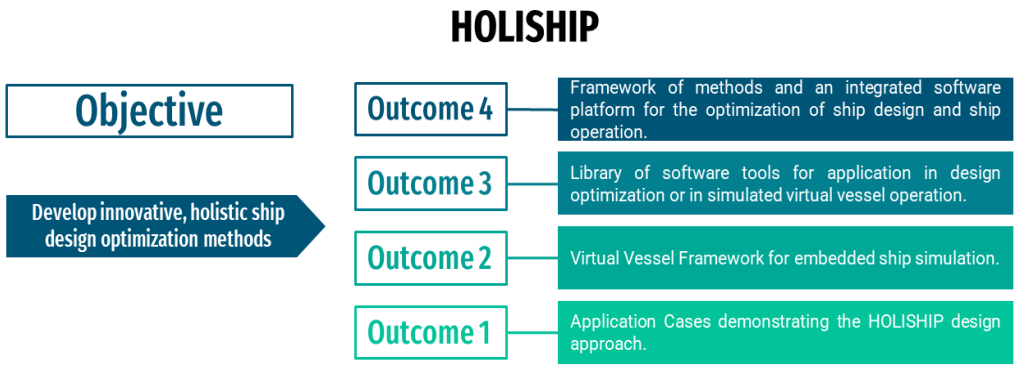

Figure 3-9: Objectives and Outcomes of the HOLISHIP Project

The LINCOLN project aimed to develop and demonstrate a range of innovative technologies for the next generation of lightweight and green ships, including advanced materials and manufacturing processes, hybrid electric propulsion systems and smart shipping systems[56]. The project delivered several prototypes and demonstrators, as well as recommendations for the integration of these technologies into future ships[57].

[54] HOLISHIP. (n.d.). Objectives and targeted results
[55] European Commission. (2020). HOLIstic optimisation of SHIP design and operation for life cycle
[56] LINCOLN. (n.d.). Summary and structure
[57] European Commission. (2020). Lean innovative connected vessels

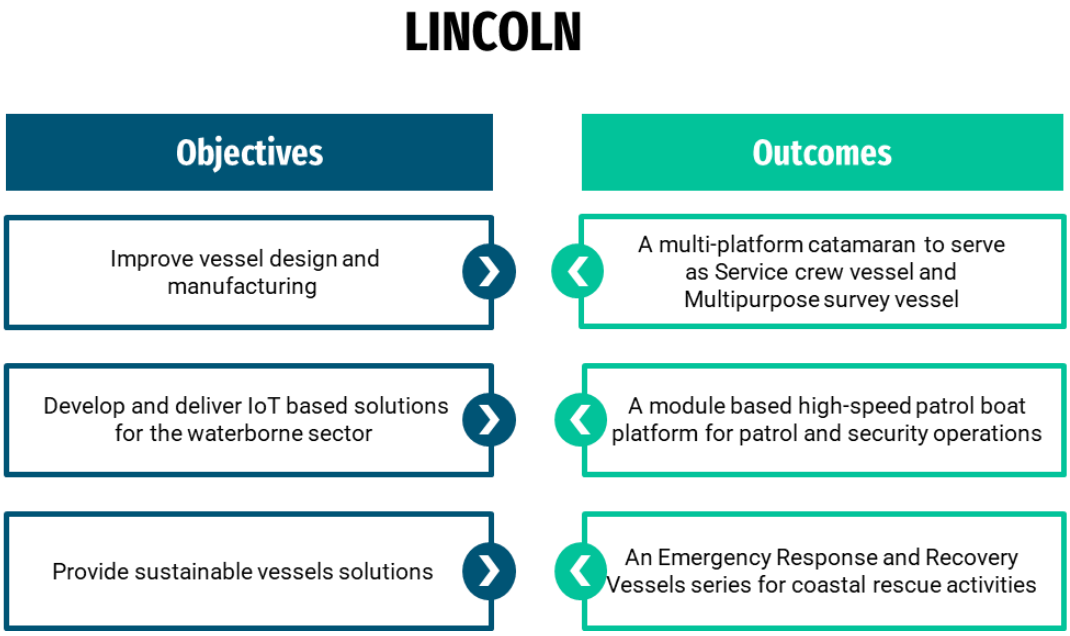

Figure 3-10: Objectives and Outcomes of the LINCOLN Project

The NEXUS project aimed to develop and demonstrate a range of innovative technologies for the next generation of efficient and sustainable operation vessels. The project delivered advanced demonstrators, as well as concepts for optimizing vessels' performance and reducing CO_2 emissions in the following years[58].

[58] European Commission. (2021). Towards Game-changer Service Operation Vessels for Offshore Windfarms

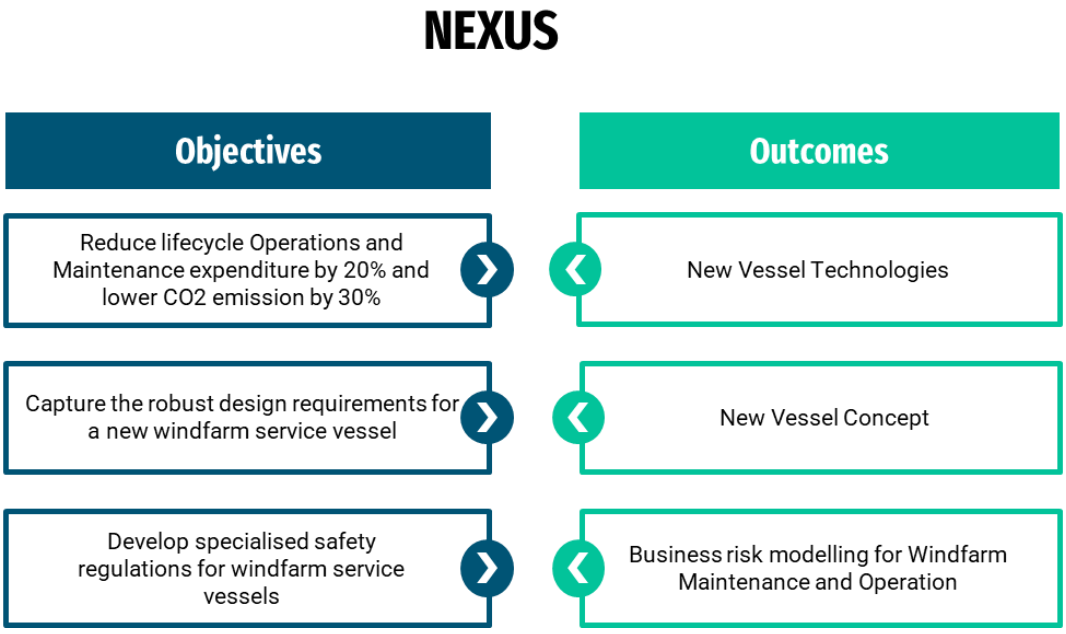

Figure 3-11: Objectives and Outcomes of the NEXUS Project

The FIBRESHIP project aimed to develop and demonstrate a new generation of large passenger ships using fibre-reinforced polymer composites, with a focus on reducing weight and environmental impact[59]. The project delivered a range of innovative design

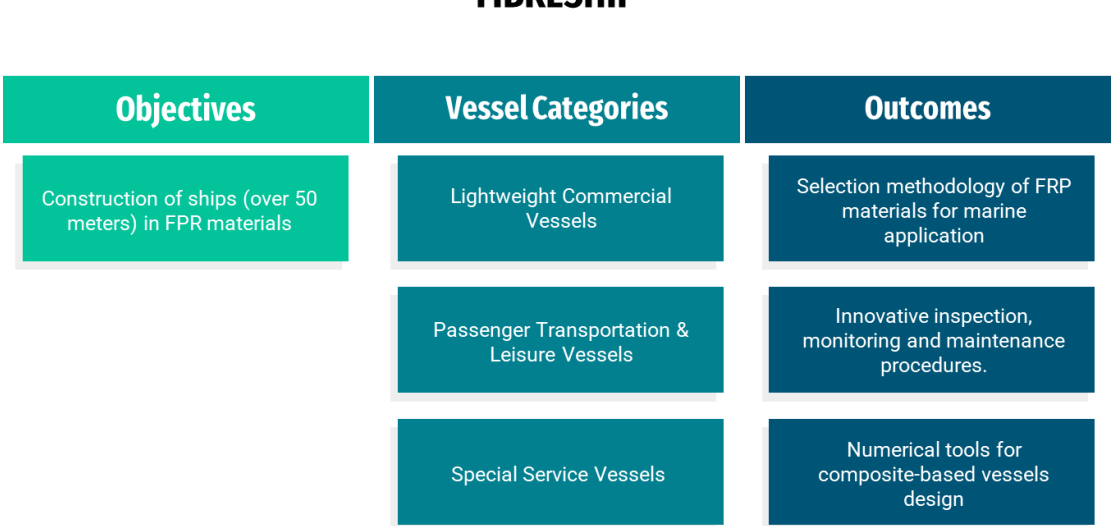

Figure 3-12: Objectives and Outcomes of the FIBRESHIP Project

[59] FIBRESHIP. (n.d.). Concept

and manufacturing solutions, including a new hybrid manufacturing process and a suite of design tools for composite ships[60].

The RAMSSES project aimed to develop and demonstrate a range of innovative technologies for reducing the environmental impact and improving the efficiency of shipping operations, including improved ship design and hull coatings, energy-efficient propulsion systems and smart shipping systems[61]. The project delivered numerous prototypes, as well as recommendations for the design and operation of future vessels[62].

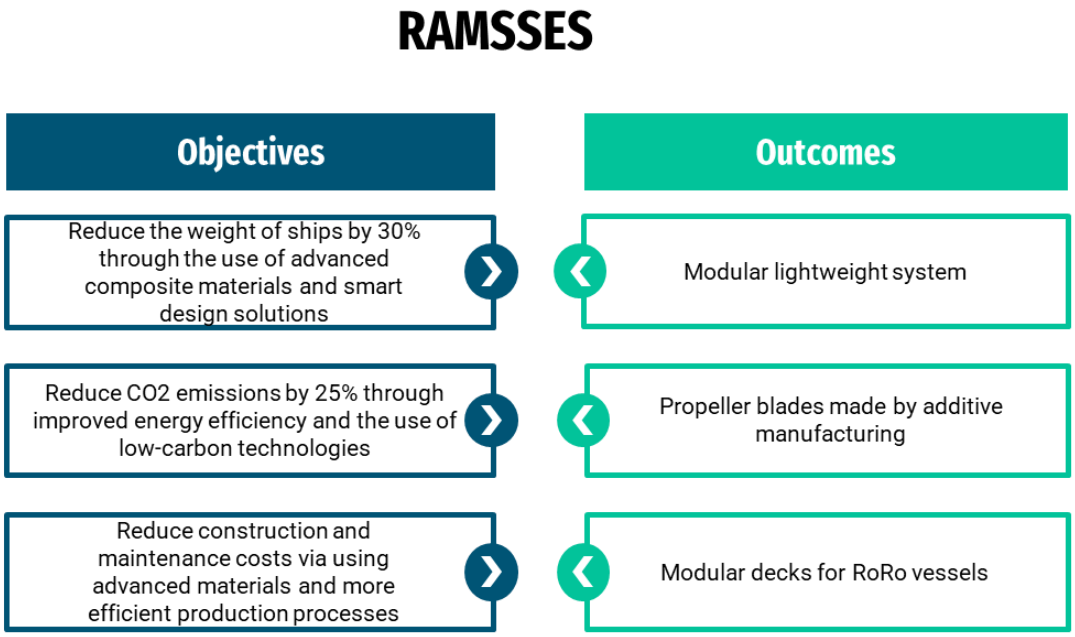

Figure 3-13: Objectives and Outcomes of the RAMSSES Project

[60] European Commission. (2020). Engineering, production and life-cycle management for the complete construction of large-length FIBRE-based SHIPs
[61] RAMSSES. (n.d.). Our Mission at RAMSSES Project for Sustainable and Efficient Ships
[62] European Commission. (2021). Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships

The HYSEAS III project aimed to develop and demonstrate a new generation of zero-emission hydrogen fuel cell vessels for the passenger and freight transport sectors[63]. The project delivered a range of innovative solutions, including a new fuel cell powertrain and a demonstration vessel for use in real-world conditions[64].

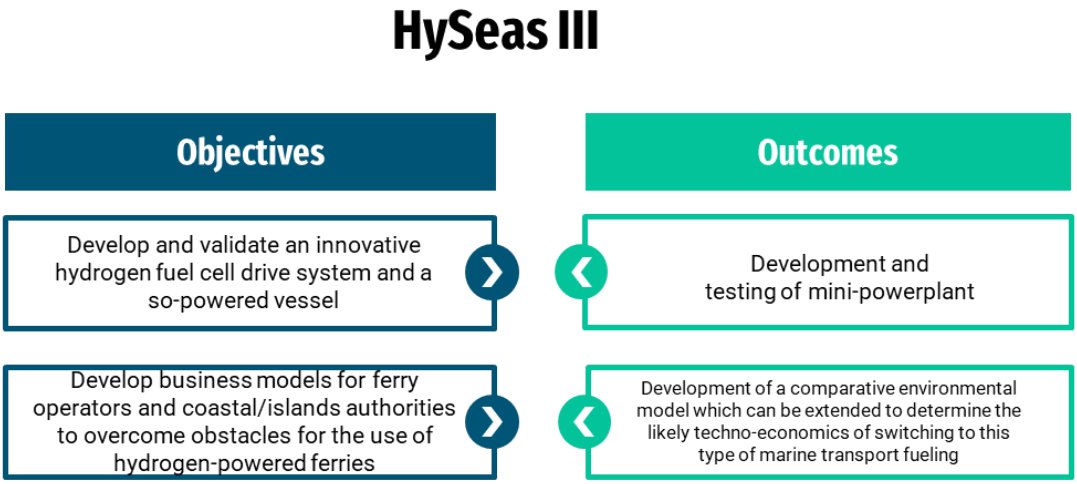

Figure 3-14: Objectives and Outcomes of the HySeas III Project

The NAVAIS project aimed to develop and demonstrate a range of innovative technologies for improving the efficiency of vessel design, including platform-based ship product family designs[65]. The project implemented all its original objectives and contributed to the improvement of ship construction by providing sustainable concepts and solutions[66].

[63] HySeas III. (n.d.). The Project
[64] European Commission. (2021). Realising the world's first sea-going hydrogen-powered RoPax ferry and a business model for European islands
[65] NAVAIS. (n.d.). About the Project
[66] European Commission. (2022). New, Advanced and Value-Added Innovative Ships

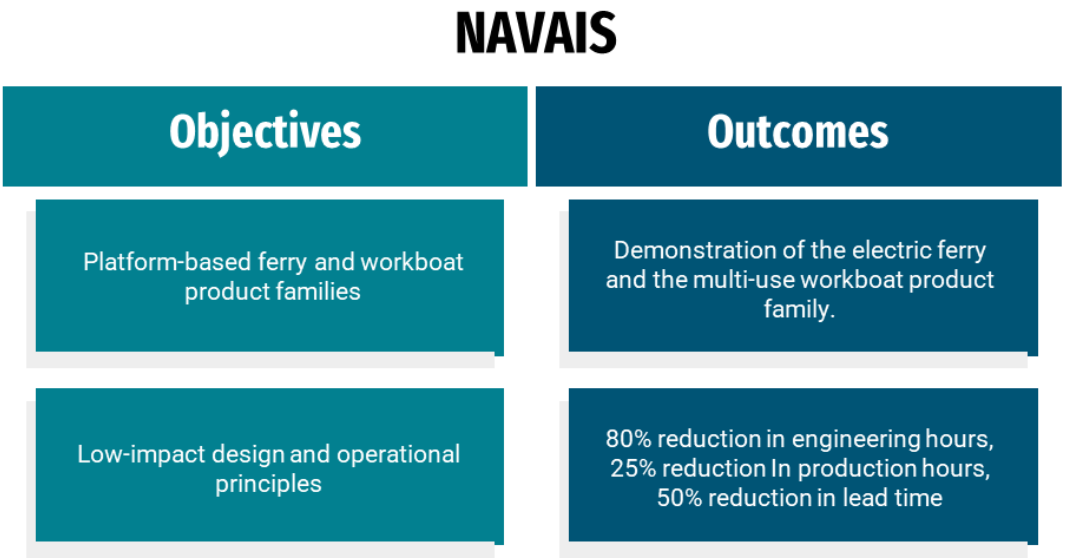

Figure 3-15: Objectives and Outcomes of the NAVAIS Project

The ARICE project aimed to enhance European researchers' access to polar research vessels and improve understanding of the Arctic region[67]. The project successfully developed strategies for optimal use of existing icebreakers, provided transnational access to key icebreakers for European scientists, facilitated breakthrough research on climate change, established collaborations with the maritime industry, and developed digital tools for data access and analysis[68]. These outcomes strengthened research capabilities, fostered international cooperation and contributed to a sustainable and informed approach to Arctic exploration and climate monitoring.

[67] ARICE. (n.d.). "Goals and Objectives"

[68] European Commission. (2023). "Arctic Research Icebreaker Consortium: A strategy for meeting the needs for marine-based research in the Arctic"

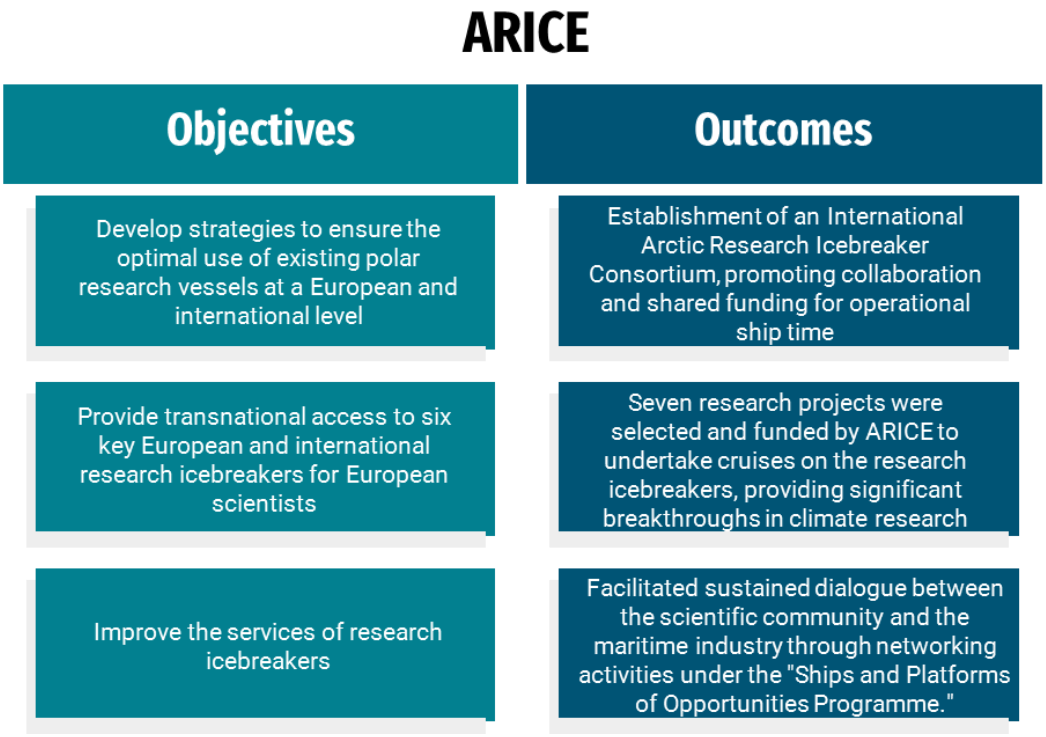

Figure 3-16: Objectives and Outcomes of the ARICE Project

The ProZero project aimed to introduce carbon fibre boats in the professional fast boat market, overcoming barriers and challenges associated with their adoption. The objectives included developing cost-effective production methods, showcasing operational use, and providing a complete product range. The project successfully achieved these goals by implementing a modular design platform, demonstrating significant weight and fuel savings compared to aluminium boats, and offering tailor-made solutions at competitive costs. The ProZero boats made of carbon fibre composites proved to be durable, energy-efficient, low-maintenance and environmentally beneficial for the marine industry[69].

[69] European Commission. (2018). "ProZero - carbon based fast boats for professional use"

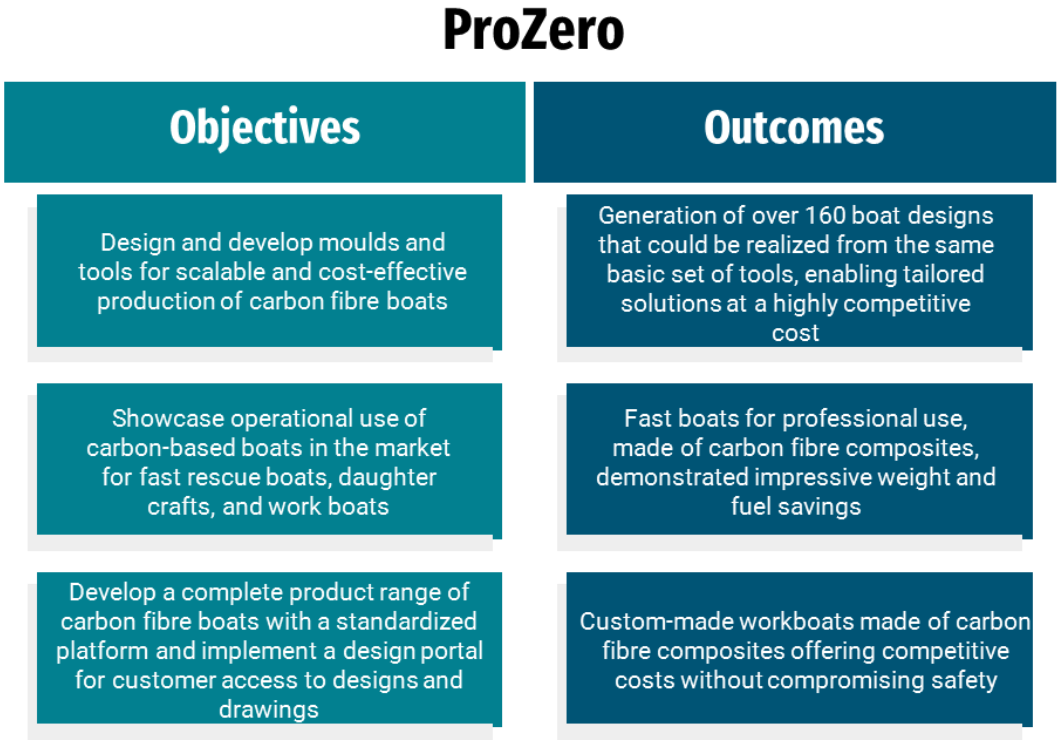

Figure 3-17: Objectives and Outcomes of the ProZero Project

3.5.3. NEW AND IMPROVED WATERBORNE TRANSPORT CONCEPTS

H2020 Waterborne topics under the operational objective of New and Improved Waterborne Transport Concepts, consists of eight closed and six active projects aiming to integrate the development of new cutting-edge technologies in the maritime industry with the objective of its continuous deployment and progressiveness towards a more efficient and sustainable future. Such undertake was financed with € 124.370.685,00 of which approximately 89% came from European funding.

To illustrate, three projects emphasized on research over the maritime environment and the improvement of its monitoring in order to exploit it in a more sustainable and economically viable manner. Moreover, two projects resulted in the deployment of innovative maritime transport concepts by exploiting Compressed Natural Gas (CNG) and investing in automation with the development of unmanned Follower Ships, while

two recently completed projects were working on achieving the launching of new generation autonomous ships in Europe and the integration of new technologies in studying and monitoring seabed with the least possible involvement of the human factor. R&I in the advancement of autonomous vessels as well as the evolution of the supply chain continues with three active projects aspiring to improve logistics by moving freight through water-sustainable infrastructure and the usage of innovative vessels.

The following table lists in detail all the approved topics and projects the operational objective of New and Improved Waterborne Transport Concepts, as well as the total funding they have received.

Table 3-3: Overview of Topics and Projects under the Operational Objective of New and Improved Waterborne Transport Concepts

Topics	Projects	EU Funding	Total Cost	Duration
		111.748.438,90 €	124.370.685,00 €	
Preparing for the future innovative offshore economy		1.977.951,25 €	1.977.951,25 €	
	MARIBE	1.977.951,25 €	1.977.951,25 €	03/2015-08/2016
New and improved transport concepts in waterborne transport		19.921.113,75 €	19.921.113,75 €	
	GASVESSEL	11.997.162,50 €	11.997.162,50 €	06/2017-03/2022
	NOVIMAR	7.923.951,25 €	7.923.951,25 €	06/2017-11/2021
Delivering the sub-sea technologies for new services at sea		12.422.992,50 €	13.127.816,25 €	
	DexROV	4.631.182,50 €	5.336.006,25 €	03/2015-08/2018
	BRIDGES	7.791.810,00 €	7.791.810,00 €	03/2015-08/2019

Unmanned and autonomous survey activities at sea		7.908.265,00 €	8.747.765,00 €	
	ENDURUNS	7.908.265,00 €	8.747.765,00 €	11/2018-07/2023
Moving freight by Water: Sustainable Infrastructure and Innovative Vessels		32.851.637,50 €	32.851.637,50 €	
	IW-NET	8.302.733,75 €	8.302.733,75 €	05/2020-04/2023
	NOVIMOVE	8.916.378,75 €	8.916.378,75 €	06/2020-05/2024
	AEGIS	7.510.375,00 €	7.510.375,00 €	06/2020-05/2023
	MOSES	8.122.150,00 €	8.122.150,00 €	07/2020-06/2023
The Autonomous ship		20.109.109,13 €	29.546.161,25 €	
	AUTOSHIP	20.109.109,13 €	29.546.161,25 €	06/2019-11/2023
EGNSS Transport applications		2.489.382,25 €	2.999.117,50 €	
	H2H	2.489.382,25 €	2.999.117,50 €	11/2017-05/2021
Multi-use of the oceans marine space, offshore and near-shore: Enabling technologies		6.766.793,02 €	7.629.927,50 €	
	Space at Sea	6.766.793,02 €	7.629.927,50 €	11/2017-10/2020
De-stressing the supply chain		7.301.194,50 €	7.569.195,00 €	
	SYNCHRO-NET	7.301.194,50 €	7.569.195,00 €	05/2015-10/2018

Regarding the outcomes of the above projects, eight out of the fourteen approved ones were completed by January 2023 and according to their deliverables, they presented the following findings.

The MARIBE project aimed to develop new business models for the Blue Economy, with a focus on multi-use offshore platforms[70]. The project developed new tools and

[70] European MSP Platform. (n.d.). Marine Investment for the Blue Economy

methods to assess the economic and environmental viability of different multi-use platform scenarios and produced guidelines for their implementation[71].

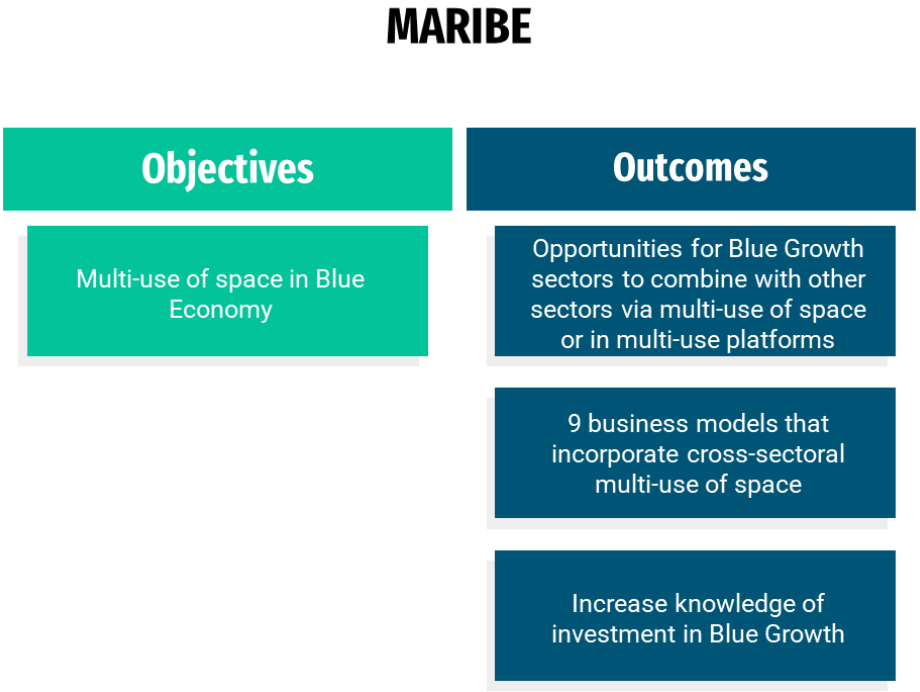

Figure 3-198: Objectives and Outcomes of the MARIBE Project

The GASVESSEL project developed a new type of vessel that runs on LNG as its primary fuel, with the aim of reducing emissions and improving energy efficiency[72]. The project developed the design, construction, and testing

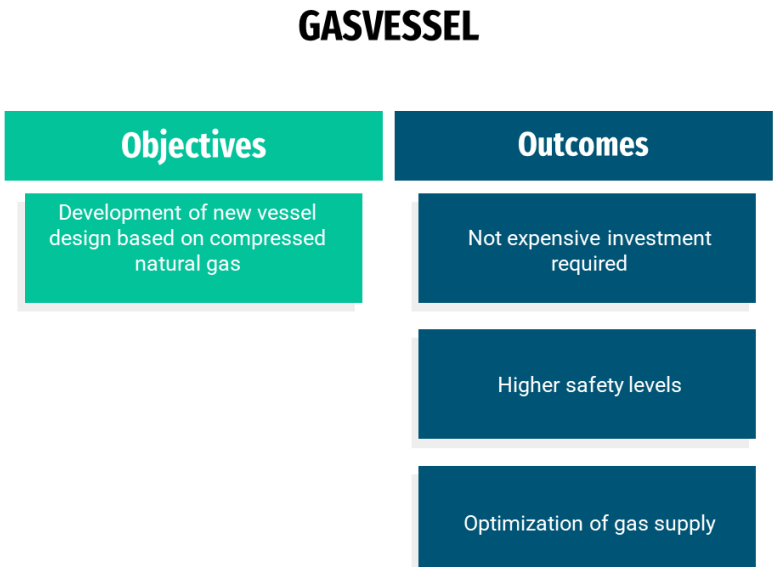

Figure 3-189: Objectives and Outcomes of the GASVESSEL Project

[71] European Commission. (2016). Marine Investment for the Blue Economy
[72] GASVESSEL. (n.d.). The GASVESSEL Project

of the vessel, including the proposal of safety standards and regulations for LNG-powered vessels[73].

The NOVIMAR project aimed to develop a new logistics system for short-sea shipping using innovative vessel designs and new technologies[74]. The project developed and tested new ship designs and technologies, including a fully automated cargo handling system and a new type of propulsion system. The project provided innovative solutions to the improvement of waterborne operations and inland waterway logistics[75].

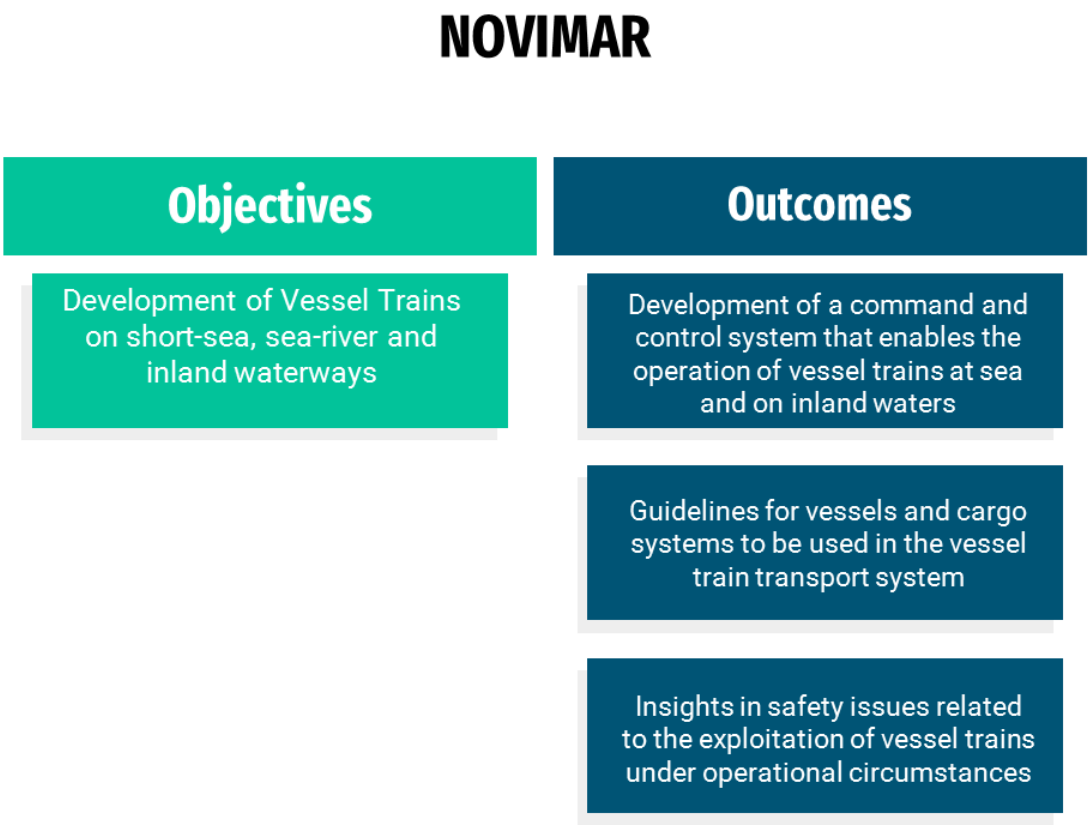

Figure 3-20: Objectives and Outcomes of the NOVIMAR Project

The DexROV project developed a new type of remotely operated vehicle (ROV) for deep-sea exploration and maintenance tasks[76]. The project developed the design and

[73] European Commission. (2022). Compressed Natural Gas Transport System
[74] NOVIMAR. (n.d.). NOVIMAR Vesseltrain
[75] European Commission. (2021). NOVel Iwt and MARitime transport concepts
[76] DEXROV. (n.d.). DEXROV: HOW IT WORKS

construction of the ROV, including the development of new control and sensor systems. The project also conducted several field tests to validate the ROV's capabilities[77].

