



**ZERO-EMISSION
SHIPPING**
MISSION

SEPTEMBER 2022
1ST EDITION

ACTION PLAN FOR THE ZERO-EMISSION SHIPPING MISSION



About the Mission

The Zero-Emission Shipping Mission is an ambitious alliance between countries, the private sector, research institutes, and civil society. The Mission will demonstrate commercially viable zero-emission ships by 2030 by focusing on the entire value chain: the ship, the fuel production, and the fuel infrastructure, driving the sector to a tipping point in its transition to well-to-wake zero-emission fuels as soon as possible. This will lay the foundation for a zero-emission shipping future and accelerate progress towards zero by 2050.

THE MEMBERS

The Mission is driven by our 12 current members from around the globe, and co-led by the governments of Denmark, Norway, and the United States, along with the Global Maritime Forum and Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (MMMCZCS) as industry co-leads.

Co-leads

Denmark

Ministry of Industry, Business and Financial Affairs, Ministry of Climate, Energy and Utilities and Ministry of Foreign Affairs

Norway

Ministry of Climate and Environment

The United States

U.S. Department of Energy

Global Maritime Forum

Representing the Getting to Zero Coalition

Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

Core Mission Members

The United Kingdom

Department for Transport

Morocco

Ministry of Energy Transition & Sustainable Development

India

Ministry of Science and Technology

Singapore

Maritime and Ports Authority

Mission Support Group

France

Ministry of the Sea

Ghana

Ghana Maritime Authority

South Korea

Ministry of Trade, Industry and Energy

Ministerial Statements

DENMARK

“Denmark is a large shipping nation and an advocate for urgent climate action. That is why we have taken lead in the Zero-Emission Shipping Mission to make sure that decarbonisation of shipping is accelerated through global action. We are looking forward to seeing how our international public-private partnership will deliver concrete actions. Changing the course for international shipping to a green and sustainable future will be a win-win for people and planet and with great possibilities for businesses across the globe.”

Simon Kollerup *Danish Minister for Industry, Business, and Financial Affairs and*

Dan Jørgensen *Danish Minister for Climate, Energy and Utilities*

NORWAY

“As co-lead of the Mission and a leading nation in green shipping, Norway is proud to support the Action Plan for the Zero-Emission Shipping Mission. The Action Plan will strengthen international collaboration across the maritime value chain for fuel production, fuel infrastructure and ships. It will be fundamental in realizing the Mission’s zero-emission goals.”

Espen Barth Eide *Minister of Climate and Environment, and*

Terje Aasland *Minister of Petroleum and Energy, Norway*

USA

“The U.S. is committed to lowering our carbon footprint across all transportation sectors, including maritime, and is proud to be co-leading the Mission Innovation: Zero-Emission Shipping Mission to see demonstrations of zero-emission ships on the water by 2030. Today, we are very excited to share the Shipping Mission’s Action Plan, which outlines the actions and projects needed to meet that goal and to help tackle the climate crisis.”

David M. Turk *Deputy Secretary, U.S. Department of Energy*

Executive Summary

Following the Mission Roadmap, **this Action Plan outlines the actions needed, with their respective timescales and required stakeholder participation, to reach Mission goals.** This Action Plan aims to bridge innovation gaps faced by the sector and shape the analysis and demonstration projects that will ultimately accelerate the adoption of zero-emission fuels for ocean-going vessels.

The actions, in this Action Plan, were identified through extensive analysis and data collection from industry stakeholders, and 43 were prioritized by the Mission with timescales between 2022 and 2030. The priority actions focus on building the foundations for demonstrations and wider deployment.

The purpose of the Action Plan is two-fold. Firstly, of the 43 prioritized actions, it identifies 18 actions that the Mission will lead on and 25 actions where the Mission has a role as supporter to other stakeholders. To operationalize these, the Action Plan furthermore presents an initial program consisting of concrete projects will address a range of the prioritized actions.

Secondly, this Action Plan is a call to action from stakeholders across the maritime value chain; both for stakeholders who have been involved in the development of this Action Plan and others who have not been involved but can play a part in the transition to zero-emission shipping. For each action, a suggested stakeholder group is identified. In these actions, the Mission's role will be to inform and encourage their development and progression.

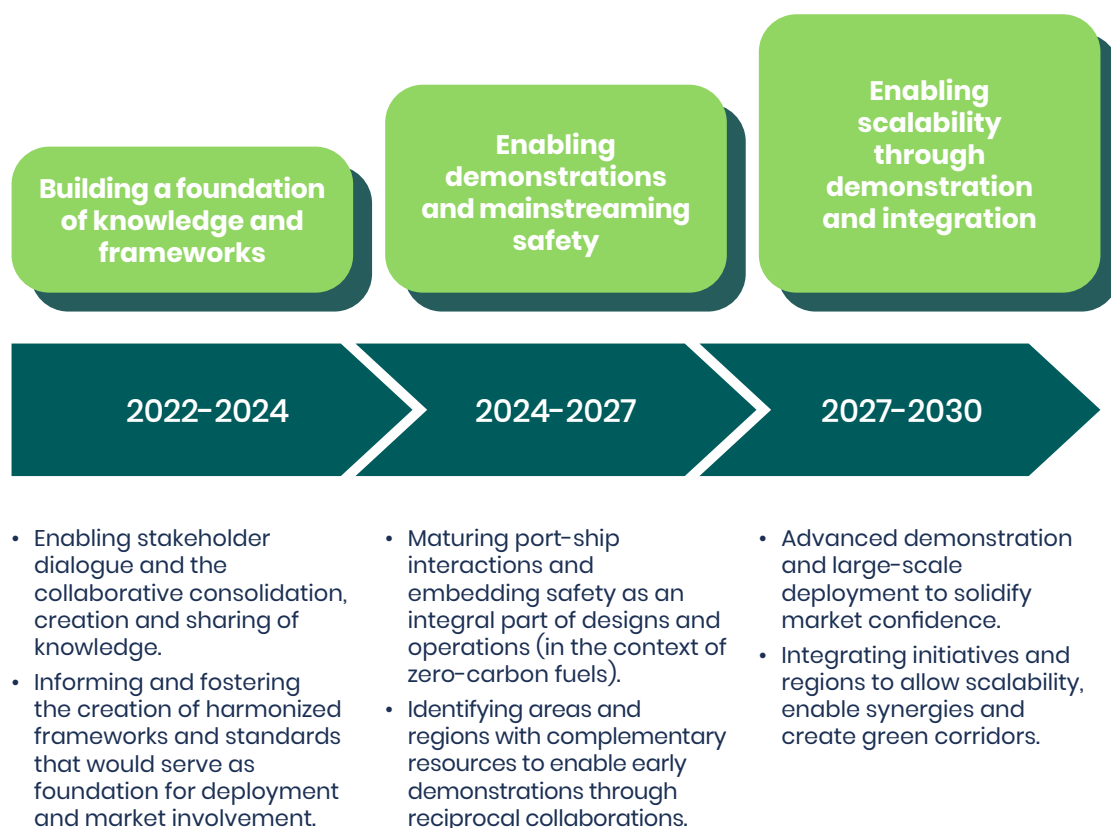
No matter who leads the action, all must be delivered through collaboration across the maritime value chain.

This Action Plan, the actions and projects identified within it, create a path to achieving outcomes that coincide with the Mission's 2030 goals.



Figure 1 summarizes the focus of actions identified between now and our 2030 goals.

Figure 1: Focus of actions up to 2030



This document is not static and is only the initial Action Plan for the Mission. The Mission will conduct regular reviews and refinement to make sure that it is adapted to emerging needs and new opportunities from across the sector as markets and technologies evolve.



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1. The Shipping Mission

The Zero-Emission Shipping Mission ('the Mission') brings together a high-ambition alliance of countries, the private sector, research institutes and members of the civil society to support demonstration of zero-emission deep sea shipping by 2030.

1.1 Mission scope

The work of the Mission is organized into three pillars, as shown in Figure 2, each with a goal for 2030. The pillars and goals reflect the need for action by the entire shipping value chain – from the ships, to the fuels that they will rely on, and the infrastructure that will supply them – to drive the sector to a tipping point in its transition that can create self-sustaining growth to reach its longer-term targets.

Figure 2: The three pillars and their 2030 goals

 Ships	 Fuels	 Fueling Infrastructure
<p>New deep-sea ships on zero-emission fuels are produced at same price (max +5%) as comparable fossil ships.</p> <p>→ <i>By 2030, at least 200 of these ships to primarily use these zero-emission fuels across the main deep sea shipping routes.</i></p>	<p>Prices (incl. policy support) on some zero-emission fuels are at max 10-20% more expensive than fossil fuels.</p> <p>→ <i>By 2030, at least 5% of the global deep-sea fleet as measured by fuel consumption to be made of ships capable of running on well-to-wake zero-emission fuels.¹</i></p>	<p>Large global trade ports need to be able to supply zero-emission fuels for ship owners to use and rely on when investing in ZEVs.</p> <p>→ <i>By 2030, 10 large trade ports covering at least three continents supply zero-emission fuels.</i></p>

The fuels considered in scope for the Shipping Mission include: advanced biofuels, green ammonia, hydrogen, and methanol. Within this scope, the Mission remains technology-neutral and recognizes that action is needed both on retrofits and on new builds to achieve both pre-2030 and post-2030 decarbonization goals.

¹ To put this into context, it is estimated that the overall energy needed for shipping will be 12.9 Exajoules in 2030. 5% of this amounts to 0.64 Exajoules, or 15.8 million tons of heavy fuel oil equivalent. Assuming that the hydrogen-based fuel used is ammonia, to produce it in this amount would require roughly 60 gigawatts of green hydrogen electrolyzer capacity. For additional information, please refer to: [Five percent zero emission fuels needed by 2030](#).

