MEDITERRANEAN ACTION PLAN (MAP)
REGIONAL MARINE POLLUTION EMERGENCY RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)

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Agenda Item 8: Reduction of GHG emissions from ships

Study on the Implementation of Emission Control and Energy Efficiency Measures for Ships in Port Areas in the Mediterranean Region

REMPEC
Malta, 2025

Note by the Secretariat

This document presents the Study on the Implementation of Emission Control and Energy Efficiency Measures for Ships in Port Areas in the Mediterranean Region.

Background

1 The ship-port interface is defined as the area of coverage of a ship's operation from the time the pilot boards the vessel at the pilot station to help it berth. The coverage extends to the time the pilot leaves the vessel at the pilot station when the vessel departs from the port and includes the time the vessel is at the port. During this period, the vessel is involved in cargo operation, crew change, provision, bunker, ship surveys and repair, etc. Emissions happen during ship-port interface in berthing process, cargo operations and various other reasons.

2 Measures such as the use of Energy Saving Devices (ESDs), Propulsion Improving Devices (PIDs) and Onboard Carbon Capture and Storage (OCCS) are critical to reduce emissions in the deep sea, but their effectiveness is limited during ship-port interface. However, the Mediterranean region can curtail emissions from vessels in the ship-port interface area by reducing vessel waiting time, using low-emission tugboats, Onshore Power Supply (OPS), electrifying cargo handling equipment, Light Emitting Diode (LED) lighting, efficient cargo loading/unloading, quick turnaround of a vessel, use of low-/zero-carbon fuels and various digital platforms for port clearance, etc.

3 Ports also play a major role in reducing emissions during the ship-port interface; accordingly, some ports have implemented sustainability strategies such as becoming energy hubs. However, the ports managing energy demand using offshore, wind and tidal energy can face a conflict of interest with energy companies as per their local regulations.

4 In this context, the Secretariat commissioned Drewry Maritime Services, to prepare a Study on the Implementation of Emission Control and Energy Efficiency Measures for Ships in Port Areas in the Mediterranean Region, hereinafter referred to as the Study, in order to support any possible future regulatory or policy action by the Contracting Parties to the Barcelona Convention, in their efforts to mobilise and implement innovative solutions to reduce GHG emissions from ships in selected ports, including through energy efficiency and decarbonisation.

5 The Study was carried out, pursuant to the Programme of Work and Budget for 2024-2025 of the Mediterranean Action Plan (MAP) of the United Nations Environment Programme (UNEP), adopted by the Twenty-third Ordinary Meeting of the Contracting Parties to the Barcelona Convention and its Protocols (Portorož, Slovenia, 5-8 December 2023).

6 This activity was financed by the voluntary contribution from the French Ministry for Europe and Foreign Affairs.

7 The Study is presented in the **Appendix** to the present document.

Action requested by the Meeting

8 **The Meeting is invited to take note** of the information provided in the present document.

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Appendix

Study on the Implementation of Emission Control and Energy Efficiency Measures for Ships in Port Areas in the Mediterranean Region

MEDITERRANEAN ACTION PLAN (MAP)
REGIONAL MARINE POLLUTION EMERGENCY RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)

Final report

Study on the Implementation of Emission Control and Energy Efficiency Measures for Ships in Port Areas in the Mediterranean Region

Prepared by Drewry Maritime Services, November 2024

This activity is financed by the voluntary contribution from the French Ministry for Europe and Foreign Affairs and is implemented by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), in cooperation with the International Maritime Organization (IMO).

Table of Contents

1 Executive Summary ... 10

2 Introduction to the ship-port interface ... 13

2.1 Definition of the ship-port interface ... 13

2.2 Basic process flow during the ship-port interface ... 13

2.3 Vessel-related activities at port ... 14

2.4 Stakeholders involved in the ship-port interface ... 14

2.5 Emissions from vessels during the ship-port interface ... 16

2.6 Emission control measures ... 17

2.7 Section summary ... 17

3 Emission reduction measures from vessels during the ship-port interface ... 19

3.1 Emission reduction from the vessel's auxiliary engine ... 19

3.1.1 Use of sustainable biofuels ... 19

3.1.2 Use of hybrid engines/fuel cells ... 19

3.1.3 Use of auxiliary engines driven by low-/zero- carbon fuels ... 19

3.2 Bow thrusters ... 20

3.3 Cargo operations-related smart systems on vessels for power reduction ... 20

3.4 LED lighting on vessels ... 21

3.5 Onshore power supply (OPS) ... 22

3.6 Onboard Carbon Capture and Storage (OCCS) ... 24

3.7 Others ... 25

3.7.1 Measures by ship operators/ship managers for efficient vessel turnaround at berth 25

3.7.2 Swappable batteries for vessels ... 26

3.7.3 Overview of measures taken on ships to reduce emissions during sailing ... 28

3.7.3.1 Engine Power Limitation (EPL) ... 28

3.7.3.2 Propulsion improving devices ... 28

3.8 Section summary ... 29

4 Emission reduction measures in ports during the ship-port interface ... 30

4.1 Background ... 30

4.2 Emission reduction from tugboats ... 30

4.3 Onshore power availability at berth ... 33

4.4 Cargo operations-related emission reduction by port ... 37

4.5 LED lighting at port ... 38

4.6 Just-In-Time (JIT) berthing ... 40

4.7 Carbon Capture, Utilisation, and Storage (CCUS) value chain 42
4.7.1 Industrial usage for carbon 42
4.7.2 CCS facilities 44
4.8 Liquid CO_2 terminals 47
4.9 Others 48
4.9.1 Measures by port for efficient vessel turnaround at berth 48
4.9.2 Digital solutions to reduce delays in pilot arrivals 48
4.9.3 Solar power generation at ports 48
4.9.4 Wind power 50
4.9.5 Heavy-duty vehicles 50
4.9.6 Railroad locomotives 51
4.9.7 Power consumption of reefers 51
4.9.8 Green construction of ports 51
4.9.9 Dynamic Under Keel Clearance (DUKC) 52
4.9.10 Main engine maintenance at berth 52
4.9.11 Allowing bunkering and provision supply at berth 52
4.9.12 Low-/zero-carbon fuel production and bunkering hubs 52
4.10 Section summary 55
5 Policies and regulatory measures to reduce emissions during the ship-port interface 60
5.1 Regulations affecting the ship-port interface 60
5.1.1 EEDI/EEXI 60
5.1.2 CII regulation 61
5.1.3 The EU ETS Directive 61
5.1.4 The FuelEU Maritime Regulation 61
5.1.5 Alternative Fuel Infrastructure Regulation (AFIR) 62
5.1.6 Other Market Based Measures (MBM) 62
5.2 Green corridors 62
5.3 Examples of best practices 66
5.3.1 Port of Los Angeles (USA) and Port of Long Beach (USA) 67
5.3.2 Port of Singapore 68
5.3.3 Port of Rotterdam (Netherlands) 70
5.3.4 Example of ports in the Mediterranean region 72
5.4 Speed limits and incentives in major ports 74
5.5 Discount on port dues for low-emission ships 74
5.6 Section summary 76
6 Stakeholder Analysis 78

6.1 Feedback related to emission reduction measures from vessels during ship-port interface 78

6.2 Feedback related to emission reduction measures in ports during ship-port interface . 80

6.3 Feedback related to policies and regulatory measures to reduce emissions during ship-port interface 81

6.4 Other feedback from various stakeholders 82

6.5 Section summary 83

7 Challenges, opportunities and recommendations 85

7.1 Challenges in the implementation of emission control and energy efficiency measures for ships in port areas 85

7.2 Opportunities in the implementation of emission control and energy efficiency measures for ships in port areas 86

7.3 Recommendations 87

7.3.1 Recommendations related to emission reduction measures from vessels 88

7.3.2 Recommendations related to emission reduction measures in ports 88

7.3.3 Recommendations related to policy and regulatory measures 90

7.3.4 Recommendations related to other measures 91

8 Roadmap and action plan for the implementation of emission control and energy efficiency measures for ships in port areas in the Mediterranean region 92