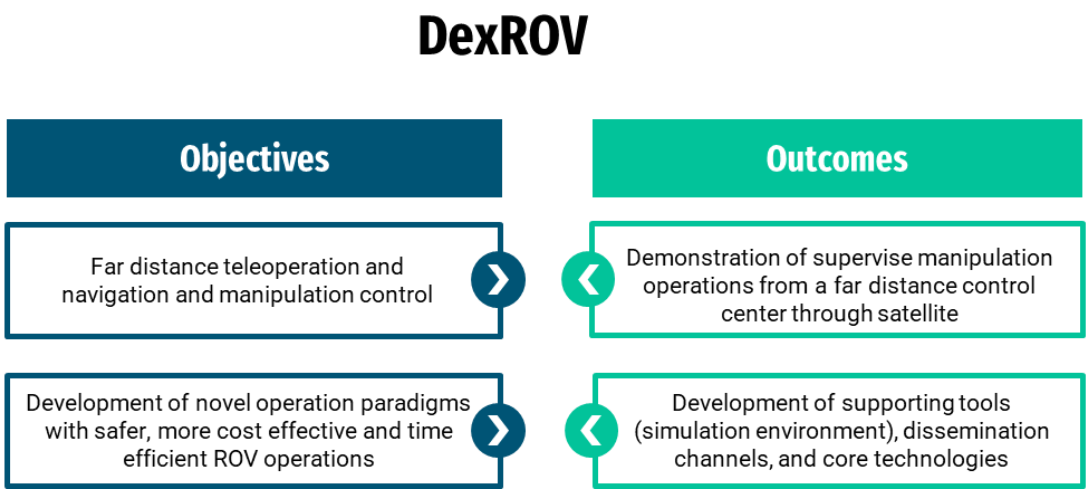

Figure 3-21: Objectives and Outcomes of the DexROV Project

The BRIDGES project aimed to develop new technologies and methods for underwater inspection and maintenance of offshore structures[78]. The project developed new sensors, data analysis tools, and robotics systems for inspection and maintenance tasks[79].

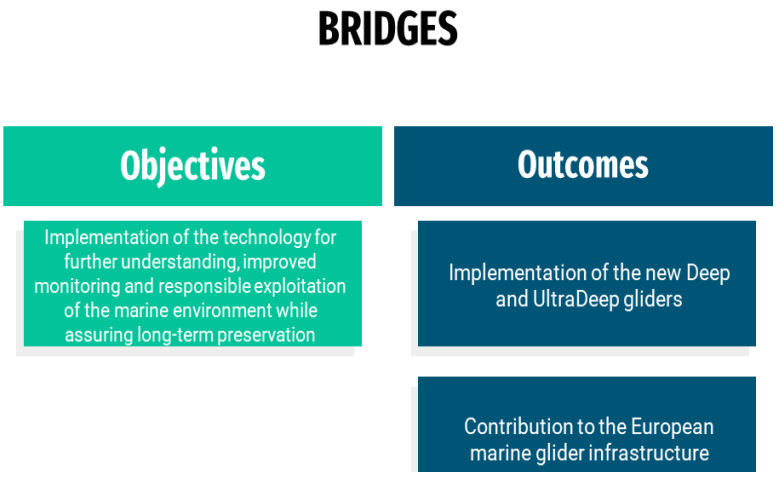

Figure 3-22: Objectives and Outcomes of the BRIDGES Project

[77] European Commission. (2018). Dexterous ROV: effective dexterous ROV operations in presence of communication latencies.
[78] BRIDGES. (n.d.). Main Objective of BRIDGES
[79] European Commission. (2019). Bringing together Research and Industry for the Development of Glider Environmental Services

The H2H project aimed to address the need for safe navigation in close proximity to other vessels and objects, benefiting both mariners and autonomous vessels[80]. The project successfully developed a technology that allows precise establishment of uncertainty zones for vessels and neighboring objects, supporting efficient and safe maritime operations. Demonstrations and presentations generated significant interest in the H2H concept, validating its potential. The project also explored use cases such as simultaneous operations, auto-mooring, and inland waterways, demonstrating the effectiveness of the H2H system in improving ship handling accuracy and providing valuable feedback for further development[81].

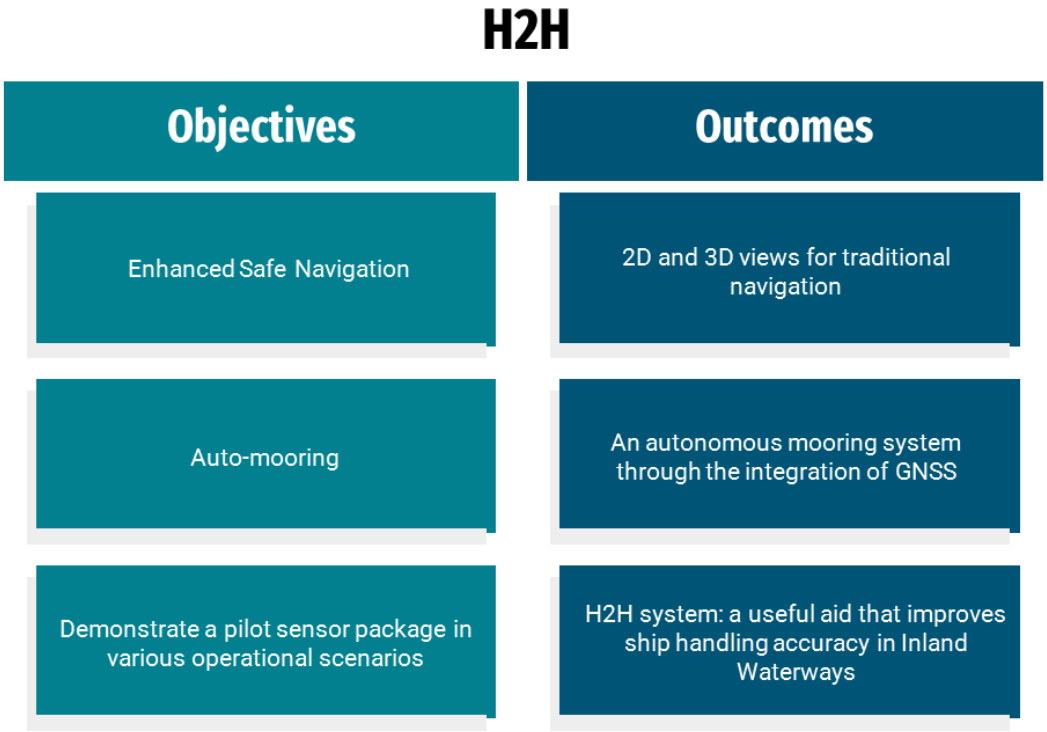

Figure 3-23: Objectives and Outcomes of the H2H Project

[80] EGNSS Hull to Hull. (n.d.). "Objectives"
[81] European Commission. (2022). "EGNSS Hull-to-Hull"

The objective of the Space@Sea project was to develop multipurpose floating islands with low environmental impact and evaluate their business cases in European regions[82]. The project successfully demonstrated core designs, including a basic floater, a modular platform mooring system, and an operation and maintenance platform for floating wind farms. It aimed to provide solutions for efficient use of the maritime environment, addressing population growth, urbanization and offshore activities. The project aimed to contribute to the development of regulations and governance for floating islands and concluded with a roadmap for their deployment[83].

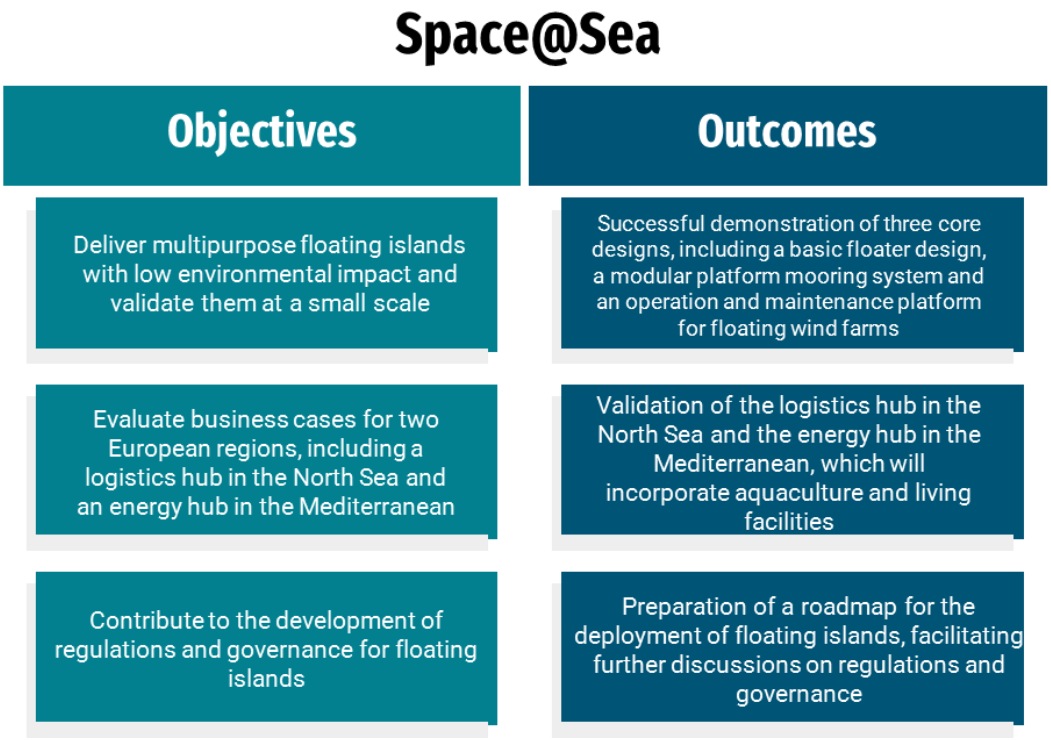

Figure 3-24: Objectives and Outcomes of the Space@Sea Project

The SYNCHRO-NET project aimed to catalyze the adoption of synchro-modality and slow steaming concepts in the supply chain by developing an integrated optimization and simulation eco-NET. The project successfully developed interoperable logistics

[82] SPACE@SEA. (n.d.). "About SPACE@SEA"
[83] European Commission. (2020). "Multi-use affordable standardised floating Space@Sea"

planning software modules, implemented ship software models, and created a user-friendly front-end interface. It also introduced risk analysis and optimization submodules, weather routing capabilities, and a cooperative speed pilot module. The project's outcomes include reducing costs, CO2 emissions, congestion, and waiting times while increasing the adoption of greener transport, optimizing resource utilization, and improving collaboration and reliability in the supply chain[84].

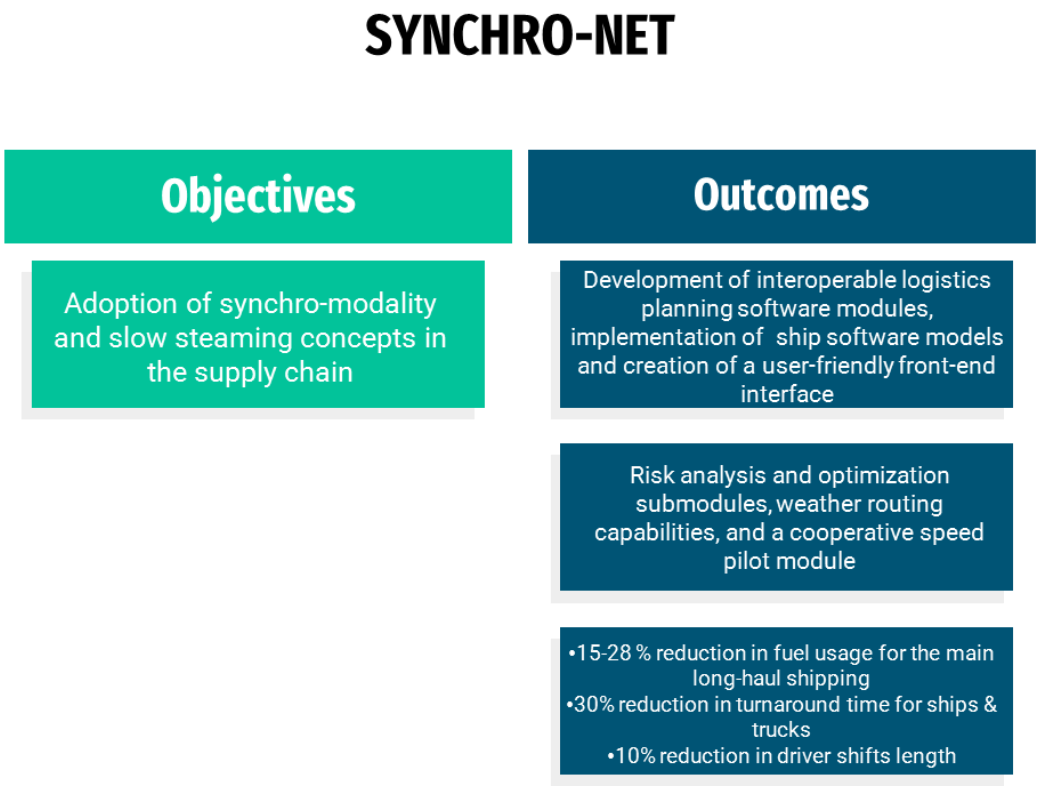

Figure 3-25: Objectives and Outcomes of the SYNCHRO-NET Project

3.5.4. ENERGY EFFICIENCY AND ZERO EMISSION VESSELS

The importance of achieving the operational objectives set under the thematic area of Energy efficient and zero emission vessels can be better understood if considering the number of the projects and the funding they have received. With an overall budget of €

[84] European Commission. (2021). "Synchro-modal Supply Chain Eco-Net"

220.839.466,49, EU has funded almost 86% of a total of fifteen closed and fourteen active projects in order to quantify and assess the impacts of shipping emissions and support inland navigation.

In particular, five projects have illustrated results towards energy efficient and emission free vessels, including the demonstration of prototype vessels, marine engines, disruptive hull coating and hydrogen-methanol ship propulsion systems, while "PROMINENT" focused on providing solutions in minimizing air pollution in inland navigation and, therefore, making it as competitive as road transport.

Moreover, two projects are addressing the challenges in decarbonizing the maritime industry by developing a future-proof vessel design platform and progressing at the R&I of carbon-free fuels. In this direction, three projects focus on researching ways to reduce the impact of waterborne transport in the air quality, the marine environment and the decrease of underwater noise.

In addition to financing projects regarding the development of new cutting-edge technologies, EU's funding has also financed four projects that work on providing retrofitting solutions for existing vessels, in order to seamlessly adapt to a new and technologically evolved era, by producing hybrid energy systems, promoting the adaptation of methanol technology and enhancing the development of innovative propulsion systems. Those state-of-the-art technological achievements constitute the deployment of brand-new information at this point, therefore the need has arisen for stakeholders to better communicate these innovations to the entire maritime community, thus promoting them and increasing, simultaneously, the societal engagement in order to, ultimately, achieve zero-emission waterborne transport through the close collaboration of academia and industry.

The following table lists in detail all the approved topics and projects related to the operational objective of Energy efficient and zero emission vessels, as well as the total funding they have received.

Table 3-4: Overview of Topics and Projects under the Operational Objective of Energy efficient and zero emission vessels

Topics	Projects	EU Funding	Total Cost	Duration
		190.794.282,62 €	220.839.466,49 €	
Quantify and assess the impacts of shipping emissions		130.068.799,35 €	155.566.912,24 €	
Towards the energy efficient and emission free vessel		47.706.793,48 €	67.962.746,49 €	
	E-FERRY	15.141.035,88 €	21.303.820,74 €	06/2015-05/2020
	LeanShips	15.752.357,97 €	21.550.240,57 €	05/2015-04/2019
	HERCULES-2	16.813.399,63 €	25.108.685,18 €	05/2015-10/2018
Innovations for energy efficiency and emission control in waterborne transport		13.737.207,38 €	15.189.851,25 €	
	AIRCOAT	5.299.097,38 €	5.901.541,25 €	05/2018-04/2022
	HYMETHSHIP	8.438.110,00 €	9.288.310,00 €	07/2018-11/2021
InCo flagship on reduction of transport impact on air quality		4.987.619,25 €	5.060.306,75 €	
	SCIPPER	4.987.619,25 €	5.060.306,75 €	05/2019-01/2023
Ship emission control scenarios, marine environmental impact and mitigation		7.493.885,00 €	7.493.885,00 €	
	EMERGE	7.493.885,00 €	7.493.885,00 €	02/2020-01/2024
Retrofit Solutions and Next Generation Propulsion for		22.890.332,99 €	26.607.161,50 €	

Waterborne Transport				
	Nautilus	7.892.362,50 €	7.892.362,50 €	07/2020-06/2024
	FASTWATER	4.999.217,51 €	6.357.962,50 €	06/2020-05/2024
	GATERS	4.999.509,98 €	5.878.364,25 €	02/2021-01/2024
	SeaTech	4.999.243,00 €	6.478.472,25 €	06/2020-05/2023
Structuring R&I towards zero emission waterborne transport		1.498.687,50 €	1.498.687,50 €	
	STEERER	1.498.687,50 €	1.498.687,50 €	12/2019-11/2022
Under water noise mitigation and environmental impact		8.965.963,75 €	8.965.963,75 €	
	SATURN	8.965.963,75 €	8.965.963,75 €	02/2021-01-2025
Improving impact and broadening stakeholder engagement in support of transport research and innovation		3.288.313,75 €	3.288.313,75 €	
	LASTING	1.288.456,25 €	1.288.456,25 €	01/2021-12/2023
	PLATINA 3	1.999.857,50 €	1.999.857,50 €	01/2021-06/2023
Decarbonising long distance shipping		19.499.996,25 €	19.499.996,25 €	
	CHEK	9.999.996,25 €	9.999.996,25 €	06/2021-05/2024
	ENGIMMONIA	9.500.000,00 €	9.500.000,00 €	05/2021-04/2025
Promoting innovation in the Inland Waterways Transport (IWT) sector		6.249.997,75 €	6.572.616,25 €	
	PROMINENT	6.249.997,75 €	6.572.616,25 €	05/2015-04/2018
Reducing the cost of large batteries for waterborne transport		21.568.351,50 €	21.578.352,50 €	
	Current Direct	11.979.875,00 €	11.989.875,00 €	01/2021-12/2023

	SEABAT	9.588.476,50 €	9.588.477,50 €	01/2021-12/2024
PNR on hydrogen-based fuels solutions for passenger ships		2.500.000,00 €	2.500.000,00 €	
	e-SHyIPS	2.500.000,00 €	2.500.000,00 €	01/2021-12/2024
Development of next generation biofuel and alternative renewable fuel technologies for aviation and shipping		4.998.653,75 €	4.998.653,75 €	
	BioSFerA	4.998.653,75 €	4.998.653,75 €	04/2020-03/2024
Small business innovation research for Transport and Smart Cities Mobility		5.072.907,50 €	7.742.369,00 €	
	EEECSM-2	1.062.337,50 €	1.517.625,00 €	08/2016-11/2018
	HCR	1.460.620,00 €	2.086.600,00 €	04/2018-09/2022
	SEAHUB	50.000,00 €	71.429,00 €	11/2016-02/2017
	Agro Highway	2.499.950,00 €	4.066.715,00 €	09/2015-02/2018
Fast Track to Innovation		4.417.203,77 €	5.912.193,75 €	
	eSHaRk	2.055.165,63 €	2.823.718,75 €	12/2015-05/2019
	SleekShip	2.362.038,14 €	3.088.475,00 €	04/2020-07/2022
Enabling decarbonisation of the fossil fuel-based power sector and energy intensive industry through CCS		15.918.369,00 €	15.968.369,00 €	
	STEMM-CCS	15.918.369,00 €	15.968.369,00 €	03/2016-02/2020

Regarding the outcomes of the above projects, eight out of the eighteen approved ones were completed by January 2023 and according to their deliverables, they presented the following findings.

The E-FERRY project aimed to design and demonstrate a fully electric ferry with a capacity of 30 vehicles and 200 passengers, as well as develop a charging infrastructure

for it[85]. The deliverables included the design and construction of the ferry, its testing and validation, and the implementation of the charging infrastructure[86].

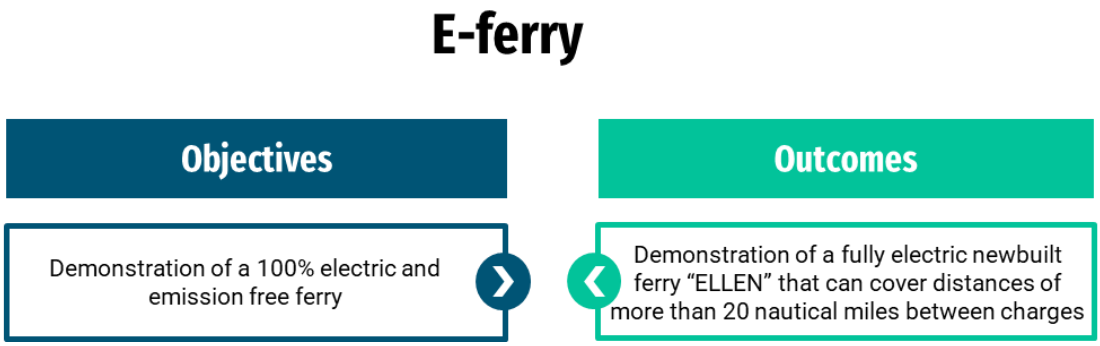

Figure 3-26: Objectives and Outcomes of the E-FERRY Project

The LeanShips project aimed to increase energy efficiency and reduce the environmental impact of ships by implementing innovative technologies and methodologies[87]. The deliverables included the development and testing of new technologies such as air lubrication systems and waste heat recovery systems, as well as the optimization of ship design and operation[88].

[85] E-ferry. (n.d.). Objectives
[86] European Commission. (2020). E-ferry – prototype and full-scale demonstration of next generation 100% electrically powered ferry for passengers and vehicles
[87] LeanShips. (n.d.). Project description of LeanShips
[88] European Commission. (2019). Low Energy And Near to zero emissions Ships

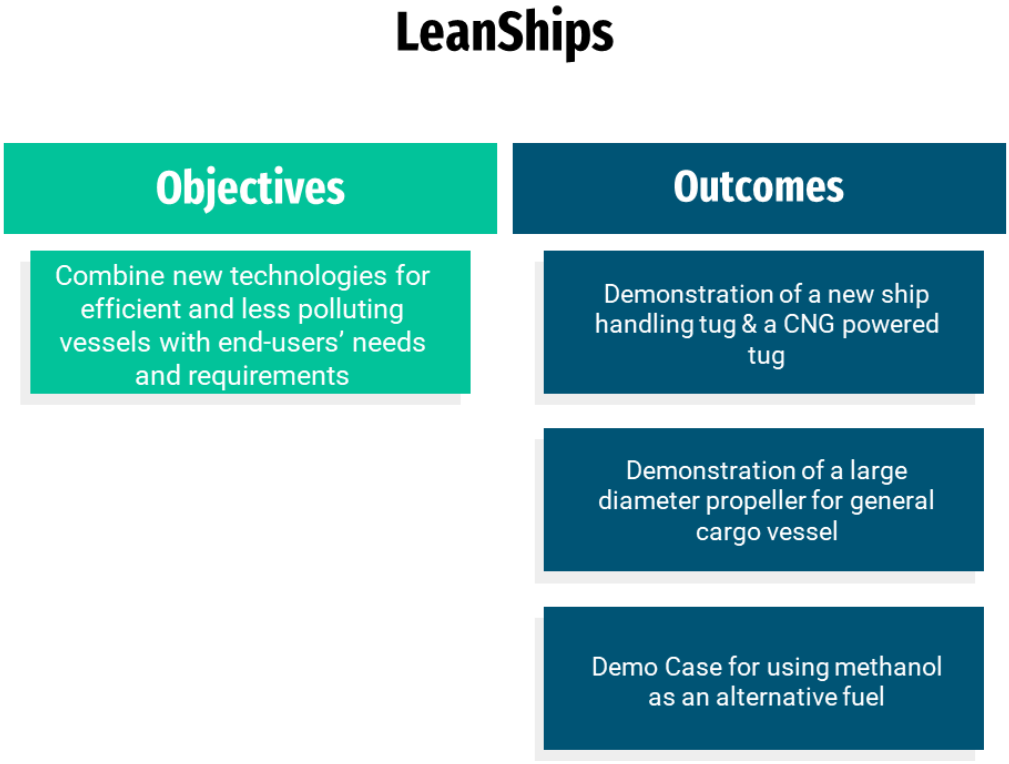

Figure 3-27: Objectives and Outcomes of the LeanShips Project

The HERCULES-2 project aimed to develop new technologies for the marine engine industry that would increase energy efficiency, reduce emissions and noise and improve reliability and safety[89]. The deliverables included the development and testing of new designs that facilitated the use of sustainable alternative fuels and power resources, in order to promote the level of construction of zero-emission vessels[90].

[89] HERCULES-2. (n.d.). Objectives
[90] European Commission. (2019). FUEL FLEXIBLE, NEAR -ZERO EMISSIONS, ADAPTIVE PERFORMANCE MARINE ENGINE

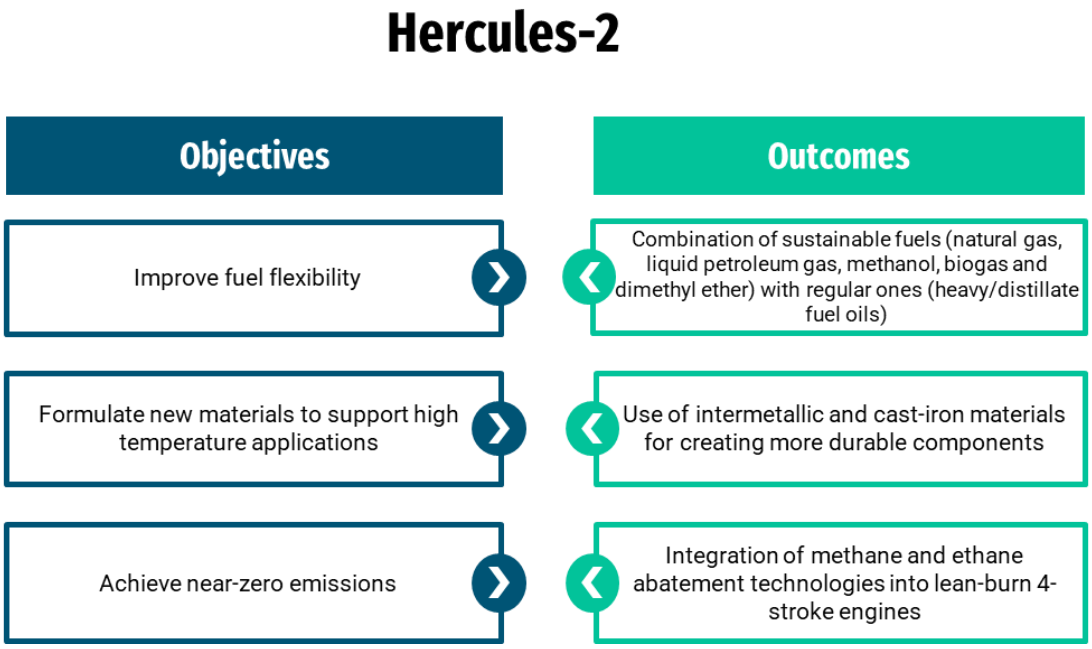

Figure 3-28: Objectives and Outcomes of the HERCULES-2 Project

The AIRCOAT project aimed to develop a new type of coating for ship hulls that would reduce drag and thus fuel consumption and emissions[91]. The deliverables included the development of the coating material, its application and testing on a ship and the demonstration of its effectiveness[92].

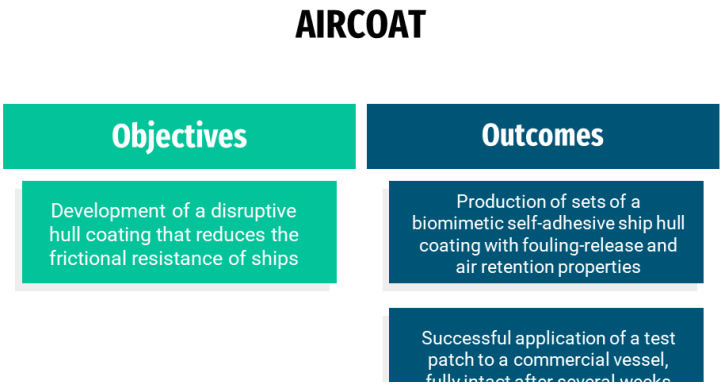

Figure 3-29: Objectives and Outcomes of the AIRCOAT Project

[91] AIRCOAT. (n.d.). AIRCOAT research and product development
[92] European Commission. (2022). Air Induced friction Reducing ship COATing

The HYMETHSHIP project aimed to develop and demonstrate a hydrogen fueled combustion engine for vessels that would reduce fuel consumption and emissions[93]. The deliverables included the design and construction of the hydrogen fueled combustion engine, its testing and validation and the demonstration of its effectiveness[94].

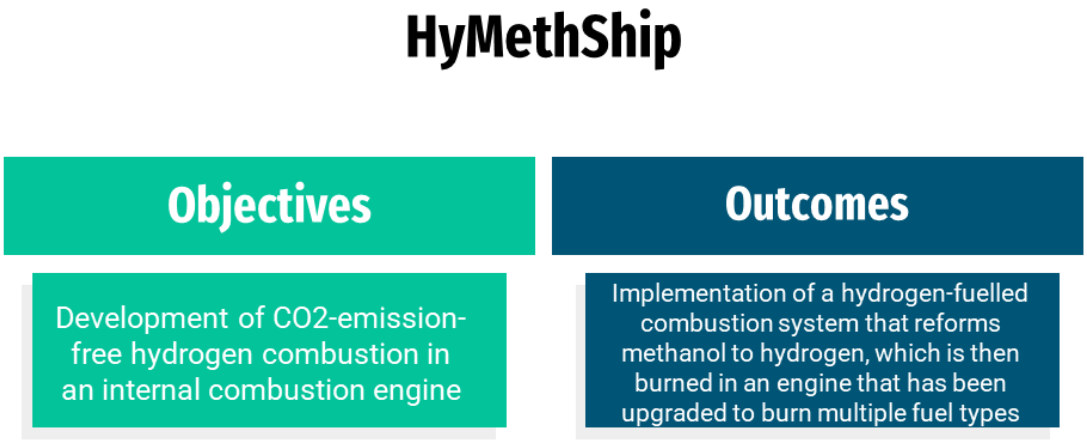

Figure 3-30: Objectives and Outcomes of the HyMethShip Project

The SCIPPER project aimed to develop and implement new technologies and practices for improving the safety and efficiency of maritime transport[95]. The deliverables included the development and testing of new technologies such as on-board sensors and optical systems, as well as the development of regulatory enforcement scenarios[96].

[93] HYMETHSHIP. (n.d.). HYMETHSHIP System
[94] European Commission. (2022). Hydrogen-Methanol Ship propulsion system using on-board pre-combustion carbon capture
[95] SCIPPER. (n.d.). The SCIPPER Project Concept
[96] European Commission. (2022). SHIPPING CONTRIBUTIONS TO INLAND POLLUTION PUSH FOR THE ENFORCEMENT OF REGULATIONS

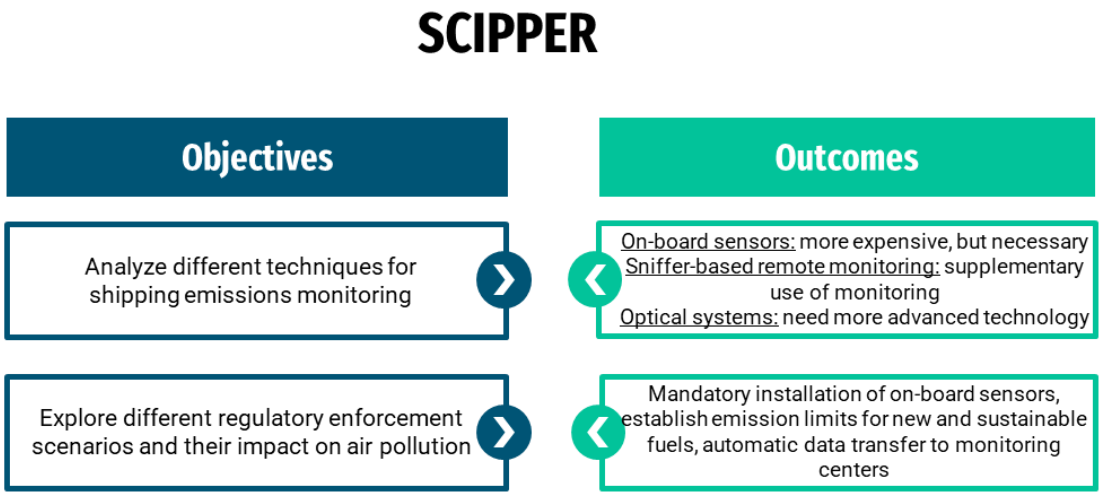

Figure 3-31: Objectives and Outcomes of the SCIPPER Project

The STEERER project aimed to update the Strategic Research and Innovation Agenda in order to align with the constant changing requirements of the waterborne sector[97].