1.2 The Mission's role in driving change

Real-world demonstrations and zero-emission shipping niches² are vital precursors to wider adoption of zero-emission shipping. First, these forms of early deployment enable the learning by doing and lays the foundation for economies of scale that will together make zero-emission shipping viable. Second, and just as importantly, they also show the world that zero-emission shipping is possible, creating the confidence needed to invest in zero-emission technologies.

For this reason, **the efforts of the Mission are centered on increasing the number, breadth, and coverage of zero-emission shipping demonstrations and zero-emission shipping niches.**

The Mission will do this in a number of ways:

- **Building a common vision for innovation** in the sector – By laying out the key innovation gaps and actions needed to close them through our Industry Roadmap and Action Plan, the Mission will enable prioritized and coordinated action across the sector.
- **Boosting the coordination of feasibility research and demonstrations** – There is no one silver bullet technology to decarbonize the shipping sector, and this means that efforts to develop and commercialize multiple fuels must take place simultaneously. Through engagement across the value chain, the Mission will build a holistic view of actions taking place in the sector, to identify and direct stakeholders towards 'innovation blind spots.'
- **Undertaking Mission-led projects** – The Mission will launch new public-private projects in urgent and impactful areas that leverage our strengths as a group.
- **Collecting, analyzing, and disseminating learnings from demonstrations** – An ever-increasing number of zero-emission demonstrations will yield valuable learnings which can inform policymakers, safety frameworks, and guide future demonstrations and their deployment. The Mission will look to collate these learnings and help them reach relevant innovators and decision-makers.

With these principles, Mission-led projects and coordination efforts help to grow the expansion of demonstrations. Meanwhile, the learnings that are generated by these demonstrations are collected, synthesized, and disseminated to key decision-makers. Through these multiple waves of input and iteration, the Mission will accelerate progress towards its 2030 goals together with stakeholders across the shipping industry.

² Niches are 'protective spaces' where innovative technologies can be tested, nurtured, and scaled.

1.3 Mission stakeholder's role in driving change

Not all the actions within the Action Plan are well-suited for the scope and resources of the Mission. For example, while new policy and regulations are required to decarbonize shipping, it is not the role of the Mission to author such policies. Rather, the Mission can perform research, share knowledge, and support dialogues across Mission members and industry stakeholders to enable activity, inform policymakers and collaboratively close the gaps.

The actions listed in this Action Plan require collaboration with other entities outside of the Mission members. The Mission does not act in a vacuum, and the following stakeholder categories have been used to show where other agents of change are necessary to meet both the Mission goals and international targets for 2050.

Figure 3: Stakeholder categories and their role

Government/ Regulators

International, national, regional, local, maritime authorities



Though regulation and policy development is not within the scope of the Mission, coordination and collaboration with governments and regulators are important for reaching the Mission's goals. Besides acting as regulators, governments can fund research and analyses, invest in new technologies, etc.

Maritime Industry R&D

Research institutes, OEMs, shipyards, manufacturers



The role of Research & Development in the Maritime Industry stakeholders is paramount to achieving the Mission's objectives. RD&D and engineering is required for multiple actions to not only enable the use of zero-emission fuels in ships and ports, but also supporting safety, efficiency, standardization and effective competition at scale.

Ship owners/ operators

Manufacturers, system integrators, designers



Both in the short and immediate term, ship owners and operators have a key role to play in building and sharing knowledge and best practices for zero-emission fuels and in carrying out key demonstrations to answer some of the industry's most pressing questions.

Fuel producers & providers

Upstream industry, supply chain



Sitting at the upstream of the zero-emission fuel value chain, the role of the fuel providers and upstream industry stakeholder group is crucial for achieving the Mission's targets. Many of the actions this stakeholder group is well-positioned to lead are of the highest priority.

Ports, terminals and infrastructure

All ports, terminals, infrastructure



The role of Ports within the Mission is crucial in the immediate term and continues into the medium term. Ports should lead the way in addressing some of the main uncertainties and challenges around zero-emission shipping, in particular the availability of zero-emission refueling infrastructure, which will need to be optimized to cope with vessels' need for increased frequency of refueling.

Knowledge community

Academia, thinktanks, digital services, start-ups, financial institutions



Knowledge communities are seen as the natural lead for many of the Mission's immediate term priority actions, as well as some medium-term actions. The research, development, and innovation capabilities of these communities and subsequent ability to address key innovation gaps and questions, make them a highly valuable group within the Mission.

2. Action Plan

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2.1 Innovation gaps to action

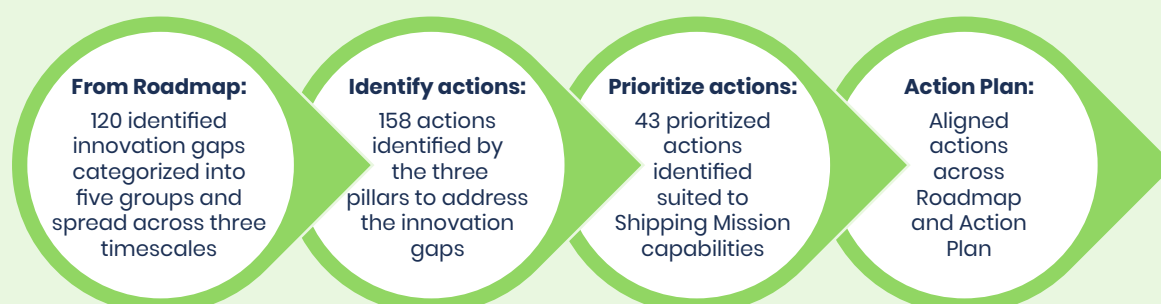
In April 2022, the Mission published an Industry Roadmap for Zero-Emission Shipping which identified **120 innovation gaps to be addressed to meet the Mission's goals**, which are spread across the three pillars – ships, fuels and fueling infrastructure. These gaps fall into the five main groups shown below in Figure 4.

Figure 4: Innovation gaps to action

Group 1. Safety & operational risk management 	Gaps related to safety guidelines, methodologies and procedures for handling or storage of fuels, as well as standards and training for the same.
Group 2. Policy & regulation 	Gaps related to the national and international policy that inform regulations or market incentives.
Group 3. Market development, business model & financial innovation 	Gaps related to the economic readiness for new fuels, including novel business models, economic modeling, as well as financial identification of cost drivers, or subsidies and related funding mechanisms.
Group 4. Technology development & adaptation 	RD&D gaps related to the technical development and adaptation of engines and vessels, fuels, and associated infrastructure. Examples include life cycle emissions modeling, electricity integration, next to retrofits and new designs for vessels and port equipment.
Group 5. Market analysis 	Gaps related to the creation, consolidation, and dissemination of market knowledge related to the vessels, fuels, and refueling infrastructure. Examples include geographic diversity and feedstock availability assessments, availability of fuels and fueling infrastructure, or sharing best practices.

This Action Plan describes the next steps needed to reach the Mission's goals and address some of the high-priority innovation gaps identified in the Roadmap. The steps taken to identify and prioritize actions are shown in Figure 5, and more detail is provided in Appendix 1. The actions presented in this document are a subset of those needed for the broader maritime energy transition (see Appendix 2 for the complete list of actions).

Figure 5: Steps taken to identify and prioritize actions in the Action Plan



2.2 Summary of Mission-led actions

Figure 6 shows high level descriptions of the priority actions for the Mission to lead, and for the Mission to support overleaf. Each action has been assigned a reference number, which is shown in the graphic below and is also used in the more detailed descriptions in later sections. The full list of actions can be found in Appendix 2.