References 96

List of Figures

Figure 2.1 The ship-port interface 13
Figure 2.2 Primary stakeholders 15
Figure 2.3 Secondary stakeholders 15
Figure 2.4 Main sources of emission at ports 16
Figure 2.5 Emission reduction enabling actions 17
Figure 3.1 Bow thrusters 20
Figure 3.2 LED lighting on Royal Caribbean Cruise Ship Harmony of the Seas 21
Figure 3.3 Onshore power supply to a ship at berth – Example no. 1 22
Figure 3.4 Onshore power supply to a ship at berth – Example no. 2 22
Figure 3.5 ABB enables emission-free port stays for Corsica Lines vessels by providing OPS .. 23
Figure 3.6 ABB plugs Holland America Lines to low-emission onshore power worldwide 24
Figure 3.7 Swappable batteries pack 26
Figure 3.8 Singapore's first all-electric cargo boat 27
Figure 4.1 Global tugboat fleet alternative fuel uptake 31
Figure 4.2 Global tugboat alternative fuel type 32
Figure 4.3 Global tugboat orderbook alternative fuel uptake 32
Figure 4.4 Alternative fuel type orderbook of tugboat 33
Figure 4.5 EU ports with OPS 35
Figure 4.6 Port of Savannah (USA) arrivals from Port of Norfolk (USA), 2023 – comparison of inbound voyage speed to length of pre-berth waiting 40
Figure 4.7 CCUS value chain 42
Figure 4.8 Overview of existing and planned CCUS facilities in Europe 44
Figure 4.9 Liquid CO_2 handling at the port through pipelines 47
Figure 4.10 CO_2 container discharging at port 47
Figure 5.1 Stakeholders of green corridor 63
Figure 5.2 Eight most promising green corridor routes (Spanish ports) 64
Figure 5.3 Assessment of the relative impact and feasibility of the eight promising routes 65
Figure 5.4 Multicriteria assessment of the selected routes 66
Figure 5.5 Pathway to carbon emission reduction in the Port of Rotterdam (Netherlands) 72
Figure 5.6 Ports which have agreed to incentivise low-emission vessels based on their ESI score 75
Figure 6.1 Respondents view on the effectiveness of deep-sea GHG emission reduction measures in ship-port interface 78
Figure 6.2 Responders' primary choice to reduce GHG emissions during navigation of a vessel in the port area 79
Figure 6.3 Responses for GHG emission reduction methods for vessels at berth 79
Figure 6.4 Stakeholder responses regarding the most effective measure to reduce GHG emissions in ports 80
Figure 6.5 Stakeholder responses for reducing GHG emissions from tugboats 81
Figure 6.6 Stakeholder responses for policies to be undertaken by ports in order to reduce GHG emissions from ship-port interface 82
Figure 6.7 Responses regarding challenges faced by stakeholders 83

List of Tables

Table 4.1 OPS in ports of the Mediterranean coastal States 36
Table 4.2 CO_2 usage across industries and its utilisation 43
Table 4.3 CCS projects in the Mediterranean region 46
Table 4.4 Projection for various Mediterranean coastal States and potential for future 53
Table 5.1 Speed limit and incentives in different ports 74
Table 5.2 Examples of ports incentivising low-emission vessels 75
Table 8.1 Recommended roadmap and action plan for the implementation of emission control and energy efficiency measures for ships in port areas in the Mediterranean region. 92

Abbreviations

Short form	Full form
AFIR	Alternative Fuel Infrastructure Regulation
API	Application Programming Interface
BCTN	Benelux Container Terminal Network
BEST	Barcelona Europe South Terminal
CARB	California Air Resources Board
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CEF	Connecting Europe Facility
CII	Carbon Intensity Indicator
CMIT	Cai Mep International Terminal
CO_2	Carbon Dioxide
CPs	Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (the “Barcelona Convention”)
CPP	Controllable pitch propeller
CSA	Coastal Sustainability Alliance
CTF	Clean Truck Fund
CTP	Clean Trucks Programme
DCSA	Digital Container Shipping Association
EC	European Commission
DUKC	Dynamic Under Keel Clearance
DWT	Deadweight
eRTG	Electric Rubber-Tyred Gantry
EEA	European Economic Area
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
EFIP	European Federation of Inland Ports
EMSA	European Maritime Safety Agency
EOR	Enhanced Oil Recovery
EPL	Engine Power Limitation
EPA	U.S. Environmental Protection Agency
ERDF	European Regional Development Fund
ESD	Energy Saving Device
ESI	Environmental Ship Index
ESPO	European Ship Port Organisation
EU	European Union
EU ETS	European Union Emissions Trading System
EUA	European Union Allowance
GEF	Global Environment Facility
GHG	Greenhouse Gas

GIA	Global Industry Alliance
GPP	Green Port Programme
GT	Gross Tonnage
IAPH	International Association of Ports and Harbours
IC	Internal Combustion
ICS	International Chamber of Shipping
IEE	International Energy Efficiency
IMO	International Maritime Organization
JIT	Just-In-Time
LCA	Life Cycle Assessment
LCO_2	Liquid Carbon Dioxide
LED	Light Emitting Diode
LNG	Liquefied Natural Gas
MAG	Metal Active Gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MBM	Market Based Measures
MCR	Maximum Continuous Rating
MIG	Metal Inert Gas
MoU	Memorandum of Understanding
MPA	Maritime and Port Authority of Singapore
MRV	Monitoring, Reporting and Verification
MWp	Mega Watt Peak
NO_x	Nitrogen Oxide
NZE	Near Zero Emission
OCCS	Onboard Carbon Capture and Storage
OPEX	Operational Expenses
OPS	Onshore Power Supply
OSV	Offshore Support Vessel
PBCF	Propeller Boss Cap Fins
PEM	Polymer Electrolyte Membrane
PID	Propulsion Improving Device
PMIS	Port Management Information System
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
RMG	Rail-mounted Gantries
ROI	Return on Investment
RTG	Rubber-Tyred Gantry
SC	Straddle Carriers
SO_x	Sulphur Oxide
STS	Ship-To-Ship
TFB	Barcelona Ferry Terminal
UK	United Kingdom of Great Britain and Northern Ireland
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

USA	The United States of America
USD	United States Dollar
VBS	Vehicle Booking System
VFD	Variable Frequency Drive
VLSFO	Very Low Sulphur Fuel Oil
VHF	Very High Frequency
VSRIP	Vessel Speed Reduction Incentive Programme
WAPS	Wind Assisted Propulsion System
WPCAP	World Ports Climate Action Programme
WPSP	World Ports Sustainability Program
WtW	Well to Wake
ZE	Zero Emission
ZES	Zero Emission Services

1 Executive Summary

Drewry was appointed by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) to undertake the Study on the Implementation of Emission Control and Energy Efficiency Measures for Ships in Port Areas in the Mediterranean Region ("the Study"). The ship-port interface is defined as the area of coverage of a ship's operation from the time the pilot boards the vessel at the pilot station to help it berth. The coverage extends to the time the pilot leaves the vessel at the pilot station when the vessel departs from the port and includes the time the vessel is at the port. During this period, the vessel is involved in cargo operation, crew change, provision, bunker, ship surveys and repair, etc. Emissions happen during ship-port interface in berthing process, cargo operations and various other reasons.

Measures such as the use of Energy Saving Devices (ESDs), Propulsion Improving Devices (PIDs) and Onboard Carbon Capture and Storage (OCCS) are critical to reduce emissions in the deep sea, but their effectiveness is limited during ship-port interface. This was also agreed by most respondents during the stakeholder feedback conducted by Drewry for the Study.

However, the Mediterranean region can curtail emissions from vessels in the ship-port interface area by reducing vessel waiting time, using low-emission tugboats, Onshore Power Supply (OPS), electrifying cargo handling equipment, Light Emitting Diode (LED) lighting, efficient cargo loading/unloading, quick turnaround of a vessel, use of low-/zero-carbon fuels and various digital platforms for port clearance, etc.

Ports also play a major role in reducing emissions during the ship-port interface; accordingly, some ports have implemented sustainability strategies such as becoming energy hubs. However, the ports managing energy demand using offshore, wind and tidal energy can face a conflict of interest with energy companies as per their local regulations.

Legislation such as the FuelEU Maritime Regulation is driving the usage of OPS in the Mediterranean region; however, there are issues due to high infrastructure cost, the lack of clarity in the concession agreement about the party responsible for investing in infrastructure, existing energy regulations and preventing commercialisation of electricity to ports or terminals in some Mediterranean coastal States, etc.

Just-In-Time (JIT) system has the potential to reduce the waiting time of the vessel, lowering emissions but it requires various stakeholders of the Mediterranean coastal States to work together for its implementation. In addition, antitrust concerns, resistance to data sharing, and contractual relationship concerns between the shipowner and the charterer are the other challenges in implementing it. However, platforms like the 'Digital Port Call' being implemented at the Port of Gothenburg (Sweden) to provide updated information flow among stakeholders to improve the efficient utilisation of resources, could be adopted by ports of the Mediterranean coastal States and would help in reducing emissions.

Regional measures are in place to reduce emissions in the European Union (EU) such as the EU Emissions Trading System (EU ETS). However, there are challenges in implementing such measures in the Mediterranean region as it includes States that are not EU Member states. Meanwhile, some Mediterranean coastal States like Türkiye are taking the initiative to establish their own carbon pricing scheme comparable with the EU ETS, and such initiatives should be adopted by other Mediterranean coastal States that are not EU Member States. In addition, at a global level, the International Maritime Organization (IMO) also initiated the comprehensive impact assessment of the basket of candidate mid-term Greenhouse Gas (GHG) reduction measures.

The use of green fuel is a key part of the strategy towards decarbonisation, and green corridors play a critical role in this. Many green corridors have been identified on different routes, and a few green corridor routes in the Mediterranean region or passing through this region are expected to create demand for low-/zero-carbon fuel in the Mediterranean region.