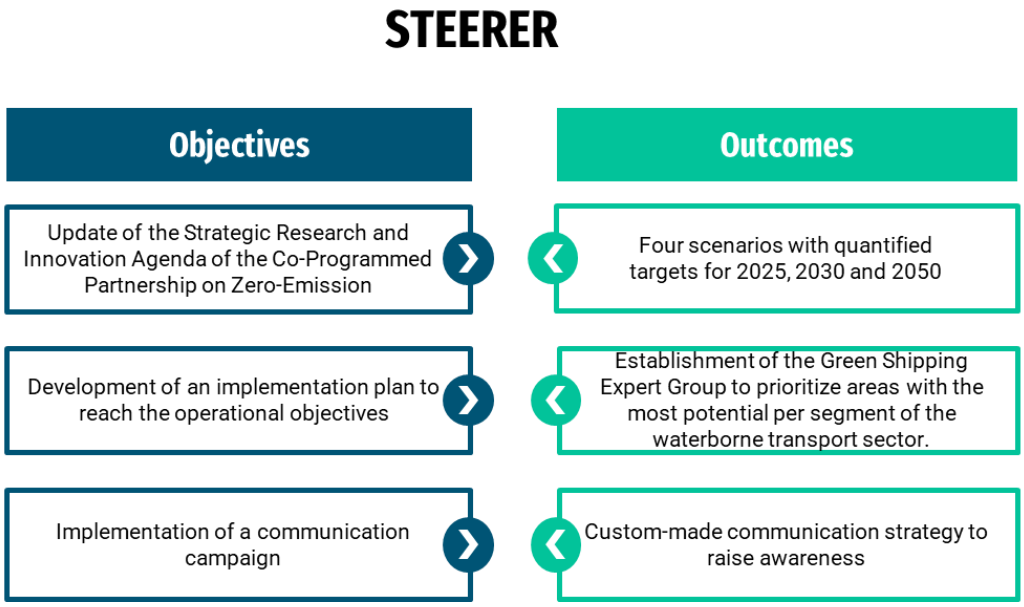

Figure 3-32: Objectives and Outcomes of the STEERER Project

The deliverables included a renovated implementation plan in contemplation of

[97] Waterborne TP. (n.d.). STRUCTURING TOWARDS ZERO-EMISSION WATERBORNE TRANSPORT

achieving the operational objectives and the design of a custom-made communication strategy to raise awareness of green shipping[98].

The PROMINENT project aimed to develop and test new technologies for monitoring and predicting the structural integrity of ships, with the goal of improving safety and reducing maintenance costs[99]. The deliverables included the development and testing of new sensors and monitoring systems, as well as the implementation of predictive maintenance systems[100].

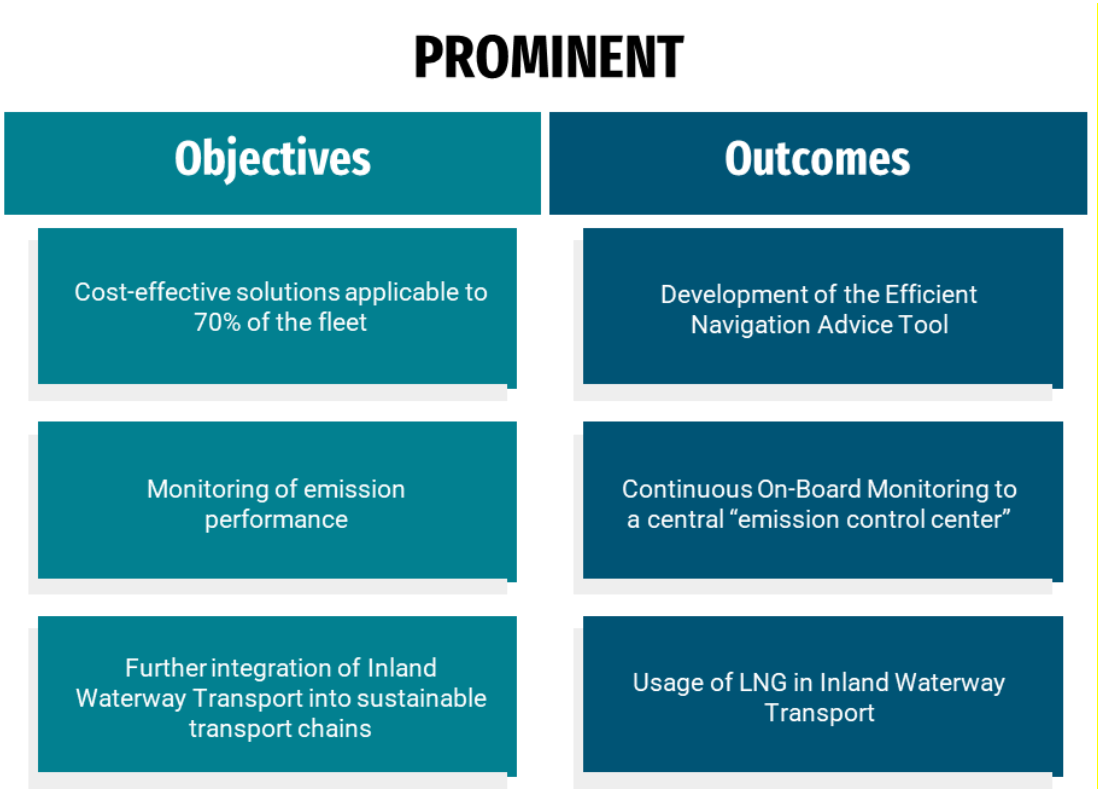

Figure 3-33: Objectives and Outcomes of the PROMINENT Project

The objective of the EEECSM-2 project was to optimize energy circulation on sea-faring vessels by developing a new cooling technology that harnesses waste heat to power air conditioning systems. The project successfully demonstrated the innovation

[98] European Commission. (2023). STRUCTURING TOWARDS ZERO EMISSION WATERBORNE TRANSPORT
[99] PROMINENT. (n.d.). Project Structure
[100] European Commission. (2018). Promoting Innovation in the Inland Waterways Transport Sector

onboard a hybrid ferry and scaled it up to a full-scale demonstrator ready for market introduction. The eco-friendly cooling solution eliminates the need for harmful hydrofluorocarbon gases, reduces CO_2 emissions and contributes to the sector's overall environmental sustainability while improving cost-effectiveness in the maritime industry[101].

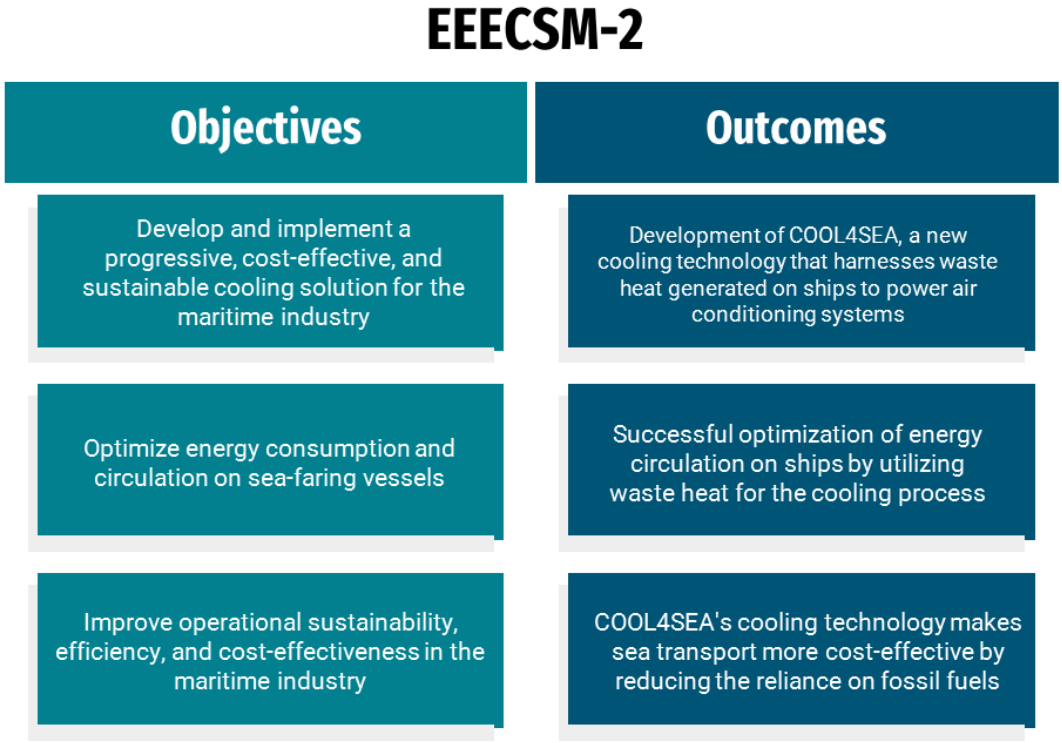

Figure 3-34: Objectives and Outcomes of the EEECSM-2 Project

[101] European Commission. (2019). "Energy and Environmentally Efficient Cooling System for Maritime use"

The HCR project aimed to develop and implement the first on-board automatic cleaning robot for ship hulls[102]. The outcomes included the successful creation of the HCR robot, which enables continuous cleaning, preventing early fouling formation and achieving fuel consumption savings of up to 10% per year over 5 years[103]. The use of HCR improves sustainability by reducing GHG emissions, minimizing invasive species transport and enhancing workplace safety. With these achievements, the project's coordinator, Cliin, is well-positioned to capitalize on the projected market value and generate significant revenue in the coming years.

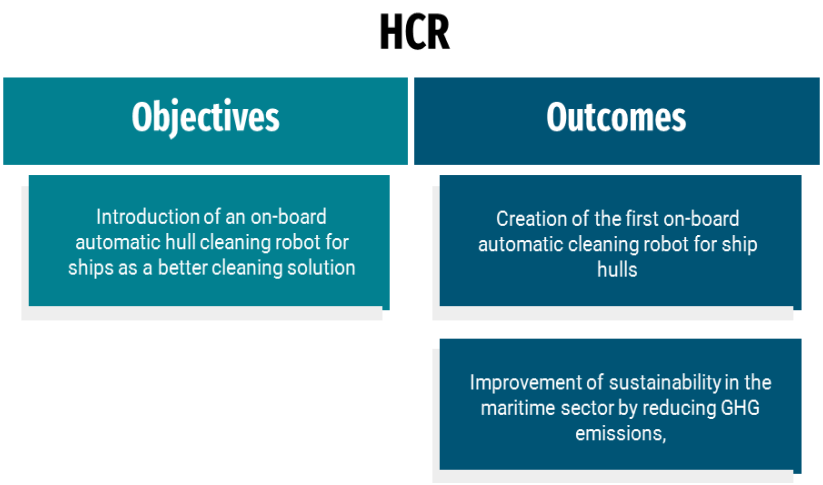

Figure 3-35: Objectives and Outcomes of the HCR Project

The SEAHUB project aimed to develop an innovative energy management solution for merchant ships, known as Seahub. The objectives were to enhance fuel efficiency, reduce operational costs, and comply with environmental regulations. The outcome of the project is the creation of Seahub, which combines a server-based reporting tool and a Fleet Performance Center. It enables real-time analysis of ship data, provides recommendations for energy efficiency improvements, allows comprehensive fleet monitoring and achieves significant fuel savings of up to 15-20%, leading to economic benefits and reduced emissions[104].

[102] European Commission. (2023). "Market maturation of the first on-board autonomous biofouling cleaning system to keep ship's hull clean at all times"
[103] Waterborne TP. (n.d.). "MARKET MATURATION OF THE FIRST ON-BOARD AUTONOMOUS BIOFOULING CLEANING SYSTEM TO KEEP SHIP'S HULL CLEAN AT ALL TIMES"
[104] European Commission. (2017). "Real-time Fleet Performance Center (FPC) to optimize energy efficiency in Maritime Transport to reduce fuel consumption and harmful emissions"

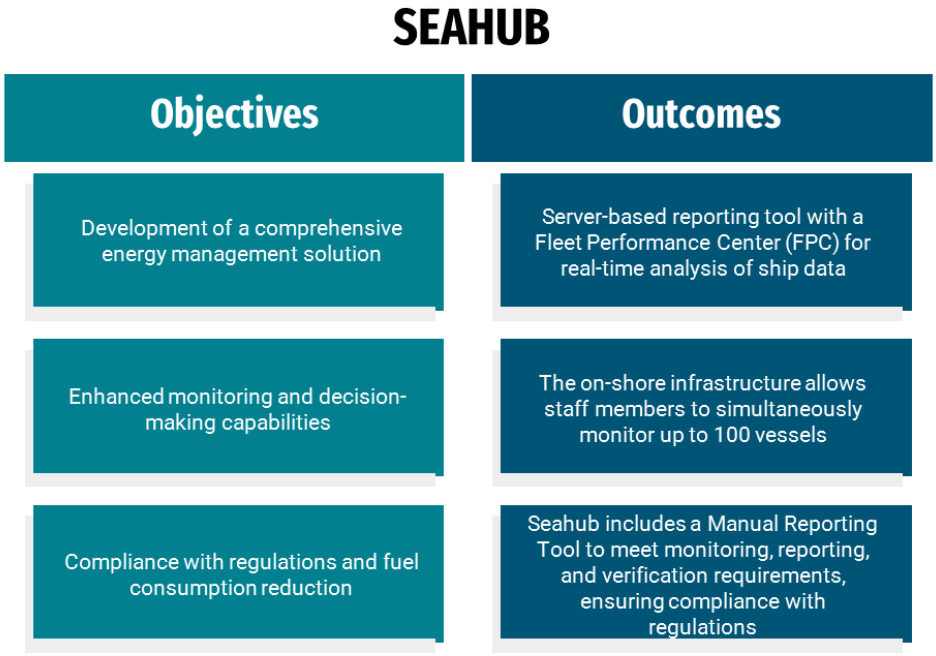

Figure 3-36: Objectives and Outcomes of the SEAHUB Project

The Agro Highway project aimed to develop an innovative water transport system, known as the Liquid Ferry, for perishable food liquids. The objectives included providing a flexible maritime solution, reducing costs for transport, increasing maximum transport distance and capacity, optimizing supply chains, and creating new market opportunities[105]. The project successfully developed the Liquid Ferry, enabling efficient transportation of large cargoes, ensuring aseptic conditions, and eliminating the need for extensive pre- and post-processing. These outcomes offer growth opportunities for SMEs, reduce transportation costs and open up new markets for the agricultural sector, resulting in increased profitability and market value[106].

[105] Agro Highway. (n.d.). "Background"
[106] European Commission. (2018). "Demonstration of an Innovative concept for high quality Transport of Perishable Agro Food Liquids inducing a Modal shift to Short Sea and River transport"

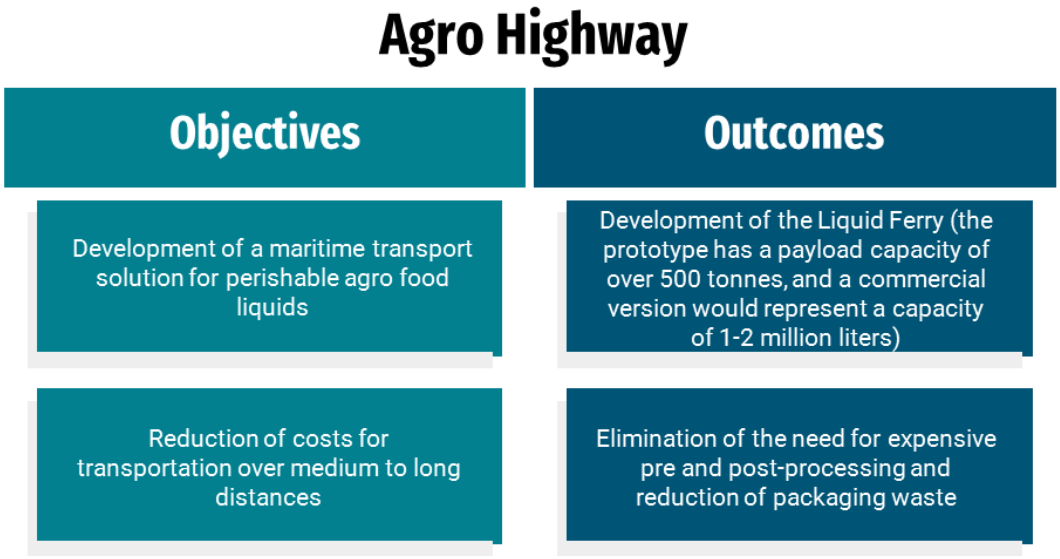

Figure 3-37: Objectives and Outcomes of the Agro Highway Project

The eSHaRk project aimed to develop an innovative fouling protection system for commercial vessels and accelerate its market entry. By utilizing self-adhesive foil technology, the project sought to provide a superior solution to existing paint-based anti-fouling coatings in terms of eco-friendliness, ease of application, robustness, and drag reduction effects. The project focused on optimizing the surface morphology of the foil, developing a robotized laminator for automated application and conducting full-scale testing on a cruise vessel. The outcomes included significant drag reduction, fuel savings, GHG emissions reduction and potential commercial applications beyond ship hull protection[107].

[107] European Commission. (2020). "eco-friendly Ship Hull film system with fouling Release and fuel saving properties"

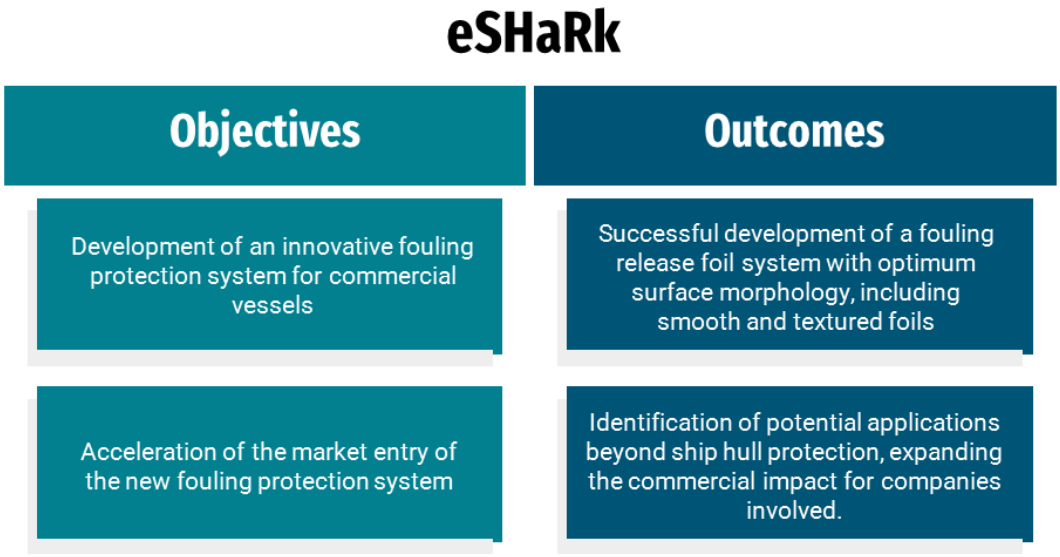

Figure 3-38: Objectives and Outcomes of the eSHaRk Project

The objectives of the SleekShip project were to develop technology for early detection and management of hull biofouling, optimize cleaning schedules and reduce maintenance costs. The project successfully created a semi-autonomous underwater vehicle equipped with a multispectral camera for early detection and a cavitation cleaning system for gentle and paint-safe cleaning. The technology enables cost savings of over a million euros per vessel annually, decreases CO_2 emissions by over 100 million tonnes and contributes to efficient biofouling management in

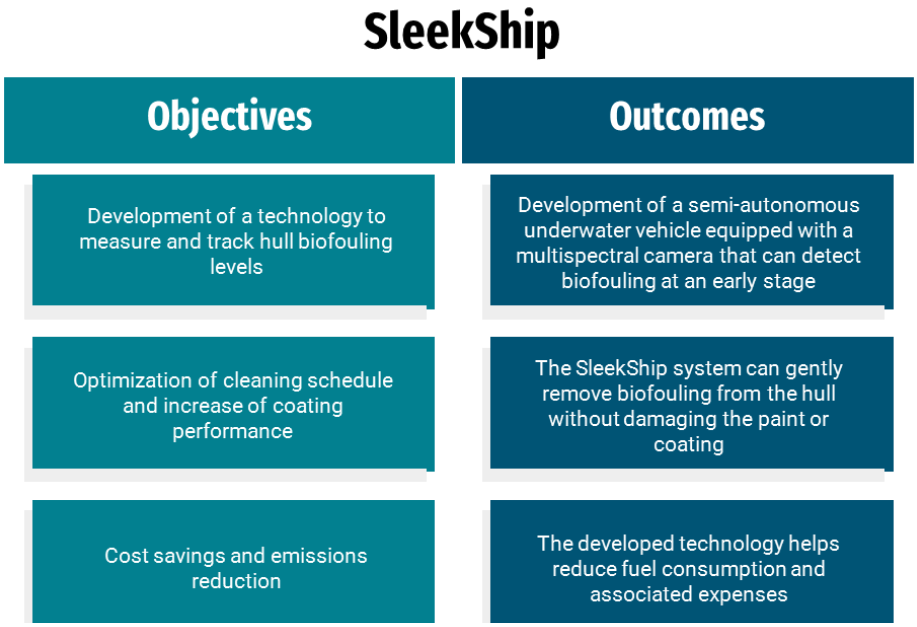

Figure 3-39: Objectives and Outcomes of the SleekShip Project

the shipping industry[108].

The objective of the STEMM-CCS project was to develop and demonstrate technologies for the safe and effective monitoring of offshore carbon capture and storage (CCS) reservoirs. The project aimed to detect and quantify CO_2 leakage, assess the impact on the marine environment and provide guidelines and tools for CCS site selection, risk assessment, and mitigation. The outcomes of the project include the successful detection of small CO_2 leaks in a real-world deep-water experiment, the development of sensor technologies and monitoring tools and enhanced confidence in the environmental safety of offshore CCS operations[109].

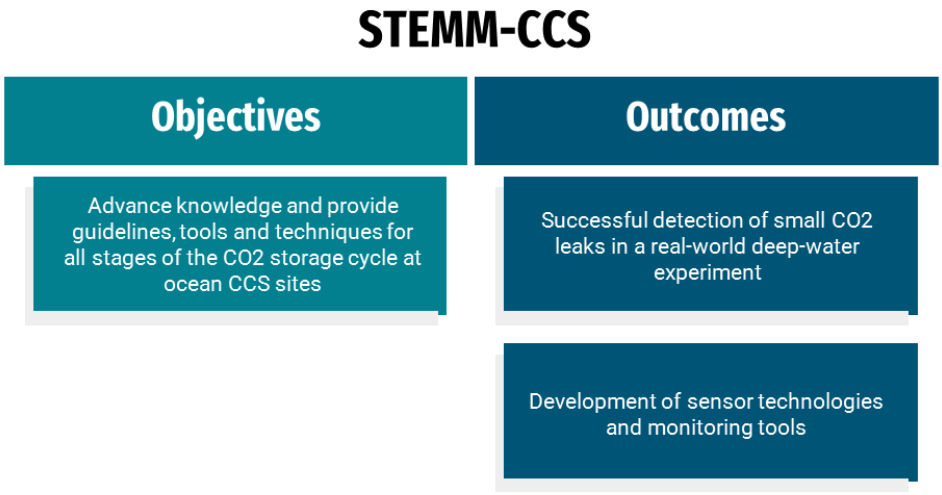

Figure 3-40: Objectives and Outcomes of the STEMM-CCS Project

3.5.5. SAFER AND MORE EFFICIENT WATERBORNE OPERATIONS

The final operational objective was set to address challenges in the area of Safer and more efficient waterborne operations, where EU funded eleven projects with an overall

[108] European Commission. (2022). "Spectral Imaging Powered Ship Hull Biofouling Detection and Cleaning"
[109] European Commission. (2020). "Strategies for Environmental Monitoring of Marine Carbon Capture and Storage"

budget of € 86.204.931,32. In particular, three projects provided solutions and developed technologies for more efficient marine traffic management and the optimization of evacuation systems, especially in the Arctic region, while "GRACE" engaged with the environmental impact of oil spills and presented response actions, such as optimized prediction measurements. Moreover, five projects are developing innovative systems in response to marine accidents, for instance, for fire and flooding incidents, or for evacuation and rescue procedures under extreme circumstances, as well as assessing the legislative framework on the human factor.

The following table lists in detail all the approved topics and projects under the operational objective of Safer and more efficient waterborne operations, as well as the total funding they have received.

Table 3-5: Overview of Topics and Projects under the Operational Objective of Safer and more efficient waterborne operations

Topics	Projects	EU Funding	Total Cost	Duration
		75.738.968,30 €	86.204.931,32 €	
Safer waterborne transport and maritime operations		6.498.752,50 €	6.726.565,00 €	
	SEDNA	6.498.752,50 €	6.726.565,00 €	06/2017-11/2020
Response capacities to oil spills and marine pollutions		5.277.554,00 €	5.513.252,50 €	
	GRACE	5.277.554,00 €	5.513.252,50 €	03/2016-08/2019
Human Factors in Transport Safety		6.988.032,06 €	10.683.032,06 €	
	SAFEMODE	6.988.032,06 €	10.683.032,06 €	06/2019-11/2022
Safer and more efficient waterborne operations through new technologies		17.056.293,16 €	21.610.003,39 €	

and smarter traffic management				
	EfficienSea2	9.795.318,16 €	11.455.000,89 €	05/2015-04/2018
	LYNCEUS2MARKET	7.260.975,00 €	10.155.002,50 €	05/2015-11/2018
Marine Accident Response		38.799.019,58 €	40.090.399,37 €	
	LASHFIRE	12.209.148,33 €	13.490.527,24 €	09/2019-08/2023
	SAFEPASS	8.270.366,25 €	8.270.366,25 €	09/2019-12/2022
	FLARE	9.375.730,00 €	9.385.730,00 €	06/2019-11/2022
	PALAEMON	8.943.775,00 €	8.943.775,88 €	06/2019-01/2023
Small and Medium Enterprise (SME) based EGNSS applications		1.069.317,00 €	1.510.250,00 €	
	spyGLASS	1.069.317,00 €	1.510.250,00 €	01/2015-12/2017
SME instrument		50.000,00 €	71.429,00 €	
	AnchorGuardian	50.000,00 €	71.429,00 €	07/2019-12/2019

Regarding the outcomes of the above projects, ten out of the eleven approved ones were completed by January 2023 and according to their deliverables, they presented the following findings.

The SEDNA project aimed to improve maritime safety in Arctic regions by developing new technologies, standards, and regulations[110]. Some of the key deliverables of the project include an Arctic risk assessment methodology, a decision support system for safe Arctic navigation and a set of guidelines for Arctic search and rescue operations[111].

[110] Waterborne TP. (n.d.). SAFE MARITIME OPERATIONS UNDER EXTREME CONDITIONS: THE ARCTIC CASE

[111] European Commission. (2021). Safe maritime operations under extreme conditions: the Arctic case

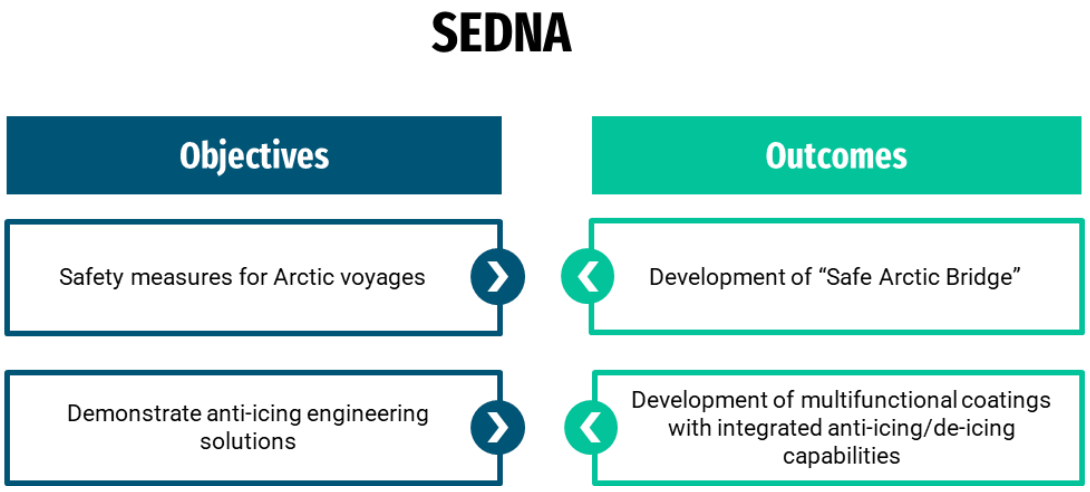

Figure 3-41: Objectives and Outcomes of the SEDNA Project

The GRACE project aimed to develop and test innovative technologies, tools and methods to enhance preparedness and response to oil spills and to minimize the environmental impact of such incidents, in order to increase safety and security on and off shore and to demonstrate sustainable solutions that could prevent accidents caused by oil spills[112].

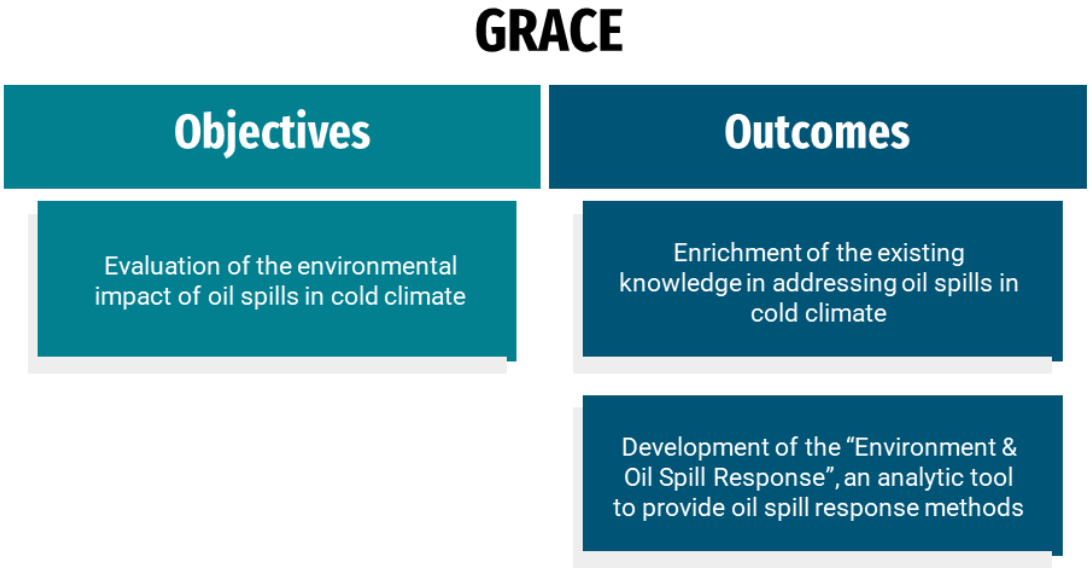

Figure 3-42: Objectives and Outcomes of the GRACE Project

[112] European Commission. (2019). Integrated oil spill response actions and environmental effects

The SAFEMODE project aimed to address the human factors and behavioral aspects onboard ships to ensure safe and efficient operation[113]. The project developed new innovative tools which can record in a single database useful information about the human factor and extract viable proposals for prevention and treatment[114].

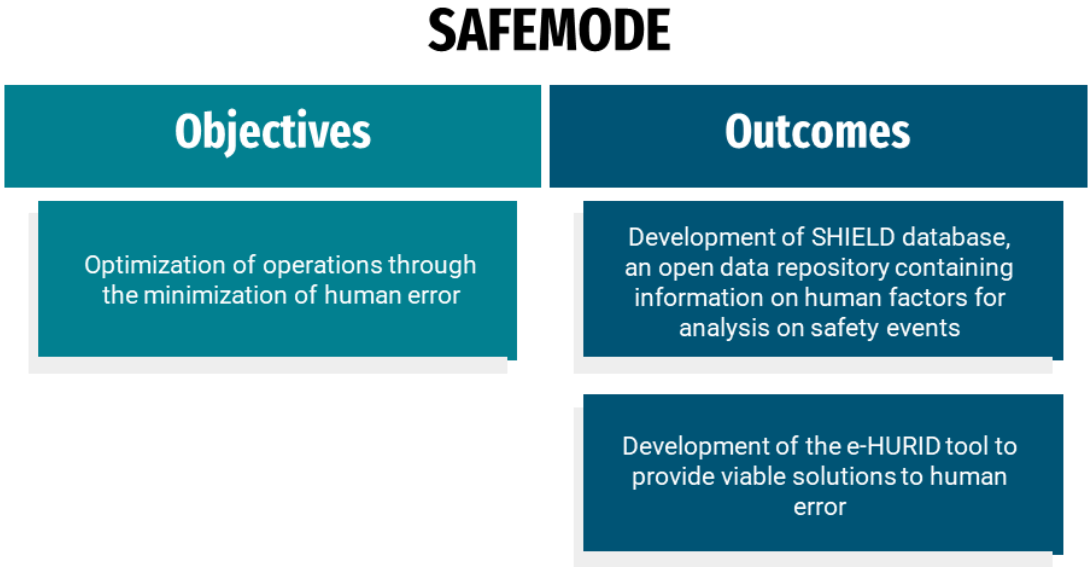

Figure 3-43: Objectives and Outcomes of the SAFEMODE Project

The EfficienSea2 project aimed to create a more connected, efficient and environmentally sustainable maritime sector and focused on improving communication between different stakeholders, such as ships, ports and coastal authorities through the integrations of new technologies[115]. The deliverables included the development of advanced e-navigation solutions and the Maritime Connectivity Platform (MCP), a digital infrastructure that enables secure communication between ships and shore-based systems[116].