Figure 6: Summary of actions

ACTIONS FOR THE MISSION TO LEAD

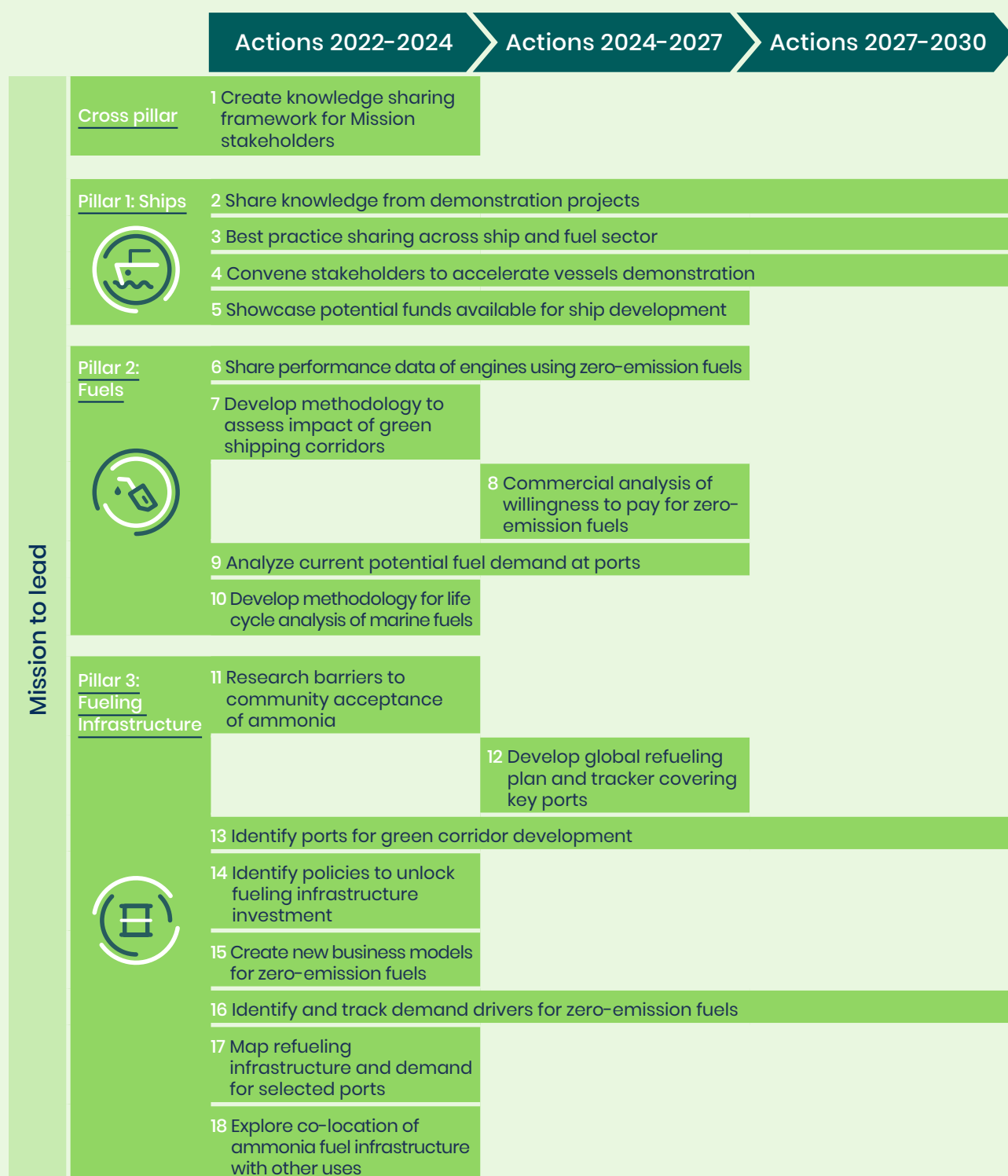


Figure 6: Summary of actions (continued)

ACTIONS FOR THE MISSION TO SUPPORT

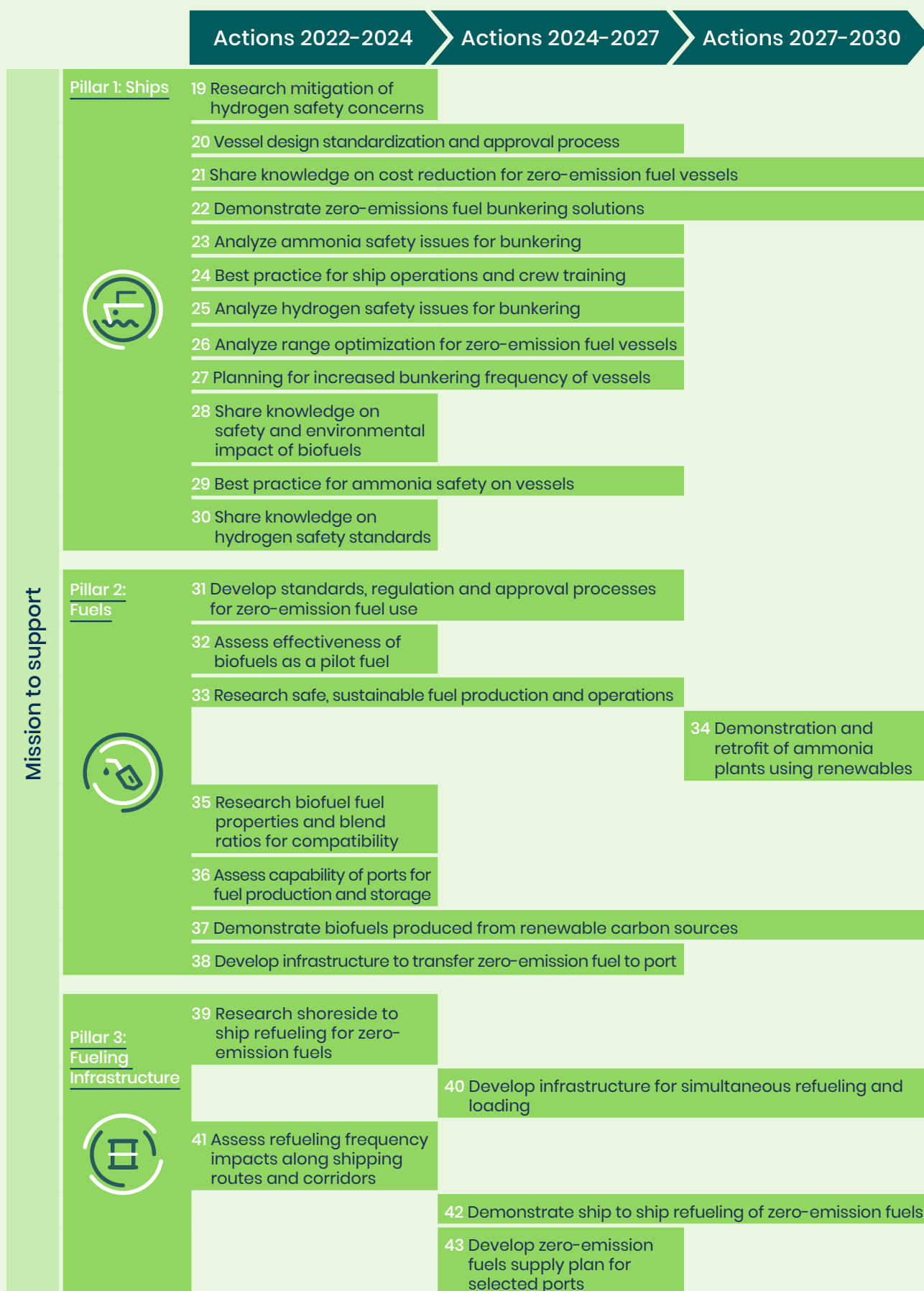


Figure 6 illustrates that there are actions the Mission will lead on, and others which will not be led by the Mission in which the Mission will provide a supporting role. These actions will be led by other stakeholders as illustrated in the sections below.

The Mission will seek to **support every action** set out in this Action Plan. From research and mapping to framework and demonstrations, the Mission will play a vital role in enabling actions to come to fruition.

2.3 Mission-led actions

The Actions that the Mission will lead on are described in Figure 7 on the next page. Each action is associated with a mission pillar, and the fuel or fuels to which they are directed. Several actions are strategically aimed at enabling dialogue, promoting knowledge sharing and shaping the research with the aim of aligning stakeholders, enabling public-private partnerships, and unlocking synergies between actors. There are also actions focused on enabling meaningful demonstrations to provide early market acceleration and bring the – in many cases – high-TRL technologies into the commercial sphere.

The Mission has tangible deployment targets for 2030 but considerable innovation gaps still exist. Therefore, a significant proportion of the actions are of high priority and with completion timescales in the immediate term. Although ambitious, achieving these immediate actions would build the foundation upon which the Mission's targets can be reached and both wide scale deployment and accelerated uptake of zero-emission fuels can occur.



Figure 7: Mission-led actions

● Ammonia ● Biofuels ● Hydrogen ● Methanol

S = Supporting stakeholders

Pillar	ID	Action	Fuel(s)	Timescale			Supporting Stakeholders					
				2022-2024	2024-2027	2027-2030	Maritime Industry R&D	Government/Regulators	Ship owners/operators	Ports	Fuel producers & providers	Knowledge community
Cross pillar	1	Create a framework for knowledge sharing between zero-emission fuel vessel stakeholders with a Mission focus on 2030	● ● ● ●	✓			S	S				S
Pillar 1: Ships 	2	Share knowledge from test pilot and demonstration projects (both new builds and retrofits)	● ● ● ●	✓	✓		S		S			S
	3	Share knowledge on information and best practices between ships owners, operators, and fuel suppliers	● ● ● ●	✓	✓	✓			S		S	
	4	Bring together relevant international players in order to accelerate demonstration and deployment of zero-emission fuel vessels and new ship technologies in green corridors, with a particular focus on obtaining experience in global supply chains	● ● ● ●	✓	✓	✓	S	S	S	S	S	S
	5	Showcase the possible support funds available for zero-emission fuel ship design from national, regional and global actors	● ● ● ●	✓	✓			S				S
Pillar 2: Fuels 	6	Collect and share knowledge on performance of engines using methanol, ammonia, hydrogen, and advanced biofuels	● ● ● ●	✓	✓		S		S			S
	7	Develop and agree a methodology and framework for analyzing the impact of green shipping corridors	● ● ● ●	✓	✓			S	S	S	S	S
	8	Commercial testing and analysis to find the place on the value chain where there is willingness to pay extra for the use of renewable energy and green fuels, and where the willingness to pay is lowest	● ● ● ●	✓	✓			S	S	S	S	S
	9	Analyze the current and forecasted fuel demand at different ports to understand quantities needed for production scaling	● ● ● ●	✓	✓				S	S	S	S
	10	Develop and agree a methodology for performing well-to-wake life cycle analysis of marine fuels	● ● ● ●	✓							S	S
Pillar 3: Fueling Infrastructure 	11	Research and share barriers to community acceptance of ammonia, e.g. due to safety concerns	●		✓			S	S	S	S	S
	12	Develop global refueling plan and progress tracker covering key ports, including an overview of existing and planned infrastructure, refueling needs/demand, fuel capacity and availability, port development etc.	● ● ● ●	✓				S	S	S	S	S
	13	Identify ports and groups of ports for green corridor development	● ● ● ●	✓	✓			S	S	S	S	S
	14	Identify near term levers and policies to unlock fueling infrastructure investment	● ● ● ●	✓				S	S	S	S	S
	15	Create new business models and commercial strategies for zero-emission fuels	● ● ● ●	✓	✓			S	S	S	S	S
	16	Identify and track demand drivers for future fuels	● ● ● ●			✓		S	S	S	S	S
	17	Map existing refueling networks and demand for selected ports, including port support vehicles e.g. Container Handling Equipment	● ● ● ●	✓					S	S	S	S
	18	Identify opportunities to co-locate ammonia production and refueling infrastructure with other uses, e.g. cracking for power generation	●	✓						S	S	S

The Action Plan has been developed to demonstrate the Mission's lead in addressing the actions shown in the first table above. Merely identifying an action does not address the innovation gap that it is meant to close. Actions must be converted into projects with resources and committed partners.