Many ports are taking a step forward to reduce GHG emissions by enforcing speed limits, discounting low-emission vessels, supplying green fuels and investing in renewable energy. Overstay dockage policy adopted by the Jurong Port (Singapore) is another measure, which could be adopted by ports of the Mediterranean coastal States.

To reduce GHG emissions, around 89% of respondents preferred the use of low-/zero-emission fuel during navigation in the port areas and 56% chose reduced speed requirements in the ports of the Mediterranean coastal States. While at berth, all respondents show their support for OPS, 89% of respondents recommend electrification of port equipment. The need for financial investments was highlighted by a few respondents to improve green technologies onboard a vessel. Meanwhile, 67% of the respondents also proposed solar energy to be the source of this power requirement in ports. About 55% of the respondents believe that ports of the Mediterranean coastal States should take green corridor initiatives, which would boost green technologies in the Mediterranean region. Other policy recommendations include reduced port dues for greener vessels, and establishing green fuel bunkering infrastructure. Life Cycle Assessment (LCA) of bunkers is gradually gaining momentum and will lead to regionalisation of bunker procurement. In addition, higher space requirements for low-/zero-carbon fuels on vessels may lead to more frequent bunkering. Therefore, bunkering hubs are expected to shift to new locations. This also offers opportunities for Mediterranean coastal States to establish themselves as bunkering hubs.

Almost 70% of respondents highlighted the lack of availability of green fuels and their bunkering infrastructure as one of the critical challenges. Lack of clarity regarding new regulations is also one of the challenges faced by stakeholders. One of the stakeholders also cited the need to train different stakeholders involved in the chain.

After considering stakeholder concerns as well as the various challenges and opportunities identified in the Study, a set of recommendations have been suggested. For instance, shipowners can consider OPS, management of bow thrusters, variable frequency drive in the ship's crane and LED lighting, etc. to lower emissions.

Mediterranean coastal States should consider having their ports investing in green tugboats, low-emission port equipment, digital tools and platforms, solar power generation, usage of LED lighting, formation of an overstay dockage policy and sustainable port construction methods. Dynamic Under Keel Clearance (DUKC) systems for tidal ports are also lucrative options for consideration to reduce carbon footprint.

Mediterranean coastal States should also consider having their ports improvising their terms and conditions to allow immobilisation of the main engine at berth for maintenance jobs (weather permitting), bunkering, provision supply, repair works, etc. Port authorities need to provide electricity to vessels at cheaper rates than the cost of energy incurred by vessels to motivate ship owners to opt for OPS and also amend the concession agreements as required to incorporate OPS.

Port authorities should also coordinate with all stakeholders to include JIT for efficient berthing. Green corridors require supporting policies and collaboration amongst all stakeholders and port authorities should play an instrumental role in the establishment of green corridors.

Industrial usage of CO_2 and its importance as a key member in attaining zero emissions make Carbon Capture and Storage (CCS), OCCS and liquid CO_2 infrastructure, including terminals, an essential requirement in the future. Mediterranean coastal States should encourage such facilities in their ports.

Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (the "Barcelona Convention") (CPs) should provide grants to various emission reduction initiatives by vessels and ports. CPs should review laws related to data sharing for the development of an information-sharing platform where a neutral third party could bring stakeholders to common ground as a facilitator. CPs should amend their existing energy legislation to allow the ports to manage their energy sources. CPs should also take the initiative to educate the various stakeholders and train the required staff to make them fully aware of the green transition underway and take action accordingly.

Efforts should continue to increase the demand and supply of green fuels and reduce their costs. The ship-port interface is a crucial link to be addressed for emission reduction and collaboration by multiple stakeholders in the Mediterranean region is vital for it.

2 Introduction to the ship-port interface

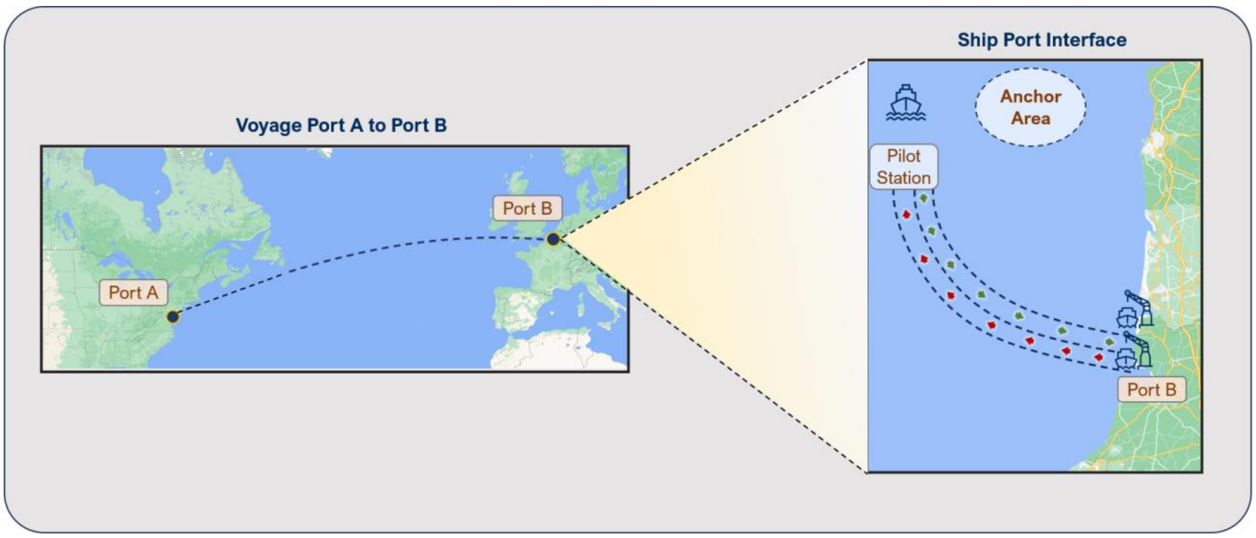
This section explains the basic process flow during the ship-port interface as well as vessel-related activities at the port. It also gives an overview of the stakeholders involved during the ship-port interface in addition to an overview of the emissions from vessels during this period.

Emissions in the deep sea have an overall environmental impact, but those in the ship-port interface impact the local area and, hence, are critical for the local community.

2.1 Definition of the ship-port interface

The ship-port interface is defined as the area of coverage of a ship's operation from the time the pilot boards the vessel at the pilot station to help it berth. The coverage extends to the time the pilot leaves the vessel at the pilot station when the vessel departs from the port and includes the time the vessel is at the port.

Figure 2.1 The ship-port interface



Source: Drewry (2024)

2.2 Basic process flow during the ship-port interface

Container vessels berth at fixed ports on a liner service and usually run on the same route for a certain length of time. The vessel's arrival at the specified port is known/planned a few weeks in advance with the berth reserved for its next call, provided it arrives during the predetermined window. These vessels can adjust their speed to reach the ports during the scheduled period.

Dry bulk vessels and most of the vessels in other sectors are usually on tramp trade and therefore are not on fixed routes. These vessels need to reach their load/discharge ports as soon as they possibly can so as to get a berth, which is assigned on a first-come, first-serve basis.

After the sea voyage, the vessel reaches the pilot station where the pilot boards. Pilots are local experts with knowledge of navigation in shallow waters of the area, the current, the tide, etc. Large cargo vessels are not easy to manoeuvre, and small boats called tugboats are used to assist the vessel to berth.

2.3 Vessel-related activities at port

Vessels are involved in various activities at port:

.1 Cargo operation: A vessel loads and discharges cargo at the port.

.2 Crew change: At times some crew members leave the ship upon completion of their contract and are replaced by new crew members who join the vessel at the port. The change of crew usually involves road transport between the port and the airport.

.3 Provisions: Ship chandlers deliver provisions or other items ordered by the vessels. These are usually brought to the vessel at port via trucks or boats.

.4 Bunker: Vessels are refuelled at the port via shore pipeline, trucks at berth or small vessels known as bunker barges that carry bunker (marine fuel).

.5 Others: Other activities such as ship surveys and repair are also carried out at the port.

2.4 Stakeholders involved in the ship-port interface

Various stakeholders involved in the port activities include:

.1 Port authorities: They are focused on port processes such as dredging and nautical services.

.2 Terminal operators: They are focused on berth and yard operations, efficiency of loading/unloading as well as storage of cargo.

.3 Vessel service providers (tugs, pilots): These include tugs and pilots that assist vessels to berth at the port. If these arrive late, it results in additional emissions from the vessels.

.4 Shipping lines: They are focused on vessel schedules, vessel fleet and vessel speeds, and can influence vessel emissions while navigating, waiting or at berth.

.5 Supply chain stakeholders: These include inland transport.

.6 Ship agents: They coordinate with various parties for berthing of the vessel while also taking the required clearances for it.

.7 Customs: They handle the duties, fees or taxes charged on items being shipped from one country to another.

.8 Ship crew: They oversee the operations during a port call.