[113] SAFEMODE. (n.d.). Objectives
[114] European Commission. (2023). Strengthening synergies between Aviation and maritime in the area of human Factors towards achieving more Efficient and resilient MODE of transportation
[115] EfficienSea2. (n.d.). Aim
[116] European Commission. (2018). EfficienSea 2 - Efficient, Safe and Sustainable Traffic at Sea

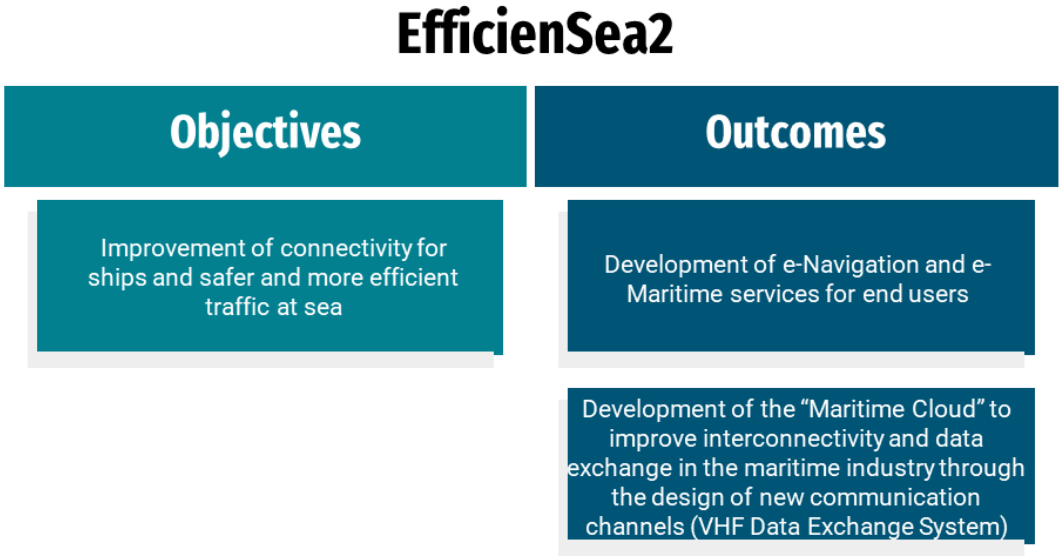

Figure 3-44: Objectives and Outcomes of the EfficienSea2 Project

The LYNCEUS2MARKET project aimed to develop an innovative people localization system for safe evacuation of large passenger ships. The system integrated a range of technologies to accurately locate passengers and crew members during an emergency evacuation. The project also aimed to develop an intelligent decision support system that may provide real-time information to crew members and emergency responders to help them make informed decisions during an evacuation[117]. The deliverables of the project included improved safety and efficiency in emergency situations, reduced

[117] European Commission. (2023). An innovative people localisation system for safe evacuation of large passenger ships

evacuation times and increased passenger and crew survivability in the event of an accident[118].

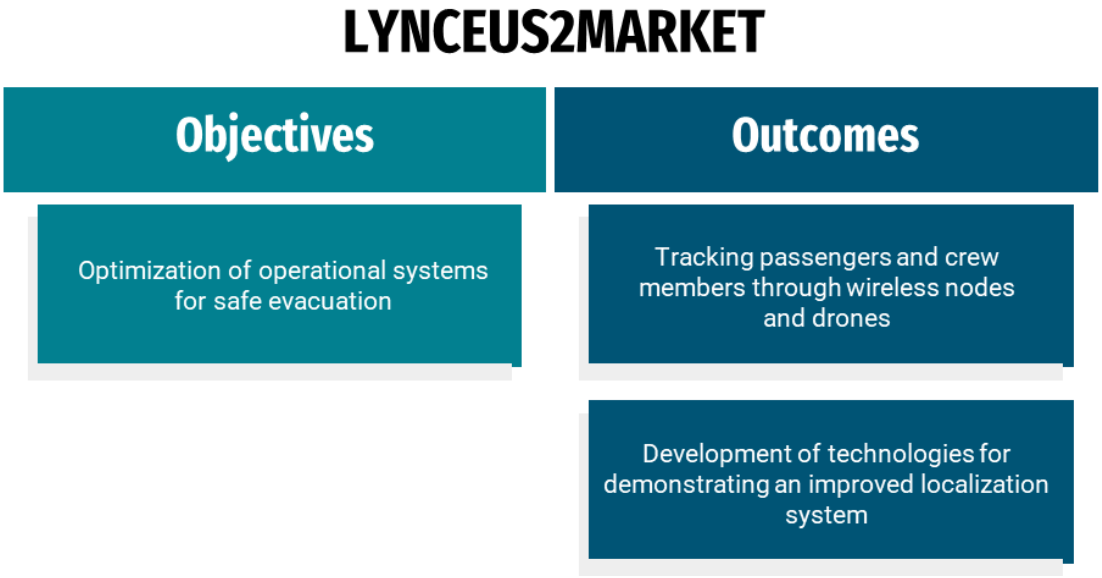

Figure 3-45: Objectives and Outcomes of the LYNCEUS2MARKET Project

The SafePASS project aimed to design and demonstrate a novel, efficient, and cost-effective evacuation system with advanced technologies and innovative solutions, including wireless technologies and virtual reality, to enhance situational awareness, passenger guidance and crew response[119]. The project delivered several key outputs, including a system architecture that defines the integration of sensors, communication and decision-making systems, a portable wireless network for reliable communication, a passenger locator system to quickly locate passengers during evacuation and virtual reality training scenarios for crew training and certification. The project's outcomes have the potential to improve the safety and survival rates of passengers and crew during critical situations, such as fires or collisions and enhance the efficiency and effectiveness of evacuation operations[120].

[118] European Commission. (2023). An innovative people localisation system for safe evacuation of large passenger ships
[119] SafePASS. (n.d.). The SafePASS scope
[120] European Commission. (2021). Next generation of life Saving appliances and systems for saFE and swift evacuation operations on high capacity PASSenger ships in extreme scenarios and conditions

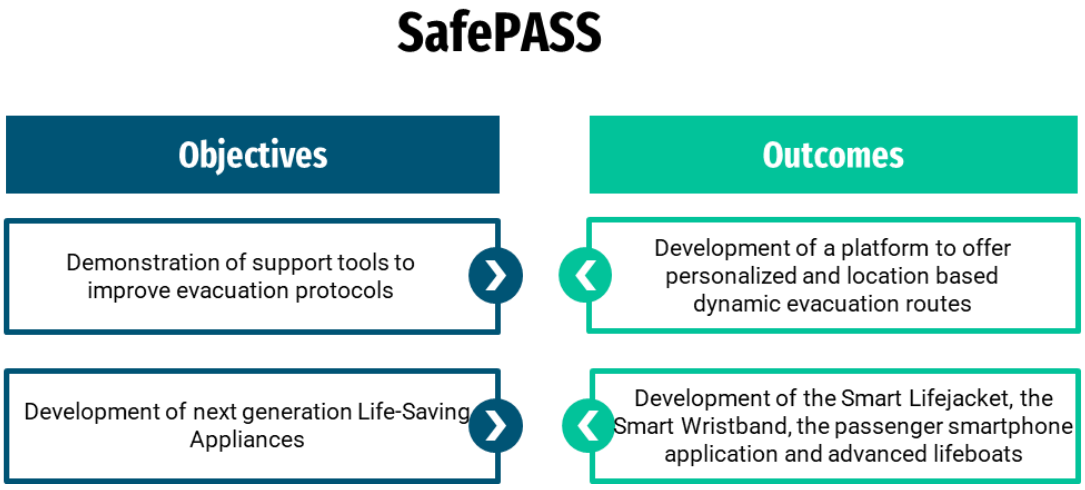

Figure 3-46: Objectives and Outcomes of the SafePASS Project

The FLARE project aimed to provide a fast and effective response in case of flooding, thereby saving lives and reducing damage to property and infrastructure[121]. The main deliverables of the project included the development of a flood warning and forecasting system, as well as a real-time monitoring system for critical infrastructure[122].

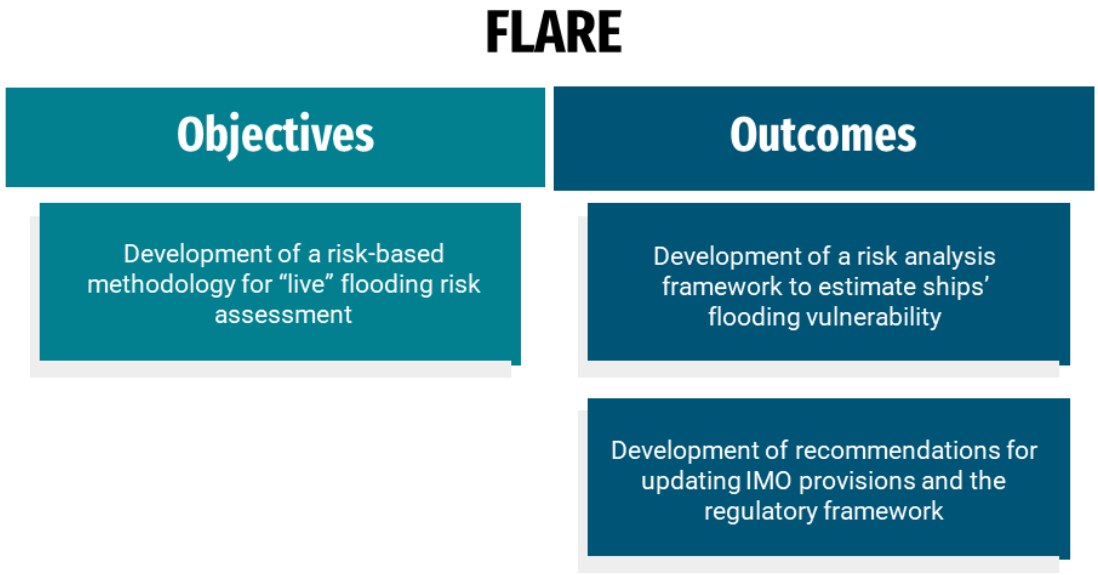

Figure 3-47: Objectives and Outcomes of the FLARE Project

[121] Waterborne TP. (n.d.). SAILING TOWARDS NEW FLOOD RISK ASSESSMENT FOR SHIPS
[122] European Commission. (2023). FLooding Accident REsponse

The PALAEMON project aimed to develop a holistic evacuation and rescue ecosystem that integrates different technologies and systems to enhance passenger safety in the event of an emergency[123].

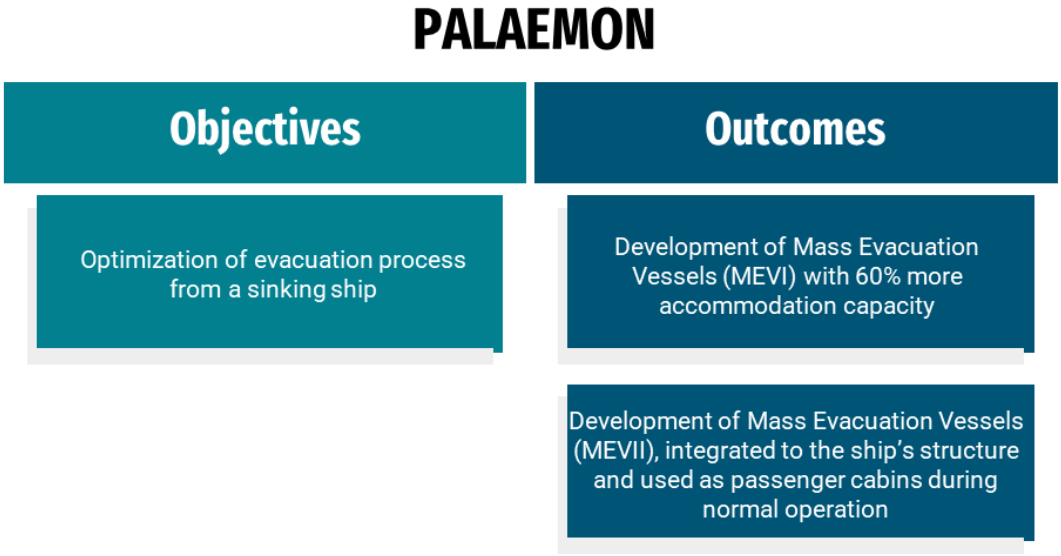

Figure 3-48: Objectives and Outcomes of the PALAEMON Project

The spyGLASS project aimed to develop a Passive Bistatic Radar (PBR) system based on Galileo transmissions for maritime surveillance. The project successfully introduced a prototype of the PBR technology, which is low-cost, completely passive, and allows covert operation. The system utilizes multiple constellations, including Galileo, for extended coverage capability and worldwide surveillance. It offers advantages over active radar systems, such as reduced size, lower energy consumption and limited environmental impact. The project demonstrated the feasibility and effectiveness of the system, eliciting positive feedback from potential end users. The final product is commercially available, with strong interest from entities involved in maritime security[124].

[123] European Commission. (2020). PALAEMON – A holistic passenger ship evacuation and rescue ecosystem
[124] European Commission. (2018). "GALILEO-BASED PASSIVE RADAR SYSTEM FOR MARITIME SURVEILLANCE"

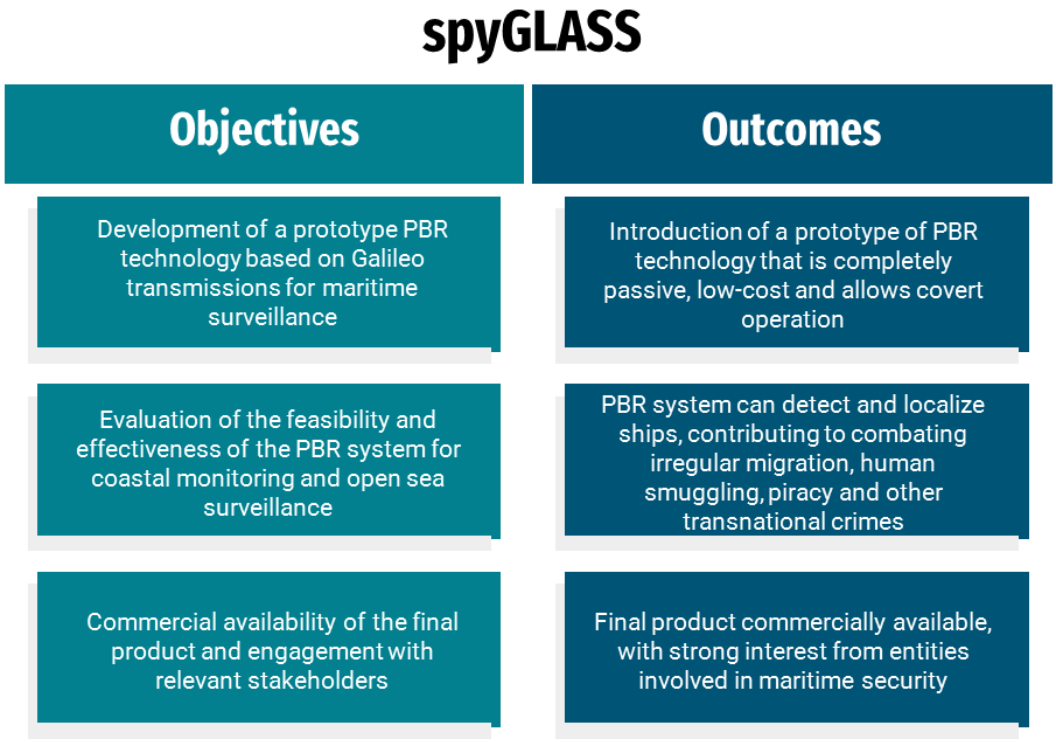

Figure 3-49: Objectives and Outcomes of the spyGLASS Project

The AnchorGuardian project aimed to address the safety concerns and environmental risks associated with anchor dragging in the maritime industry. The project successfully developed a smart device that detects anchor movement with high accuracy and provides early warning alarms. Prototypes were tested in sea trials, securing grants, patents and investor funding. The project's outcomes include the advancement of anchor technology, improved safety for sailors and ships and the potential to minimize environmental impacts and economic losses caused by anchor dragging incidents[125].

[125] European Commission. (2020). "AnchorGuardian, providing safety during anchoring by monitoring the position and absolute movement of a ships anchor."

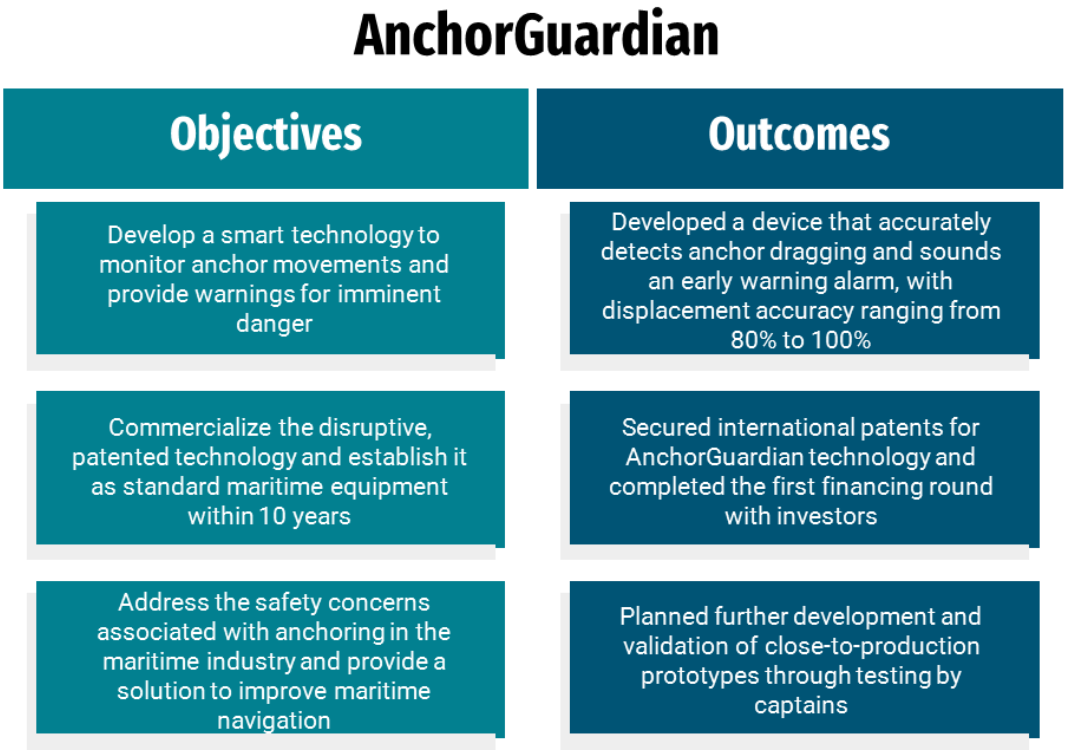

Figure 3-50: Objectives and Outcomes of the AnchorGuardian Project

3.6. GAP ANALYSIS

The H2020 Framework Programme was designed by the EC to achieve the Europe 2020 strategy for smart, sustainable and inclusive growth for the European region[126]. For its planning and implementation, the assessment and evaluation of the FP7 were taken into consideration in contemplation of creating a new FP that would bridge at a greater extent the scientific field to the industry, focus on critical challenges per designated key strategic areas and accelerate the development of groundbreaking innovations and cutting-edge technology.

Correspondingly, in July 2017 a middle-term assessment was published by Pascal Lamy, chair of the High Level Group on maximizing impact of EU R&I

[126] European Commission. (2010). EUROPE 2020 A strategy for smart, sustainable and inclusive growth

Programmes[127]. In his report, P. Lamy concluded that, considering the outcomes of the projects approved by the EC until that moment, the continuous simplification of procedures, the enhancement of creating international synergies, as well as the reinforcement of open access to all citizens were of significant importance in order to improve the generated results and accomplish a higher level of R&I.

In addition, the interim evaluation of H2020 has pointed out a few elements in need of improvement regarding the underfunding of the FP's instruments[128]. For instance, it has been noticed that due to the increased appeal of the Programme, approximately € 636 million per year were spent from applicants in order to prepare their proposals, resources that otherwise could have been invested for substantial R&I progress[129]. Moreover, the oversubscription from H2020's popularity has created an overwhelming quantity of proposals which may lead to resubmissions or even the lack of grant for high TRL-level topics.

Regarding the waterborne sector and by scrutinizing closed projects, one can easily conclude that there have been major breakthroughs towards a green transformation of the maritime industry. To illustrate, under the operational objective of Energy Efficient and zero-emission vessels, the "E-FERRY" project was completed in May 2020 and managed to develop a 100% electrical and operational car-passenger prototype, thus establishing a state-of-the-art vessel and paving the way for the complete electrification of fleets in the near future.

Despite such a success story, other waterborne transport projects have yet to deliver the expected outcome or have done so on a small scale or in a controlled environment. Numerous projects were forced to delay the demonstration of prototypes, mostly, due to the COVID-19 pandemic impact and the societal restrictions that came along.

[127] ERA PORTAL AUSTRIA. (2018). Horizon 2020 Interim Evaluation
[128] European Union Law EUR-Lex. (2018). Horizon 2020 interim evaluation: maximising the impact of EU research and innovation
[129] European Commission. (2017). IN-DEPTH INTERIM EVALUATION of HORIZON 2020

Meanwhile, other projects were successful in achieving their overall objectives, but only under certain circumstances or by the use of specific instruments not obtainable by the majority of end-users. For instance, the "EFFICIENSEA[2]" project managed to create new standards for safer and more efficient waterborne operations based on the Maritime Connectivity Platform (MCP), which up to this point enumerates no more than twenty Member States worldwide[130].

By reviewing the deliverables of the completed projects under the operational objective of Infrastructures, certain gaps have been identified in need of improvement. Despite the projects' ambitious objectives and the fact that in their majority they were fulfilled at a great extent, there are still gaps in the development and implementation of Internet of Things (IoT) technology in the port industry. Challenges such as data interoperability, security and privacy concerns need to be addressed. Furthermore, the adoption of these new technologies is also limited by the lack of awareness, training and technical expertise in port communities.

Moreover, the deliverables from these projects surfaced issues related to ports in the areas of financing, governance and regulatory frameworks. A need has been identified that projects related to Infrastructure could benefit from stronger collaboration with the financial sector, policymakers and port authorities to develop innovative financing models and regulatory frameworks. To conclude, the biggest issue that arises concerns the lack of awareness and understanding of the benefits from all the above-mentioned innovative solutions among port stakeholders, but also the necessity of more robust monitoring and evaluation frameworks that can provide accurate and reliable data on the impact of these solutions on society, economy and the environment.

In terms of gaps regarding the operational objective of Innovative Shipbuilding and Complex value-added specialized vessels, there is still a need for further research and development in ship lifecycle management and optimization. While "SHIPLYS" and

[130] Maritime Connectivity Platform. (n.d.). Maritime Connectivity Platform Consortium

“HOLISHIP” made significant progress in this area, there is still room for improvement, particularly in integrating new technologies and data sources into the ship design and operation process. In addition, the “LINCOLN” and the “NEXUS” projects both focused on developing connected vessel concepts, but further research is needed to fully realize the potential of these technologies in the maritime sector. This includes addressing concerns around cybersecurity and data privacy.

Moreover, there has been significant progress in developing new lightweight materials and production processes for shipbuilding, but further research is needed to improve the scalability and cost-effectiveness of these solutions. As for the use of hydrogen as fuel for maritime transport, there are still issues regarding the fuel availability and the existence of the necessary infrastructure to be resolved. Finally, the “NAVAIS” project highlighted the need for ongoing innovation in ship design and construction to address sustainability and environmental concerns. Continued research and development in this area will be crucial for the maritime industry to reduce its environmental impact and achieve more sustainable operations.

Regarding the operational objective of New and Improved waterborne transport concepts and due to the fact that five out of the total eleven projects have been completed, the research gaps that can be observed mainly concern further technological development and demonstration of such innovations that facilitate the implementation of the initial operational objectives. These include the development of more efficient and sustainable propulsion systems, the reduction of emissions from shipping and maritime industries and the improvement of data collection and analysis for environmental management. There is also a need for greater collaboration between academia, industry and policymakers to address these challenges and promote the development of a sustainable blue economy.

The H2020 FP has funded several projects focused on developing more sustainable and efficient waterborne transport solutions under the operational objective of Energy

efficient and zero emission vessels. By reviewing the fifteen out of twenty-nine closed projects, certain gaps for further future research could be identified.

Initially, while some of the projects touched upon the life cycle of ships, none specifically addressed the end-of-life disposal of ships. This is a significant issue in the maritime industry, as end-of-life ships can pose environmental and safety hazards if not properly disposed of. Furthermore, many of the projects focused on improving the efficiency and sustainability of ships, but did not address how ships can be integrated with other modes of transport to create a more efficient and sustainable overall transportation system. Last but not least, several projects have included the environmental and economic sustainability of the maritime industry in their objectives, but there have been few references to issues related to social sustainability, such as labor rights and working conditions.

Lastly, the operational objective of Safer and more efficient waterborne operations has demonstrated significant progress in improving safety, sustainability and efficiency in the maritime industry. However, there is a need for more focus on the human element of maritime operations, including training and education for seafarers, as well as the development of technologies and processes to improve their safety and well-being at sea. While some projects have addressed this issue, more needs to be done to ensure that the human element is fully integrated into the design and operation of maritime systems and processes, especially since the majority of the deliverables rely on digitalization and innovative new technologies that require specialized knowledge and training.

In comparison to FP7, H2020 demonstrates an increase regarding the awareness level of European citizens related to R&I. However, there is still the need for greater outreach to members of the community aiming to orient research towards the actual needs of the markets. Consumers and end-users are the instruments that shape the model of demand and their more active participation in the programming and the implementation of the

FP will assist to adopt a more mission-focused approach. In addition, waterborne transport is the most eligible means of freight transportation and as climate change increasingly affects humanity, it is deemed imperative that all contracting parties contribute to the decarbonization of the industry.

To sum up, the main research gaps that can be distinguished from the results of the completed projects so far, initially, regard the need for increased coordination and collaboration between different stakeholders in the maritime industry, including ship owners, operators, ports and regulators. While some projects have made progress in this area, more needs to be done to ensure that all stakeholders are working together towards common goals.

Another gap is the need for more research and development in the areas of autonomous and unmanned vessels. While several projects have focused on this area, there is still a long way to go in terms of developing the technology and regulatory frameworks necessary for widespread adoption.

There is also a need for more emphasis on the use of renewable energy sources in the maritime industry. While some projects have explored this area, more needs to be done to develop practical and cost-effective solutions for reducing GHG emissions and other environmental impacts.

CHAPTER 4: HORIZON EUROPE

This chapter will demonstrate an overview of the research statements under Horizon Europe (HEU), which is the 9th EU's Framework Programme for Research and Innovation for the period 2021-2027, with a budget of approximately € 95,5 billion and the successor to the 8th Horizon 2020 Framework Programme (2014 - 2020)[131]. The overview will be conducted on the open topics and funded projects of the HEU until January 2023, emphasizing in the specific agenda for Zero Emission Waterborne Transport and contemplates to identify potential gaps in the existing state of research statements in correlation to the EGD's objectives. Such a gap assessment shall be useful in the design of the following Work Programmes (WP) of HEU for the period 2025-2027.

4.1. STRATEGIC PRIORITIES

In general, the strategic plan contemplates to ensure an effective interface between EU policy priorities, and Programme activities and, eventually, the research and innovation projects funded by HEU. The objective is to encourage research and innovation investments in order to address the challenges that society is facing, and, above all, deliver results.

Regarding the European waterborne sector, the missions that have been designed focus on the transformation of waterborne transport, blue growth activities and the integration of shipping and inland navigation into seamless port and logistics operations[132].

Subsequently, waterborne stakeholders have set out three fundamental priorities, which are thoroughly analyzed below.

[131] European Commission. (2020). Horizon Europe
[132] Waterborne TP, (2021). Strategic Research and Innovation Agenda for the European Waterborne Sector Executive Summary

4.1.1. THE SUSTAINABLE TRANSFORMATION OF EUROPEAN WATERBORNE TRANSPORT

The first priority that the waterborne stakeholders have set out is the transition of waterborne transport into a more secure and greener mode of transport, while considering all economic, ecologic and social aspects of sustainability. Therefore, their intention is to eliminate, as far as possible, harmful environmental emissions, water pollution and noise emissions with the least possible consequences regarding accidents and loss of life. Under HEU, and in order to achieve these objectives, the sector proposed to establish the co-Programmed Partnership Zero-Emission Waterborne Transport (cPP-ZEWT) and has embraced a new approach to risks leading towards a Zero-Accident Waterborne Industry (TZAWI).

In addition, digitalization is a key component in order to improve operations, safety and the energy-efficiency of waterborne transport. By adapting to system integration and to the application of new products and business models, the data flows will improve resulting to a more connected and automated waterborne transport system. The transformation of waterborne transport will require safe, competitive and eco-friendly shipyards and production sites along the entire production chain.

4.1.2. DEVELOPING EUROPEAN LEADERSHIP, NEW BUSINESS MODELS AND PARADIGMS FOR THE BLUE GROWTH SECTORS

In contemplation of increasing social awareness, the waterborne sector aspires to comprehend the waterborne environment, namely oceans, seas and inland waters, by interacting closely with civil society and not solely from a scientific perspective.

In order to facilitate the sustainable exploration and exploitation of waterborne natural resources, the waterborne sector will contribute to the development of sustainable technologies and systems, hence assisting to the decarbonization process. This

contribution will be better achieved by constant monitoring and digitalization, as it shall provide a new paradigm for marine research, operating as an enabler for integrating new and existing technologies.

At the same time, and aiming at the envisaged transition to a sustainable economy based on Blue Growth, it is expected to promote the safety, security and protection of human activity in the waterborne environment, by incorporating innovative technologies, which will facilitate human lives and activities.

4.1.3. INTEGRATING SHIPPING AND INLAND NAVIGATION INTO SEAMLESS PORTS AND LOGISTICS OPERATIONS

Waterborne transport is widespread due to its potential for large-scale freight transportation, and therefore, is estimated to face a tremendous increase in global trade, especially considering the impact of the COVID-19 pandemic. To the extent of supporting this increase in global trade, there is a need for adequate infrastructure to address congestion in ports and other probable challenges that may hamper their potential development.

Digitization will also be a crucial factor in the modernization of port infrastructure, so that they can meet the demands of increased traffic in maritime and hinterland transport. The transition towards zero emission ports is considered to be demanding, and in order to adapt to new business models for waterborne transport, greater emphasis should be placed upon the integration of inland ports in transport and logistics supply chains.

4.2. STRATEGIC RESEARCH AND INNOVATION AGENDA

Aiming at the most efficient achievement of the envisaged objectives, the waterborne sector has established a Strategic Research and Innovation Agenda (SRIA) which is

divided in three main areas regarding Ships and Shipping, Blue Growth along with Ports and Logistics.

This categorization favors the adequate distribution of resources per research area, with the aim of more efficient specialization and the production of more immediate and excelling results.

4.2.1. SHIPS AND SHIPPING

The future of ships' manufacturing lies towards a Zero-Accident Waterborne Industry. Their design intends to make of full use of the newest digital technologies, in order to expand their life circle, enhance their operations and designate them safer for use. Of primary importance are the ships in which the European maritime technology sector specializes, such as high-sea cruise ships, yachts, passenger and cargo short-sea vessels, river-cruising and inland-waterway vessels, research, off-shore and blue economy specialized vessels[133]. By using innovative digitization technologies, smart ships and vessels will be able to communicate with each other, as well as with smart ports and infrastructures. These developments in the shipbuilding sector will facilitate the transition into a more autonomous era regarding ship operations, maritime and inland navigation, along with remote control of the vessels.

Automation on ships is deemed imperative, as it will allow ships to perform a part of their operations without human interference either for a specific amount of time during a voyage or for the entire duration of it. Procedures such as gathering autonomously information and data from its surroundings or moving cargo off the road and onto the sea without the involvement of any human factor, may, in due time, result in lowering maintenance costs, improving port congestion and eventually reducing carbon emissions while increasing security and safety.

[133] Waterborne TP, (2021). Strategic Research and Innovation Agenda for the European Waterborne Sector Ships & Shipbuilding

These developments will maximize cost-efficiency and cultivate competitiveness, in an attempt to, ultimately, facilitate system integration and information between different stakeholders and professionals. Ships and the entire shipping industry will be able to transition into a more sustainable era, while exploiting opportunities for the development of methods which will decrease possible displeasing activities.

This particular strategy aspires to diminish accidents occurring during waterborne transport operations. In pursuance of accomplishing that, the need arises for the creation of new systems that will be able to cope with the new conditions and face any challenges that may emerge on board.

4.2.2. BLUE GROWTH

The EC defines Blue Growth as "*the long term strategy to support sustainable growth in the marine and maritime sectors as a whole*"[134]. Blue Growth's strategic agenda engages in carbon-neutrality and uses the digitalization of seas and oceans towards managing marine resources in a more sustainable manner, without excluding activities related to inland waterways and lakes[135].

In addition to the above, Blue Growth's ambition is to cultivate sustainable blue economies at sea, primarily by devoting effort into activities addressing CO_2 neutrality of seas and oceans, for instance research in the fields of Ocean energy, Carbon Capture and Storage (CCS) and CO_2 conversion. The strategy will also involve the Maritime Spatial Planning (MSPs), with the expectation to present sustainable solutions regarding offshore platforms and sites, aquaculture installations and deep-sea mining. Through continuous monitoring and the exploitation of new digital innovations, this

[134] European Commission, (n.d.). Blue Growth Supporting sustainable growth of the marine and maritime sectors
[135] Waterborne TP, (2021). Strategic Research and Innovation Agenda for the European Waterborne Sector Blue Growth

strategic agenda contemplates to convert into Marine robotics and engage in perceptions of Digital Ocean and Intelligent sensors.

4.2.3. PORTS AND LOGISTICS

The strategic activities related to the Ports and Logistics agenda focus on establishing zero emission port areas by facilitating flexible bunkering and generating more climate-resilient waterborne and port infrastructures[136]. In order to fulfill the above-mentioned strategic objectives, it is crucial to optimize and exploit digitalization processes which can also result in immense accomplishments in the fields of automation and robotization. Thereby, the integration of ports will be achieved seamlessly, resulting to the optimization of the entire waterborne transport sector.

4.3. OPERATIONAL OBJECTIVES

The cPP-ZEWT operates within the framework of HEU. Its main goal is to deliver and showcase zero-emission solutions for all major ship types and services by the year 2030. This aims to support the broader operational objective of achieving zero-emission waterborne transport by 2050[137].

The Partnership has set several specific objectives regarding aspects of the scientific, economic and social dimension of the waterborne sector.

The Partnership has a clear scientific goal to accomplish before 2030, which involves developing technological advancements that will enable the decarbonization and elimination of harmful emissions associated with specific ship types and services.

[136] Waterborne TP, (2021). Strategic Research and Innovation Agenda for the European Waterborne Sector Ports & Logistics
[137] Waterborne TP, (2021). Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport

Moreover, the Partnership has a specific economic aim to accomplish before 2030, which involves integrating the aforementioned technological advancements into the broader European region in a financially sustainable manner.

The specific societal objectives of the Partnership, primarily, concern the creation and establishment of policies and regulations at national and international level, which will institute and ensure the technological innovations that will have been developed regarding achieving waterborne transport without any emissions by the year 2030, at the latest. At the same time, the Partnership intends to assist the progress of the adaptation of state-of-the-art zero-emission waterborne transport technologies and solutions within the European waterborne sector, while supporting economic growth and employment.