The Mission will lead the actions shown above, but every action will only be made successful through collaboration across the global shipping sector. **Individual Mission members and wider industry stakeholders can and should contribute** to these actions. Stakeholders suggested as best placed to support each action are also indicated.

The Mission clustered similar activities into discrete projects to maximize the Mission's impact, which can be read in the following sections.

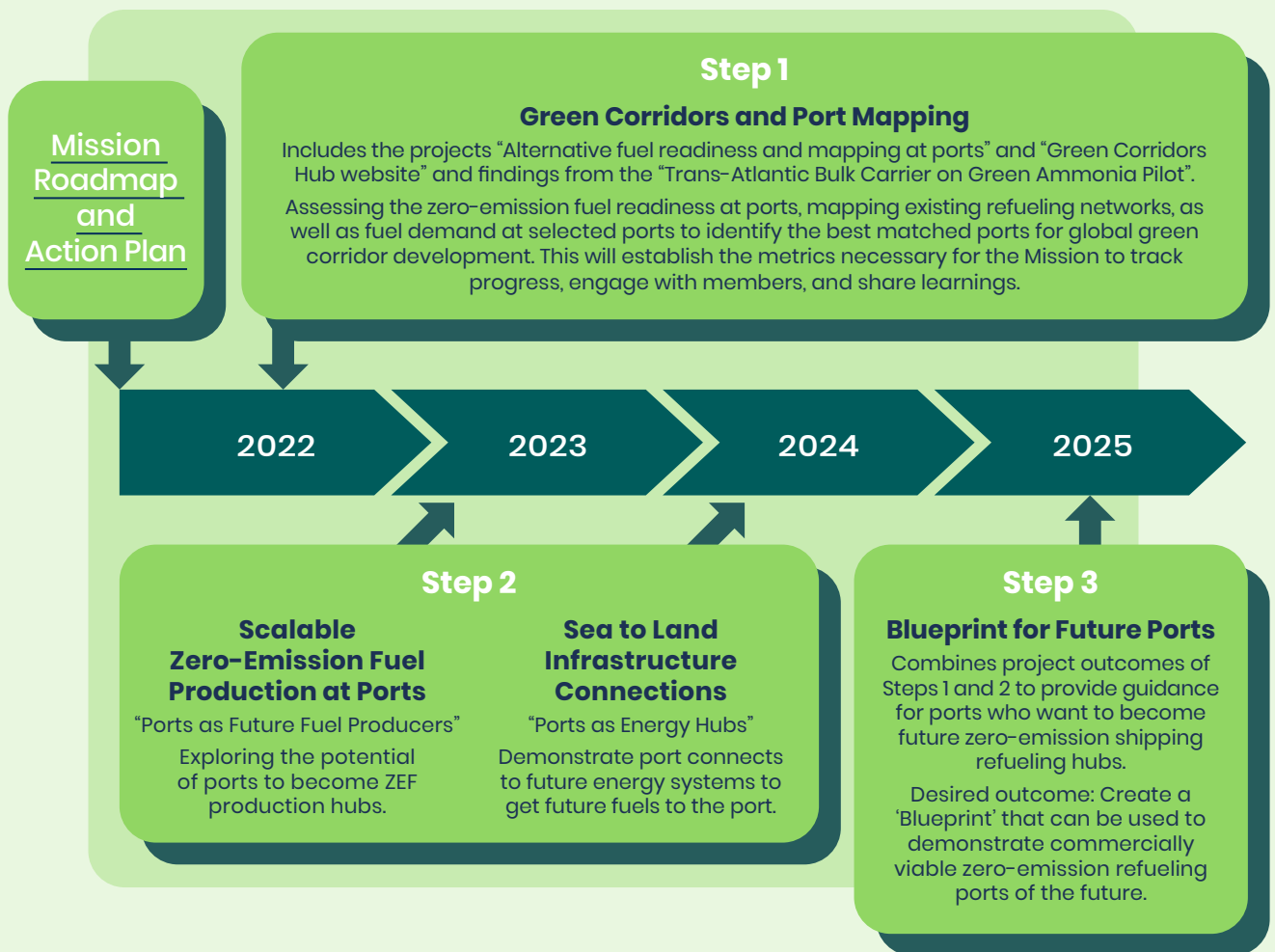
A collection of similar projects, or a program, coordinated by the Mission, can promote change and accelerate adoption. To pursue this, several high-impact projects have been clustered into a program and set to begin in the immediate timescale. This first program combines four unique projects that will all focus on Ports and their role as zero-emission fuel hubs to develop what a port in the 2030's will look like, what it will be required to provide to zero-emission vessels and how these ports make up the infrastructure of Green Shipping Corridors. The program called "Blueprint for Future Ports" is briefly described below followed by brief project descriptions of the projects the program entails and what actions these projects address.

2.3.1 Blueprint for Future Ports program

This first program for the Mission is a collection of projects that will create a "Blueprint for Future Ports" that aims to provide zero-emission fuels at key ports along the major deep-sea shipping routes and green corridors.

The goal of the Blueprint for Future Ports program is to envision what the future infrastructure will look like for the zero-emission ready vessels that will be deployed over the coming years. The program will be Mission-led in collaboration with partners across the maritime value chain, with the aim to demonstrate a commercially viable future for zero-emission shipping.

The program consists of the three steps described below with the included projects under each step.

Figure 8: The three steps for the Blueprint for Future Ports program

Whilst the Mission has set program building blocks, it recognizes that actions and priorities will change over time. The actions and activities in the first project will be some of the first to be launched by the Mission to address high-priority innovation gaps. Future work within this program will be tailored to account for actions and achievements within the industry.

More detail on this program will be available on the [Mission’s official website](#).

2.3.2 Examples of Mission-led projects

The Mission has already made progress towards its goals with some initial projects being scoped that are built around high-priority actions identified in this Action Plan, such as in the “Blueprint for Future Ports” program. The tables below show project examples and the actions, they address:

ALTERNATIVE FUEL READINESS AT PORTS

<u>Activity & Description</u>	To reduce emissions on ships, sufficient volumes of zero-emission fuels and suitable infrastructure for refueling is required. It is not known how prepared the major deep-sea ports are with respect to developing infrastructure or safely providing the volumes of fuel that will be needed. This project will review and establish metrics for assessing the readiness of ports to provide zero-emission and alternative fuels that meets the goals of the ZESM. This work will be coordinated in partnership with the World Ports Climate Action Program (WPCAP) and the International Association of Ports and Harbors (IAPH) to leverage the Port Readiness Level framework under development.
<u>Responsible</u>	Zero-Emission Shipping Mission Fuels Working Group
<u>Timeline</u>	Launch at COP27 (TBC)
<u>Partners</u>	IAPH, U.S. DoE, WPCAP Potential Knowledge partners: DNV Insight Platform, Green Marine, American Association of Ports and Harbors, SSA Marine
<u>Geographic coverage</u>	Global
<u>Funding</u>	Funded
<u>Connection to Actions</u>	13 – Identify ports for green corridor development 14 – Identify policies to unlock fueling infrastructure investment 31 – Develop standards, regulation and approval processes for zero-emission fuel use 33 – Research safe, sustainable fuel production and operations 36 – Assess capability of ports for fuel production and storage 38 – Research shoreside to ship refueling for zero-emission fuels 39 – Research and development of terminal infrastructure for simultaneous refueling and cargo loading/unloading for zero-emission

GREEN CORRIDORS 'HUB' WEBPAGE

Activity & Description	Mission-hosted webpage serving as 'one stop shop' for information on green corridors and home for a new toolkit to drive corridor efforts.
Responsible	Zero-Emission Shipping Mission Infrastructure Working Group
Timeline	Beta release at COP27 (TBC)
Partners	GMF, U.S. DoE, MMMCZCS
Geographic coverage	Global
Funding	Partially funded
Connection to Actions	4 - Convene stakeholders to accelerate vessels demonstration 7 - Develop methodology to assess impact of green shipping corridors 9 - Analyze current potential fuel demand at ports 12 - Develop global refueling plan and tracker covering key ports 13 - Identify ports and groups of ports for green corridor development 16 - Identify and track demand drivers for future fuels 17 - Map existing refueling networks and demand for selected ports 36 - Assess capability of ports for fuel production and storage 41 - Assess refueling frequency impacts along shipping routes and corridors

FINDINGS FROM THE TRANS-ATLANTIC BULK CARRIER ON GREEN AMMONIA

Activity & Description	The overall pilot business case has five separate workstreams, where "Green Ammonia availability" (in relevant regions and ports), "ESG and Finance" and "Operations" are the most relevant workstreams for the projects and activities in this program. The GSP will provide input from these workstreams relevant to the activities in this program based on findings and experiences from the pilot. The highlights of the findings may be included in the final report.
Responsible	Zero-Emission Shipping Mission Ships Working Group
Timeline	Findings to be shared spring 2023 (TBC)
Partners	Norway, Denmark, MMMCZCS Green Shipping Program (GSP)
Geographic coverage	Transatlantic route – Europe to U.S., to South America, and back
Funding	Funded
Connection to Actions	1 - Create knowledge sharing framework for mission stakeholders 2 - Share knowledge from demonstration projects 3 - Best practice sharing across ship and fuel sector 4 - Convene stakeholders to accelerate vessels demonstration 5 - Showcase potential funds available for ship development 6 - Share performance data of engines using zero-emission fuels 11 - Research barriers to community acceptance of ammonia 16 - Identify and track demand drivers for future fuels 18 - Explore co-location of ammonia fuel infrastructure with other uses 20 - Vessel design standardization and approvals process 21 - Share knowledge on cost reduction for zero-emission fuel vessels 23 - Analyze ammonia safety issues for bunkering 33 - Research safe, sustainable fuel production and operations 39 - Research shoreside to ship refueling for zero-emission fuels

2.4 Mission-supported actions

Whilst the Mission is well placed to lead the actions described in the previous section, there are several prioritized actions that require capabilities and resources beyond the reach of the Mission. This highlights the need for cross-sector, worldwide collaboration. These actions will rely on the proactiveness and leadership of other groups. The overarching role of the Mission regarding these actions will be to **inform** those stakeholder groups on the need for these actions to come to fruition and to **encourage** them to drive them forward, helping coordinate and share knowledge whenever possible.