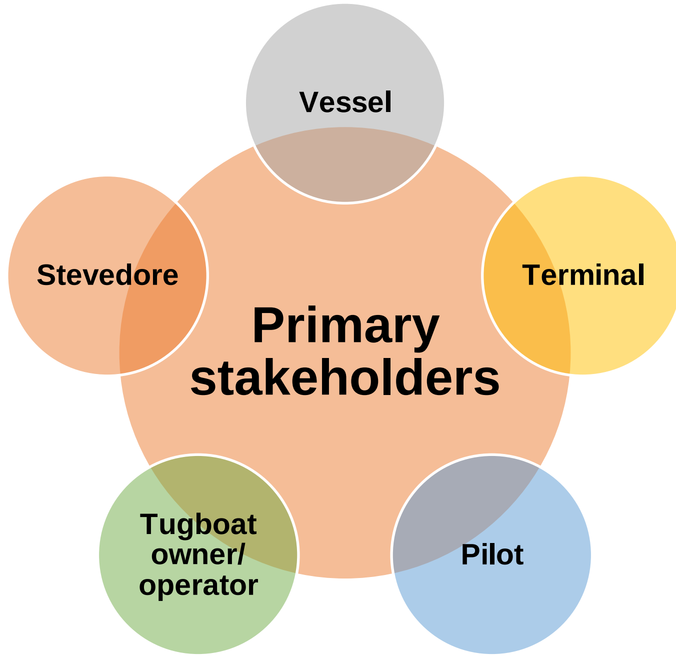
All stakeholders can be subdivided into two broad categories:

.1 Primary stakeholders; and

.2 Secondary stakeholders.

Primary stakeholders are directly involved in the ship-port interface and include vessels, port authorities/regulators, pilots, tugboats, terminals and stevedores (shore staff who carry out cargo loading and/or discharging).

Figure 2.2 Primary stakeholders



Source: Drewry (2024)

Secondary stakeholders, such as agents, cargo owners/charterers, perform a secondary role and are indirectly involved in the ship-port interface. These are shown in the graph below.

Figure 2.3 Secondary stakeholders

Source: Drewry (2024)

2.5 Emissions from vessels during the ship-port interface

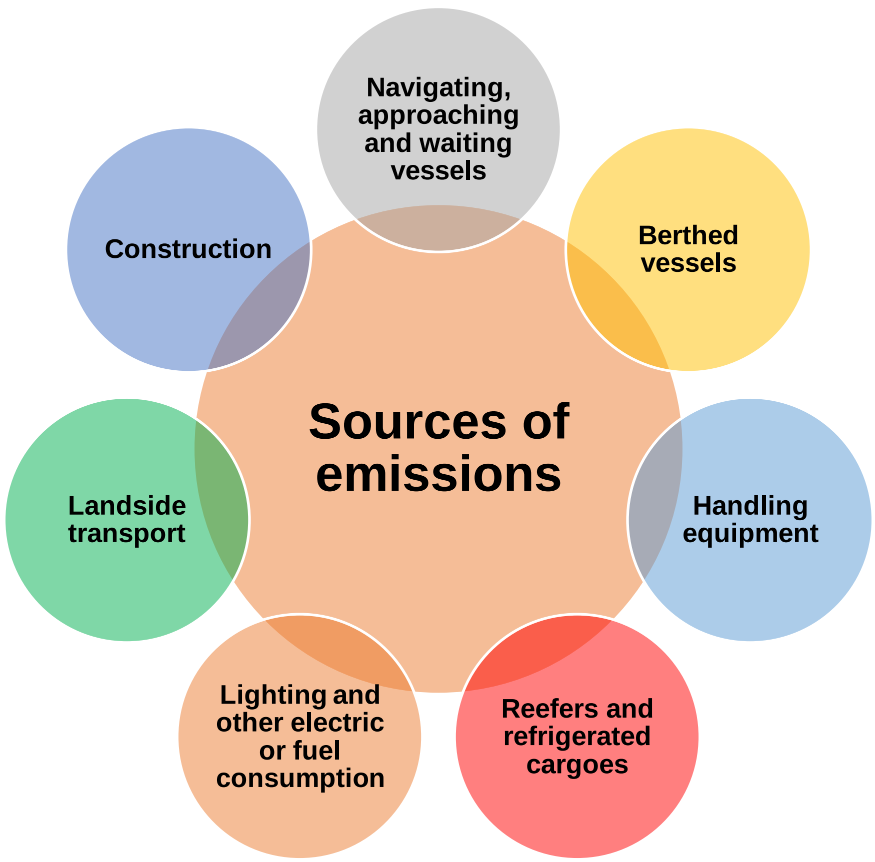
There are many sources of emissions during the ship-port interface.

.1 Emissions during the process of berthing: These emissions are mainly from the vessels and tugboats.

.2 Emissions during cargo operations: These emissions are mainly from shore cranes, from berthed vessels for electricity generation, from port lighting, from heavy-duty vehicles and railroad locomotives, amongst others. Power consumption by reefers is another important source of emissions. Sustainable construction of berths helps reduce emissions.

.3 Other emissions: These emissions are due to various reasons including the time when the vessel is at berth during non-cargo operations, port lighting during non-cargo operations, bunkering, movement of vehicles for crew change, delivery of provisions by ship chandler, movement of vehicles for agents and surveyors, amongst others.

Figure 2.4 Main sources of emission at ports

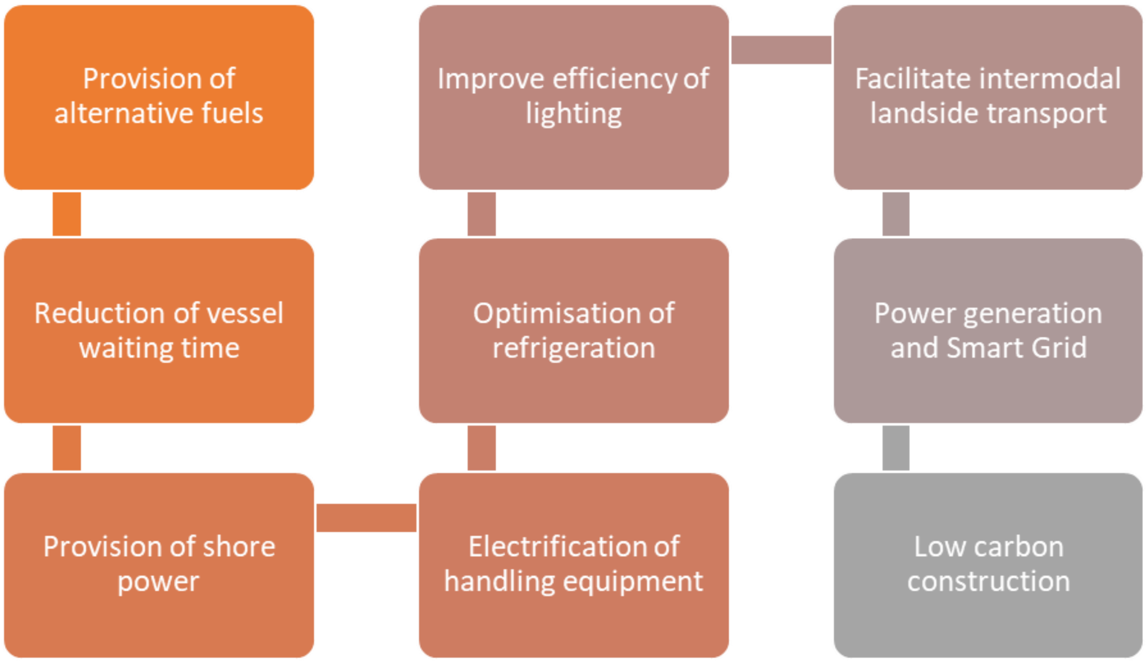


Source: Drewry (2024)

2.6 Emission control measures

Several emission reduction measures are available: switching to low-/zero-carbon fuel, reducing vessel waiting time, using onshore power, electrifying cargo handling equipment, using LED lights, optimising refrigeration and power generation, etc.

Figure 2.5 Emission reduction enabling actions



Source: Drewry (2024)

2.7 Section summary

The ship-port interface is defined as the area of coverage of a ship's operation from the time the pilot boards the vessel at the pilot station to help it berth. The coverage extends to the time the pilot leaves the vessel at the pilot station when it departs from the port and includes the time the vessel is at the port. Emissions in the deep sea have an overall environmental impact, but those in the ship-port interface impact the local area and, hence, are critical for the local community.

After the sea voyage, the vessel reaches the pilot station where the pilot boards. Pilots are local experts with knowledge of navigation in shallow waters of the area, its current and tide, etc. Large cargo vessels are not easy to manoeuvre and are assisted by small tugboats to berth.

In the process of ship-port interface, the vessel gets involved in various crucial activities in port such as:

.1 Cargo operation: A vessel loads and discharges cargo at the port.

.2 Crew change: At times some crew members leave the ship upon completion of their contract and are replaced by new crew members who join the vessel at the port. The change of crew usually involves road transport between the port and the airport.