The specific objectives have been divided into a set of operational objectives focused on eliminating GHG emissions, air pollution and water pollution.

4.3.1. ELIMINATION OF GHG EMISSIONS

The operational objectives that focus on the elimination of GHG emissions primarily aim to cultivate alternative and sustainable fuels for ships to use, which will produce lesser emissions, especially when it comes to ships that have a high energy demand, such as in long-distance shipping. Moreover, they aspire to resolve issues concerning high-capacity batteries which are used as a single energy source at short-sea shipping and affect in a tremendous way environmentally sensitive areas. Another objective is to fortify port infrastructures in order to provide solutions concerning bunkering issues by using alternative fuels and electricity.

All of the above-mentioned objectives intend to reduce GHG emissions by the end of 2030 by at least 55%, either by developing new technological innovations regarding

ship building or by exploiting alternative sources of energy for usage of fuels and sustainable ship mobility.

It is believed that a transition from the use of fossil fuels into using alternative ones is the fundamental operation in order to achieve a zero-emission mode of transport. Therefore, the Partnership is committed not only to develop a new line of innovative and sustainable alternative fuels, but also to ensure that these new fuels will be established and used properly by the maritime industry. This encompasses the safe storage and utilization of these fuels on ships, as well as the conversion of the fuel into usable energy using fuel cells, turbines or advanced internal combustion engines.

But the real challenge in this fuel transition is to assimilate all new technologies not only at the newbuilds, but especially in the integration of it into the existing ones. The safe adaptation of new fuel technologies on board of vessels that have been built with completely different systems entails risks of overhauling the vessel and causing excessive downtime. Therefore, the need arises to develop modular approaches, which will be cultivated by the Activity on Design and Retrofitting.

New innovative technologies, however, equate to more expensive products which require special treatment and handling. Therefore, the operational objective of the elimination of GHG emissions requires the formation of an Activity on Energy Efficiency whose primarily duty is to provide solutions for a seamless adaptation of these innovations by the shipping industry.

The new sustainable fuels are expected to take up more space on board, and therefore, the Energy Efficiency activity is called upon to face this challenge. Their work revolves around finding ways to reduce fuel consumption, hence free up space on board, so that the cargo load wouldn’t have to be decreased or the sailing range wouldn’t be limited. In other words, the required amount of energy from fuels should be diminished, in order to facilitate the market uptake of alternative fuels.

The Activity on Ports plays an important role in achieving this objective, as the safe bunkering of sustainable alternative fuels is critical in establishing these fuels onboard.

The second operational objective regarding the elimination of GHG emissions is the Electrification of ships. It has been noticed that transferring electricity into a fuel and carrying it onboard isn't as efficient as using electricity directly from a renewable source. If, however, we consider the total amount of power that is needed on ships, the usage of batteries or any other electricity storage is not sufficient enough to serve long-distance shipping, rather for shorter ranges from 150 to 200 nautical mile, for instance. Regarding long-distance shipping, it is estimated to use electrification as an auxiliary power source. As a result, this could enhance the efficiency of utilizing alternative fuels by providing electricity to meet a portion of the onboard power requirements.

The fundamental challenge that electrification of shipping faces regarding the use of alternative fuels lies in the adaptation of new technologies onboard both on newbuilds and existing vessels. Newbuilds' power train will be replaced from the conventional direct mechanical drive systems into an electrical drive. The electrical drive systems provide higher efficiency through higher controllability and dynamic performance. Minimizing the use of high-density batteries alongside inflammable alternative fuels may prevent possible accidents and increase safety on board. On the other hand, existing vessels will require modular set-ups in order to retrofit with electrical auxiliary power.

Moving forward, the third operational objective is related to the increase of Energy Efficiency. In other words, the more efficient the energy used by ships is, the less of it will be required for their mobility, and therefore bringing us closer to the initial objective of a zero-emission waterborne sector. This particular operational objective can be accomplished, primarily, from switching to alternative renewable energy sources, for instance wind and solar. Moreover, Energy Efficiency will address matters

related to optimizing energy distribution, implementing air lubrication, enhancing hydrodynamics, applying coatings that reduce resistance, recovering waste heat and improving thermal insulation. These efforts aim to minimize overall energy requirements.

By using digitalization and its newly accomplished innovations, the energy efficiency of ships in a fleet could be optimized, simply by extracting new data and applying big-data analysis via the Activity of Digital Green. Such processes will enable on board crew and onshore operations' departments stuff to better foresee and manage the energy performance of vessels, and therefore take actions that will reduce emissions.

Furthermore, the fourth operational objective is related to the Ports Activity, which aspires to enable safer and more efficient bunkering of the new designed alternative fuels and to contribute to a more effective way in charging of high-power batteries.

Subsequently, the fifth operational objective for the diminution of GHG emissions is associated with establishing cleaner and more climate resilient inland waterway vessels, by using some of the technologies that already apply to sea-going vessels. However, inland waterway vessels are characterized by a long lifetime, therefore the need arises for more economically viable solutions regarding their retrofitting. The most promising way of achieving that is through the electrification of the fleet, for instance by using containerized or exchangeable battery packs, since they operate in a relatively short range. Given their high life expectancy and the nature of their routes (shallow water routes, constant maneuvering, etc.), inland waterway vessels face many challenges in adapting to a greener and more sustainable way of operating.

4.3.2. ELIMINATION OF AIR POLLUTION

The operational objective related to reducing air pollution in waterborne transport concentrates on significantly reducing coastal and inland air pollution caused by inland

waterway transport and the maritime industry. The aim is to achieve a minimum 50% reduction in air pollution levels by 2030, compared to the current levels.

In order to achieve this operational objective, the Activity on the use of Sustainable Alternative Fuels (SAF) was designed, with the duty to compose hydrogen-based solutions which will eradicate air pollution. Initially, they envisage to transform coastal ships into vessels that operate entirely in an electrical manner. As far as larger vessels are concerned, they intend to use batteries as auxiliary power or fuel cells in order to enable electrical sailing into ports or around pristine areas, which will result in an optimal use of hybrid power generation systems and eventually at energy saving. Finally, inland vessels will be battery electrified or will operate on fuel cells based on hydrogen, in contemplation of eliminating any negative effects on air quality in cities along rivers.

In the meantime, the Activity on Energy Efficiency intends to extend the range of electrical sail for terms of minimizing air pollution by reducing the energy required for the operation of the vessel. For existing vessels, it is anticipated to develop new innovations which will allow the transition to a greener and more sustainable era, using processes that, for example, include clean combustion engines or after-treatment systems.

4.3.3. ELIMINATION OF WATER POLLUTION

The operational objective related to the elimination of water pollution is to minimize any form of pollution, including underwater noise that the ships and the shipping industry are producing during their operations by the year 2030.

Beneficial to achieving this operational objective, the Activity on the use of Sustainable Alternative Fuels will concentrate on producing fuel cells that do not contain lubricants, contributing this way to the elimination of chemical emissions. The Activity of

Electrification will be contributing by developing groundbreaking innovations and technologies that can reduce the noise produced by the ships' engines, and therefore, minimize underwater noises. To elaborate, fully electrified smaller ships do not contain noisy internal combustion engines. As for larger electrified vessels, it is possible to operate the internal combustion engines at lower power requirements through the use of auxiliary power or even completely shut them down in maritime environmentally sensitive areas, while still maintaining the desired operational sailing speeds.

An additional aspect that can significantly contribute to the elimination of water pollution is the pursuit of innovations in new propulsion systems. This approach not only enhances energy efficiency but also effectively reduces noise levels, further aiding in the overall objective. In addition, optimization of air lubrication is examined, taking into consideration noise criteria, in order to minimize the release of harmful chemicals into the water and decrease resistance.

In conclusion, as with all new technological advances, so in this case the challenge is the seamless integration of these innovations into both existing and newbuild vessels. In addition to reducing noise pollution and air lubrication, there is an urgent need to develop new procedures that will, in effect, allow the removal of pollution from scrubbers.

4.4. RESEARCH STATEMENTS

Recent studies show that the transport accounts for approximately 23% of CO_2 emissions and still relies on oil for 92% of its energy requirements[138]. Despite the fact that technology has developed radically in recent decades, the increase in transport demand does not favor the reduction of GHG emissions. For this reason, there is an urgent need to fund research, with the aim of developing new technologies that will

[138] International Transport Forum, (2018). How Transport CO_2 Reduction Pledges Fall Short

help reduce emissions and consequently protect the environment, always taking into consideration to optimize the human standard of living.

HEU consists of a Destination regarding its research statements, which aims to propel Europe as the pioneering digitally empowered circular, climate-neutral and sustainable economy. This vision can be realized by transitioning mobility, energy, construction and production systems into a new era of sustainability. Additionally, it involves promoting open strategic autonomy through emerging digital technologies, sectors and value chains, with a focus on human-centered technologies and innovations to drive the green transitions.

The expected impact, according to the EC, is to contribute "*towards climate-neutral and environmentally friendly mobility through clean solutions across all transport modes while increasing global competitiveness of the EU transport sector"*[139].

Topics covered within this Destination will address matters concerning the emergence of a sustainable and digitized era for business models, smart ports, automation in shipping, cargo-handling operations and autonomous vessels. The ultimate goal is to attain climate-neutrality and safeguard the marine environment, aligning with the cPP-SRIA for ZEWT thoroughly described in the beginning of this chapter.

The fundamental impacts to be delivered by topics regarding waterborne transport are:

- The development of climate-neutral fuels and progression in the electrification of shipping.
- The increase of overall energy efficiency and reduction of fuel consumption of vessels.
- The implementation of innovative port infrastructure.

[139] European Commission, (2021). Mobility Strategy

- To support the development of environmentally friendly and carbon-neutral inland waterway vessels before 2030, aiming at green fleet renewal.
- The technological innovations regarding the elimination of air and water pollution.
- To enhance the transition into a digitalized and autonomous era for maritime and inland shipping into the logistic chains.
- To support the growth of employment in the European region by facilitating competitive waterborne industries into green and digital innovators[140].

4.4.1. TOPICS AND PROJECTS 2021-2022

The topics for the period 2021 - 2022 can be divided into six main sub-headings which deal, for the most part, with issues related to the use of Sustainable Alternative Fuels, Electrification, Energy Efficiency, Design and Retrofitting, Digital Green and Ports. Overall, twenty eight projects have been granted regarding the waterborne sector with a total cost of € 230 million of which approximately € 190,2 million are EU-funded. To demonstrate, a comprehensive analysis of the projects' costs as well as the EU's financial contribution are presented in the chart below.

[140] European Commission, (2022). "Horizon Europe Work Programme 2021-2022"

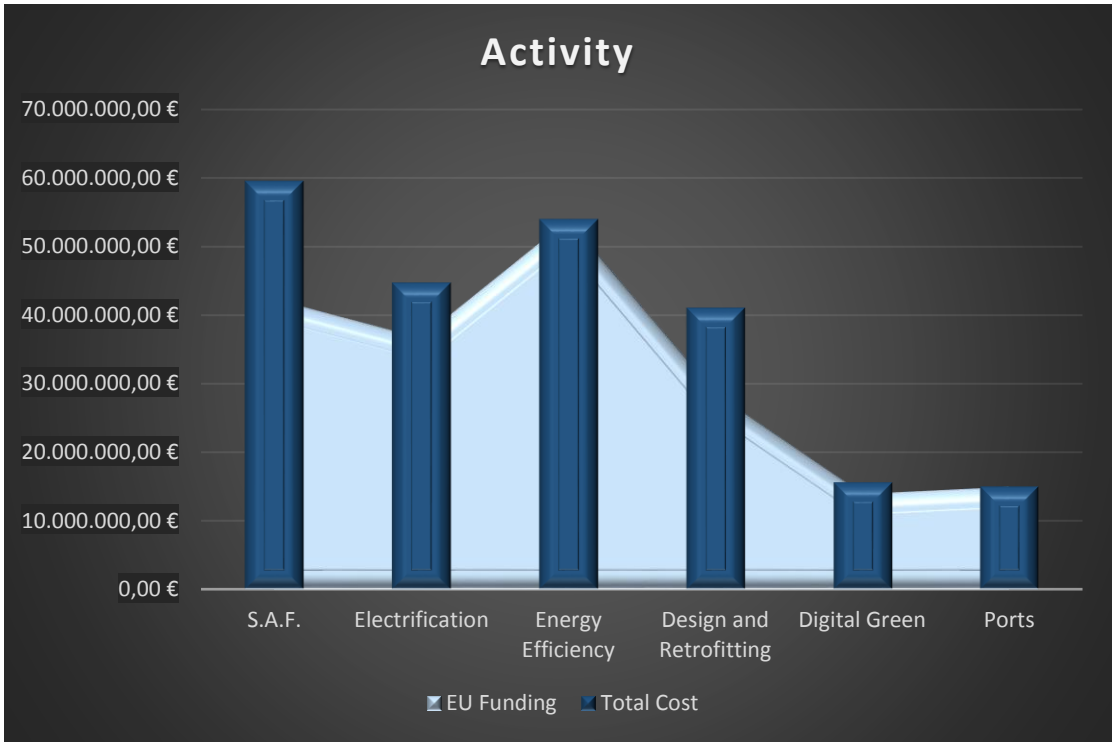

Figure 4-1: Budget Allocation for HEU projects per Activity

4.4.1.1. USE OF SUSTAINABLE ALTERNATIVE FUELS

Initially, topics under the Activity of SAF aspire to primarily replace the traditional and so far used fuels for ships' operations with alternative ones, therefore reducing GHG emissions. Four topics were proposed by the cPP-ZEWT in coordination with the EC to deal with the matter of decarbonizing the waterborne transport sector.

In further detail, these topics concentrate on developing innovative alternative fuels which will apply to ships with high energy demand, such as ships used in long distance shipping, as well as inland waterway vessels. Moreover, attention has befallen into resolving the effect of ships in water pollution, mainly by causing excessive underwater noise from the use of obsolete turbines and combustion engines.

The short-term goal is to achieve the above mentioned by the year 2030 with a demonstration of systems fit for purpose in operations. For this reason, these topics have access to a budget of approximately € 42,3 million and are classified as a high priority compared to the rest for their implementation and planning of the topics for the next period 2023-2024. The following figure presents a comprehensive roadmap towards achieving the climate-neutrality through the Activity of S.A.F.

The following table demonstrates in detail the individual topics and projects under the Activity of SAF.

Table 4-1: Overview of Topics and Projects under the Activity of Sustainable Alternative Fuels

The Activity of Sustainable Alternative Fuels				
Topics	**Projects**	**EU Funding**	**Total Cost**	**Duration**
		42.296.600,20 €	59.468.095,25 €	
Enabling the safe and efficient on-board storage and integration within ships of large quantities of ammonia and hydrogen fuels		17.118.716,45 €	27.158.202,75 €	
	NH3CRAFT	8.497.104,00 €	12.862.888,75 €	01/06/2022-31/05/2025
	sHYpS	8.621.612,45 €	14.295.314,00 €	01/06/2022-31/05/2026
Enabling the full integration of very high power fuel cells in ship design using co-generation and combined cycle solutions for increased efficiency with multiple fuels		14.866.244,50 €	15.670.245,00 €	
	HELENUS	14.866.244,50 €	15.670.245,00 €	01/06/2022-30/06/2027
CSA identifying waterborne sustainable fuel deployment scenarios		523.437,00 €	523.437,50 €	

	NEEDS	523.437,00 €	523.437,50 €	01/05/2022-31/10/2023
Proving the feasibility of a large clean ammonia marine engine		9.788.202,25 €	16.116.210,00 €	
	Ammonia2-4	9.788.202,25 €	16.116.210,00 €	01/05/2022-30/04/2026

4.4.1.2. ELECTRIFICATION

In addition, topics under the area of Electrification anticipate to resolve issues where the use of alternative fuels is not achievable. Due to the long-life expectancy of a ship, some vessels do not qualify to be altered and use more sustainable fuels, or in some cases, such thing is achievable, but the cost in order to produce such a result is excessive.

There are three topics concerning Electrification with an estimated budget of approximately € 45 million. These topics will attempt to utilize electrical energy storage systems and maximize the use of large battery electric power in fully battery electric and hybrid ships. Additionally, emphasis will be given into developing a system for hyper powered vessel battery charging and the applications of electric energy storage systems in the waterborne sector.

The short-term goal is to achieve all the above mentioned by the year 2030 in addition to designing innovative port infrastructure which will be able to support fully electrified newbuild ships and the modifications that the old vessels have undergone.

The following table demonstrates in detail the individual topics and projects under the Activity of Electrification.

Table 4-2: Overview of Topics and Projects under the Activity of Electrification

The Activity of Electrification				
Topics	**Projects**	**EU Funding**	**Total Cost**	**Duration**
		36.597.720,96 €	44.669.457,46 €	
Hyper powered vessel battery charging system		6.657.528,00 €	9.350.775,00 €	
	HYPOBATT	6.657.528,00 €	9.350.775,00 €	01/06/2022-30/11/2025
Exploiting electrical energy storage systems and better optimising large battery electric power within fully battery electric and hybrid ships		15.721.936,25 €	21.100.425,75 €	
	NEMOSHIP	7.870.268,00 €	11.284.796,00 €	01/01/2023-31/12/2026
	FLEXSHIP	7.851.668,25 €	9.815.629,75 €	01/01/2023-31/12/2026
Innovative energy storage systems on-board vessels		14.218.256,71 €	14.218.256,71 €	
	POSEIDON	4.993.106,96 €	4.993.106,96 €	01/01/2023-31/12/2026
	AENEAS	4.987.277,25 €	4.987.277,25 €	01/02/2023-31/01/2026
	V-ACCESS	4.237.872,50 €	4.237.872,50 €	01/02/2023-31/01/2026

4.4.1.3. ENERGY EFFICIENCY

Furthermore, topics under the Activity of Energy Efficiency concern a complete reconfiguration of vessels' architecture and the design of ships that will be requiring less power to operate by exploiting alternative renewable systems, such as wind powered. In collaboration with topics under the area of Electrification and Digital Green, it is expected to provide renewable and free energy solutions for reducing the need of fuel consumption during a voyage and unessential on board fuel storage space.

The short-term goal is to provide solutions for reducing the energy needs and access alternative renewable free energy sources. Ultimately, these topics intend to optimize the vessels' operations and utterly derive ships' design in order to adapt to a new zero-emission era for the waterborne transport sector. There are three topics regarding Energy Efficiency with an estimated budget of € 54 million, which represents 24% of the total budget provided to cPP-ZEWT partnership for topics regarding the waterborne sector.

The following table demonstrates in detail the individual topics and projects under the Activity of Energy Efficiency.

Table 4-3: Overview of Topics and Projects under the Activity of Energy Efficiency

The Activity of Energy Efficiency				
Topics	**Projects**	**EU Funding**	**Total Cost**	**Duration**
		53.828.022,25 €	53.896.780,00 €	
Enabling the full integration of very high power fuel cells in ship design, using co-generation and combined cycle solutions for increased efficiency with multiple fuels		14.999.509,00 €	14.999.513,25 €	
	SHIP-AH2OY	14.999.509,00 €	14.999.513,25 €	01/01/2023-31/12/2027
Innovative on-board energy saving solutions		13.778.524,25 €	13.778.526,25 €	
	ZHENIT	4.384.488,25 €	4.384.488,75 €	01/06/2022-30/11/2025
	OPTIWISE	4.660.337,00 €	4.660.337,50 €	01/06/2022-31/05/2025
	HEMOS	4.733.699,00 €	4.733.700,00 €	01/05/2022-30/04/2025
Exploiting renewable energy for shipping, in particular focusing on the potential of wind energy		17.981.460,50 €	18.050.210,50 €	

	Orcelle	8.989.977,50 €	9.058.727,50 €	01/01/2023-31/12/2027
	WHISPER	8.991.483,00 €	8.991.483,00 €	01/01/2023-31/12/2026
Innovative on-board energy saving solutions		7.068.528,50 €	7.068.530,00 €	
	RESHIP	3.758.912,50 €	3.758.912,50 €	01/09/2022-31/08/2025
	CoPropel	3.309.616,00 €	3.309.617,50 €	01/06/2022-31/05/2025

4.4.1.4. DESIGN AND RETROFITTING

Similarly, the Activity of Design and Retrofitting consists of topics that focus on the implementation of procedures for green designing, manufacturing and retrofitting of the existing fleet and newbuild vessels.

Topics under this activity emphasize on new design approaches that will integrate the most recent technologies in safe clean and cost-effective ship solutions. Furthermore, it relates to innovating methods regarding new green systems that can replace the existing ones, but also to procedures of modular ship architectures that will ensure low-cost retrofitting for reducing emissions throughout a ship's life cycle.

The short-term objective is to address the methane slip issue, to provide refitting solutions for energy efficiency ships, to update the existing design methodologies into new more flexible and integrated ones in order to achieve a smooth transition into the use of alternative fuels and the adaptation of eco-sustainable manufacturing approaches towards green shipping by 2030.

The following table demonstrates in detail the individual topics and projects under the Activity of Design and Retrofitting.

Table 4-4: Overview of Topics and Projects under the Activity of Design and Retrofitting

The Activity of Design and Retrofitting				
Topics	**Projects**	**EU Funding**	**Total Cost**	**Duration**
		28.571.297,78 €	41.026.250,08 €	
Transformation of the existing fleer towards greener operations through retroffiting		21.598.175,28 €	30.517.427,78 €	
	HyEkoTank	5.092.999,00 €	8.342.499,75 €	01/02/2023-31/01/2026
	SYNERGETICS	4.184.312,03 €	5.321.955,05 €	01/01/2023-30/06/2026
	Apollo	4.999.999,25 €	7.314.447,98 €	01/01/2023-31/12/2025
	RETROFIT55	4.109.030,00 €	5.626.300,00 €	01/01/2023-31/12/2025
	GreenMarine	3.211.835,00 €	3.912.225,00 €	01/02/2023-31/12/2027
Assessing and preventing methane slip from LNG engines in all conditions within both existing and new vessels		6.973.122,50 €	10.508.822,30 €	
	GREEN RAY	6.973.122,50 €	10.508.822,30 €	01/06/2022-31/05/2027

4.4.1.5. DIGITAL GREEN

Moreover, the Activity of Digital Green consists of two topics regarding digital twin models as well as the development of innovative computational tools for application in shipbuilding, in order to enable green ship operations with an estimated budget of € 15,5 million.

To illustrate, the Digital Green Activity aspires to use digitalization in contemplation of improving ship and infrastructures' efficiency and reducing emissions. The development of any digital twin model can facilitate the monitoring and collection of data and provide alternative solutions without resorting to any physical testing activity. Therefore, energy efficiency is expected to be improved throughout all stages of a

vessel's life cycle. Any upgrades or modifications needed will be discovered at an early stage so the vessel's performance will immediately be corrected and increased.

The following table demonstrates in detail the individual topics and projects under the Activity of Digital Green.

Table 4-5: Overview of Topics and Projects under the Activity of Digital Green

The Activity of Digital Green				
Topics	**Projects**	**EU Funding**	**Total Cost**	**Duration**
		13.979.532,50 €	15.578.000,50 €	
Digital Twin models to enable green ship operations		6.987.331,00 €	6.987.333,00 €	
	DT4GS	6.987.331,00 €	6.987.333,00 €	01/06/2022-31/05/2025
Computational tools for shipbuilding		6.992.201,50 €	8.590.667,50 €	
	SEUS	6.992.201,50 €	8.590.667,50 €	01/01/2023-31/12/2026

4.4.1.6. PORTS

Last but not least, the Ports' Activity, primarily attended to a topic of a € 15 million budget contemplating to address issues concerning infrastructure for bunkering of alternative fuels at maritime ports, the supply of electricity to vessels, in addition to demonstrate solutions on reducing air and water pollution, mainly, from inland waterway and maritime transport.

This topic's short-term objective is to develop a zero-emission and climate-resilient port model by the year 2030. Ports are considered to be the major hubs that connect maritime transport to hinterland and are the checkpoints of linking the entire logistics network to the consumers. Therefore, their transition into a zero-emission infrastructure should be carefully designed and tend to, not only, resolve emerging problems caused

by the new innovative technologies, but to also address preexisting issues, such as port congestion.

Such an undertaking, however, would presuppose the existence of such innovations in the field of sustainable alternative fuels and the electrification of ships. Therefore, along the way the partnership decided to primarily prioritize and fund topics related to the Activities of SAF and Electrification for the period of 2021-2022 and mark as high-priority port-related topics for the period of 2023-2024.

The following table demonstrates in detail the project under the Activity of Ports.

Table 4-6: Overview of Topics and Projects under the Activity of Ports

The Activity of Ports				
Topics	**Projects**	**EU Funding**	**Total Cost**	**Duration**
		14.968.315,00 €	14.968.315,00 €	
Seamless safe logistics through an autonomous waterborne freight feeder loop service		14.968.315,00 €	14.968.315,00 €	
	SEAMLESS	14.968.315,00 €	14.968.315,00 €	01/01/2023-31/12/2026

All things considered, EU has set incredibly ambitious goals towards achieving climate neutrality in the European region and is eager to finance R&I attempts in order to facilitate the transition towards a greener waterborne sector. Each of the above mentioned projects has set specific individual objectives and aspires to deliver successful outcomes that will contribute at the overall operational objectives. To elaborate, the following chart demonstrates the total number of the granted projects under HEU since its launch towards zero emission waterborne transport in correlation with the EU's financial contribution they have received and according to the operational objective they intend to resolve. The bubble size indicates the total cost of each project.

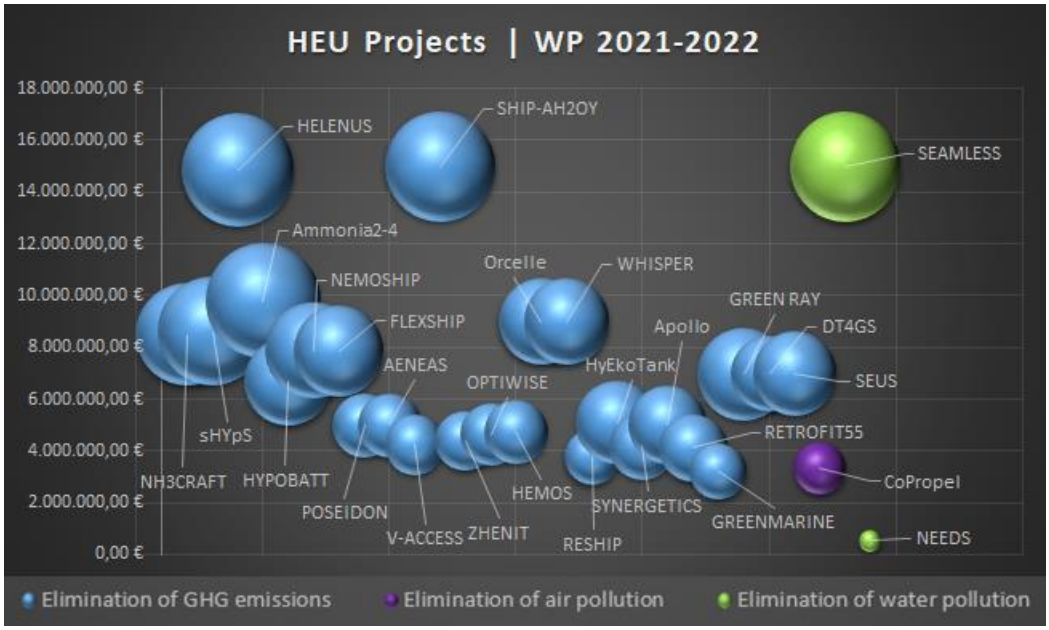

Figure 4-2: Correlation between HEU Projects, budget allocation and expected outcomes per Operational Objective

4.4.2. OPEN TOPICS 2023-2024

The open topics for 2023-2024 follow a similar categorization to the topics presented for the period 2021-2022. Their goal is to strengthen the efforts of the topics that are already running for the period 2021-2022, to provide specialized solutions to any issues that still remain unresolved and to, ultimately, establish the maritime industry a zero-emission sector by the year 2050.

The orientations for the period 2023-2024 consist of thirteen topics in need of further development towards achieving EGD's primarily objectives. Those topics are expected to receive an estimated budget of more than € 150 million which will be distributed according to the needs of each topic in nearly twenty projects.

4.4.2.1. USE OF SUSTAINABLE ALTERNATIVE FUELS

The activity of SAF is projected to receive funding of around € 50 million to tackle challenges related to power conversion technologies for sustainable alternative carbon-neutral fuels and their safe utilization in real-world scenarios.

The objective is to generate new technologies which will convert existing ships into zero-emission units, while at the same time creating a next-generation fleet that will operate solely on eco-friendly and sustainable fuels or other alternative energy sources.

The real challenge is to integrate these new technologies in real-time conditions through a seamless transition without causing any negative societal and economic effects. Operations involved in this transition, such as storage, bunkering and on-board handling, should be thoroughly tested before integrating new innovations across the maritime industry and make sure that the actual performance of the systems is in line with the required objectives.

The table below shows the topics under the use of SAF Activity in correlation with an indicative budget allocation and number of projects per topic.

Table 4-7: Overview of Open Topics under the Activity of Sustainable Alternative Fuels

The Activity of Sustainable Alternative Fuels				
Topics	**Indicative number of projects expected to be funded**	**Expected EU contribution per project**	**Indicative budget**	**Duration**
Demonstration to accelerate the switch to safe use of new sustainable climate neutral fuels in waterborne transport	3	8.000.000,00 € - 13.000.000,00 €	34.000.000,00 €	Opening: 13/12/2022 Deadline: 20/04/2023
Developing the next generation of power conversion technologies for sustainable alternative	2	8.000.000,00 €	16.000.000,00 €	Opening: 13/12/2022 Deadline: 20/04/2023

carbon neutral fuels in waterborne applications				
		40.000.000,00 € - 55.000.000,00 €	50.000.000,00 €	

4.4.2.2. ELECTRIFICATION

In the Electrification area, topics will focus on the modernization of traditional methods, the development of long-range batteries that can power large-scale ships for a significantly longer amount of time, as well as the establishment of fully Direct Current (DC) electric grids, emphasizing on the power supply of ships during their stay in port.

The above-mentioned topics are expected to receive € 38,5 million in funding to be distributed to around five projects expecting to alter the power generation architecture for shipping, to maximize the use of electric power as a source of powering ships' operations and to demonstrate whether these new findings are applicable in real-life conditions in order to transform conventional vessels into smart electric systems.

The table below shows the topics under the Electrification Activity in correlation with an indicative budget allocation and number of projects per topic.

Table 4-8: Overview of Open Topics under the Activity of Electrification

The Activity of Electrification				
Topics	**Indicative number of projects expected to be funded**	**Expected EU contribution per project**	**Indicative budget**	**Duration**
Demonstrating efficient fully DC electric grids within waterborne transport for large ship applications	2	7.500.000,00 €	15.000.000,00 €	Opening: 07/12/2023 Deadline: 18/04/2024

Achieving high voltage, low weight, efficient electric powertrains for sustainable waterborne transport	2	7.500.000,00 €	15.000.000,00 €	Opening: 07/12/2023 Deadline: 18/04/2024
Developing a flexible offshore supply of zero emission auxiliary power for ships moored or anchored at sea deployable before 2030	1	8.500.000,00 €	8.500.000,00 €	Opening: 13/12/2022 Deadline: 20/04/2023
		38.500.000,00 €	38.500.000,00 €	

4.4.2.3. ENERGY EFFICIENCY

In the Energy Efficiency front, topics will be facing challenges regarding efficiency improvement technologies towards achieving EGD's "Fit for 55" target. In other words, a proposed budget of € 15 million is expected to fund two projects which will concentrate in developing energy efficient solutions in energy savings for both existing and newbuild ships. The objective is to combine new technologies presented by projects under the Electrification and Digital Green activities, in order to demonstrate a newly designed ship with at least 55% emission reduction by 2030.

The table below shows the topics under the Energy Efficiency Activity in correlation with an indicative budget allocation and number of projects per topic.

Table 4-9: Overview of Open Topics under the Activity of Energy Efficiency

The Activity of Energy Efficiency				
Topics	**Indicative number of projects expected to be funded**	**Expected EU contribution per project**	**Indicative budget**	**Duration**

Combining state-of-the-art emission reduction and efficiency reduction and efficiency improvement technologies in ship design and retrofitting for contribution to the "Fit for 55" package objective by 2030	2	7.500.000,00 €	15.000.000,00 €	Opening: 07/12/2023 Deadline: 18/04/2024
		15.000.000,00 €	15.000.000,00 €	

4.4.2.4. DESIGN AND RETROFITTING

In the Design and Retrofitting, more than € 20 million are proposed to be spent upon five projects that will be addressing the reduction of underwater noise, as well as the environmental impact of shipyards. Topics under this thematic area will attempt, on one hand, to develop technologies capable of minimizing underwater noise stemming from waterborne transport by providing solutions both to upgrade the design of newbuilds and to modify retrofitted ships towards Underwater Radiated Noise (URN) reduction. Regarding shipyards, the objective is to optimize their performance during ship repair processes in order to achieve a greener transition and the reduction of environmental impact from shipping.

The table below shows the topics under the Design and Retrofitting Activity in correlation with an indicative budget allocation and number of projects per topic.

Table 4-10: Overview of Open Topics under the Activity of Design and Retrofitting

The Activity of Design and Retrofitting				
Topics	**Indicative number of projects expected to be funded**	**Expected EU contribution per project**	**Indicative budget**	**Duration**
Demonstration of Technologies to minimize underwater noise generated by waterborne transport	1	6.000.000,00 €	6.000.000,00 €	Opening: 07/12/2023 Deadline: 18/04/2024

Developing small, flexible, zero-emission and automated vessels to support shifting cargo from road to sustainable Waterborne Transport	2	4.500.000,00 €	9.000.000,00 €	Opening: 13/12/2022 Deadline: 20/04/2023
Reducing the environmental impact from shipyards and developing a whole life strategy to measure and minimise the non-operational environmental impacts from shipping	2	4.500.000,00 €	9.000.000,00 €	Opening: 13/12/2022 Deadline: 20/04/2023
		24.000.000,00 €	24.000.000,00 €	

4.4.2.5. DIGITAL GREEN

At the Digital Green Activity, a budget of more than € 7 million has been proposed to implement one project regarding the transition to a more automated waterborne transport. In particular, the project under this activity will focus on the development of Digital Twin Green Vessels, a research innovation that aspires to duplicate individual components of a ship by selecting data from monitoring and through simulation to optimize the vessel's operations. Another objective to be implemented through this topic is the design of small fully automated vessels with customized zero-emission propulsion systems with the view of decongestioning the road transport chain, achieving, simultaneously, reduced costs with an emission-free solution.