The table in Figure 9 lists these actions and the stakeholder groups whose collaboration would be key to drive them forward. While Figure 9 also indicates which groups are best suited to lead, the leading role is not always clear; actions may require joint leadership or may be pushed by different groups at separate stages. However, who leads these actions is not nearly as important as completing them, and **the Mission encourages all stakeholders to take a leading role in any of the actions they can.**
















Figure 9: Actions for stakeholder to lead or support

● Ammonia ● Biofuels ● Hydrogen ● Methanol

L = Suggested lead stakeholder S = Supporting stakeholders

Pillar	ID	Action	Fuel(s)	Timescale			Supporting Stakeholders					
				2022-2024	2024-2027	2027-2030	Maritime Industry R&D	Government/Regulators	Ship owners/operators	Ports	Fuel producers & providers	Knowledge community
Pillar 1: Ships 	19	Research and assessment into addressing and mitigating significant safety concerns connected to hydrogen, including flammability, low activation and ignition energy	●	✓			L	S	S		S	S
	20	Collect and share knowledge on zero-emission fuel design approval processes and standardization for vessels able to use zero-emission fuels, including new builds and retrofits	● ● ● ●	✓	✓		S	L	S			
	21	Collect and share knowledge on best practices on how to reduce costs further for zero-emission fuel vessels, e.g. in terms of redundant systems, double piping, sensors	● ● ● ●	✓	✓	✓	L		S			S
	22	Demonstrate bunkering of zero-emission fuels including ship to ship and ship to infrastructure	● ● ● ●	✓	✓	✓	S		L	S		
	23	Review and analyze the safety issues when bunkering with ammonia, including when bunkering simultaneously to loading cargo	●	✓	✓			S	L	S		S
	24	Share best practices and run campaigns on operational manuals and crew training with a focus on zero-emission fuels and crew safety	● ● ● ●	✓	✓				L	S	S	
	25	Review and analyze the safety issues when bunkering with hydrogen, including when bunkering simultaneously to loading cargo	●	✓	✓			S	L	S		S
	26	Analyze and demonstrate range optimization for zero-emission fuel vessels, e.g. increased refueling frequency or cargo capacity tradeoff as a result of energy density and volume considerations	● ● ● ●	✓	✓				L	S		S
	27	Develop, test, and analyze optimization of potential increased frequency of bunkering requirements with zero-emission fuels	● ● ● ●	✓	✓		S	S	S	S	L	S
	28	Map and share knowledge on standards for safety and environmental considerations and regulations for biofuels, including consideration of NO _x emissions compliance	●	✓				S			S	L
	29	Collect and showcase best practices from industry on managing ammonia safely on vessels, including toxicity risks	●	✓	✓		S		S			L
	30	Map and share knowledge on the current work on standards for safety, all ship-regulated regulations, and prescriptive rules for hydrogen	●	✓			S	S			L	

Pillar	ID	Action	Fuel(s)	Timescale			Supporting Stakeholders					
				2022-2024	2024-2027	2027-2030	Maritime Industry R&D	Government/Regulators	Ship owners/operators	Ports	Fuel producers & providers	Knowledge community
Pillar 2: <u>Fuels</u> 	31	Develop standards, regulation and approval processes for zero-emission fuel use in shipping		✓	✓		S	L	S	S	S	S
	32	Assess the efficiency and quantity of biofuel as a pilot fuel for methanol and ammonia engines		✓			L		S		S	
	33	Research safe and sustainable fuel production, handling and downstream operations to inform international standards or certifications		✓	✓		S	S	S	S	L	S
	34	Demonstration and retrofitting of existing ammonia plants with renewable energy supply				✓					L	S
	35	Research biofuel properties (viscosity, flash point, etc.) and blend ratios with traditional fossil fuels for compatibility with existing marine engines		✓			S		S		L	S
	36	Assess the fuel production locations or synthesis capabilities and storage potential at ports		✓					S	S	S	L
	37	Test and demonstrate biofuels produced from renewable carbon sources, such as lignocellulosic biomass, organic wet wastes, and biogas which are at a lower CRI but could potentially unlock much larger supplies		✓	✓	✓			S		L	S
	38	Research and development of port connections to land-based infrastructure to transfer zero-emission fuel to the port, including innovative siting and onsite production		✓	✓		L	S		S	S	S
Pillar 3: <u>Fueling Infrastructure</u> 	39	Research and share knowledge on truck to ship refueling for zero-emission fuels		✓						L	S	S
	40	Research and development of terminal infrastructure for simultaneous refueling and cargo loading/unloading for zero-emission fuel vessels			✓		L		S	S		
	41	Map shipping routes and assess how frequently vessels will need to refuel along routes with zero-emission fuels		✓					S	S		L
	42	Develop and demonstrate ship to ship refueling of zero-emission fuels			✓		S			L		S
	43	Develop zero-emission fuel supply plan for selected ports			✓				S	S	S	L

The assignment of actions to stakeholder group is intended as **guidance only** and should not be assumed as limited or final. Should a different stakeholder group feel they are better placed to lead a particular action, the Mission will welcome a discussion.

2.5 Mission collaboration

If you are interested in helping deliver the Zero-Emissions Shipping Mission and its Action Plan, or simply wish to **find out more** about the Mission's current plans and activities, please contact shippingmission@dma.dk

Addressing the actions identified in this Action Plan will be a **global effort**. It will require commitment, resources, and collaboration not only from existing Mission Members, but from others across the full spectrum of the maritime value chain.

As such, **the Mission is open to collaborating with other organizations equally committed to ambitious action**. Potential partners could include:



At a minimum, prospective partners must:

1. Share the objectives of the Mission
2. Be willing to actively support the Mission's objectives and contribute to the work to achieve them

We welcome different types and levels of contribution, from co-leading a new flagship project, to supporting an existing project, to providing advice and validation of Mission outputs, to information sharing, and beyond.

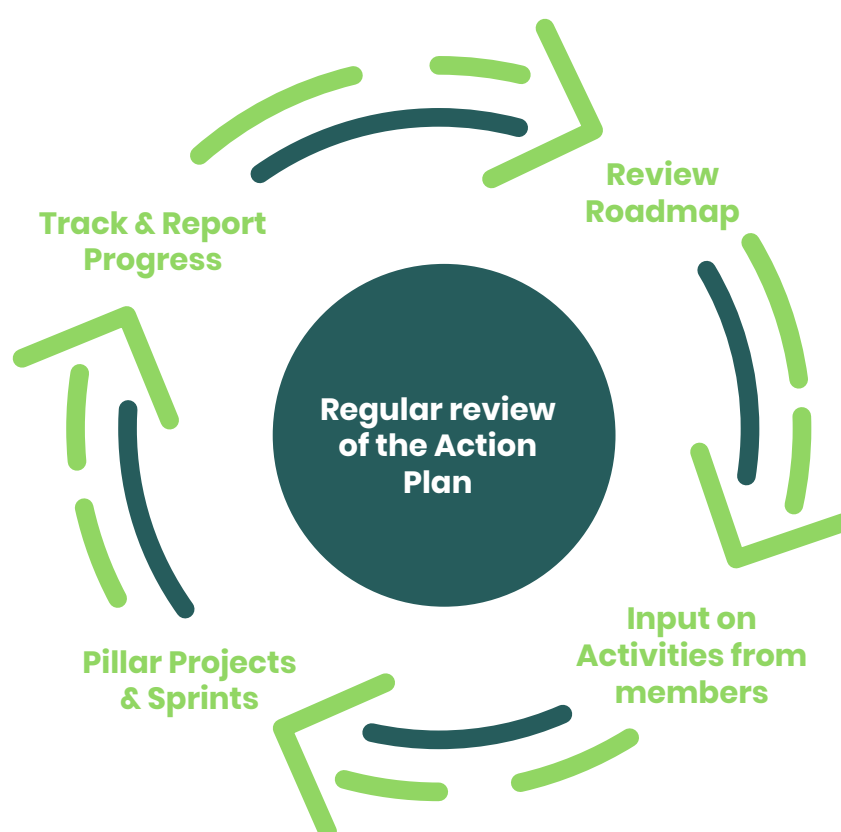
To actively participate in the Mission, prospective members will be asked to endorse our Mission Statement. The Statement is an expression of intent to support the Mission and does not create any legal or financial obligations.

Naturally, commitments to deliver specific actions and projects in line with the Action Plan do entail a level of financial and human resourcing. Proposals for flagship projects are subject to a set of criteria and are processed in form of a High-level Commitment Submission, which will be reviewed by the Mission Secretariat.

3. Progress monitoring and next steps

The Mission will use the Roadmap, this Action Plan, and a set of KPIs (detailed in Appendix 3) as indicators to identify success and analyze progression towards its goals. The diagram in Figure 10 shows a visual representation of how the Mission will track and report progress to industry, review this Action Plan, and establish next steps.

Figure 10: Steps involved in the regular review of the Action Plan



NEXT STEPS

Going forward, the Mission will work with its members to coordinate and address actions within this Action Plan, and continue to encourage external stakeholders to accelerate actions undertaken by the broader ecosystem as a way of reaching 2030 goals. The Mission will track progress, as well as emerging gaps and opportunities, to further refine this Action Plan, ensuring it remains representative and continuously reflects the evolving needs of the shipping sector during the energy transition.