.3 Provisions: Ship chandlers deliver provisions or other items ordered by the vessels. These are usually brought to the vessel at port via trucks or boats.

.4 Bunker: Vessels are refuelled at the port via shore pipeline, trucks at berth or small vessels known as bunker barges that carry bunker (marine fuel).

.5 Others: Other activities such as ship surveys and repair are also carried out at the port.

The above-mentioned activities are a cumulative result of the successful involvement of various stakeholders, which can be categorised as primary and secondary stakeholders depending on their roles.

The primary stakeholders are directly involved in the ship-port interface and include vessels, port authorities/regulators, pilots, tugboats, terminals and the stevedores (shore staff who carry out cargo loading and/or discharging). Secondary stakeholders perform secondary roles and are indirectly involved in the ship-port interface such as agents, cargo owners, etc.

Emissions during the ship port interface happen in three categories: firstly, during the berthing, with the emissions generated from vessels and tugboats; secondly, from carrying out cargo operations, which comprises emissions from shore cranes, berthed vessels for electricity generation, port lighting, heavy-duty vehicles and railroad locomotives, amongst others; and lastly, at berth during non-cargo operations, port lighting during non-cargo operations, as well as during bunkering, with emissions from the movement of vehicles for crew change, delivery of provisions and movement of vehicles for agents and surveyors and so on.

Several emission reduction measures are available during ship-port interface such as switching to low-/zero-carbon fuel, reducing vessel waiting time, using Onshore Power Supply (OPS), electrifying cargo handling equipment, using LED lights, optimising refrigeration systems, and low carbon construction methods.

3 Emission reduction measures from vessels during the ship-port interface

International shipping contributes about 3% to the total GHG emissions with a sizable portion emitted at ports where ships call for cargo operations and other purposes. Therefore, it is prudent to reduce emissions from vessels when they are at port. While there are several ways to reduce these emissions, a few popular options as listed below, could be considered globally as well as in the Mediterranean region:

3.1 Emission reduction from the vessel's auxiliary engine

When the vessel is at berth, its main engines and propulsion systems are stopped, but its auxiliary engines are still working to cater to the vessel's power requirement at berth, releasing air pollutants. Following are a few methods to reduce emissions from auxiliary engines at port:

3.1.1 Use of sustainable biofuels

The use of sustainable biofuels along with conventional fuels in auxiliary engines can significantly reduce emissions. Sustainable biofuels are estimated to reduce CO_2 emissions by about 85%, but even if they are blended with conventional fuels in limited quantities such as 10%, 20% or 30%, they can help reduce emissions. Since 100% blending or complete replacement of conventional fossil fuels with sustainable biofuels can only be done with some upgrades/modifications to the existing engine, it is slowly gaining popularity with shipowners/ship managers. Besides, the supply of sustainable biofuels for shipping is limited. However, several shipowners such as Norden, K Line and CSL, Jan de Nul have already conducted pilot tests with B100 bunkering.

3.1.2 Use of hybrid engines/fuel cells

Conventional fossil fuel engines can be used in hybrid mode whereby a part of the energy/power requirement is supplied by either high-powered batteries or fuel cells operated with cleaner fuels such as hydrogen. A designated space is required on board the vessel for these batteries, fuel cells or the fuel itself. Fossil fuel with electric batteries is the most popular hybrid option at present but the combination of fossil fuels along with a fuel cell system driven by clean fuel is gaining popularity. These options are economically viable for small vessels.

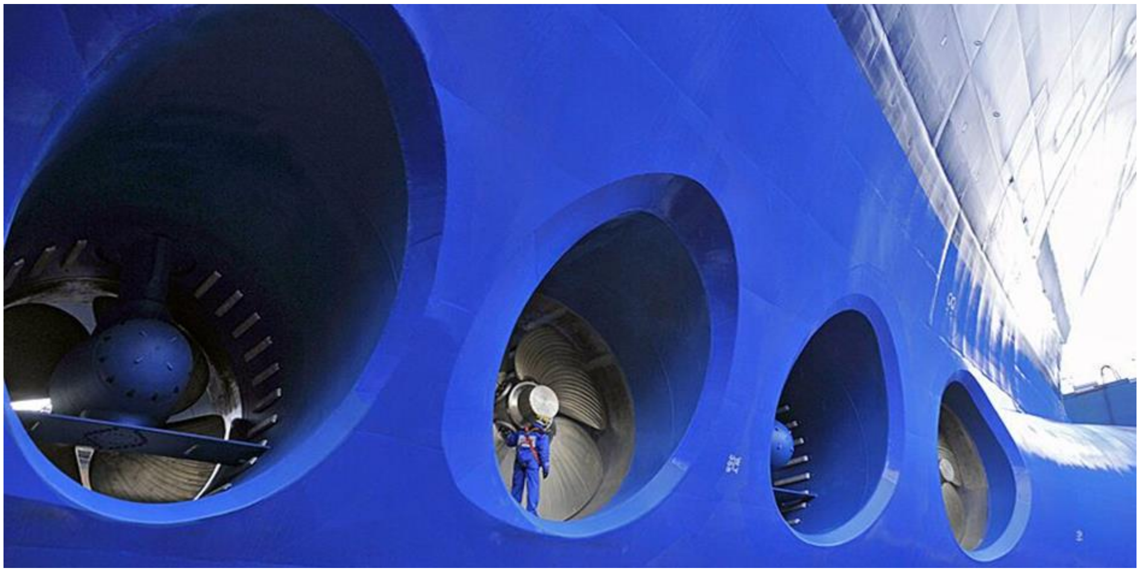
3.1.3 Use of auxiliary engines driven by low-/zero- carbon fuels

There is an increasing focus on developing new auxiliary engines that use low-/zero-carbon fuels such as Liquefied Natural Gas (LNG), methanol, hydrogen and ammonia. While engines using LNG and methanol have already been developed, those that use hydrogen and/or ammonia are currently under development. These new fuels will certainly reduce or eliminate carbon emissions, but each has its respective challenges. For example, hydrogen requires a lot of volumetric storage onboard, LNG has the problem of methane slip, and methanol and ammonia are highly toxic and flammable. Meanwhile, engine developers and other associated stakeholders are making intense efforts to overcome these challenges.

3.2 Bow thrusters

Many vessels use bow thrusters at ports to improve manoeuvrability while berthing/unberthing. A bow thruster is a lateral thruster fitted in an athwartships tunnel near the bow. Water jets emanating from bow thrusters create a vacuum and counteract the thrust produced by the main propulsion devices. This helps in the vessel's lateral (side-to-side) movement and manoeuvrability in tight spaces as well as during difficult weather conditions.

Figure 3.1 Bow thrusters



Source: Ship Nerd News

Efficient management of bow thrusters helps reduce fuel consumption, while increasing manoeuvrability at ports lowers the time required to berth the vessels. This time saving at the port can be used by vessels to sail at slower speeds thereby reducing fuel costs and emissions.

In accordance with a study carried out by the Maritime University of Szczecin, Poland (Jaroslaw, A., Pawel, Z., 2021), the use of a bow thruster on a generic ferry vessel operating in the Baltic Sea between Poland and Sweden saved up to 10% energy by optimising performance using joystick controls and a thrust allocator.

According to Wärtsilä (Amanda, T., 2023), for container vessels, a minor reduction in ship speed led to significant fuel savings and increasing the thrust capacity of bow thrusters reduced time for manoeuvring at port by 0.6 hours. For container vessels with three port calls in China and three in Europe sailing speeds reduced by 0.1 knots (from 20.0 knots to 19.9 knots) while still maintaining the schedule. Fuel saving for 0.1 knot speed resulted in reducing the vessel's emissions as well.

3.3 Cargo operations-related smart systems on vessels for power reduction

Energy efficiency measures for cargo operations on board a ship depends on the type of cargo carried by the ship. For an oil tanker, for example, cargo pumps on board are operated for unloading and therefore, efficient use of cargo pumps and use of 'variable frequency drives (VFDs)' in cargo pumps are some measures that could help reduce power consumption and emissions.

Deck cranes are provided for loading/unloading from general cargo vessels and bulk carriers, and their efficient use can save energy. A few simple measures such as good oil quality, proper adjustment of brakes, efficient greasing of pulleys and negligible backlash in turntable gearings can help save energy. The use of VFDs in crane motors can also help in energy saving if the motor is compatible with VFD.

For refrigerated cargo operations on board, simple measures such as proper insulation and heat leakage control, proper ventilation, pre-trip inspections, automated temperature management and smart refrigerant systems help save energy.

3.4 LED lighting on vessels

LEDs help reduce power consumption and operational costs when compared with traditional fluorescent lamps as the former substantially reduces electrical load which in turn improves the ship's efficiency in terms of energy and fuel.

Deployment of advanced lighting control systems such as KNX/DALI can bring additional benefits in the form of improved energy efficiency, reduced power consumption and better safety in the work environment. These systems can also be integrated with the ship's digital systems for better results.