The table below shows the topics under the Digital Green Activity in correlation with an indicative budget allocation and number of projects per topic.

Table 4-11: Overview of Open Topics under the Activity of Digital Green

The Activity of Digital Green				
Topics	**Indicative number of projects expected to be funded**	**Expected EU contribution per project**	**Indicative budget**	**Duration**

Advanced digitalization and modeling utilizing operational and other data to support zero emission waterborne transport	1	7.700.000,00 €	7.700.000,00 €	Opening: 07/12/2023 Deadline: 18/04/2024
		7.700.000,00 €	7.700.000,00 €	

4.4.2.6. PORTS

Topics regarding Port-related activities will focus on improving ships' operational efficiency during their arrival or departure from ports. More specifically, two projects with a proposed budget of € 15 million intend to optimize port operations and services, such as arrival times, which estimate to cause a tremendous amount of emissions and noise pollution. These projects contemplate on using digitalization in order to address port congestion and the environmental impact of berthing and on-site maneuvering.

The table below shows the topics under the Ports Activity in correlation with an indicative budget allocation and number of projects per topic.

Table 4-12: Overview of Open Topics under the Activity of Ports

The Activity of Ports				
Topics	**Indicative number of projects expected to be funded**	**Expected EU contribution per project**	**Indicative budget**	**Duration**
Integrated real-time digital solutions to optimize navigation and port calls to reduce emissions from shipping	2	7.500.000,00 €	15.000.000,00 €	Opening: 13/12/2022 Deadline: 20/04/2023
		15.000.000,00 €	15.000.000,00 €	

4.4.2.7. COORDINATION AND SUPPORT ACTIONS

In horizontal level, the above-mentioned activities are supplemented by Coordination and Support Actions (CSA). These actions refer to accompanying measures, such as public awareness, communication, networking, etc. and aim, primarily, at commercializing the innovations that will be developed through HEU's projects. In other words, topics under the CSA area assist ongoing R&I projects to become widely known, thus increasing their impact on society and rendering their effortless adaptation. Additionally, the CSA is responsible for the coordinated collaboration of the member states associated to each project, as well as bridging gaps between universities, the scientific community and the industry's representatives, but also for attracting new private-entity investors.

The table below shows the topics under the CSA in correlation with an indicative budget allocation and number of projects per topic.

Table 4-13: Overview of Open Topics under Coordination and Support Actions

Coordination and Support Actions				
Topics	**Indicative number of projects expected to be funded**	**Expected EU contribution per project**	**Indicative budget**	**Duration**
Coordinating and supporting the combined activities of member and associated states towards the objectives of the Zero-Emission Waterborne Transport Partnership so as to increase synergies and impact	1	1.500.000,00 €	1.500.000,00 €	Opening: 07/12/2023 Deadline: 18/04/2024
Structuring the Waterborne Transport Sector, including through changed business and industrial model in order to achieve commercial zero-emission waterborne transport	1	850.000,00 €	850.000,00 €	Opening: 07/12/2023Deadline: 18/04/2024

		2.350.000,00 €	2.350.000,00 €	

4.5. GAP ANALYSIS

The HEU Framework Programme has been designed by the EC to take Europe one step closer to climate neutrality through enhanced research and the synergy of the continent's scientific and academic institutions. Each topic has been designed in such a way as to meet the needs that have been created in relation to the achievement of the above purpose.

Taking into consideration the first two years since the launch of HEU and by assessing the projects that have been granted, certain challenges have been identified that require to be addressed in order to strengthen this FP's vision.

Initially, the progress demonstrated by the open projects can be considered quite indistinct, as thirteen out of a total of twenty-eight projects started around mid-2022 and the rest in early 2023. Therefore, they are in the early stages of development and have not yet produced any satisfactory results. This fact causes an immediate need for more often feedbacks from each project regarding its progress, in order to assess any further needs that arise related to the reinforcement of infrastructures, such as software and hardware laboratories, training and knowledge exchange. Furthermore, a more frequent briefing can facilitate the better distribution of funding by reducing the waste of resources. Additionally, a more-often evaluation on their progress can examine whether the strategic challenges and objectives are clearly translated into those specific projects. Each topic serves a specific purpose and the combination of results that all the projects will provide aspire to fulfill the objectives set by the Partnership. Therefore, more frequent feedback can check the feasibility of each topic and whether the targets for expenditure on sustainable development and climate action are met.

In the R&I front, certain gaps can be identified regarding the quality and availability of the data, as EU lags behind in breakthrough, market-creating innovation. The operational objectives set from the Partnership and the EC are considered extremely high and innovative, to the point that occasionally the current infrastructure cannot meet certain conditions for achieving immediate outcomes. This challenge can be intensified taking into account any time-lags that may occur during the implementation of the projects. A good example is the comparison between the number of granted projects for the period 2021-2022 under the Activity of Energy Efficiency and the Activity of Ports. Under the Activity of Energy Efficiency, eights projects have been granted, and whose expected outcomes include the development of low-carbon technologies, such as renewable energy sources, carbon capture and storage and energy storage systems. On the other hand, only a single project has been funded under the Activity of Ports, which will be called upon to face challenges of upgrading and optimizing the necessary infrastructures to incorporate the new technological achievements of the other projects.

Orientations and topics should be carefully designed considering the operational objectives that they intend to implement and ensuring, at the same time, the appropriate balance of TRL. Consequently, the data and publications that are developing under HEU's projects should be even more openly accessible. In addition, the feedback from projects to policymaking can be further strengthened in order to achieve the next framework's regulatory improvement and to ensure that the efforts made have been carried out efficiently and effectively.

Additionally, another gap that can be identified is that of a low societal engagement. Although since the H2020 civil society engagement has increased, there is still room for improvement in bringing R&I closer to the general public. HEU is considered one of the greatest initiatives to promote research, improve the standard of living and develop sustainable alternatives to preserve the environment, yet the progress in spreading the excellence throughout Europe is relatively slow. Society needs to have

better access to R&I developments in order to be constantly educated, to actively participate in shaping a better environment and in optimizing its life habits.

Based on the initial stage of the Programme's implementation, it is quite early to identify specific research gaps resulting from the funded projects in accordance to the operational objectives of the Partnership. However, it is important to note that the achievement of these objectives requires ongoing research and development efforts, as well as continuous evaluation of the effectiveness of solutions implemented. This evaluation can identify areas where further research and innovation are needed to achieve the desired results.

For example, in the case of the objective of eliminating GHG emissions, ongoing research is needed to develop and improve techniques for the production, storage and use of low-carbon and zero-carbon fuels, such as hydrogen and ammonia. Additionally, research is needed to evaluate the environmental impact of these fuels over their entire life cycle, including the production and transportation of fuels.

Similarly, in the case of the objective of eliminating air pollution, ongoing research is needed to develop and improve technologies for reducing emissions of pollutants from marine vessels, such as particulate matter and nitrogen oxides. This includes the development of low-emission engine technologies, as well as the evaluation of alternative fuels and their environmental impact.

Finally, in the case of the objective of eliminating water pollution, ongoing research is needed to develop and improve technologies for treating and preventing the discharge of pollutants into waterways. This includes the development of advanced treatment technologies, as well as the implementation of best practices and regulations to prevent pollution from occurring in the first place.

In conclusion, the main gaps that can be observed so far are associated to factors related to scalability, efficiency and environmental impact. Many of the projects focus on developing individual technologies, but there is a need to integrate them into complete systems that can be scaled up for real-world applications, as well as tested for their durability and reliability under real-world conditions to ensure their effectiveness in achieving the expected outcomes. Moreover, the cost of implementing the technologies developed under these projects needs to be reduced to make them more accessible and widely adopted by the industry, while conducting comprehensive assessments of their environmental impact to ensure that they do not result in unintended environmental consequences.

At this point, this gap analysis will focus on the technology development provided by the EU-funded projects under the HEU framework programme and whether they have addressed the original operational objectives. In order to perform such an assessment, a comparative analysis should be made between the initial objectives set by the Partnership and the projects that were awarded EU-grant under the HEU. This analysis will assist to better understand the progress made so far, whether the funded projects can fulfill the EGD goals and what measures should be taken in addition, towards achieving climate-neutrality by the year 2050.

According to the Waterborne' s TP SRIA the use of SAF Activity outlines several key objectives related to the development and demonstration of sustainable and climate-friendly solutions in the maritime industry. These objectives include:

a) The development of an overall scenario for sustainable alternative fuels in waterborne transport, considering fuels derived from sustainable biomass or renewable electricity.

b) The identification of technical capabilities required to integrate the use of sustainable alternative fuels onboard waterborne transport vessels.

c) The exploration of technologies for power conversion of sustainable alternative fuels into high-efficiency fuel-flexible prime movers, including internal combustion engines (reciprocal or continuous) and fuel cells.

For the implementation of these objectives, the Partnership, in collaboration with the EC, has, up to this point, published the following topics that will tackle with issues related to:

1. Enabling the safe and efficient onboard storage and integration within ships of large quantities of ammonia and hydrogen fuels
2. Enabling the safe deployment of low-flashpoint GHG neutral shipping fuels underpinned by the necessary norms and regulations
3. Enabling the full integration of very high-power fuel cells in ship design using cogeneration and combined cycle solutions for increased efficiency with multiple fuels
4. Ensuring clean, efficient engines using new carbon neutral fuels separately and in combination
5. Proving the feasibility of large clean ammonia marine engine
6. Identifying waterborne sustainable fuel deployment scenarios
7. Demonstrations to accelerate the switch to safe use of new sustainable climate neutral fuels in waterborne transport
8. Developing the next generation of power conversion technologies for sustainable alternative carbon neutral fuels in waterborne applications

The following figure presents a comprehensive demonstration of the above-mentioned topics. To illustrate, the figure displays in orange color the topics for the WP 2021-2022[141] that managed to award grants in projects and in red color the topics for the WP

[141] European Commission, (2022). "Horizon Europe. Work Programme 2021-2022. 8. Climate, Energy and Mobility"

2023-2024[142] that are expecting the results of the Call for proposals. Each topic has been placed in the figure below according to the specific objective it aspires to deliver and its importance towards achieving a zero-emission waterborne transport.

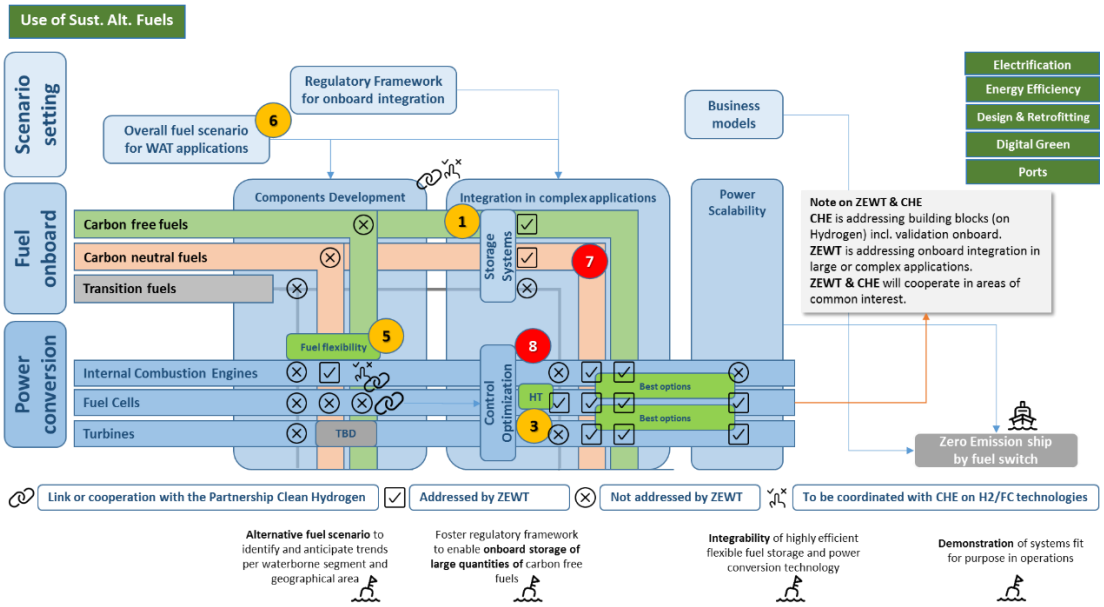

Figure 4-3-1: Topics for the Use of S.A.F. Activity under the HEU Programme[143]

Based on the objectives and research projects described, it appears that significant emphasis has befallen in the development of sustainable alternative fuels for waterborne transport. However, there are still gaps and additional technological aspects that could be enhanced to achieve the desired impact. Some potential areas to focus on include:

- Energy Storage and Integration: While the research projects are trying to address the safe and efficient onboard storage of fuels like ammonia and hydrogen, further advancements can be made in optimizing energy storage systems for different ship types and operational profiles. This could involve exploring innovative storage technologies, such as advanced batteries or hybrid energy storage systems, to improve

[142] European Commission, (2023). "Horizon Europe Work Programme 2023-2024"
[143] Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport", edited by author

energy efficiency and address the variability of power demand. Such an undertake should be considered in collaboration with the Energy Efficiency and Electrification Activity.

- Integration of Multiple Power Conversion Technologies: The research projects have emphasized, up to this point, to the integration of high-power fuel cells and efficient engines using carbon-neutral fuels. To further enhance technology development, it would be beneficial to explore the integration of multiple power conversion technologies within the same vessel. This could involve developing hybrid power systems that combine fuel cells, internal combustion engines and other renewable energy sources to maximize efficiency and provide flexibility in power generation.

- Digitalization and Smart Systems: The advancement of digitalization and smart systems can play a crucial role in optimizing energy consumption, vessel performance and operational efficiency. Integrating digital technologies, such as advanced monitoring and control systems, data analytics and predictive modeling, can enable real-time decision-making, condition monitoring and energy management. This can lead to further fuel savings, emissions reductions and overall operational improvements. Potential orientations could be made in joint efforts with the Digital Green Activity.

- Advanced Propulsion Systems: While the projects have been focusing on power conversion technologies, there is scope for enhancing propulsion systems. Exploring innovative propulsion systems, such as electric propulsion, hybrid propulsion, or alternative propulsion methods like wind-assist or sail-assist technologies, can contribute to further reducing fuel consumption and emissions. These advancements can be especially relevant for short-distance shipping and inland waterway transport, with the assistance of projects under the Design and Retrofitting Activity.

- Life Cycle Assessment and Environmental Impact: To achieve a comprehensive understanding of the environmental impact of alternative fuel and technology solutions, it is essential to conduct life cycle assessments (LCA) that consider the entire life cycle of a vessel, including manufacturing, operation and end-of-life. By assessing the environmental impact of different technologies holistically, it becomes possible to identify areas for improvement and prioritize sustainable solutions. Such assessments could be directed from potential orientations under the Design and Retrofitting Activity.

By addressing these gaps and enhancing these technological aspects, it will be possible to develop a more comprehensive and integrated approach towards achieving the desired impact. The proposed enhancements can contribute to an alternative fuel scenario that accounts for evolving trends, foster the development of regulatory frameworks and enable the demonstration of fit-for-purpose systems in real-world operations.

Moreover, the Electrification Activity outlines several key objectives related to the development and implementation of innovative solutions for integrating electrification with alternative fuels in waterborne transport applications. These objectives include:

d) The development of energy models to optimize the use of available energy resources, the selection and modeling of suitable energy storage systems.
e) The establishment of an innovative grid architecture and control system.

For the implementation of these objectives, the Partnership, in collaboration with the EC, has, up to this point, published the following topics that will tackle with issues related to:

9. Hyper powered vessel battery charging system
10. Exploiting electrical energy storage systems and better optimizing large battery electric power within fully battery electric and hybrid ships

11. Innovative energy storage systems on-board vessels
12. Demonstrating efficient fully DC electric grids within waterborne transport for large ship applications
13. Achieving high voltage, low weight, efficient electric powertrains for sustainable waterborne transport
14. Developing a flexible offshore supply of zero emission auxiliary power for ships moored or anchored at sea deployable before 2030

The following figure presents a comprehensive demonstration of the above-mentioned topics. To illustrate, the figure displays in orange color the topics for the WP 2021-2022 that managed to award grants in projects and in red color the topics for the WP 2023-2024 that are expecting the results of the Call for proposals. Each topic has been placed in the figure below according to the specific objective it aspires to deliver and its importance towards achieving a zero-emission waterborne transport.

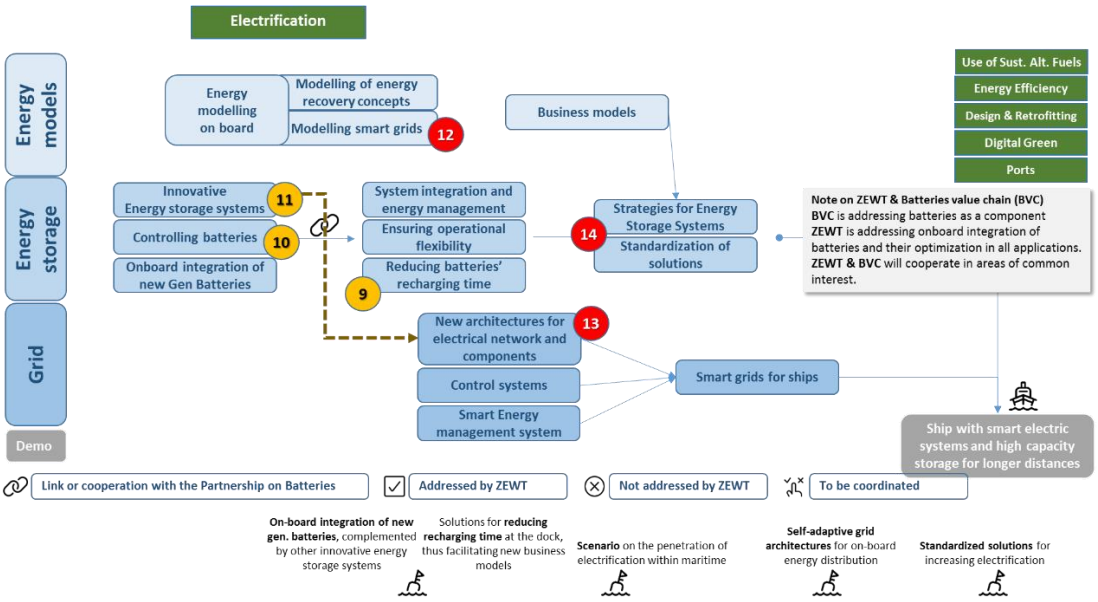

Figure 4-3-2: Topics fot the Electrification Activity under the HEU Programme[144]

[144] Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport", edited by author

Based on the objectives and research projects described above, it appears that the Electrification Activity has focused on developing energy models, optimizing energy storage systems and establishing an innovative grid architecture and control system to promote electrification within waterborne transport. To bridge the technology development gap and enhance the overall approach, some suggestions for further technological aspects include:

- Fast-Charging Infrastructure: While the research projects address battery charging systems and energy storage on board vessels, it is essential to also focus on developing fast-charging infrastructure at ports and terminals. Efficient and high-power charging stations are crucial to reduce recharging time at the dock and facilitate the widespread adoption of electrification in maritime operations. Standardized charging interfaces and protocols can further support interoperability and seamless integration of vessels with the charging infrastructure. Such an orientation could be co-designed with the Ports Activity.

- Battery Swapping and Modular Solutions: In addition to new-gen batteries and innovative energy storage systems, consideration should be taken upon exploring battery swapping and modular solutions for energy storage on board vessels. Battery swapping technology allows for quick exchange of depleted batteries with fully charged ones, reducing vessel downtime and enabling continuous operations. Modular energy storage systems provide flexibility in configuring the storage capacity based on specific vessel requirements and can adapt to changes in operational needs.

- Smart Grid Management: Enhance the innovative grid architecture by incorporating smart grid management technologies. Smart grid solutions use advanced control algorithms and real-time data to optimize energy distribution and ensure efficient utilization of power on board. These systems can dynamically manage power flows, balance loads and prioritize energy usage based on operational demands, contributing to increased energy efficiency and reduced emissions.

- Energy Harvesting and Regeneration: In collaboration with the Energy Efficiency Activity, the orientation of energy harvesting and regeneration technologies to supplement the power needs on board vessels could be considered. Harvesting energy from renewable sources like solar, wind, or waste heat can provide additional power to complement the energy storage systems. Regenerative technologies, such as kinetic energy recovery systems (KERS), can capture and store energy during braking or deceleration, improving overall energy efficiency and reducing fuel consumption.

- Grid-to-Grid Integration: The exploring of the integration of on-board energy grids with external power sources, such as shore power or renewable energy sources deployed at ports. This grid-to-grid integration allows vessels to draw power from cleaner and renewable sources when docked, reducing emissions and dependence on traditional fossil fuels. Standardized interfaces and protocols can facilitate seamless connectivity between vessel grids and shore-based power systems and correlated topics under the Ports Activity could resolve issues regarding the integration of such developments in the current state of infrastructure.

- Energy Management Optimization: Emphasis should befallen upon developing advanced energy management optimization algorithms to fine-tune the use of different energy sources on board, with the assistance of the Digital Green Activity. These algorithms can intelligently manage the balance between battery power, auxiliary power units and other energy sources based on real-time data, operational profiles and environmental conditions, ensuring the most efficient and eco-friendly energy utilization.

By addressing these technological aspects and enhancing the suggested areas, the technology development gap can be narrowed and the desired impact can be achieved. Such advancements may promote cleaner and more sustainable waterborne transport, reduce GHG emissions and pave the way for a greener future in maritime operations.

In addition, the Energy Efficiency Activity outlines several key objectives related to reducing the fuel consumption of waterborne transport by at least 55% before 2030. These focus on three main areas:

f) Ship design and operation optimization.
g) Energy-efficient technologies for all consumers.
h) The integration of renewable and free energy solutions to reduce dependence on (alternative) fuels.

For the implementation of these objectives, the Partnership, in collaboration with the EC, has, up to this point, published the following topics that will tackle with issues related to:

15. Enabling the full integration of very high power fuel cells in ship design using co-generation and combined cycle solutions for increased efficiency with multiple fuels
16. Innovative on-board energy saving solutions
17. Exploiting renewable energy for shipping, in particular focusing on the potential of wind energy
18. Combining state-of-the-art emission reduction and efficiency improvement technologies in ship design and retrofitting for contributing to the "Fit for 55" package objective by 2030

The following figure presents a comprehensive demonstration of the above-mentioned topics. To illustrate, the figure displays in orange color the topics for the WP 2021-2022 that managed to award grants in projects and in red color the topics for the WP 2023-2024 that are expecting the results of the Call for proposals. Each topic has been placed in the figure below according to the specific objective it aspires to deliver and its importance towards achieving a zero-emission waterborne transport.

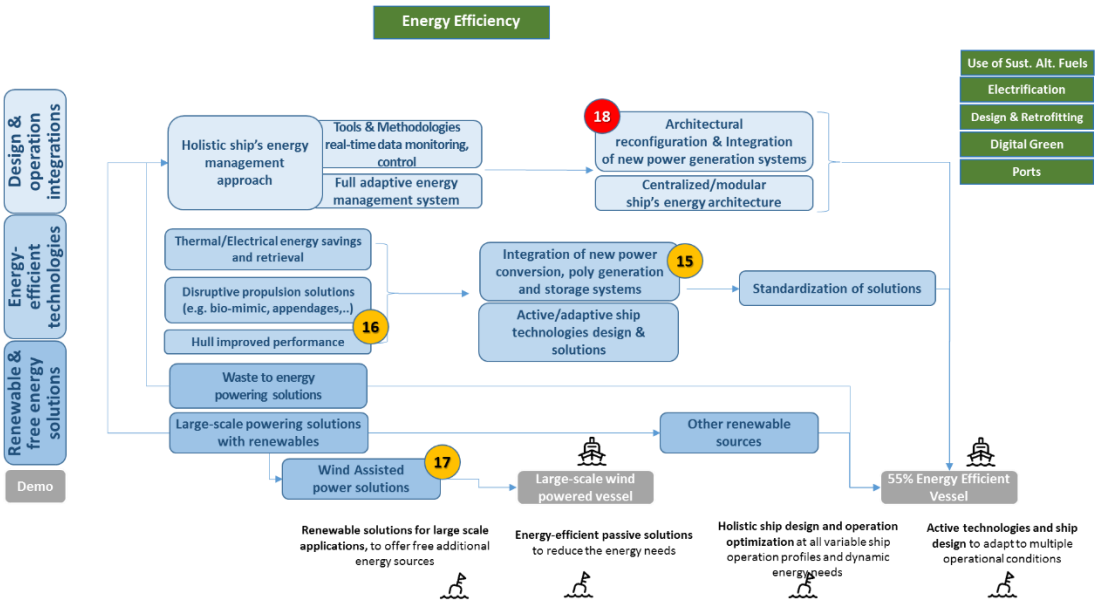

Figure 4-3-3: Topics for the Energy Efficiency Activity under the HEU Programme[145]

Based on the objectives and research projects analyzed, we can conclude that significant effort has been made in optimizing ship design and operation, developing energy-efficient technologies and integrating renewable energy solutions in the maritime sector. However, there are still gaps and additional technological aspects that could be enhanced to achieve the desired impact. Some potential areas to focus on include:

- Advanced Energy Storage Systems: While the research projects are exploring the integration of fuel cells and innovative energy saving solutions, further advancements can be made in developing advanced energy storage systems. This could involve the integration of new generation batteries, such as solid-state batteries or other emerging technologies, to enhance energy storage capacity, efficiency and reliability. Additionally, exploring novel energy storage solutions beyond batteries, such as supercapacitors or hydrogen-based storage systems, can offer alternative options for

145 145 Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport", edited by author

meeting power demands. These orientations, in order to be proven efficient, should be conducted in collaboration with the Design and Retrofitting and Ports Activity.

- Fast Recharging and Dockside Infrastructure: To facilitate the adoption of electrification and optimize ship operations, there is a need to focus on reducing recharging time at the dock. Research and development efforts can be directed towards improving charging infrastructure and developing fast recharging technologies, such as high-power charging stations or automated charging systems. This would enable more efficient use of ship downtime and support the implementation of new business models based on quick turnaround times. The Ports Activity could provide significant insights, if such a research is conducted.

- Electrification Penetration Scenarios: While the potential of wind energy and other renewable sources have been explored, further research can be conducted to develop comprehensive electrification penetration scenarios. This would involve assessing the feasibility and impact of different electrification strategies for various maritime segments, considering factors such as vessel types, operational profiles, infrastructure requirements and cost-effectiveness. It would also be valuable to analyze the potential synergies between electrification and other emission reduction technologies.

- Self-Adaptive Grid Architectures: In order to optimize energy distribution onboard ships, there is a need for self-adaptive grid architectures. This entails the development of intelligent power distribution systems that can dynamically adapt to varying energy inputs and demands, while ensuring optimal efficiency and stability. Implementing advanced control and monitoring technologies, such as smart grid solutions and energy management systems, can enhance the effectiveness of energy distribution and contribute to overall energy savings.

- Standardized Electrification Solutions: To facilitate the widespread adoption of electrification, the development of standardized solutions is essential. This involves establishing common technical standards and specifications for electric power systems, charging interfaces and other related components. Standardization efforts would simplify the implementation of electrification technologies, encourage interoperability and support the scalability of electrification across the maritime industry.

By focusing on these technological aspects, the gaps in technology development can be addressed and the desired impact can be achieved. Enhanced energy storage systems, faster recharging infrastructure, comprehensive electrification scenarios, self-adaptive grid architectures and standardized electrification solutions will contribute to ship optimization, energy efficiency and the integration of renewable energy sources. These advancements will further accelerate the transition towards a more sustainable and electrified maritime industry.

Furthermore, the Design and Retrofitting Activity outlines several key objectives related to demonstrating zero-emission solutions for all main ship types and services before 2030 and ultimately enabling zero-emission waterborne transport by 2050. These objectives include:

i) The development of an overall scenario for sustainable alternative fuels in waterborne transport, considering fuels derived from sustainable biomass or renewable electricity.
j) The identification of technical capabilities required to integrate the use of sustainable alternative fuels onboard waterborne transport vessels.
k) The exploration of technologies for power conversion of sustainable alternative fuels into high-efficiency fuel-flexible prime movers, including internal combustion engines (reciprocal or continuous) and fuel cells.

For the implementation of these objectives, the Partnership, in collaboration with the EC, has, up to this point, published the following topics that will tackle with issues related to:

19. Transformation of the existing fleet towards greener operations through retrofitting.
20. Assessing and preventing methane slip from LNG engines in all conditions within both existing and new vessels.
21. Demonstration of Technologies to minimize underwater noise generated by waterborne transport.
22. Developing small, flexible, zero-emission and automated vessels to support shifting cargo from road to sustainable Waterborne Transport.
23. Reducing the environmental impact from shipyards and developing a whole life strategy to measure and minimize the non-operational environmental impacts from shipping.

The following figure presents a comprehensive demonstration of the above-mentioned topics. To illustrate, the figure displays in orange color the topics for the WP 2021-2022 that managed to award grants in projects and in red color the topics for the WP 2023-2024 that are expecting the results of the Call for proposals. Each topic has been placed in the figure below according to the specific objective it aspires to deliver and its importance towards achieving a zero-emission waterborne transport.

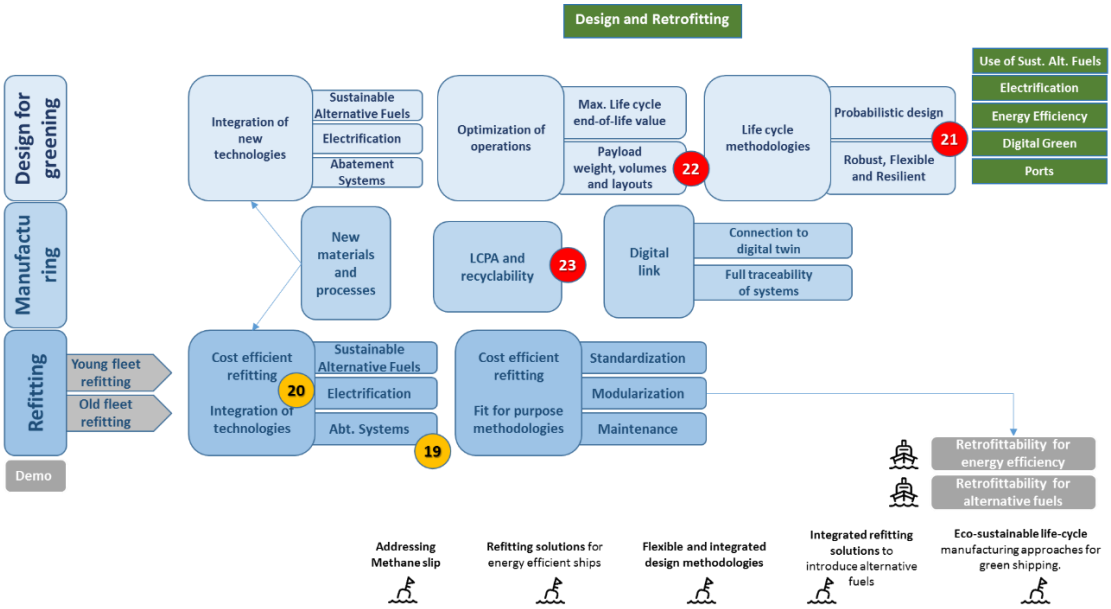

Figure 4-3-4: Topics for the Design and Retrofitting Activity under the HEU Programme[146]

Based on the stated objectives and ongoing research projects, there are several areas where technology development can be further enhanced to achieve the desired impact of addressing methane slip, providing refitting solutions for energy-efficient ships and promoting eco-sustainable life-cycle manufacturing approaches for green shipping. Here are some technological aspects to consider:

- Advanced Methane Detection and Mitigation: While the research includes assessing and preventing methane slip from LNG engines, further advancements can be made in developing advanced methane detection technologies. These technologies should enable real-time monitoring of methane emissions and facilitate prompt mitigation actions. Implementing feedback control systems that adjust engine parameters to minimize methane slip can also be explored.

- Alternative Fuels and Powertrains: To achieve energy-efficient and zero-emission ships, focus on expanding the range of sustainable alternative fuels beyond

146 146 Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport", edited by author

LNG. Research and develop solutions for integrating other alternative fuels, such as biofuels, hydrogen and ammonia, into existing and new vessels. Additionally, a possible orientation could explore the use of fuel cells and high-efficiency electric powertrains as alternative propulsion systems for different ship types.

- Life-Cycle Assessment and Circular Economy: Promote a life-cycle assessment approach that evaluates the environmental impact of ships from construction to decommissioning. Implement circular economy principles by designing ships and ship components for easy refurbishment, recycling, or repurposing to minimize waste and enhance sustainability.

- Zero-Emission Port Infrastructure: An enhanced collaboration with the Ports Activity to develop infrastructure that supports the use of alternative fuels and enables zero-emission operations. This could include the establishment of fueling stations for alternative fuels, charging infrastructure for electric vessels and grid connections for shore power supply.

- Digitalization and Data Analytics: Utilize advanced digitalization and data analytics to optimize ship operations, monitor fuel consumption, and identify areas for improvement. Machine learning and artificial intelligence algorithms can help optimize ship performance and reduce emissions based on historical data and real-time feedback.

- Industry Collaboration and Policy Support: Encourage collaboration among industry stakeholders, research institutions and policymakers to foster the adoption of sustainable practices and technologies. Develop supportive policies and regulations that incentivize the use of sustainable alternative fuels, energy-efficient technologies and eco-friendly shipbuilding practices.