4. Appendices

4.1 Appendix 1 – Roadmap to Action Plan

This appendix details the process used to build on the work of the Roadmap into the Action Plan described in this document.

The Roadmap – Identifying innovation gaps

The Mission’s initial roadmap identified 120 innovation gaps along five major groups – or themes – that must be bridged to enable widescale deployment of zero-emission fuels.

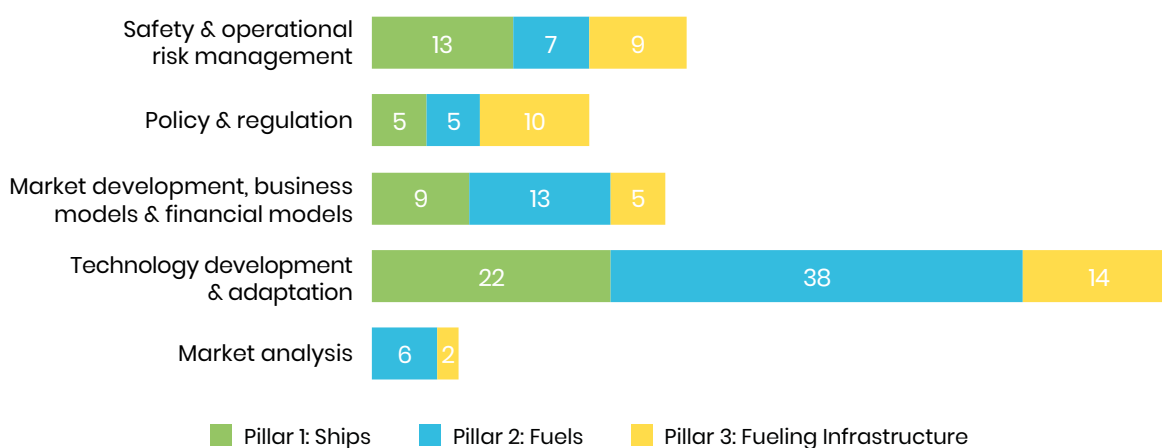
Figure 11: Innovation gaps to action (same as Figure 4)

<p><u>Group 1. Safety & operational risk management</u></p> 	<p>Gaps related to safety guidelines, methodologies and procedures for handling or storage of fuels, as well as standards and training for the same.</p>
<p><u>Group 2. Policy & regulation</u></p> 	<p>Gaps related to the national and international policy that inform regulations or market incentives.</p>
<p><u>Group 3. Market development, business model & financial innovation</u></p> 	<p>Gaps related to the economic readiness for new fuels, including novel business models, economic modeling, as well as financial identification of cost drivers, or subsidies and related funding mechanisms.</p>
<p><u>Group 4. Technology development & adaptation</u></p> 	<p>RD&D gaps related to the technical development and adaptation of engines and vessels, fuels, and associated infrastructure. Examples include life cycle emissions modeling, electricity integration, next to retrofits and new designs for vessels and port equipment.</p>
<p><u>Group 5. Market analysis</u></p> 	<p>Gaps related to the creation, consolidation, and dissemination of market knowledge related to the vessels, fuels, and refueling infrastructure. Examples include geographic diversity and feedstock availability assessments, availability of fuels and fueling infrastructure, or sharing best practices.</p>

Stakeholder input – Identifying actions

Building on this work, a long list of over 150 actions were identified in order to fill the identified innovation gaps. This was achieved through focused work of the Mission pillars (ships, fuels and fueling infrastructure) and engagement with industry stakeholders. Figure 12 illustrates the spread of actions across innovation gap groups and pillars.

Figure 12: The spread of actions across Innovation gap groups and pillars



The full list of actions is provided in Appendix 2.

Stakeholder engagement – Prioritizing and planning

Through extensive engagement – workshops, surveys, discussions – involving the Mission’s global network of experts, as well as external support, actions were prioritized, assigned a timeframe and proposed stakeholder groups to support and lead them.

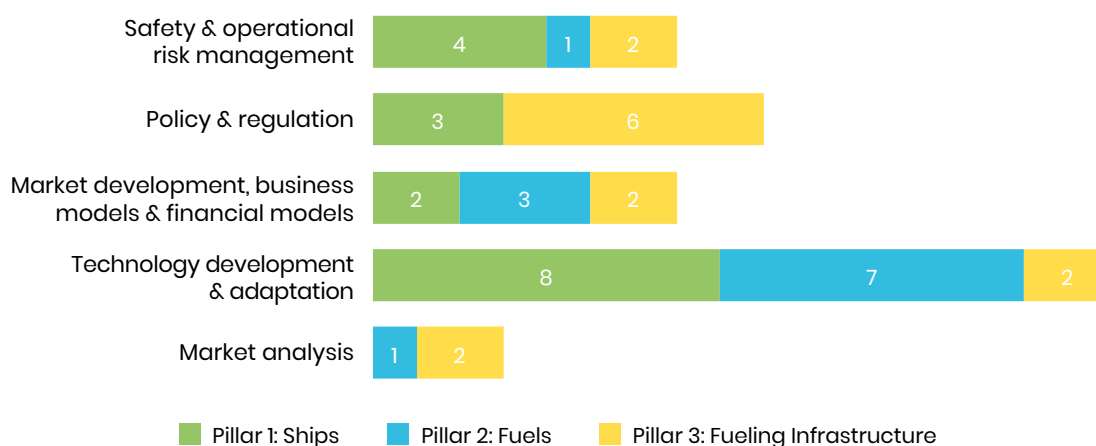
Action prioritization: Special focus was given to:

- Actions in which the Mission can carry out a primary role and deliver unique value
- Actions which involve or impact multiple fuels or pillars

Action Plan – Defining the Mission’s role and key actions

The prioritization process resulted in a set of 43 prioritized actions that leverage the capabilities of the Mission and address key needs of the industry that are unattended or overlooked at present. Figure 13 illustrates the spread of prioritized actions across innovation gap groups and pillars.




Figure 13: Prioritized actions across the innovation gap groups and pillars



The prioritized actions are indicated in the full list of actions in Appendix 2.

The focus of the actions considered within each pillar along the five innovation gap groups is summarized in the table below.

Figure 14: Challenges addressed across the innovation gap groups and pillars

Category of Innovation Gaps	Ships 	Fuels 	Fueling Infrastructure 
1. Safety & operational risk management	Mainstreaming and streamlining safety in refueling and both ports and ship operations	Attending to fuel-specific pressing or overlooked safety concerns	Safe handling, appropriate standards and safety mechanisms
2. Policy & regulation	Cooperation and knowledge Exchange between industry and authorities to reduce policy & regulation lead times	Enable scalability and cost competitive production of zero-emission fuels	Common port regulations and procedures for refueling Enabling levers and policies
3. Market development, business models & financial innovation	Innovation and demonstration on the implications of using zero-emission fuels	Frameworks for adequate and competitive production Clear signals for demand and investment	Tracking of developments and infrastructure Forward visibility of supply
4. Technology development & adaptation	Key fuel-specific innovation Need to deploy and integrate existing high-TRL technologies	Enable competitive, efficient and scalable production of zero-emission fuels	Connecting port infrastructure to land-based energy infrastructure Technology adoption and development
5. Market analysis	Assessment of techno-economic potential to understand cost drivers, supply and demand		

4.2 Appendix 2 – Full list of actions



Prioritized actions

Figure 15 is a complete list of the prioritized actions, with the ID number used throughout this document, and an indication of pillar and timescales.

Figure 15: Prioritized actions across the pillars

Pillar	ID	Action	2022–2024	2024–2027	2027–2030
Cross pillar	1	Create a framework for knowledge sharing between zero-emission fuel vessel stakeholders with a Mission focus on 2030	✓	✓	
Pillar 1: Ships	2	Share knowledge from test pilot and demonstration projects (both new builds and retrofits)	✓	✓	✓
	3	Share knowledge on information and best practices between ships owners, operators, and fuel suppliers	✓	✓	✓
	4	Bring together relevant international players in order to accelerate demonstration and deployment of zero-emission fuel vessels and new ship technologies in green corridors, with a particular focus on obtaining experience in global supply chains	✓	✓	✓
	5	Showcase the possible support funds available for zero-emission fuel ship design from national, regional and global actors	✓	✓	
Pillar 2: Fuels	6	Collect and share knowledge on performance of engines using methanol, ammonia, hydrogen, and advanced biofuels	✓	✓	
	7	Develop and agree a methodology and framework for analyzing the impact of green shipping corridors	✓		
	8	Commercial testing and analysis to find the place on the value chain where there is willingness to pay extra for the use of renewable energy and green fuels, and where the willingness to pay is lowest		✓	
	9	Analyze the current and forecasted fuel demand at different ports to understand quantities needed for production scaling	✓	✓	✓
	10	Develop and agree a methodology for performing well-to-wake life cycle analysis of marine fuels	✓		
Pillar 3: Fueling Infrastructure	11	Research and share barriers to community acceptance of ammonia, e.g. due to safety concerns	✓		
	12	Develop global refueling plan and progress tracker covering key ports, including an overview of existing and planned infrastructure, refueling needs/demand, fuel capacity and availability, port development etc.		✓	
	13	Identify ports and groups of ports for green corridor development	✓	✓	✓
	14	Identify near term levers and policies to unlock fueling infrastructure investment	✓		
	15	Create new business models and commercial strategies for zero-emission fuels	✓		
	16	Identify and track demand drivers for future fuels	✓	✓	✓
	17	Map existing refueling networks and demand for selected ports, including port support vehicles e.g. Container Handling Equipment	✓		
	18	Identify opportunities to co-locate ammonia production and refueling infrastructure with other uses, e.g. cracking for power generation	✓		