Power saved using LEDs on ships varies by ship type. For example, savings would be huge in a cruise ship or a passenger ferry where accommodation and other deck areas are always lit.

Several cruise ships globally as well as in the Mediterranean region have replaced their normal lighting with LED lighting, lowering power consumption and emissions.

Figure 3.2 LED lighting on Royal Caribbean Cruise Ship Harmony of the Seas

Source: Shermanstravel website

Royal Caribbean's Harmony of the Seas switched to LEDs in 2016. The vessel's maintenance and power requirements have since reduced, which has also lowered the heat generation, lessening the burden on its air conditioning system. All of this translated in huge power, fuel and emission savings which extended to other areas as well. With LED systems, there was less cabling, fewer connections and no dimmers.

3.5 Onshore Power Supply (OPS)

Onshore power is the process of connecting ships to a port electric grid to power onboard services, systems and equipment. A ship can turn off its auxiliary engine once the onshore power is connected, reducing emissions from vessels at the port, provided onshore power is generated from clean sources such as solar and wind.

Figure 3.3 OPS to a ship at berth – Example no. 1

Source: Cavotec website

Figure 3.4 OPS to a ship at berth – Example no. 2

Source: ETO website

The installation of onshore power connection on a ship needs capex of $0.2-$0.4 million, however, it could be higher for some types of vessels. In any cases, this will be a worthwhile initial investment by shipowners/ship managers considering the long-term benefits it brings.

Onshore power can be designed from the ground up for marine use, producing regulated and stable output, regardless of changes in power from the berth or from load demand onboard. It is designed to work in marine environments where temperatures may be high and with any marine power system worldwide.

OPS is normally available in the power range 0-20 MVA. Smaller vessels such as ferries typically use low-voltage solutions, while larger vessels such as cruise and containerships require higher voltages. Sockets and plugs are standardised for ro-ro vessels as well as passenger ferries (11 kV), containerships (6.6kV) and cruise ships (6.6kV, 11kV). Standardised cable management systems are available for these vessel types.

A few of the many examples of ships opting for Onshore power connection in the Mediterranean region are listed below:

MSC Cruises expressed its commitment to decarbonisation by successfully connecting its vessel MSC World Europa to onshore power in the Port of Valletta (Malta). It is the first operational onshore power facility in the Mediterranean in July 2024. MSC World Europa will call at the Port of Valletta (Malta) every week in 2024 and 2025 and will connect every time to onshore power while in the port. This will result in significant savings in terms of fuel, energy and emissions. Since 2017, every new ship joining the fleet of MSC Cruises has been equipped with an onshore power connection and plans are underway to retrofit older ships.

ABB is providing shore-to-ship power connections for ferries and cruise ships in the Port of Toulon (France), cutting emissions and noise during port stays. The Port of Toulon (France), which handles over 1.6 million ferry and cruise passengers annually, has committed to the ABB Onshore Connection technology which will eliminate more than 80% of pollutant emissions and save 9,000 hours of vessels running on diesel annually. A few more examples of ABB providing Onshore power connections on vessels are shown in the images below:

Figure 3.5 ABB enables emission-free port stays for Corsica Lines vessels by providing OPS

Source: ABB website

Figure 3.6 ABB plugs Holland America Lines to low-emission onshore power worldwide

Source: ABB website

3.6 Onboard Carbon Capture and Storage (OCCS)

Onboard Carbon Capture and Storage (OCCS) deploys a CO_2 scrubber through which the ship's exhaust gases are made to pass. The solution in the scrubber absorbs CO_2 and redirects it into liquid CO_2 storage containers onboard or in liquid CO_2 tanks. While this technology is increasingly becoming popular, ports need to build the infrastructure to receive liquid CO_2 or CO_2 storage containers.

Carbon capture technologies are useful for reducing emissions in hard-to-abate sectors such as power plants as well as cement and steel manufacturing. Once the supply chain develops, there could be great potential for liquid CO_2 transportation. These will then result in ports developing infrastructure for loading and discharging the cargo of liquid CO_2, and will give further impetus for the development of OCCS.

Examples of OCCS:

.1 <u>Evergreen containership retrofitted with full carbon system</u>

A Chinese shipyard completed the first retrofit of a fully functioning carbon capture system aboard a large containership. This installation was undertaken in early 2024.

.2 <u>Mitsui O.S.K. Lines (MOL) to install carbon capturing system</u>

Japanese shipping company, MOL has decided to equip its LR1 product tanker with Value Maritime's Filtree System, an OCCS with a Sulphur Oxide (SO_X) scrubber. The installation is set to take place around the end of the year 2024.

.3 <u>Diana Shipping Capesize gets Carbon Capture and Storage (CCS) system onboard</u>

This system is designed to capture 25% of the CO_2 emitted in the exhaust gas and temporarily store it onboard in liquid form. Sinotech provided the expertise for a full feasibility study, engineering and overall turn-key package for the installation with crew training as well as full support towards type approval certification of the installed system by the vessel's administration.

3.7 Others

Besides these, there are other emission reduction measures, which are briefly covered in this section.

3.7.1 Measures by ship operators/ship managers for efficient vessel turnaround at berth

Some measures which a vessel's operator/manager can undertake to ensure quick turnaround at berth include timely cargo loading/unloading, efficient crew changes and delivery of supplies/spares, timely tug and pilot assistance, and efficient documentation.

Efficient cargo unloading/loading process is a joint responsibility between the port and the vessel. While ports play a dominant role here, vessels can also contribute towards timely loading/unloading. Since the ship crew knows what will be loaded or unloaded at the port, they can prepare the space on board in advance instead of waiting for the vessel to berth. The crew can also finalise any loading/unloading sequence after prior consultation with Port Authorities and can start removing lashings before the vessel arrives at berth, without compromising on safety. They can coordinate with port authorities to ensure that all material handling equipment at the berth is kept ready and on stand-by and no time is lost in arranging/preparing them after the vessel has berthed.

Since crew changes as well as delivery of essential supplies and spares are mainly done at the port, efficient and advance liaising with ship agents and other stakeholders can ensure that these activities cause no delay to the departure schedule of the vessel.

A vessel has to depend on tug and pilot assistance from the port for berthing/unberthing. Effective coordination among the ship crew, ship agent and port authorities can ensure that such assistance is made available to the vessel in a timely manner which ensures quick turnaround.

When a vessel berths at a port, it can be subjected to several inspections from third parties such as customs, port authorities, flag authorities, classification authorities and service providers. As most of these inspections require efficient and timely documentation, the crew can organise the documentation in advance which can ensure timely turnaround of the vessel with the use of Port clearance portal and data platforms of port authorities such as digitalPORT@SG and Maritime and Port Authority of Singapore (MPA)'s digitalOCEANSTM respectively to streamline the operation.

Regular hull cleaning and propeller polishing as a part of biofouling management practice could reduce marine growth on the vessel's hull and propeller, which will eventually reduce emissions from vessels. However, only a few ports allow this at berth. Hence, vessels go to anchorage for such work, with certain ports restricting such activities even at anchorage because non-captured or non-filtered cleaning could result in biological or chemical pollution.

Some maintenance on board could be carried out by a riding team (a small team that sails on the vessel for a few weeks for specific maintenance work), which reduces the time required at anchorage/repair berth and thereby helps in reducing emissions.

3.7.2 Swappable batteries for vessels

Battery swapping or battery switching is a process which allows prompt exchange and discharge of battery packs on battery-powered vessels. Swappable energy storage systems are mostly in the form of containerised battery packs which can be removed from vessels and stored/recharged in locations along the waterway or at ports.

These systems work as an alternative to recharging the vessel via a charging station which is time consuming. They are ideal for vessels that need to be turned around quickly at the port or for ports that do not have charging facilities at berth.

There are many examples of ships opting for swappable batteries in the Mediterranean region and other regions with a few popular ones listed below:

.1 The first inland cargo vessel running entirely on a new swappable battery system for zero-carbon emissions is expected in 2024 in the Netherlands. The 295-foot vessel Den Bosch Max Groen owned by Nedcargo and operated in partnership with inland terminal operator Benelux Container Terminal Network (BCTN), is currently undergoing conversion at the Concordia Damen shipyard which also built the vessel in 2020. The vessel originally had a diesel generator which was replaced by a standard 20-foot modular energy container with swappable batteries.

Figure 3.7 Swappable batteries pack

Source: The Maritime Executive Article

.2 ZESpacks are self-contained battery containment systems, designed for loading on ships and then swapped as and when power is expended. Zero Emission Services (ZES) is building a strategically placed network of 1 MW charging stations where batteries can be recharged in three hours. However, instead of waiting for the recharge, the vessel swaps the units and continues sailing with minimum downtime.

.3 Japanese feeder operator Imoto Lines partnered with the country's technology company Marindows to build a zero-emission container vessel with swappable batteries at Miura Shipbuilding. When it is built in 2027, the container vessel, which will feature Japan's first swappable container batteries, will be tested on the Kobe-Hiroshima service. This vessel will not only reduce carbon emissions during operations but also achieve zero emissions over its entire lifecycle (fuel mining, manufacturing, usage).