By enhancing technology development in these areas, the objectives of developing a sustainable fuel scenario, identifying technical capabilities for alternative fuel

integration and exploring power conversion technologies can be realized effectively. Furthermore, it will contribute to the transformation of the maritime industry towards greener and more environmentally friendly practices, ultimately achieving the desired impact of addressing methane slip, energy-efficient refitting and eco-sustainable manufacturing in shipping.

Correspondingly, the Digital Green Activity outlines several key objectives related to demonstrating zero-emission solutions for all main ship types and services before 2030 and ultimately enabling zero-emission waterborne transport by 2050. These objectives include:

l) Gathering and analyzing data from vessels, ports, and traffic to enable a comprehensive understanding of operational conditions and ship health.
m) Creating a virtual representation of the ship and its systems that is connected to the physical ship.
n) Developing a decision support system that utilizes the insights from monitoring, big data collection and the Digital Twin to optimize vessel operations and achieve zero-emission goals.

For the implementation of these objectives, the Partnership, in collaboration with the EC, has, up to this point, published the following topics that will tackle with issues related to:

24. Digital Twin models to enable green ship operations.
25. Computational tools for shipbuilding.
26. Advanced digitalization and modelling utilizing operational and other data to support zero emission waterborne transport.

The following figure presents a comprehensive demonstration of the above-mentioned topics. To illustrate, the figure displays in orange color the topics for the WP 2021-2022

that managed to award grants in projects and in red color the topics for the WP 2023-2024 that are expecting the results of the Call for proposals. Each topic has been placed in the figure below according to the specific objective it aspires to deliver and its importance towards achieving a zero-emission waterborne transport.

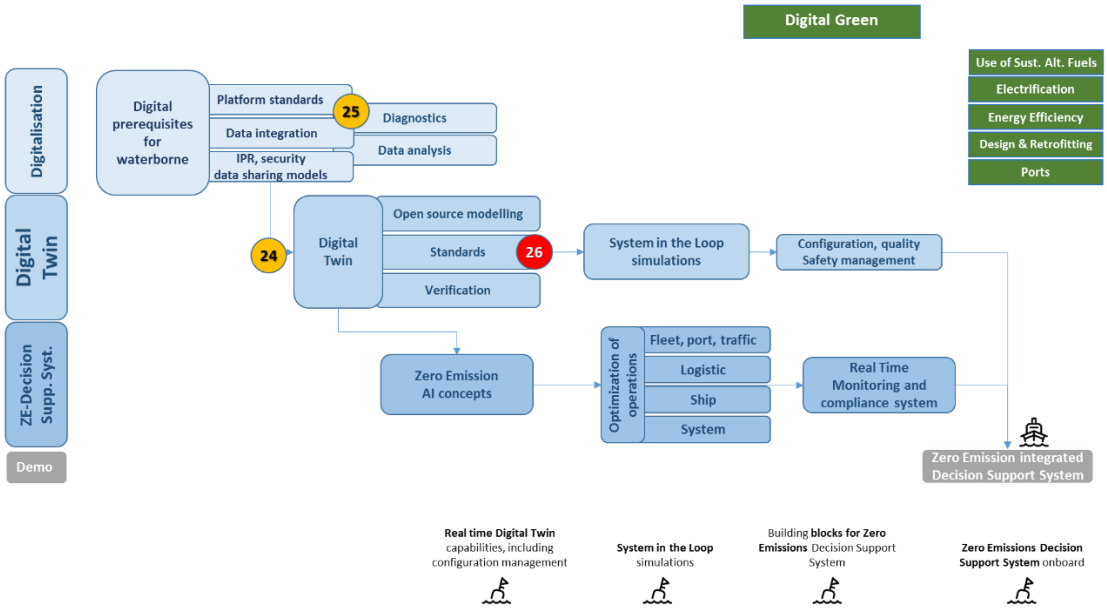

Figure 4-3-5: Topics for the Digital Green Activity under the HEU Programme[147]

Based on the objectives and research projects described, there is a clear focus on data gathering and analysis, creating virtual representations of ships and developing decision support systems to optimize vessel operations and achieve zero-emission goals. To bridge the technology development gap and enhance the overall approach, here are some suggestions for further technological aspects:

- Advanced Predictive Analytics: Enhance the capabilities of data analysis by incorporating advanced predictive analytics techniques. This involves utilizing machine learning algorithms and artificial intelligence to extract valuable insights from the collected data. By analyzing historical and real-time data, predictive models can be

147 147 Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport", edited by author

developed to anticipate operational conditions, optimize energy consumption and identify potential areas for emission reduction. These predictive capabilities can further enhance the decision support system and provide proactive recommendations for optimizing vessel operations.

- Real-Time Monitoring and Feedback: Strengthen the real-time monitoring capabilities by integrating sensor technologies and IoT devices onboard vessels. By continuously monitoring parameters such as fuel consumption, emissions and system performance, real-time data can be collected and fed into the decision support system. This allows for immediate feedback and adjustments to optimize vessel operations and ensure compliance with emissions targets. Real-time monitoring also enables early detection of potential issues or anomalies, supporting preventive maintenance and reducing the risk of operational disruptions.

- Cybersecurity and Data Privacy: Prioritize the development of robust cybersecurity measures and data privacy protocols. With increased connectivity and data exchange, it is crucial to protect the integrity and confidentiality of the collected data. Implementing secure data transmission protocols, encryption mechanisms and access controls will safeguard the sensitive information and prevent unauthorized access or data breaches. Adhering to strict data privacy regulations will build trust and encourage data sharing among stakeholders.

- Integration with Port and Traffic Management Systems: Foster integration between the vessel's decision support system and port and traffic management systems, in collaboration with the Ports Activity. By establishing seamless communication and data exchange between these systems, a holistic approach to optimizing vessel operations can be achieved. This integration enables better coordination of vessel arrivals, berth assignments and cargo handling, reducing congestion, optimizing routes and minimizing waiting times. Coordinated port and traffic management contribute to

overall emissions reduction and improve efficiency in the waterborne transport network.

By addressing these technological aspects and enhancing the suggested areas, the technology development gap can be narrowed and the desired impact of real-time digital twin capabilities, a robust decision support system and zero-emission onboard operations can be achieved. These advancements will support the comprehensive understanding of operational conditions, enable data-driven optimization and facilitate the transition to zero-emission waterborne transport.

Last but not least, the Ports Activity outlines several key objectives related to demonstrating zero-emission solutions for all main ship types and services before 2030 and ultimately enabling zero-emission waterborne transport by 2050. These objectives include:

o) The design of strategies and solutions for ports to achieve net-zero emissions in waterborne transport and related activities within port facilities.
p) The presentation of resilient solutions within ports and waterways to minimize the impact of climate change on operations.
q) The development of ports and infrastructure solutions, including those along inland waterways, to enable the transition of waterborne transport towards the use of alternative fuels.

For the implementation of these objectives, the Partnership, in collaboration with the EC, has, up to this point, published the following topics that will tackle with issues related to:

27. Seamless safe logistics through an autonomous waterborne freight feeder loop service.

28. Integrated real-time digital solutions to optimize navigation and port calls to reduce emissions from shipping.

The following figure presents a comprehensive demonstration of the above-mentioned topics. To illustrate, the figure displays in orange color the topics for the WP 2021-2022 that managed to award grants in projects and in red color the topics for the WP 2023-2024 that are expecting the results of the Call for proposals. Each topic has been placed in the figure below according to the specific objective it aspires to deliver and its importance towards achieving a zero-emission waterborne transport.

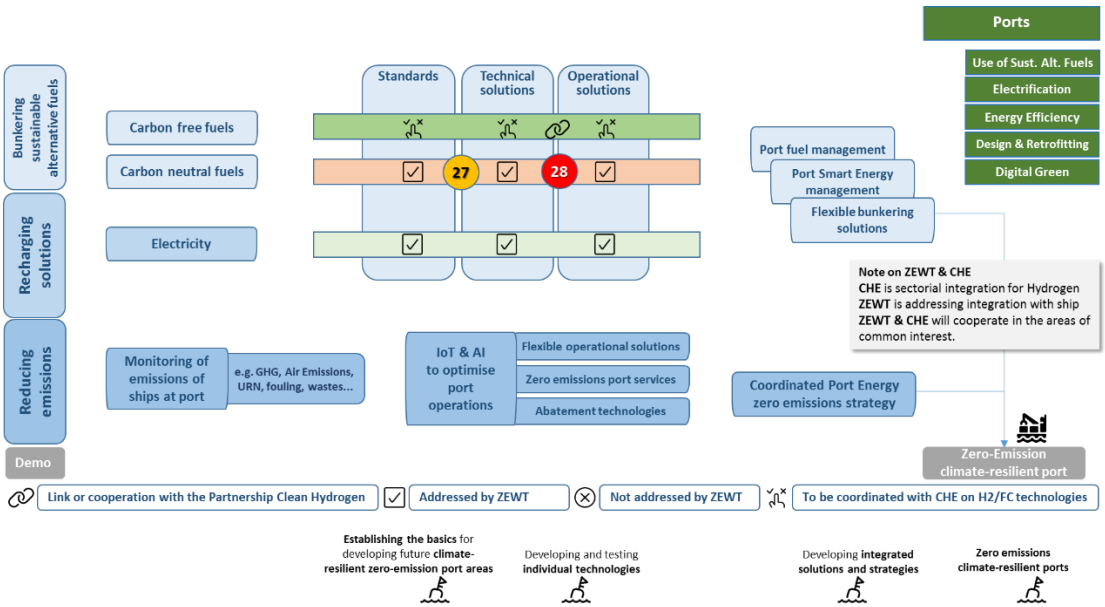

Figure 4-3-6: Topics for the Ports Activity under the HEU Programme[148]

To achieve the desired impact of establishing future climate-resilient zero-emission port areas and developing zero emissions climate-resilient ports, the technology development should focus on the following aspects and address potential gaps:

148 148 Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport", edited by author

- Smart Infrastructure and Port Planning: Integrate smart and sustainable technologies into port infrastructure planning. This includes renewable energy sources for port operations, electrified equipment for cargo handling and efficient lighting systems. Implementing smart grids and energy management systems can help optimize energy use and minimize environmental impact. Such leaps in technology development could be achieved in collaboration with the Energy Efficiency and the Electrification Activities.

- Alternative Fuel Bunkering Infrastructure: Develop and implement infrastructure solutions for the bunkering of alternative fuels at ports and along inland waterways. This could involve establishing facilities to safely and efficiently store, handle and supply sustainable alternative fuels to waterborne transport vessels that will be demonstrated by projects under the Use of SAF Activity.

- Resilient Port Designs: Consider the potential impact of climate change on port operations and design resilient port facilities to adapt to changing environmental conditions. Implement measures such as coastal protection, flood defenses and flexible infrastructure layouts to minimize disruptions and ensure continuous operations.

- Autonomous and Green Logistics: Further advance research and development on autonomous waterborne freight feeder loop services to improve logistics efficiency and reduce emissions. Implementing autonomous vessels and integrating them into a seamless logistics network can enhance the sustainability of waterborne transport.

- Sustainable Supply Chain Management: Promote sustainable supply chain management practices within port facilities to reduce emissions throughout the entire transportation process. This includes optimizing cargo handling, minimizing waste and promoting eco-friendly transport options.

- Green Certification and Standards: Establish green certification programs and standards for ports to incentivize and recognize efforts towards zero-emission and climate-resilient operations. Certification schemes can encourage port operators to adopt sustainable practices and technologies.

- Public Policy and Incentives: Advocate for supportive public policies and incentives that promote the adoption of sustainable technologies and practices in ports. Government support can accelerate the transition to zero-emission and climate-resilient ports.

By focusing on these technological aspects and addressing any potential gaps in technology development, the objectives of achieving climate-resilient zero-emission port areas, developing integrated solutions and creating zero-emission ports can be effectively pursued. This will significantly contribute to the overall sustainability of waterborne transport and related port activities.

Overall, while projects funded under the HEU Programme are an important step towards achieving those operational objectives and, ultimately, a zero-emission waterborne transport, ongoing research and development efforts are necessary to continue to identify and address research gaps and to ensure the long-term sustainability of the waterborne transport sector.

CHAPTER 5: FUTURE RESEARCH AVENUES

This chapter focuses on identifying potential avenues for future research that can contribute to addressing the challenges and advancing the goals of the EGD in the maritime industry. It covers a wide range of areas in order to enhance sustainability and promote the transition towards a greener maritime sector. These potential future research directions have been based to a large extent on the findings indicated by this study on the gap assessment of H2020 and HEU Framework Programmes.

One major challenge that can be further investigated is the need for more frequent feedback from each project to assess progress, reinforce necessary infrastructures and ensure efficient funding distribution. This need arises from the lack of distinct progress demonstrated by open projects, with most projects being in their early stages and lacking satisfactory results. This feedback will also help evaluate if the strategic challenges and objectives are being translated effectively into the projects' goals.

In terms of R&I, there are gaps in the quality and availability of data, particularly in breakthrough, market-creating innovation. The operational objectives set by the EC under the EGD are ambitious and sometimes exceeding the capabilities of existing infrastructure, which can be intensified by potential time-lags in project implementation. This gap can be seen in the discrepancy between the number of projects granted under different activities, emphasizing the need for a more balanced approach considering the operational objectives and TRL.

Moreover, there is a societal engagement gap, with the need for better public access to R&I developments. Despite being a significant initiative for research and sustainable alternatives, progress in spreading excellence across Europe has been relatively slow. To address this, strategies should be developed to increase public engagement and education, promoting active participation in environmental improvements.

While it's early to identify specific research gaps from funded projects, it's crucial to recognize that achieving HEU's objectives requires continuous research and development efforts. For instance, ongoing research is needed for the objective of eliminating GHG emissions, as well as developing and evaluating low-carbon and zero-carbon fuel techniques. Similarly, ongoing research is essential for reducing emissions of pollutants from vessels, including low-emission engine technologies and alternative fuels and evaluating their environmental impact. Also, further research is needed to develop technologies for treating and preventing water pollution.

In conclusion, the main research avenues should focus on enhancing project monitoring and evaluation, improving data quality and availability, balancing technology readiness levels, strengthening feedback to policymaking, enhancing societal engagement and addressing specific research needs for ongoing operational objectives. Additionally, research should aim at integrating technologies, ensuring scalability, reducing implementation costs and assessing environmental impacts. By exploring these avenues, the HEU Framework Programme can better contribute to Europe's climate neutrality and sustainable development goals.

CHAPTER 6: CONCLUSIONS

In this master thesis, a comprehensive exploration of the European maritime industry's pathway towards aligning with the ambitious environmental goals outlined in the EGD has been conducted. It is evident that the industry stands at a critical crossroads, facing the dual challenge of retaining its economic significance while addressing its environmental impact.

As established in this analysis, the EU has taken decisive steps to address these challenges through RD&I as a means to enhance sustainability and maintain global competitiveness. The H2020 framework Programme and its recognition of the need to mitigate the ecological footprint of waterborne transport were instrumental in laying the foundation for this venture.

H2020's strategic priorities in the waterborne sector were focused on sustainable waterborne transport, the harvesting of offshore resources and minimizing the impact on oceans. These priorities aimed to develop innovative technologies, improve safety and security, reduce environmental impact and enhance competitiveness in the maritime industry. Achieving these priorities required investments in research, development and education to foster technological breakthroughs and cultivate a skilled workforce.

The Waterborne Strategic Research Agenda, aligned with the Waterborne Vision 2020, played a crucial role in achieving the goals of H2020. Vision 2020 contemplated to a safer, more sustainable and efficient future for waterborne operations, with reduced CO_2 emissions, expanded offshore renewable energy markets and retrofitting of existing ships. Through research and innovation, H2020 established new quality standards for maritime operations and accelerated the pace of technological advancements.

As far as the maritime industry is concerned, the implementation of the H2020 programme in the waterborne sector has led to significant advancements and achievements in various operational objectives. The projects funded by the EC have contributed to the improvement of infrastructure, innovative shipbuilding, complex value-added specialized vessels and the development of new and improved waterborne transport concepts. These projects have received substantial EU funding, with a total cost of over €500 million.

In conclusion, the projects funded by H2020 in the waterborne sector have yielded significant achievements and contributed to the overall objectives of the program. The projects have improved infrastructure, shipbuilding and waterborne transport concepts, while promoting sustainability, efficiency and competitiveness in the maritime industry. The outcomes of these projects have paved the way for further advancements and innovations in the sector, supporting the EU's vision for a greener, more connected and technologically advanced waterborne sector.

The enactment of the EGD represents a pivotal moment in the EU's commitment to environmental sustainability, encompassing all sectors, including the maritime industry. The framework outlines a clear path towards climate change mitigation, environmental protection and sustainable development. Importantly, it designates the waterborne sector as a fundamental component in achieving these objectives and the HEU framework programme is the financial instrument to these transformative efforts.

HEU aligns with the EGD and its policies targeting climate change, air pollution and water degradation. The EGD aims to make Europe the first climate-neutral continent by 2050, with a focus on sustainable and integrated development, enhanced mobility and a transition to a clean zero-carbon economy. The programme supports the reduction of transport emissions and GHG emissions, in line with the IMO's Initial Strategy for reducing GHG emissions from ships. Short-term regulations focus on improving

technical and operational ship efficiency, while medium-term measures include the uptake of alternative fuels and market-based approaches.

The interim evaluation of H2020 identified areas for improvement, including simplification, support for breakthrough innovation, mission-oriented and citizen involvement, synergies with other EU funding programs, strengthening international cooperation, reinforcing openness and rationalizing the funding landscape. HEU aims to address these recommendations and build on the progress made in H2020.

The strategic priorities outlined in the waterborne sector's plan emphasize the need for a sustainable transformation of European waterborne transport, the development of new business models and paradigms for blue growth sectors and the integration of shipping and inland navigation into seamless port and logistics operations. These priorities reflect the sector's commitment to addressing environmental, economic and social challenges while promoting research, innovation and results.

To achieve the sustainable transformation of waterborne transport, the sector aims to transition into a greener and more secure mode of transport. This includes efforts to eliminate harmful environmental emissions, water pollution and noise emissions, while also embracing digitalization for improved operations, safety and energy efficiency. The establishment of the cPP ZEWT and the pursuit towards a Zero-Accident Waterborne Industry are crucial steps in realizing these objectives.

The waterborne sector also recognizes the importance of developing European leadership, new business models and paradigms for blue growth sectors. By engaging closely with civil society and utilizing sustainable technologies and systems, the sector aims to facilitate the exploration and exploitation of waterborne natural resources while ensuring the safety, security and protection of human activity in the waterborne environment.

Additionally, the integration of shipping and inland navigation into seamless ports and logistics operations is crucial for accommodating the anticipated increase in global trade. The sector acknowledges the need for adequate infrastructure, digitalization and the transition to zero-emission ports to address challenges such as congestion and to optimize the efficiency of waterborne transportation.

The strategic research and innovation agenda, categorized into ships and shipping, blue growth and ports and logistics, provides a framework for specialization and the production of efficient and impactful results. The agenda emphasizes the utilization of digital technologies, the development of sustainable fuels, electrification and increased energy efficiency to support the transition towards a zero-emission waterborne transport sector and the growth of sustainable blue economies.

To achieve these strategic objectives, the waterborne sector has set forth a series of operational objectives. These objectives include the elimination of GHG emission, air and water pollution through the development and adoption of alternative and sustainable fuels, electrification of ships, increased energy efficiency measures and the establishment of cleaner and climate-resilient inland waterway vessels.

The cPP-ZEWT focuses on key areas such as the Use of SAF, Electrification, Energy Efficiency, Design and Retrofitting, Digital Green and Ports. The topics under these Activities address various challenges in the waterborne sector and aim to develop innovative solutions.

SAF topics primarily aim to replace traditional fuels with alternative options, reduce GHG emissions and resolve issues related to water pollution caused by outdated turbines and combustion engines. Electrification topics focus on utilizing electrical energy storage systems and optimizing battery electric power in ships. Energy Efficiency topics seek to reconfigure vessel architecture, reduce power consumption and exploit renewable energy sources like wind power. Design and Retrofitting topics

aim to greenify the existing fleet through retrofitting, improve design methodologies and address issues like methane slip. Digital Green topics aim to leverage digitalization to enhance efficiency, reduce emissions and develop computational tools for shipbuilding.

In conclusion, the topics and projects for the period 2021-2022 cover a wide range of challenges in the waterborne transport sector. These initiatives prioritize the development of climate-neutral fuels, electrification, energy efficiency, green design and retrofitting and digitalization to achieve the goal of a zero-emission waterborne transport system by 2050. By investing in research and innovation, the partnership aims to contribute to climate neutrality, environmental protection and the growth of green and digital waterborne industries in Europe while addressing global competitiveness.

The HEU has also set ambitious goals to transition the maritime industry into a zero-emission sector by 2050. The open topics for 2023-2024 aim to strengthen ongoing efforts, provide specialized solutions for unresolved issues and develop new technologies to achieve these objectives. The topics are categorized into different activities, namely SAF, Electrification, Energy Efficiency, Design and Retrofitting, Digital Green, Ports and CSA.

Under the Use of SAF Activity, funding will be allocated to projects focused on power conversion technologies and demonstrating the safe use of sustainable climate neutral fuels. The goal is to convert existing ships into zero-emission units and develop a next-generation fleet operating on eco-friendly fuels. The Electrification Activity aims to modernize traditional methods, develop long-range batteries and establish fully DC electric grids for ships. Energy Efficiency projects will focus on improving energy savings and emission reductions in both existing and newbuild ships.

In the Design and Retrofitting Activity, projects will address underwater noise reduction and the environmental impact of shipyards. The objective is to develop

technologies that minimize noise and optimize shipyard processes for a greener transition. The Digital Green Activity will focus on the development of digital twin green vessels and small automated vessels with zero-emission propulsion systems to decongest road transport. Port-related activities aim to optimize port operations and services through digitalization, reducing emissions and noise pollution.

The CSA projects will support ongoing R&I projects in increasing their impact and commercialization. They will facilitate collaboration among member states, universities, scientific communities and industry representatives, attracting new private investors.

To sum up, the H2020 and the HEU Framework Programmes have played significant roles in advancing research, innovation and sustainability in the European region. Through the assessment of completed projects and the analysis of ongoing initiatives, several research gaps and challenges have been identified that require attention and further development.

In the case of the H2020 Framework Programme, assessments have highlighted the need for improved coordination and collaboration among stakeholders in the maritime industry, including ship owners, operators, ports and regulators. While progress has been made in this area, there is still work to be done to ensure that all stakeholders are aligned towards common goals.

Additionally, gaps have been identified in areas such as autonomous and unmanned vessels, integration of ships with other modes of transport, renewable energy sources, ship lifecycle management and the use of lightweight materials in shipbuilding. These gaps underscore the need for continued research and development to realize the full potential of sustainable and efficient waterborne transport.

Furthermore, societal engagement and awareness of the benefits of research and innovation need to be further strengthened. The dissemination of information and the active involvement of the public are crucial in fostering a sustainable blue economy and ensuring the adoption of innovative solutions.

Similarly, in the case of the HEU Framework Programme, it is still early to identify specific research gaps resulting from funded projects. However, ongoing research is needed to address challenges related to technology readiness levels, open accessibility of data and publications and societal engagement.

To achieve the operational objectives set by these framework programs, ongoing research and development efforts are necessary. This includes the development of new technologies, evaluation of their effectiveness, assessment of their environmental impact and integration into complete systems that can be scaled up for real-world applications. It is also important to consider the cost-effectiveness of these technologies to ensure their wide adoption by the industry.

The gap analysis highlights several challenges that need to be addressed to strengthen the HEU Framework Programme. Feedback and evaluation of project progress should be more frequent to assess needs, reinforce infrastructures and ensure the targets for sustainable development and climate action are met. Improvements in data quality and availability are necessary, as well as increased openness and accessibility of project outcomes. Societal engagement should be enhanced to raise awareness and actively involve the public in shaping a better environment.

In conclusion, the H2020 and HEU Framework Programmes have paved the way for significant advancements in research, innovation and sustainability in the European region. However, there are still research gaps and challenges that need to be addressed to achieve the desired outcomes. Continued collaboration among stakeholders, increased societal engagement, ongoing research and development and the integration

of new technologies into comprehensive systems are essential to ensure the long-term sustainability of the waterborne transport sector and the overall vision of a climate-neutral Europe.

REFERENCES

Arief, I. S., & Fathalah, A. Z. M. (2022). Review Of Alternative Energy Resource For The Future Ship Power. In *IOP Conference Series: Earth and Environmental Science* (Vol. 972, No. 1, p. 012073). IOP Publishing.

Attinasi, M. G., Balatti, M., Mancini, M., & Metelli, L. (2022). Supply chain disruptions and the effects on the global economy. *Economic Bulletin Boxes*, *8*.

Baker, J. (2021). "Green Deal will bring opportunities and challenges to European ports", https://www.wartsila.com/insights/article/eu-green-deal-takes-bold-steps-toward-cutting-shipping-emissions, last accessed: 16/01/2022

Balogh, A. (2019). "Europe is finding its hidden treasures to build its green, digital and climate-neutral economy", *Horizon The EU Research & Innovation Magazine*, https://ec.europa.eu/research-and-innovation/en/horizon-magazine/europe-finding-its-hidden-treasures-build-its-green-digital-and-climate-neutral-economy, last accessed: 16/01/2022

Bask, A., & Rajahonka, M. (2017). The role of environmental sustainability in the freight transport mode choice: A systematic literature review with focus on the EU. *International Journal of Physical Distribution & Logistics Management*.

Cheung, W. M. (2022). A scenario-based approach to predict energy demand and carbon emission of electric vehicles on the electric grid. Environmental Science and Pollution Research, 29(51), 77300-77310.

Claeys, G., Tagliapietra, S., & Zachmann, G. (2019). How to make the European Green Deal work. Brussels, Belgium: Bruegel.

Comer, B., O'Malley, J., Osipova, L., & Pavlenko, N. (2022). Comparing the Future Demand For, Supply Of, and Life-Cycle Emissions From Bio, Synthetic, and Fossil LNG Marine Fuels in the European Union.

Doelle, M., & Chircop, A. (2019). Decarbonizing international shipping: An appraisal of the IMO's Initial Strategy. Review of European, Comparative & International Environmental Law, 28(3), 268-277.

Fabian, P., & Krištofová, L. (2015). TRANSPORT RESEARCH AND INNOVATION IN THE EU HORIZON 2020 PROGRAMME.

Galieriková, A. (2019). The human factor and maritime safety. *Transportation research procedia, 40,* 1319-1326. https://doi.org/10.1016/j.trpro.2019.07.183

Gebraad, J. (2020). "STEERER. D 3.2. Terms of Reference for the Green Shipping Expert Group", https://www.waterborne.eu/images/downloads/210308-d32_steerer_terms_of_refeference_for_the_green_shipping_expert_group_final_version.pdf, last accessed: 28/01/2023

Gebraad, J. (2020). "Strategic Research Agenda for the European Waterborne Sector", https://www.businessfinland.fi/490702/globalassets/finnish-customers/horizon-2020/esitysaineistot/27_01-2-gebraad-200126-waterborne.pdf, last accessed: 30/01/2023

Gkoumas, K., van Balen, M., Tsakalidis, A., & Pekar, F. (2022). Evaluating the development of transport technologies in European research and innovation projects between 2007 and 2020. *Research in Transportation Economics*, *92*, 101113.

Gl, D. N. V. (2017). MARITIME FORECAST TO 2050—Energy Transition Outlook 2019. *DNV GL, Oslo*.

Grosso, M., Marques dos Santos, F. L., Gkoumas, K., Stępniak, M., & Pekár, F. (2021). The Role of Research and Innovation in Europe for the Decarbonisation of Waterborne Transport. Sustainability, 13(18), 10447, https://www.mdpi.com/2071-1050/13/18/10447, last accessed: 19/07/2022

Grosso, M., Marques dos Santos, F. L., Gkoumas, K., Stępniak, M., & Pekár, F. (2021). The Role of Research and Innovation in Europe for the Decarbonisation of Waterborne Transport. Sustainability, 13(18), 10447.

Grosso, M., Marques Dos Santos, F., Gkoumas, K., Ortega Hortelano, A., Stepniak, M., Tsakalidis, A., & Pekar, F. (2021). Waterborne transport in Europe—The role of Research and Innovation in Decarbonization.

International Transport Forum, (2018). "How Transport CO_2 Reduction Pledges Fall Short", https://www.itf-oecd.org/co2-reduction-pledges#:~:text=The%20transport%20sector%20is%20responsible,have%20been%20limited%20and%20insufficient., last accessed: 19/02/2022

Jones L., (2022). “Flag state’s role in decarbonising the shipping industry”, https://www.lngindustry.com/special-reports/26042022/flag-states-role-in-decarbonising-the-shipping-industry/, last accessed: 01/06/2023

Laros, W., & Benedetti, L. (2012). Designing the WATERBORNE R&D RoapMap Long Term Vision. Procedia-Social and Behavioral Sciences, 48, 1923-1933.

Muntión, E.G., Granados, M.A., & Hernandez, V.R. (2014). RTDI - A Complete Guide to HORIZON 2020., https://www.slideshare.net/mazgra/rtdi-a-guide-to-horizon-2020, last accessed: 25/10/2023.

Olmer, N., Comer, B., Roy, B., Mao, X., & Rutherford, D. (2017). Greenhouse gas emissions from global shipping, 2013-2015 Detailed methodology.

Tsakalidis, A., Gkoumas, K., Grosso, M., & Pekár, F. (2020). TRIMIS: Modular Development of an Integrated Policy-Support Tool for Forward-Oriented Transport Research and Innovation Analysis. Sustainability, 12(23), 10194.

Tsakalidis, A., van Balen, M., Gkoumas, K., & Pekar, F. (2020). Catalyzing sustainable transport innovation through policy support and monitoring: The case of TRIMIS and the European green deal. *Sustainability*, *12*(8), 3171.

Tsakalidis, A., van Balen, M., Gkoumas, K., Ortega Hortelano, A., Grosso, M., Haq, G., & Pekár, F. (2020). Indicators for monitoring the Strategic Transport Research and Innovation Agenda (No. JRC120323).

UNCTAD (United Nations Conference on Trade and Development). (2019). Review of Maritime Transport 2019. *UNCTAD/RMT/2019*.

UNCTAD (United Nations Conference on Trade and Development). (2022). Review of Maritime Transport 2022. *UNCTAD/RMT/2022*.

UNCTAD. (2018). Review of Maritime Transport 2018, United Nations. Geneva, Switzerland: United Nations Conference on Trade and Development.

van Balen, M., Grosso, M., Tsakalidis, A., Gkoumas, K., Haq, G., Ortega Hortelano, A., & Pekár, F. (2018). Research and innovation capacity in smart mobility and services (No. JRC113784).

Wehn, U., & Montalvo, C. (2014). Exploring the dynamics of water innovation. Journal of Cleaner Production, 87, 3-6.

Wiesenthal, T., Condeço-Melhorado, A., & Leduc, G. (2015). Innovation in the European transport sector: A review. *Transport Policy*, *42*, 86-93.

Wolf, S., Teitge, J., Mielke, J., Schütze, F., & Jaeger, C. (2021). The European Green Deal—more than climate neutrality. Intereconomics, 56(2), 99-107.