Pillar	ID	Action	2022-2024	2024-2027	2027-2030
Pillar 1: Ships 	19	Research and assessment into addressing and mitigating significant safety concerns connected to hydrogen, including flammability, low activation and ignition energy	✓		
	20	Collect and share knowledge on zero-emission fuel design approval processes and standardization for vessels able to use zero-emission fuels, including new builds and retrofits	✓	✓	
	21	Collect and share knowledge on best practices on how to reduce costs further for zero-emission fuel vessels, e.g. in terms of redundant systems, double piping, sensors	✓	✓	✓
	22	Research, test and demonstration of infrastructure and solutions for zero-emission fuel bunkering including ship-to-ship and ship-to-land infrastructure	✓	✓	✓
	23	Review and analyze the safety issues when bunkering with ammonia, including when bunkering simultaneously with loading cargo	✓	✓	
	24	Share best practices and run campaigns on operational manuals and crew training with a focus on zero-emission fuels and crew safety	✓	✓	
	25	Review and analyze the safety issues when bunkering with hydrogen, including when bunkering simultaneously with loading cargo	✓	✓	
	26	Analyze and demonstrate range optimization for zero-emission fuel vessels, e.g. increased refueling frequency or cargo capacity tradeoff as a result of energy density and volume considerations	✓	✓	
	27	Develop, test, and analyze optimization of potential increased frequency of bunkering requirements with zero-emission fuels	✓	✓	
	28	Map and share knowledge on standards for safety and environmental considerations and regulations for biofuels, including consideration of NO _x emissions compliance	✓		
	29	Collect and showcase best practices from industry on managing ammonia safely on vessels, including toxicity risks	✓	✓	
	30	Map and share knowledge on the current work on standards for safety, all ship-regulated regulations, and prescriptive rules for hydrogen	✓		
Pillar 2: Fuels 	31	Develop standards, regulation and approval processes for zero-emission fuel use in shipping	✓	✓	
	32	Assess the efficiency and quantity of biofuel as a pilot fuel for methanol and ammonia engines	✓		
	33	Research safe and sustainable fuel production, handling and downstream operations to inform international standards or certifications	✓	✓	
	34	Demonstration and retrofitting of existing ammonia plants with renewable energy supply			✓
	35	Research biofuel properties (viscosity, flash point, etc.) and blend ratios with traditional fossil fuels for compatibility with existing marine engines	✓		
	36	Assess the fuel production locations or synthesis capabilities and storage potential at ports	✓		

Pillar	ID	Action	2022-2024	2024-2027	2027-2030
Pillar 2: Fuels 	37	Test and demonstrate biofuels produced from renewable carbon sources, such as lignocellulosic biomass, organic wet wastes, and biogas which are at a lower CRI but could potentially unlock much larger supplies	✓	✓	✓
	38	Research and development of port connections to land-based infrastructure to transfer zero-emission fuel to the port, including innovative siting and onsite production	✓	✓	
Pillar 3: Fueling Infrastructure 	39	Research and share knowledge on truck-to-ship refueling for zero-emission fuels	✓		
	40	Research and development of terminal infrastructure for simultaneous refueling and cargo loading/unloading for zero-emission fuel vessels		✓	
	41	Map shipping routes and assess how frequently vessels will need to refuel along routes with zero-emission fuels	✓		
	42	Develop and demonstrate ship-to-ship refueling of zero-emission fuels		✓	
	43	Develop zero-emission fuel supply plan for selected ports		✓	

Other actions

The following in Figure 16 below is a complete list of actions identified, which have not been prioritized, with an indication of pillar and timescales. The prefix “D” indicates that these actions have not been prioritized.

Figure 16: Other actions across the pillars

Pillar	ID	Action	2022-2024	2024-2027	2027-2030
Pillar 1: Ships 	D.1	Research and testing on how to keep lowering costs on Ammonia vessels, e.g. in terms of redundant systems, double piping, sensors	✓		
	D.2	Facilitate the analysis on the business cases for ships using ammonia as propulsion in terms of the energy density and volume of ammonia and the optimal speed and range requirements	✓		
	D.3	Enable the further development of engines for ammonia by showcasing the possible support funds from national and global actors	✓		
	D.4	Enable the further development of lean burn gas engines with hydrogen enriched ammonia by showcasing the possible support funds from national and global actors		✓	
	D.5	Enable the development of crew training to address the safety aspects of using ammonia as propulsion fuel	✓		
	D.6	Enable further development in reducing ammonia slip, N ₂ O and NO _x reduction	✓		
	D.7	Analyze and share knowledge among Mission members on which aspect of STCW could to be adjusted in terms of crew training (op. national requirements can be different)		✓	

Pillar	ID	Action	2022-2024	2024-2027	2027-2030
Pillar 1: Ships 	D.8	Collect and share best practices/knowledge on safety management on board vessel using zero-emission fuels as propulsion		✓	
	D.9	Collect and share knowledge from safety cases; toxicity, best practices from chemical industry and development of existing gas-fueled vessels, crew training programs	✓		
	D.10	Share knowledge on the development in line with a reduction in corrosion and rubber seals degradation	✓		
	D.11	Share knowledge on the hygroscopic nature of biodiesel leading to embedded water in the fuel – this requires further investigation to improve performance	✓		
	D.12	Facilitate the further research and testing of the fuel and engine stability in order to cope with changing properties of the feedstock for the production of the fuel		✓	
	D.13	Facilitate the further research and testing of the durability of the seals in engines when running biodiesel through an engine	✓		
	D.14	Research and testing on improved solutions for storage of liquid hydrogen in order to cover the needed capacity for deep sea shipping	✓		
	D.15	Promote/showcase the need for standardized solutions for modular onboard storage		✓	
	D.16	Research and testing for improving internal combustion engines, in order to improve range and availability of energy converter options.		✓	
	D.17	To study whether nuclear power can be the solution for the larger ships (20 000 TEU, Capesize, VLCC, etc.)	✓		
	D.18	Map and coordinate the development of fuel design requirements among relevant players	✓		
	D.19	Collect and share data on testing and the demonstration of fuel cell technology including conversion efficiency, lifetime and cost	✓		
	D.20	Study and share knowledge regarding technical trade-offs associated with the use of dual fuel equipment	✓		
	D.21	Facilitate the analysis of the business cases for ships using hydrogen as propulsion in terms of the energy density and volume of hydrogen and the optimal speed and range requirements	✓		
	D.22	Facilitate the analysis of the business cases for ships using methanol as propulsion in terms of the energy density and volume of methanol and the optimal speed and range requirements	✓		
	D.23	Research, test and demonstration of the usability of biofuels as pilot fuels for the use of other green fuels in vessels	✓		
	D.24	Facilitate and promote research on reduction of methane slip from engines	✓		
	D.25	Research and mapping of real operational onboard emission measurements to understand potential risk of major differences between engine test bed measurements at fixed loads and dynamic operations at sea with varying engine loads and sea states	✓		
	D.26	Facilitate and promote further research and development of net-zero pilot fuels (such as biofuels) to enable true net-zero emissions		✓	
	D.27	Research and development of fuel supply and storage technology relying on hydrogen to address concerns related to temperature requirements and adverse impact on materials		✓	
	D.28	Facilitate a dialogue with engine producers, share knowledge on approval procedures for the different kinds of biofuels to secure guidance and investment certainty for industry actors, and mitigate commercial losses	✓		

Pillar	ID	Action	2022-2024	2024-2027	2027-2030
Pillar 1: Ships 	D.29	Collect and share knowledge as well as promote further research into testing and assessment of the implications of increased fuel tanks size in regards to methane only (not applicable to other biofuels)	✓		
	D.30	Collect and share knowledge among Mission Members on enforcement of NO _x emissions compliance	✓		
	D.31	Share knowledge among Mission Members on the development of a set of prescriptive rules for ammonia in connection to the further development of the IGF code		✓	
	D.32	Share knowledge and facilitate further research into the establishment of standards for methane emissions		✓	
	D.33	Facilitate and promote further research and demonstration of energy converters capable of running on ammonia that are commercially available	✓		
Pillar 2: Fuels 	D.34	Assess the availability of excess or potential biogas sources for Renewable Natural Gas production and usage in marine industry as LNG blend or replacement keeping in mind biopower and other RNG offtakers		✓	
	D.35	Assess the seasonality in feedstocks and how it affects fuel availability, particularly with biomethanol and biofuels	✓		
	D.36	Building and demonstrations of complete integrated and operative systems (1 GW plus)			✓
	D.37	Continuing reduction in costs of materials used for the production of renewable energy e.g., photovoltaic panels (solar panels)		✓	
	D.38	Create resources to help ports electrify on a general level, so that they become charging hubs for trucks and cargo handling, and green e-fuel centres for the maritime industry		✓	
	D.39	Creating a standards and certification system for the use of hydrogen as maritime fuel			✓
	D.40	Demonstrate a green ammonia production plant on the scale of >10,000 tons/year			✓
	D.41	Demonstrate a high-volume production facility of clean hydrogen using renewable energy		✓	
	D.42	Demonstrate a high-volume production facility of clean methanol		✓	
	D.43	Demonstration of dynamic ammonia synthesis without hydrogen storage. (The Danish EUDP programme has granted funding for the Haldor Topsoe, Vestas and Skovgaard Invest project)			✓
	D.44	Demonstration of methanol synthesis from CO ₂ /H ₂ with fluctuating energy input	✓		
	D.45	Demonstration projects of efficient liquefaction technologies		✓	
	D.46	Demonstrations of the complete production system using renewable electricity	✓		
	D.47	Development and further testing of demo-plants to test the dynamic behavior when powered directly by renewable energy without the use of a (e.g. hydrogen) buffer tank			✓
	D.48	Development of cryogenic separation or pressure swing absorption to reduce inefficiencies for both processes in the production of nitrogen	✓		