.4 Wärtsilä has developed and delivered a mobile battery container solution that would enable inland waterway vessels to operate with zero emissions. The first order, comprising three units, was placed by ZES BV, a Netherlands-based company founded in 2020 by ING Bank, Engie (energy and technical service provider), the Port of Rotterdam (Netherlands) and Wärtsilä. The two containers were delivered in June 2021 and installed on a 104 TEU inland waterway container vessel, which has been modified to allow these two units to be mounted on board. The system enables the vessel to operate 100% on electric power, with no carbon emissions. The energy capacity is equivalent to that of approximately 36 electric passenger cars. When discharged, the containers can be exchanged and charged onshore using energy from renewable sources. This replaceability is unique since battery containers have thus far been stationary installations.

.5 Yinson GreenTech, sister company of oil and gas FPSO operator Yinson Production, has launched its first all-electric cargo delivery boat for harbour operations in Singapore. The newly built Hydromover has swappable batteries, zero onboard emissions, and - according to Yinson - can reduce Operational Expenses (OPEX) costs by up to 50% compared to a diesel-powered vessel. The new vessel is Singapore's first all-electric cargo boat, and its launch is a milestone for achieving the Maritime and Port Authority of Singapore's goal of electrifying the nation-state's harbour craft. Out of all of the proposals submitted to MPA for R&D grant funds, the Hydromover is the first project ready for commercial trials.

Figure 3.8 Singapore's first all-electric cargo boat

Source: Yinson Green Tech

3.7.3 Overview of measures taken on ships to reduce emissions during sailing

This section briefly describes the measures which could be taken for GHG emission reduction from ships while sailing. GHG emission reduction measures, such as Energy Saving Devices (ESDs) and Propulsion Improving Devices (PIDs), for vessels in the deep sea are not so effective while the vessel is navigating the port area. Hence, they have been mentioned only briefly in this section.

3.7.3.1 Engine Power Limitation (EPL)

EPL requires minimal changes to the ship and also retains the underlying performance of the engine, making it the simplest way for existing ships to meet European Union (EU)'s energy-efficiency requirements. Lowering the operational speeds of affected vessels would reduce fuel usage and GHG emissions. However, EPL could be ineffective if ships are already traveling slower than the required *de facto* speed.

3.7.3.2 Propulsion improving devices

PIDs are either fitted on the propeller/rudder, or in front of or behind the propeller/rudder to help improve the propulsion efficiency of a ship. A few popular PIDs have been listed below:

.1 Propeller ducting: A ducted propeller is a marine propeller fitted with a non-rotating nozzle to increase the thrust and lower various propeller losses, irrespective of the vessel's speed.

.2 Propeller nozzle: The propeller nozzle is a circular casing enclosing the propeller. Since it has very less clearance and uses the hydrofoil concept, the propeller nozzle helps increase the thrust.

.3 Propeller boss cap fins (PBCF): PBCF is a boss cap placed behind the propeller. It has several tiny fins that can revolve in unison with the propeller blades to streamline the flow behind the propeller boss.

.4 Propeller eco cap: A propeller eco cap is like a cap on the propeller hub behind the propeller. The energy lost from the flow due to the trailing edge is recovered, thereby reducing power demand.

.5 Controllable pitch propeller (CPP): A CPP is a type of propeller that can be adjusted to optimise the blade angle (pitch) under various circumstances, resulting in higher efficiency under different speeds and different loads. CPP is often used on smaller boats and tugs, and is very helpful for dynamic positioning of vessels.

.6 Propeller-rudder integration/alignment: A vessel's power efficiency depends upon the interaction between all its main components which need to form a single integrated design to achieve optimal performance. This is especially useful for offshore, shuttle tankers, ferries and Ro-Pax vessels.

.7 Rudder bulb: A rudder bulb is a streamlined bulb, which is fixed at the leading edge of the rudder. It improves the flow of water in front of the rudder and fills the vacuum behind the centre of the propeller. It is especially suited for big vessels.

.8 Gate rudder: The gate rudder is an advanced manoeuvring and energy-saving tool having a distinctive design with two foils on either side of the propeller. The hydrodynamic effects of the propeller and steering system enhance the resulting thrust performance during sailing.

.9 Air lubrication system: Air lubrication, which can be achieved by covering the entire flat bottom of the vessel's hull with a carpet of microbubbles, lowers the frictional resistance of the hull, thereby reducing the fuel consumption.

.10 Wind-assisted propulsion system: Wind-assisted propulsion systems (WAPS) using rotor, kites and sails, amongst others, are now available on ships that use wind for propulsion.

3.8 Section summary

International shipping contributes about 3% to the total GHG emissions with a sizable portion emitted at ports where ships call for cargo operations and other purposes. Therefore, it is prudent to reduce emissions from vessels when they are at port.

GHG emission reduction measures, such as ESDs and PIDs, are helpful for emission reduction for vessels in the deep sea and are not so effective while the vessel is navigating within the port area.

At port, the auxiliary engine operation is a major source of pollutant due to power requirements for cargo operation and hotel loads. These emissions can be curtailed using sustainable biofuels, hybrid engines, fuel cells and low-/zero-carbon fuels. The auxiliary engines can be shut down by using onshore power.

Additionally, variable frequency drive for cranes and cargo pumps, LED installation, efficient cargo loading/unloading are major initiatives that can be taken to reduce emission during the ship-port interface. Other measures that a vessel's operator/manager can undertake to ensure quick turnaround at berth include timely cargo loading/unloading, efficient crew changes and delivery of supplies/spares in addition to timely tug and pilot assistance.

Carbon capture technologies are useful for reducing emissions in hard-to-abate sectors. Once the supply chain develops, there could be great potential for liquid CO_2 transportation. These technologies will then result in ports developing infrastructure for loading and discharging the cargo of liquid CO_2 and will give further impetus for the development of OCCS.

Additionally, various port clearance portals and data platforms could streamline several inspections from third parties such as customs, port authorities, flag states, classification societies, etc. Regular hull cleaning and propeller polishing could reduce marine growth on the vessel's hull and propeller, which will eventually reduce emissions. However, many ports do not allow vessels to carry out these activities in port areas as well as at anchorage because non-captured or non-filtered cleaning could result in biological or chemical pollution. Riding teams on vessels may carry out maintenance while the vessel is at port, reducing the time required by vessels at anchorage/repair berth and thereby lowering emissions.

4 Emission reduction measures in ports during the ship-port interface

4.1 Background

There is increasing awareness of the importance of ports in the wider supply chain and the actions that ports can take to facilitate the reduction of GHG emissions from shipping. This section gives an overview of the emission reduction measures in ports during the ship-port interface.

Many ports are developing sustainability strategies that consider the reduction of GHG emissions within port boundaries as well as in relation to the calling ships. This incorporates terminal concession specifications, under which some clauses favour the proposing initiatives aligned with this strategy. In particular, generation of renewable energy, reduction of fuel consumption, and transition towards sustainable sources are rewarded.

Some ports are becoming energy hubs, which includes managing their energy sources (e.g. offshore wind, solar or tidal). In some cases, agreements are made with external energy companies to bring green energy to the port. However, this strategy, in some cases, conflicts with the interests of the energy companies and with local legislation.

4.2 Emission reduction from tugboats

Most of the tugboats operating in ports around the world are powered by fossil fuels and their fuel consumption is linked to the nature of the service in which they are employed and the location where they are deployed. Harbour tugs, engaged in ship assists, could operate daily except for periodic maintenance and idle days. They have powerful engines and their GHG emission is an important consideration in the port sector. In many ports, tugboats are connected to onshore power when they are at berth awaiting the next job.

Fuels like methanol, ammonia and hydrogen, in addition to systems based on electric charging with onboard battery storage, are viable options for decarbonising tugboats. Hydrogen fuel cells and electric battery are particularly appealing for tugs due to their unique load-following characteristics. Diesel engines take a little while to ramp up their power output, whereas hydrogen fuel cells and batteries can, in a shorter time, provide the sporadic high power needed for pushing large objects. Meanwhile, hydrogen in its dense form is hard to store aboard a ship.

The Port of Antwerp (Belgium) operates Hydrotug 1, a hydrogen-powered tugboat. Built by CMB.TECH, the tugboat is equipped with two BeHydro dual-fuel engines running on a mix of hydrogen and diesel. In May 2024, Damen announced that it had signed an agreement with CMB.TECH to build four hydrogen dual-fuel tugs. While the tugs will primarily run on hydrogen, they are equipped to switch to traditional fuel if hydrogen is not available and can therefore operate on 100% traditional fuel if needed. The tugs feature a total of 160 cubic meters of fuel storing capacity.

As per Clarksons, there are 40 dual-fuel tugboats in operations, mostly running on LNG (24) and sustainable biofuel (13), while the ten tugboats on the orderbook consists of six LNG, two to be powered by Methanol, one powered by Ammonia and one by Hydrogen. However, there are many innovative ideas in the pipeline:

.1 The Port of Antwerp (Belgium) plans to deploy a hybrid methanol/electric tug in the foreseeable future.