Xing, H., Stuart, C., Spence, S., & Chen, H. (2021). Alternative fuel options for low carbon maritime transportation: Pathways to 2050. *Journal of Cleaner Production*, [126651]. https://doi.org/10.1016/j.jclepro.2021.126651

Young, D. & King, S. (2013). "Demystifying European Funding", https://www.slideshare.net/lostmoya/demystifying-european-funding-from-fp7-to-horizon-2020, last accessed: 11/05/2022

Agro Highway. (n.d.). "Background". https://www.agrohighways.eu/agrohighway.eu/background, last accessed: 16/06/2023

AIRCOAT. (n.d.). "AIRCOAT research and product development". https://aircoat.eu/project/, last accessed: 09/05/2023

ARICE. (n.d.). "Goals and Objectives". https://arice-h2020.eu/about/goals-and-objectives/, last accessed: 16/06/2023

BRIDGES. (n.d.). "Main Objective of BRIDGES". http://www.bridges-h2020.eu/project-summary.php, last accessed: 09/05/2023

CINEA. (2021). "Waterborne Transport Projects. Horizon 2020 projects managed by CINEA and opportunities for synergies". https://medblueconomyplatform.org/wp-content/uploads/2022/02/waterborne-transport-projects---horizon-2020-projects-managed-by-cinea-and-opportunities-for-syne.pdf, last accessed: 15/10/2023

CINEA. (n.d.). "H2020 Programme". https://cinea.ec.europa.eu/programmes/horizon-europe/h2020-programme_en, last accessed: 11/05/2022

COREALIS. (n.d.). "The Objectives". https://www.corealis.eu/#about, last accessed: 09/05/2023

DEXROV. (n.d.). “DEXROV: HOW IT WORKS”. https://www.dexrov.eu/about-dexrov/, last accessed: 09/05/2023

DocksTheFuture. (n.d.). “Project”. https://www.docksthefuture.eu/project/, last accessed: 09/05/2023

E-ferry. (n.d.). “Objectives”. http://e-ferryproject.eu/Home/Objectives, last accessed: 09/05/2023

EfficienSea2. (n.d.). “Aim”. https://efficiensea2.org/about/aim-getting-connected/, last accessed: 09/05/2023

EGNSS Hull to Hull. (n.d.). “Objectives”. https://www.sintef.no/projectweb/hull-to-hull/, last accessed: 16/06/2023

ERA PORTAL AUSTRIA. (2018). “Horizon 2020 Interim Evaluation”. https://era.gv.at/horizon-europe/horizon-2020-new/horizon-2020-interim-evaluation/, last accessed: 25/07/2022

European Commission, (2017). “Horizon 2020. Work Programme 2016-2017. 11. Smart, green and integrated transport”, https://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-transport_en.pdf, last accessed: 26/07/2022

European Commission, (2018). “Maximising the impact of EU research and innovation”, https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/maximising-impact-eu-research-and-innovation-2018-01-11_en, last accessed: 16/01/2022

European Commission, (2019). “Horizon Europe. The next EU Research & Innovation Investment Programme (2021–2027)”, https://ec.europa.eu/info/sites/default/files/research_and_innovation/ec_rtd_he-presentation_062019_en.pdf, last accessed: 28/11/2021

European Commission, (2019). “The European Green Deal”, https://eur-lex.europa.eu/legal-content/EL/TXT/HTML/?uri=CELEX:52019DC0640&from=EN, last accessed: 26/07/2022

European Commission, (2020). “A European Green Deal Striving to be the first climate-neutral continent”, https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en, last accessed: 20/11/2022

European Commission, (2020). “Horizon 2020. Work Programme 2018-2020. 11. Smart, green and integrated transport”, https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-transport_en.pdf, last accessed: 26/07/2022

European Commission, (2021). “A deep dive into the European Green Deal Research & Innovation Call. Analysis Report”, https://ec.europa.eu/info/sites/default/files/research_and_innovation/events/documents/ec_rtd_gdce-analysis_report.pdf, last accessed: 11/05/2022

European Commission, (2021). “EU Emissions Trading System (EU ETS)”, https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en, last accessed: 11/05/2022

European Commission, (2021). “Mobility Strategy”, https://transport.ec.europa.eu/transport-themes/mobility-strategy_en, last accessed: 20/11/2021

European Commission, (2022). “Horizon Europe Work Programme 2021-2022”, https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-1-general-introduction_horizon-2021-2022_en.pdf, last accessed: 12/04/2023

European Commission, (2022). “Horizon Europe. Work Programme 2021-2022. 8. Climate, Energy and Mobility”, https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-8-climate-energy-and-mobility_horizon-2021-2022_en.pdf, last accessed: 06/01/2023

European Commission, (2023). “Horizon Europe Work Programme 2023-2024”, https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2023-2024/wp-1-general-introduction_horizon-2023-2024_en.pdf, last accessed: 12/04/2023

European Commission, (n.d.). "2050 long-term strategy", https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en, last accessed: 11/05/2022

European Commission, (n.d.). "A European Green Deal Striving to be the first climate-neutral continent", https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en, last accessed: 26/03/2023

European Commission, (n.d.). "Available budget of Cohesion Policy 2021-2027", https://ec.europa.eu/regional_policy/en/funding/available-budget/, last accessed: 19/02/2022

European Commission, (n.d.). "Biodiversity strategy for 2030", https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en, last accessed: 02/07/2023

European Commission, (n.d.). "Blue Growth Supporting sustainable growth of the marine and maritime sectors", https://s3platform.jrc.ec.europa.eu/blue-growth, last accessed: 12/12/2021

European Commission, (n.d.). "EU research projects under Horizon 2020 (2014-2020)", https://data.europa.eu/data/datasets/cordish2020projects?locale=en, last accessed: 26/07/2022

European Commission, (n.d.). "European Climate Law", https://climate.ec.europa.eu/eu-action/european-green-deal/european-climate-law_en, last accessed: 20/11/2022

European Commission, (n.d.). "Horizon 2020", https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en, last accessed: 26/07/2022

European Commission, (n.d.). "Horizon 2020", https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en#:~:text=Latest-,What%20was%20Horizon%202020%3F,of%20nearly%20%E2%82%AC80%20billion., last accessed: 20/11/2022

European Commission, (n.d.). "INEA. Horizon 2020", https://ec.europa.eu/inea/horizon-2020, last accessed: 28/04/2022

European Commission, (n.d.). "Integrated Maritime Policy", https://ec.europa.eu/info/research-and-innovation/research-area/environment/oceans-and-seas/integrated-maritime-policy_en, last accessed: 28/04/2022

European Commission, (n.d.). "Knowledge Exchange Platform (KEP)", https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/european-research-area/knowledge-exchange-platform_en, last accessed: 02/07/2023

European Commission, (n.d.). "Public-private partnerships in transport research", https://research-and-innovation.ec.europa.eu/research-area/transport/public-private-partnerships_en, last accessed: 02/07/2023

European Commission, (n.d.). "Reducing emissions from the shipping sector", https://ec.europa.eu/clima/eu-action/transport-emissions/reducing-emissions-shipping-sector_en, last accessed: 16/01/2022

European Commission, (n.d.). "Reducing emissions from the shipping sector", https://climate.ec.europa.eu/eu-action/transport-emissions/reducing-emissions-shipping-sector_en, last accessed: 20/11/2022

European Commission, (n.d.). "Skills and career development", https://oceans-and-fisheries.ec.europa.eu/ocean/blue-economy/skills-and-career-development_en, last accessed: 02/07/2023

European Commission, (n.d.). "Strategy and policy", https://commission.europa.eu/strategy-and-policy_en, last accessed: 02/07/2023

European Commission, (n.d.). "TRIMIS. Structuring Towards Zero Emission Waterborne Transport", https://trimis.ec.europa.eu/project/structuring-towards-zero-emission-waterborne-transport, last accessed: 30/01/2023

European Commission, (n.d.). "Waterborne transport research", https://ec.europa.eu/info/research-and-innovation/research-area/transport/waterborne-transport_en, last accessed: 11/05/2022

European Commission, (n.d.). "What is Horizon 2020?", https://wayback.archive-it.org/12090/20220124080448/https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020, last accessed: 20/11/2022

European Commission, (n.d.). "Zero pollution action plan", https://environment.ec.europa.eu/strategy/zero-pollution-action-plan_en, last accessed: 02/07/2023

European Commission, Directorate-General for Research and Innovation, (2017). *LAB – FAB – APP : investing in the European future we want : report of the independent High Level Group on maximising the impact of EU research & innovation programmes*, Publications Office. https://data.europa.eu/doi/10.2777/477357

European Commission, Directorate-General for Research and Innovation, (2011). "*Europe 2020 flagship initiative Innovation Union: SEC(2010) 1161, communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions"*, Publications Office. https://data.europa.eu/doi/10.2777/47750, last accessed: 15/10/2023

European Commission. (2010). "EUROPE 2020 A strategy for smart, sustainable and inclusive growth". https://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf, last accessed: 28/05/2023

European Commission. (2013). "Europe 2020: A blueprint for the Post-Crisis World". https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_13_204, last accessed: 11/05/2022

European Commission. (2016). "Commission presents its evaluation of the 7th Framework Programme for Research".

https://ec.europa.eu/commission/presscorner/detail/de/MEMO_16_146, last accessed: 07/10/2023

European Commission. (2016). "Evaluation of the 7th Framework Programme for Research". https://ec.europa.eu/commission/presscorner/detail/de/MEMO_16_146, last accessed: 02/07/2023

European Commission. (2016). "Marine Investment for the Blue Economy". https://cordis.europa.eu/project/id/652629/reporting, last accessed: 28/05/2023

European Commission. (2017). "IN-DEPTH INTERIM EVALUATION of HORIZON 2020". https://gsri.gov.gr/wp-content/uploads/2017/10/swd2017220-in-depth-interim_evaluation-h2020.pdf, last accessed: 26/07/2022

European Commission. (2017). "Real-time Fleet Performance Center (FPC) to optimize energy efficiency in Maritime Transport to reduce fuel consumption and harmful emissions". https://cordis.europa.eu/project/id/744716/reporting, last accessed: 16/06/2023

European Commission. (2018). "Demonstration of an Innovative concept for high quality Transport of Perishable Agro Food Liquids inducing a Modal shift to Short Sea and River transport". https://cordis.europa.eu/article/id/232834-moving-liquid-foods, last accessed: 16/06/2023

European Commission. (2018). "Dexterous ROV: effective dexterous ROV operations in presence of communication latencies.". https://cordis.europa.eu/project/id/635491/reporting, last accessed: 28/05/2023

European Commission. (2018). "EfficienSea 2 - Efficient, Safe and Sustainable Traffic at Sea". https://cordis.europa.eu/project/id/636329/reporting, last accessed: 28/05/2023

European Commission. (2018). "GALILEO-BASED PASSIVE RADAR SYSTEM FOR MARITIME SURVEILLANCE". https://cordis.europa.eu/article/id/227895-maritime-embraces-galileo-technology, last accessed: 16/06/2023

European Commission. (2018). “Promoting Innovation in the Inland Waterways Transport Sector”. https://cordis.europa.eu/project/id/633929/reporting, last accessed: 28/05/2023

European Commission. (2018). “ProZero - carbon based fast boats for professional use”. https://cordis.europa.eu/article/id/238600-carbon-fibre-composites-in-boat-building, last accessed: 16/06/2023

European Commission. (2019). “Bringing together Research and Industry for the Development of Glider Environmental Services”. https://cordis.europa.eu/project/id/635359/reporting, last accessed: 28/05/2023

European Commission. (2019). “Energy and Environmentally Efficient Cooling System for Maritime use”. https://cordis.europa.eu/article/id/266016-new-solution-uses-heat-waste-for-selfsustaining-cooling-at-sea, last accessed: 16/06/2023

European Commission. (2019). “FUEL FLEXIBLE, NEAR -ZERO EMISSIONS, ADAPTIVE PERFORMANCE MARINE ENGINE”. https://cordis.europa.eu/article/id/262235-ecoengines-for-sustainable-shipping, last accessed: 28/05/2023

European Commission. (2019). “Integrated oil spill response actions and environmental effects”. https://cordis.europa.eu/article/id/406999-enhanced-detection-response-and-impact-assessment-of-arctic-oil-spills, last accessed: 28/05/2023

European Commission. (2019). “Low Energy And Near to zero emissions Ships”. https://cordis.europa.eu/article/id/407000-building-the-energy-efficient-low-emission-ships-of-tomorrow, last accessed: 28/05/2023

European Commission. (2019). “Ship Lifecycle Software Solutions”. https://cordis.europa.eu/project/id/690770/reporting, last accessed: 28/05/2023

European Commission. (2020). “AnchorGuardian, providing safety during anchoring by monitoring the position and absolute movement of a ships anchor.”. https://cordis.europa.eu/article/id/418107-safe-anchoring-for-sailor-ship-and-sea, last accessed: 16/06/2023

European Commission. (2020). "Developing the methodology for a coordinated approach to the clustering, monitoring and evaluation of results of actions under the Ports of the Future topic". https://cordis.europa.eu/project/id/770064/reporting, last accessed: 28/05/2023

European Commission. (2020). "eco-friendly Ship Hull film system with fouling Release and fuel saving properties". https://cordis.europa.eu/project/id/691495/reporting, last accessed: 16/06/2023

European Commission. (2020). "E-ferry – prototype and full-scale demonstration of next generation 100% electrically powered ferry for passengers and vehicles". https://cordis.europa.eu/project/id/636027/reporting, last accessed: 28/05/2023

European Commission. (2020). "Engineering, production and life-cycle management for the complete construction of large-length FIBRE-based SHIPs". https://cordis.europa.eu/article/id/422674-composite-materials-herald-the-next-generation-of-lightweight-large-scale-ships, last accessed: 28/05/2023

European Commission. (2020). "HOLIstic optimisation of SHIP design and operation for life cycle". https://cordis.europa.eu/project/id/689074/reporting, last accessed: 28/05/2023

European Commission. (2020). "Horizon Europe". https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en, last accessed: 27/11/2021

European Commission. (2020). "Lean innovative connected vessels". https://cordis.europa.eu/article/id/415446-improving-maritime-operations-with-customised-smart-vessels, last accessed: 28/05/2023

European Commission. (2020). "Multi-use affordable standardised floating Space@Sea". https://cordis.europa.eu/article/id/422445-floating-islands-to-work-and-live-on, last accessed: 16/06/2023

European Commission. (2020). "PALAEMON – A holistic passenger ship evacuation and rescue ecosystem". https://cordis.europa.eu/project/id/814962/reporting, last accessed: 28/05/2023

European Commission. (2020). “Strategies for Environmental Monitoring of Marine Carbon Capture and Storage”. https://cordis.europa.eu/article/id/422218-advanced-tools-to-detect-and-quantify-co2-leaks-for-safer-offshore-carbon-capture-and-storage, last accessed: 16/06/2023

European Commission. (2020). “Sustainable and Smart Mobility Strategy – putting European transport on track for the future”. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0789, last accessed: 15/10/2023

European Commission. (2020). “The European Green Deal Investment Plan and Just Transition Mechanism explained”. https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_24, last accessed: 20/11/2022

European Commission. (2021). “2020 Annual Report on CO2 Emissions from Maritime Transport”. https://european-accreditation.org/wp-content/uploads/2022/06/2020-Annual-report-from-the-Commission.pdf, last accessed: 20/11/2022

European Commission. (2021). “Capacity with a pOsitive enviRonmEntal and societAL footprInt: portS in the future era”. https://cordis.europa.eu/project/id/768994/reporting, last accessed: 28/05/2023

European Commission. (2021). “Delivering the European Green Deal”. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en, last accessed: 28/05/2023

European Commission. (2021). “Next generation of life Saving appliances and systems for saFE and swift evacuation operations on high capacity PASSenger ships in extreme scenarios and conditions”. https://cordis.europa.eu/project/id/815146/reporting, last accessed: 28/05/2023

European Commission. (2021). “NOVel Iwt and MARitime transport concepts”. https://cordis.europa.eu/project/id/723009/reporting, last accessed: 28/05/2023

European Commission. (2021). “Port IoT for Environmental Leverage”. https://cordis.europa.eu/project/id/769355/reporting, last accessed: 28/05/2023

European Commission. (2021). “Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships”. https://cordis.europa.eu/project/id/723246/reporting, last accessed: 28/05/2023

European Commission. (2021). “Realising the world's first sea-going hydrogen-powered RoPax ferry and a business model for European islands”. https://cordis.europa.eu/project/id/769417/reporting, last accessed: 28/05/2023

European Commission. (2021). “Safe maritime operations under extreme conditions: the Arctic case”. https://cordis.europa.eu/article/id/429581-eu-research-cuts-the-ice-to-increase-arctic-sea-safety, last accessed: 28/05/2023

European Commission. (2021). “Synchro-modal Supply Chain Eco-Net”. https://cordis.europa.eu/project/id/636354/reporting, last accessed: 16/06/2023

European Commission. (2021). “Towards Game-changer Service Operation Vessels for Offshore Windfarms”. https://cordis.europa.eu/project/id/774519/reporting, last accessed: 28/05/2023

European Commission. (2022). “Air Induced friction Reducing ship COATing”. https://cordis.europa.eu/project/id/764553/reporting, last accessed: 28/05/2023

European Commission. (2022). “Compressed Natural Gas Transport System”. https://cordis.europa.eu/article/id/442072-breakthrough-vessel-design-makes-transport-and-storage-of-compressed-natural-gas-more-viable, last accessed: 28/05/2023

European Commission. (2022). “EGNSS Hull-to-Hull”. https://cordis.europa.eu/project/id/775998/results, last accessed: 16/06/2023

European Commission. (2022). “Hydrogen-Methanol Ship propulsion system using on-board pre-combustion carbon capture”. https://cordis.europa.eu/article/id/436378-hydrogen-based-innovation-could-help-shipping-go-green, last accessed: 28/05/2023

European Commission. (2022). “New, Advanced and Value-Added Innovative Ships”. https://cordis.europa.eu/project/id/769419/reporting, last accessed: 28/05/2023

European Commission. (2022). “SHIPPING CONTRIBUTIONS TO INLAND POLLUTION PUSH FOR THE ENFORCEMENT OF REGULATIONS”. https://cordis.europa.eu/project/id/814893/reporting, last accessed: 28/05/2023

European Commission. (2022). “Spectral Imaging Powered Ship Hull Biofouling Detection and Cleaning”. https://cordis.europa.eu/article/id/442647-shiny-ship-hull-surfaces-free-from-contaminants, last accessed: 16/06/2023

European Commission. (2022). “Waterborne Transport Projects. Horizon 2020 projects

European Commission. (2023). “An innovative people localisation system for safe evacuation of large passenger ships”. https://cordis.europa.eu/article/id/308450-new-tech-ahoy-for-safer-ship-evacuations, last accessed: 28/05/2023

European Commission. (2023). “An innovative people localisation system for safe evacuation of large passenger ships”. https://cordis.europa.eu/project/id/636286, last accessed: 28/05/2023

European Commission. (2023). “Arctic Research Icebreaker Consortium: A strategy for meeting the needs for marine-based research in the Arctic”. https://cordis.europa.eu/article/id/443639-better-access-to-arctic-icebreakers-delivers-vital-climate-data, last accessed: 16/06/2023

European Commission. (2023). “European Green Deal: EU agrees stronger rules to boost energy efficiency”. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1581, last accessed: 15/10/2023

European Commission. (2023). “FLooding Accident REsponse”. https://cordis.europa.eu/article/id/443394-sailing-safe-revolutionary-framework-for-flooding-risk-assessment, last accessed: 28/05/2023

European Commission. (2023). “Horizon Europe (HORIZON) Programme Guide”. https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/guidance/programme-guide_horizon_en.pdf, last accessed: 25/10/2023

European Commission. (2023). “Market maturation of the first on-board autonomous biofouling cleaning system to keep ship’s hull clean at all times”. https://cordis.europa.eu/project/id/806303/reporting, last accessed: 16/06/2023

European Commission. (2023). “Questions and Answers on Action Plan to protect and restore marine ecosystems for sustainable and resilient fisheries”. https://ec.europa.eu/commission/presscorner/detail/en/qanda_23_832, last accessed: 02/07/2023

European Commission. (2023). “Strengthening synergies between Aviation and maritime in the area of human Factors towards achieving more Efficient and resilient MODE of transportation”. https://cordis.europa.eu/article/id/443255-human-factors-transport-modes-collaborate-to-reduce-accidents, last accessed: 28/05/2023

European Commission. (2023). “STRUCTURING TOWARDS ZERO EMISSION WATERBORNE TRANSPORT”. https://cordis.europa.eu/article/id/443136-the-road-to-making-zero-emission-waterborne-transport-a-reality, last accessed: 28/05/2023

European Commission. (n.d.). “Energy efficiency directive”. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en, last accessed: 15/10/2023

European Commission. (n.d.). “Horizon 2020 structure and budget”. https://ec.europa.eu/research/participants/docs/h2020-funding-guide/grants/applying-for-funding/find-a-call/h2020-structure-and-budget_en.htm, last accessed: 11/05/2022

European Commission. (n.d.). “Research framework programme”. https://ec.europa.eu/invest-in-research/funding/funding01_en.htm, last accessed: 07/10/2023

European Compost Network. (2019). “EU Green Deal”. https://www.compostnetwork.info/wordpress/?newsman=email&email=6h9WqhG_rxjDNKB8pc7S3xf1p0Q, last accessed: 15/10/2023

European Council, (2023). “FuelEU Maritime initiative: Provisional agreement to decarbonise the maritime sector”, https://www.consilium.europa.eu/en/press/press-releases/2023/03/23/fueleu-maritime-initiative-provisional-agreement-to-decarbonise-the-maritime-sector/, last accessed: 01/06/2023

European Council, (2023). “Infographic - Fit for 55: towards more sustainable transport”, https://www.consilium.europa.eu/en/infographics/fit-for-55-afir-alternative-fuels-infrastructure-regulation/, last accessed: 25/10/2023

European Council. (2019). “What is the European Green Deal?”. https://www.consilium.europa.eu/en/policies/green-deal/#:~:text=The%20European%20Green%20Deal%20is%20a%20package%20of%20policy%20initiatives,a%20modern%20and%20competitive%20economy., last accessed: 25/07/2022

European Council. (2023). “Fit for 55: reform of the EU emissions trading system”. https://www.consilium.europa.eu/en/infographics/fit-for-55-eu-emissions-trading-system/, last accessed: 07/10/2023

European Council. (2023). “Fit for 55: towards more sustainable transport”. https://www.consilium.europa.eu/en/infographics/fit-for-55-afir-alternative-fuels-infrastructure-regulation/, last accessed: 07/10/2023

European Council. (2023). “Fit for 55”. https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/#what, last accessed: 07/10/2023

European Council. (2023). “Infographic - Fit for 55: increasing the uptake of greener fuels in the aviation and maritime sectors”. https://www.consilium.europa.eu/en/infographics/fit-for-55-refueleu-and-fueleu/, last accessed: 25/10/2023

European Council. (n.d.). “European Green Deal”. https://www.consilium.europa.eu/en/policies/green-deal/#what, last accessed: 07/10/2023

European Environment Agency, (2021). "EU maritime transport: first environmental impact report acknowledges good progress towards sustainability and confirms that more effort is needed to prepare for rising demand", https://www.eea.europa.eu/highlights/eu-maritime-transport-first-environmental, last accessed: 26/03/2023

European Environment Agency, (2023). "Digitalisation can support shifting to more sustainable transport in Europe", https://www.eea.europa.eu/en/newsroom/news/digitalisation-can-support-shifting-to-more-sustainable-transport-in-europe, last accessed: 02/07/2023

European Investment Bank, (2016). "Green Shipping Guaranty Proramme", https://www.eib.org/en/projects/pipelines/all/20150334#:~:text=The%20Guarantee%20programme%20is%20intended,protection%20including%20Climate%20Action%20initiatives., last accessed: 11/05/2022

European Investment Bank, (2016). "Green Shipping Proramme Loan", https://www.eib.org/en/projects/pipelines/all/20150742, last accessed: 11/05/2022

European Maritime Safety Agency. (n.d.). "Prevention of Pollution by Ships". https://www.emsa.europa.eu/we-do/sustainability/environment.html, last accessed: 02/07/2023

European MSP Platform. (n.d.). "Marine Investment for the Blue Economy". https://maritime-spatial-planning.ec.europa.eu/projects/marine-investment-blue-economy, last accessed: 28/05/2023

European Parliament, (2018). "European Parliament resolution of 25 October 2018 on deployment of infrastructure for alternative fuels in the European Union: time to act!", https://www.europarl.europa.eu/doceo/document/TA-8-2018-0438_EN.html?redirect, last accessed: 30/12/2021

European Parliament, (2020). "Decarbonising maritime transport: The EU perspective", https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2020)659296, last accessed: 26/03/2022

European Parliament, (2020). "Decarbonising maritime transport: The EU perspective", https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/659296/EPRS_BRI(2020)659296_EN.pdf, last accessed: 02/07/2023

European Parliament, (2020). "European Parliament resolution of 15 January 2020 on the European Green Deal", https://www.europarl.europa.eu/doceo/document/TA-9-2020-0005_EN.html, last accessed: 14/01/2022

European Parliament, (2020). "Monitoring, reporting and verification of CO_2 emissions from maritime transport", https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2019)642224, last accessed: 05/06/2022

European Parliament, (2022). "Enhancing policy coherence for development", https://www.europarl.europa.eu/RegData/etudes/STUD/2022/702571/EXPO_STU(2022)702571_EN.pdf, last accessed: 02/07/2023

European Parliament, (2022). "Sustainable maritime fuels (FuelEU Maritime Initiative)", https://www.europarl.europa.eu/doceo/document/TA-9-2022-0367_EN.html, last accessed: 20/11/2022

European Parliament, (2023). "Resource efficiency and the circular economy", https://www.europarl.europa.eu/factsheets/en/sheet/76/resource-efficiency-and-the-circular-economy, last accessed: 02/07/2023

European Union – Central Asia Water, Environment and Climate Change Cooperation – WECOOP, (n.d.). "EU Environment Policy", https://wecoop.eu/regional-knowledge-centre/eu-policies-regulations/, last accessed: 20/11/2022

European Union Law EUR-Lex, (2014). "Framework for State aid for research and development and innovation", https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2014.198.01.0001.01.ENG&toc=OJ:C:2014:198:TOC,

European Union Law EUR-Lex, (2018). "DECISION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on establishing the specific

programme implementing Horizon Europe – the Framework Programme for Research and Innovation", https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018PC0436&rid=8, last accessed: 13/03/2023

European Union Law EUR-Lex, (2018). "DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources", https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018L2001&qid=1627646087084, last accessed: 13/03/2023

European Union Law EUR-Lex, (2018). "Horizon 2020 interim evaluation: maximising the impact of EU research and innovation". https://eur-lex.europa.eu/legal-content/GA/TXT/?uri=COM%3A2018%3A2%3AFIN&WT.mc_id=Twitter&qid=1394708797280, last accessed: 28/04/2022

European Union Law EUR-Lex, (2019). "COMMUNICATION FROM THE COMMISSION. The European Green Deal", https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1576150542719&uri=COM:2019:640:FIN, last accessed: 05/06/2022

European Union Law EUR-Lex, (2019). "Port facilities for waste from ships, including cargo residues", https://eur-lex.europa.eu/EN/legal-content/summary/port-facilities-for-waste-from-ships-including-cargo-residues.html#:~:text=WHAT%20IS%20THE%20AIM%20OF,facilities%20for%20waste%20from%20ships., last accessed: 11/05/2022

European Union Law EUR-Lex, (2020). "An updated action plan for a sustainable, resilient and competitive blue economy in the European Union Atlantic area", https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A329%3AFIN, last accessed: 02/07/2023

European Union Law EUR-Lex, (2020). “Sustainable and Smart Mobility Strategy – putting European transport on track for the future”, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789, last accessed: 02/07/2023

European Union Law EUR-Lex, (2021). “EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil', https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021DC0400&from=EN, last accessed: 02/07/2023

European Union Law EUR-Lex, (2021). “Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC”, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0562&qid=1632150729354, last accessed: 13/03/2023

European Union Law EUR-Lex, (2021). “REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021PC0562, last accessed: 02/07/2023

European Union Law EUR-Lex, (2023). “EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries”, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX%3A52023DC0102, last accessed: 13/03/2023

FIBRESHIP. (n.d.). “Concept”. http://www.fibreship.eu/about/, last accessed: 09/05/2023

GASVESSEL. (n.d.). “The GASVESSEL Project”. https://www.gasvessel.eu/about/, last accessed: 09/05/2023

HERCULES-2. (n.d.). “Objectives”. https://www.hercules-2.com/objectives, last accessed: 09/05/2023

HOLISHIP. (n.d.). “Objectives and targeted results”. http://www.holiship.eu/objectives/, last accessed: 09/05/2023

HYMETHSHIP. (n.d.). “HYMETHSHIP System”. https://www.hymethship.com/index.html#system, last accessed: 09/05/2023

HySeas III. (n.d.). “The Project”. https://www.hyseas3.eu/the-project/, last accessed: 09/05/2023

International Chamber of Shipping, (2022). “Shipping and World Trade: World Seaborne Trade”, https://www.ics-shipping.org/shipping-fact/shipping-and-world-trade-world-seaborne-trade/, last accessed: 20/11/2022

International Maritime Organization, (2023). “2023 IMO STRATEGY ON REDUCTION OF GHG EMISSIONS FROM SHIPS”, https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/annex/MEPC%2080/Annex%2015.pdf, last accessed: 12/02/2024

International Maritime Organization, (2020). “Fourth Greenhouse Gas Study 2020”, https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx, last accessed: 20/11/2022

International Maritime Organization, (2020). “Marine Environment Protection Committee (MEPC) 75, 16-20 November (virtual session)”, https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MEPC-75th-session.aspx, last accessed: 04/10/2021

International Maritime Organization, (2021). “Environmental regulations and IMO conventions”, https://www.imo.org/en/OurWork/Environment/Pages/Regulations.aspx, last accessed: 11/05/2022

International Maritime Organization, (n.d.). “IMO’s work to cut GHG emissions from ships”, https://www.imo.org/en/MediaCentre/HotTopics/Pages/Cutting-GHG-emissions.aspx, last accessed: 20/11/2022

International Maritime Organization, (n.d.). "Initial IMO GHG Strategy", https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx, last accessed: 04/10/2021

International Maritime Organization, (n.d.). "Improving the energy efficiency of ships", https://www.imo.org/en/OurWork/Environment/Pages/Improving%20the%20energy%20efficiency%20of%20ships.aspx, last accessed: 06/02/2024

LeanShips. (n.d.). "Project description of LeanShips". https://www.leanships-project.eu/project/, last accessed: 09/05/2023

LINCOLN. (n.d.). "Summary and structure". http://www.lincolnproject.eu/project/summary-and-structure/, last accessed: 09/05/2023

managed by CINEA and opportunities for synergies". https://medblueconomyplatform.org/wp-content/uploads/2022/02/waterborne-transport-projects---horizon-2020-projects-managed-by-cinea-and-opportunities-for-syne.pdf, last accessed: 02/07/2023

Maritime Connectivity Platform. (n.d.). "Maritime Connectivity Platform Consortium". https://maritimeconnectivity.net/consortium/#Members, last accessed: 26/07/2022

NAVAIS. (n.d.). "About the Project". https://www.navais.eu/, last accessed: 09/05/2023

NOVIMAR. (n.d.). "NOVIMAR Vesseltrain". https://novimar.eu/handbook/, last accessed: 09/05/2023

PIXEL. (n.d.). "Deliverables". https://pixel-ports.eu/?page_id=30, last accessed: 09/05/2023

PortForward. (n.d.). "The Project Objectives". https://www.portforward-project.eu/about/, last accessed: 09/05/2023

PROMINENT. (n.d.). "Project Structure". https://www.prominent-iwt.eu/project-structure/, last accessed: 09/05/2023

RAMSSES. (n.d.). "Our Mission at RAMSSES Project for Sustainable and Efficient Ships". https://www.ramsses-project.eu/mission/, last accessed: 09/05/2023

Research & Innovation Foundation. (n.d.). "HORIZON EUROPE Programme". https://www.research.org.cy/en/eu-and-international-programmes/horizon-europe/#toggle-id-1, last accessed: 27/11/2021

SAFEMODE. (n.d.). "Objectives". https://safemodeproject.eu/, last accessed: 09/05/2023

SafePASS. (n.d.). "The SafePASS scope". http://www.safepass-project.eu/project, last accessed: 09/05/2023

SCIPPER. (n.d.). "The SCIPPER Project Concept". https://www.scipper-project.eu/the-scipper-project/overall-concept/, last accessed: 09/05/2023

SHIPLYS. (n.d.). "Objectives". http://www.shiplys.com/project-summary/, last accessed: 09/05/2023

SPACE@SEA. (n.d.). "About SPACE@SEA". https://spaceatsea-project.eu/about-space-at-sea, last accessed: 16/06/2023

Stambler, M. (2020). "EU Green Deal takes bold steps toward cutting shipping emissions", https://www.wartsila.com/insights/article/eu-green-deal-takes-bold-steps-toward-cutting-shipping-emissions, last accessed: 27/11/2021

Sustainable Development Solutions Network Europe. (n.d.). "The Policy Framework for Implementing the European Green Deal". https://egd-report.unsdsn.org/introduction-the-policy-framework-for-implementing-the-european-green-deal/, last accessed: 07/10/2023

The Editorial Team. (2022). "How Digitalization applies in shipping to boost operational efficiency", https://safety4sea.com/cm-how-digitalization-applies-in-shipping-to-boost-operational-efficiency/, last accessed: 20/11/2022

Union of Greek Shipowners, (2019). "Greek Shipping A Major EU Export INDUSTRY of Strategic Importance", https://www.ugs.gr/media/13634/eee_brochure.pdf, last accessed: 20/11/2022

Waterborne TP, (2011). "Strategic Research Agenda", https://www.waterborne.eu/images/documents/previous-waterborne-documents/files/wsra_2011.pdf, last accessed: 20/11/2022

Waterborne TP, (2016). "Blue Growth 'Technology Bricks' Demonstrators For the preparation of offshore pilot project(s)", https://www.waterborne.eu/images/documents/previous-waterborne-documents/files/WATERBORNE_BGWG_Headline_2018-2019-2020-vFinal.pdf, last accessed: 20/11/2022

Waterborne TP, (2020). "Report regarding the Open Consultation on the draft Strategic Research and Innovation Agenda Zero-emission waterborne transport", https://www.waterborne.eu/images/documents/201009_Partnership_Open_Consultation_Result_Final.pdf, last accessed: 04/10/2021

Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the European Waterborne Sector Executive Summary", https://www.waterborne.eu/images/210420_SRIA_Executive_Summary.pdf, last accessed: 11/05/2022

Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the European Waterborne Sector Ships & Shipbuilding", https://www.waterborne.eu/images/210606_SRIA_non-cPP_Ships__Shipping_Final.pdf, last accessed: 04/10/2021

Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the European Waterborne Sector Ports & Logistics", https://www.waterborne.eu/images/210609_SRIA_non-cPP_-_4_-_Ports_Logistics.pdf, last accessed: 28/11/2021

Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the European Waterborne Sector Blue Growth", https://www.waterborne.eu/images/210603_SRIA_non-cPP_-_3_Blue_Growth_final.pdf, last accessed: 28/11/2021

Waterborne TP, (2021). "Strategic Research and Innovation Agenda for the Partnership on Zero Emission Waterborne Transport", https://www.waterborne.eu/images/210601_e:_Zero_Emission_Waterborne_Transport_1.2_final_web_low.pdf, last accessed: 02/07/2023

Waterborne TP, (2022). “Horizon 2020 Research and Innovation delivering smart, green, safe and competitive waterborne transport”, https://www.waterborne.eu/images/events/Waterborne-Transport-Workshop-0702022/2-waterborne_transport_workshop_dirk_beckers_cinea_final.pdf, last accessed: 20/11/2022

Waterborne TP, (n.d.). “Zero Emission Waterborne Transport”, https://www.waterborne.eu/partnership/partnership, last accessed: 02/07/2022

Waterborne TP. (n.d.). “MARKET MATURATION OF THE FIRST ON-BOARD AUTONOMOUS BIOFOULING CLEANING SYSTEM TO KEEP SHIP’S HULL CLEAN AT ALL TIMES”. https://www.waterborne.eu/projects/energy-efficiency-and-zero-emissions/hcr, last accessed: 16/06/2023

Waterborne TP. (n.d.). “SAFE MARITIME OPERATIONS UNDER EXTREME CONDITIONS: THE ARCTIC CASE”. https://www.waterborne.eu/projects/ship-and-shipping-safety/sedna, last accessed: 09/05/2023

Waterborne TP. (n.d.). “SAILING TOWARDS NEW FLOOD RISK ASSESSMENT FOR SHIPS”. https://www.waterborne.eu/projects/ship-and-shipping-safety/flare, last accessed: 09/05/2023

Waterborne TP. (n.d.). “STRUCTURING TOWARDS ZERO-EMISSION WATERBORNE TRANSPORT”. https://www.waterborne.eu/projects/coordination-projects/steerer/about-steerer, last accessed: 09/05/2023