Pillar	ID	Action	2022-2024	2024-2027	2027-2030
Pillar 2: Fuels 	D.49	Establish reliable cross border certificate trading scheme for Bio LNG to allow decoupling of physical production and industry uptake		✓	
	D.50	Establishment of a clear global methodology for assessment of biomass availability and biofuel carbon intensity measure		✓	
	D.51	Further development and testing of ammonia synthesis with regards to the needs for compression and separation, with the purpose of increasing the energy efficiency		✓	
	D.52	Further development and testing of SOEC electrolyzers to improve the stability and durability		✓	
	D.53	Further development of cheap and reliable high capacity energy storage systems, including systems such as redox flow batteries		✓	
	D.54	Further development of electrolyzers to reduce capital costs by 25%		✓	
	D.55	Further development of PEM electrolyzers for high-durability and high-reliability		✓	
	D.56	Further development of the processes used to combine atmospheric N ₂ and H ₂ from seawater, with focus to increase efficiency and reducing costs.			✓
	D.57	Further innovation into alternatives to PEM electrolyzers, with a focus on reducing costs		✓	
	D.58	Further investigation into green electrolysis e.g. in terms of scalability and durability		✓	
	D.59	Further research and development into the adhesion of catalysts to the support/porous transport layer		✓	
	D.60	Further research and development into the engineering of membranes and to strengthen the ion conducting polymers for use at high temperatures in water (by reinforcing them with a porous support)		✓	
	D.61	Further research and development of alternatives to the Haber Bosch process, that could bring production costs down		✓	
	D.62	Further research and exploration of different types of electrolyzers, alkaline seems to be more developed commercially, but PEM may be a better option in the future		✓	
	D.63	Further research and testing in how to prevent contamination of methanol when stored (e.g. chloride contamination)		✓	
	D.64	Further research and testing into a broader range of biofuel feedstocks, including a shift from edible feedstocks to non-edible feedstocks, also the focus of the production being able to handle various feeds with various contents of sulfur, chloride etc.		✓	
	D.65	Further research into feedstock diversification in order to minimize plant idling		✓	
	D.66	Further research into optimization of heat and mass transfer (gas/liquid transport and separation)		✓	
	D.67	Further research into the possibilities for Power-to-X and availability of biogenic CO ₂		✓	
	D.68	Further research into the seasonality of feedstock needs to be addressed and how to overcome them		✓	
	D.69	Further research on the most sustainable production methods and feedstocks for methanol (e.g. carbon capture or green hydrogen)	✓		

Pillar	ID	Action	2022-2024	2024-2027	2027-2030
Pillar 2: Fuels 	D.70	Identification of local production sites of H ₂ that could serve maritime end-uses	✓		
	D.71	Improve process efficiency of reverse osmosis to lower the cost of hydrogen production		✓	
	D.72	Innovation and demonstration with the aims of maturing and scaling up of biofuel feedstocks and production facilities		✓	
	D.73	Legislation and regulations for green fuel requirements for ships operating in European waters		✓	
	D.74	Maritime stakeholder engagement, particularly with seafarers and port communities, to address safety concerns	✓		
	D.75	Research and testing in AEM systems to prove they can operate reliably for long durations in real environments		✓	
	D.76	Research and testing into alternative ways of produce hydrogen (e.g. thermal etc.). Currently these production methods are more expensive. Focus on reducing costs		✓	
	D.77	Research into feedstock sustainability and production volume scalability given competing end-uses		✓	
	D.78	Research into how cross sectoral competition with agriculture and other industrial applications can be addressed	✓		
	D.79	Research into how it would be possible to use hydrogen without a conversion to Power-to-X		✓	
	D.80	Research into low cost and efficient, high-volume storage of ammonia	✓		
	D.81	Research into methods and technologies that decrease the carbon footprint of the existing bio-based feedstocks	✓		
	D.82	Research into the post-combustion treatment methods for limiting NO _x , SO _x and PM emissions	✓		
	D.83	Research on low-cost storage options for liquid and gaseous hydrogen			✓
	D.84	Research on technologies and methods to minimize or mitigate spill risk	✓		
	D.85	Research supporting a certification scheme for organic feedstock material		✓	
	D.86	Research that can be used to inform safety guidelines and regulations for production and storage of hydrogen			✓
	D.87	Research that leads to lower costs of PEM electrolyzer equipment		✓	
	D.88	Setting up complete value chains in areas where a business case can be fulfilled, including value chain assessments establishing horizontal business case and risk minimisation			✓
	D.89	Techno-economic research into the reductions for operational costs through lower electricity prices and reductions of capital expenditure through improved supply chains and competition		✓	
	D.90	Test how fast Power-to-X systems can be ramped up and down to ensure dynamic production of e-fuels	✓		

Pillar	ID	Action	2022-2024	2024-2027	2027-2030
Pillar 3: Fueling Infrastructure 	D.91	Identify technology and safety gaps for transfer of ammonia to fuel storage systems	✓		
	D.92	Design and deliver programs for workforce training + certification for handling new fuels in refueling and ports	✓		
	D.93	Develop safety and risk management (plans/activities/studies) for non-refueling ports	✓		
	D.94	Create agreed protocols around responsibility for hose string crossing port (from vessel flange to land-based energy infrastructure)		✓	
	D.95	Improve understanding of safety requirements for refueling new fuels	✓		
	D.96	Create standards for safety/alarm zones in and around ports, types of buildings that can/should be built, safety mechanisms needed	✓		
	D.97	Develop common port regulations & procedures for the refueling of alternative fuels	✓		
	D.98	Create new business and operating models for ports	✓		
	D.99	Fueling and ship based infrastructure for identified fuel		✓	
	D.100	Designs, materials, and processes for storage including pipes, tanks, leakage handling, monitoring (sensors), ventilation systems	✓		
	D.101	Processes, design and components for ship-to-ship refueling		✓	
	D.102	Design tanks and piping with leak detecting sensors	✓		
	D.103	Lower operating costs of ammonia storage (e.g. electricity costs for refrigeration)	✓		
	D.104	Conversion of LPG storage, pipes and pumps for use with e-methanol		✓	
	D.105	Cost effective H ₂ storage technologies e.g. liquid H ₂ cryogenic storage tanks -253°C		✓	
	D.106	Conversion of gas pipelines to transport H ₂	✓		
	D.107	H ₂ transport using trucks with pressurized cylinders		✓	
	D.108	Develop in-situ and remote leak detection system and methodology	✓		
	D.109	Develop technology for ship-to-ship refueling for H ₂ and NH ₃		✓	
	D.110	Develop technology used for truck-to-ship refueling	✓		
	D.111	Create demand and refueling profiles	✓		
	D.112	Analysis of ease of retrofitability for existing refueling infrastructure to accommodate new fuels			✓
	D.113	Map availability of NH ₃ as well as planned NH ₃ within 24 months			✓
	D.114	Map ports with existing refueling facilities for methanol as a commodity	✓		
	D.115	Map availability of H ₂ as well as planned H ₂ within 24 months	✓		

4.3 Appendix 3 – Key performance indicators

The overall goals for the Mission are driven by the tipping point for the adoption of zero-emission fuels: 5% fuel consumption across the global fleet and 200 vessels on deep-sea routes by 2030 as well as 10 large trade ports supplying zero-emission fuels. Progress will be measured against these each year.

Other Key Performance Indicators (KPIs) for the Mission include:

#	Indicator	Measured by
1	Number of deep-sea commercial vessels using verified well-to-wake zero-emissions greenhouse gas fuels (methanol, ammonia, hydrogen, advanced biofuels) on major shipping routes.	Annual survey of qualifying vessels using well-to-wake zero-emission fuels on ocean-going routes. ³
2	Number of deep-sea commercial vessels capable of using zero-emission greenhouse gas, hydrogen-derived fuels (methanol, ammonia, hydrogen) on major shipping routes. <i>Metadata on this KPI could identify those ships that are purpose-built versus retrofitted to help track fleet turnover and adoption strategies.</i>	Determining the annual total fuel consumption of those ships capable of using alternative fuels, represented as a percentage of the global fleet's fuel consumption. ⁴
3	Number of deep-sea green shipping corridors established between, within, or involving Mission countries or organizations. <i>This KPI shall also include metadata on each green corridor route length and average number of vessels that transit the route; these values can be reported in aggregate across all green corridors.</i>	Annual survey across all countries participating in the Mission. ⁵
4	Number of zero-emission maritime research, development, and demonstration/pilot (RD&D) projects relevant to the Mission pillars in participating countries and/or with cross-partner participation. <i>Where applicable or disclosed, this KPI shall also include associated committed funds for the projects.</i>	Surveying participating members on an annual basis wherein they identify Zero-Emission Shipping Mission relevant RD&D projects. ⁶
5	Number of workshops and publications issued by the Mission, as well as engagement of these events or documents, to ensure that the Mission is serving as a thought-leader and disseminating the information to a broad audience.	Annual survey counting the number of documents published by the Mission and number of workshops held. ⁷ <i>In terms of engagement, publication engagement will be tracked by monitoring the number of downloads or unique views of the documents hosted on the Mission webpage.</i> <i>Workshop participation will be tracked by summing the number of attendees to each workshop throughout the year.</i>
6	Number of participants (co-leads, core members, supporting members) involved with the Mission and that identifies their affiliation (industry or government), country, and Pillar interests.	Annual survey of all Mission participants.

3 This metric includes all vessels, not just those that are directly affiliated with the Mission.

4 Well-to-wake emissions will be assessed using a common LCA methodology as agreed-upon by the Mission team and/or as recommended by the IMO working group.

5 Biofuels, while within scope for the mission, are intentionally excluded from this KPI since many biofuels are designed for blends with traditional fossil fuels or as drop-replacements, thereby making most marine engines already capable of using these fuels.

6 Routes that involve more than one Mission participant shall only be counted once, unless the corridor is composed of multiple legs.

7 Joint efforts of two or more members shall only be counted once.



**ZERO-EMISSION
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