.2 The United States of America (USA) has several companies, including ABB, that have partnered to construct the world's first methanol-hydrogen fuel cell tugboat.

Probably the most promising technology is electric propulsion wherein the onboard battery is charged during berthing. The advances achieved and expected in batteries (reduction in size, cost and disruptive sound) will surely boost this solution. However, according to experts, using electric tugboats involves high upfront costs, requires infrastructure for power supply at berth and has range limitations.

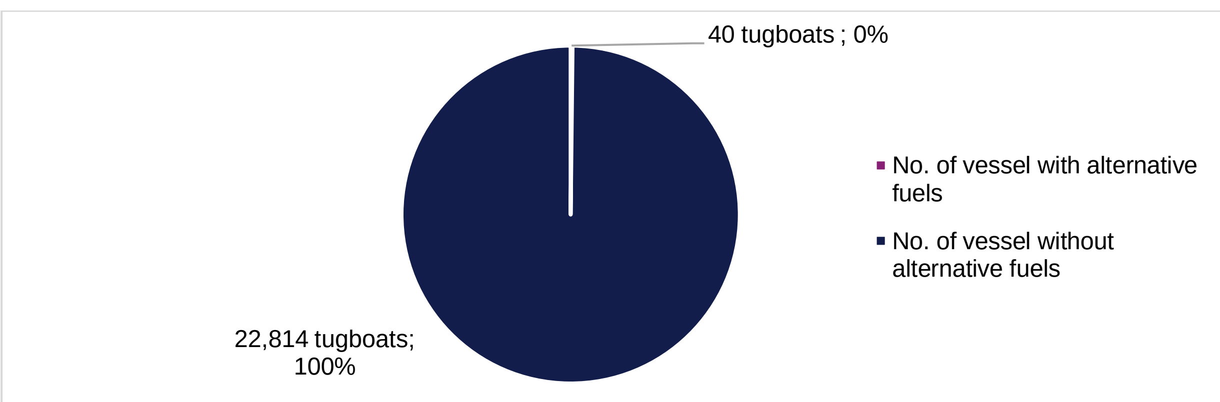
The number of electric tugs is growing around the world. In late 2022, tugboat Sparky started operations after a six-year collaboration with Damen shipyard in Vietnam and the owner, Ports of Auckland in New Zealand.

Tugboat HaiSea Wamis was built by Sanmar Shipyards in Türkiye and delivered to owner Seaspan in mid-2023. It is tasked to escort and tow LNG carriers at Kitimat, British Columbia. Other electrically powered tugs include those ordered by the Port of Antwerp-Bruges (Belgium), Port of Gisas (Türkiye), Port of San Diego (USA) and Port of Vancouver (Canada). Gisas tugboat, designed by the Turkish firm Navtek Naval Technologies, is perhaps the world's first rechargeable and fully electric-powered tugboat.

An interim efficient and eco-friendly solution is hybrid-powered tugs that combine diesel with batteries. Rotortug RT Adriaan (now named VB Kracht) started operations at Rotterdam in 2012, followed by two more hybrid propulsion Rotortugs in 2015. Another example is the hybrid-powered icebreaking escort tug designed by Robert Allan Limited for Port of Luleå (Sweden) launched in October 2023 at Gondan Shipyard in Figueras (Spain). This tug, with bollard pull of 100 tonnes, is equipped with an innovative hybrid propulsion system that includes two main diesel engines, one shaft generator and batteries for energy storage.

While acquisition costs are high, there are huge savings in fuel and maintenance when considering their life cycle. A recent study (Shanmuk, D., Razieh, K., et al., 2024) presented reference cost components associated with conventional, electric and hybrid tugboats. The initial purchase price of an electric tugboat is 100% higher than a conventional diesel tugboat, while for a hybrid tugboat, it is 50% higher. However, according to the same study, fuel and electricity consumption costs (at USA energy values in 2022) would be 50% lower for electric than conventional and 25% lower for hybrid. Maintenance costs would be equivalent for conventional and hybrid, but half as much for electric.

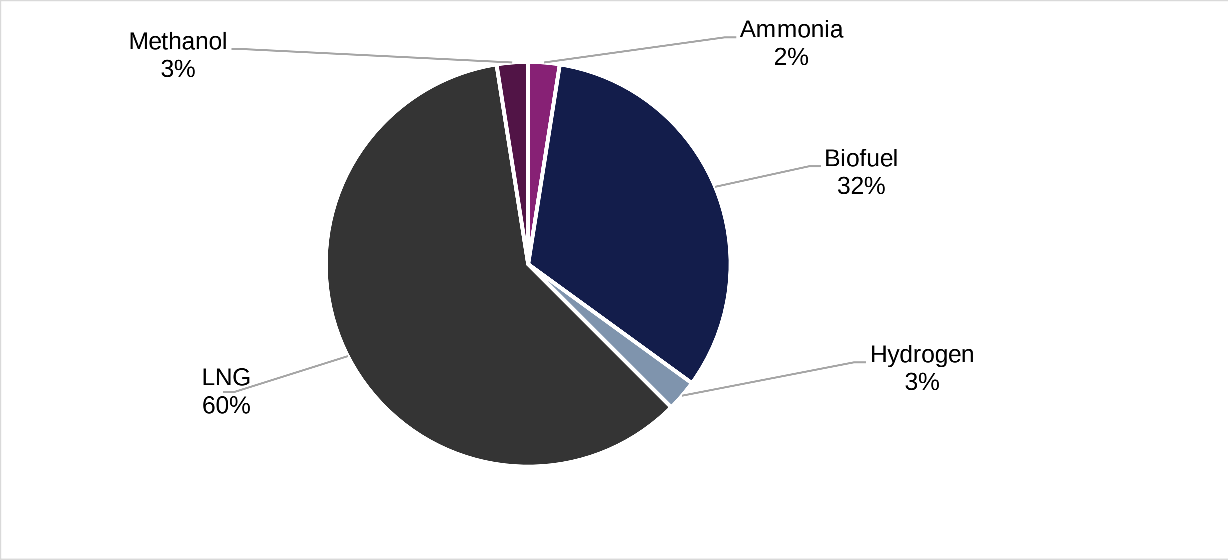
Figure 4.1 Global tugboat fleet alternative fuel[1] uptake



Source: Clarksons, Drewry (2024)

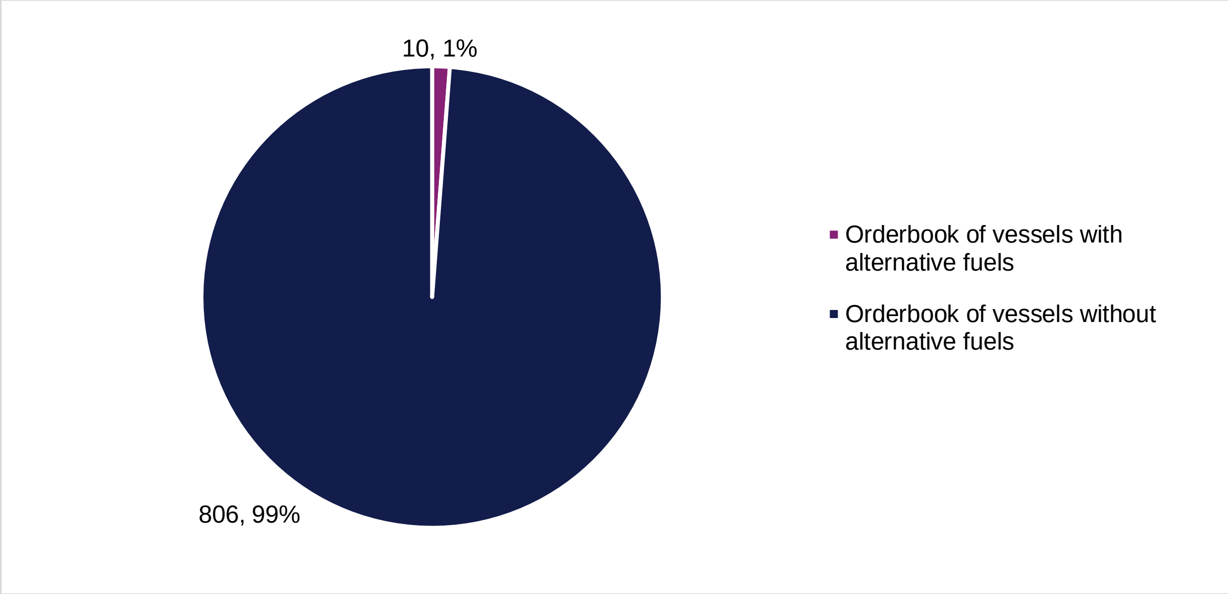
[1] Most of the alternative fuels being used at present are not low-/zero-carbon fuels, hence are referred to as alternative fuels in the title.

Figure 4.2 Global tugboat alternative fuel type



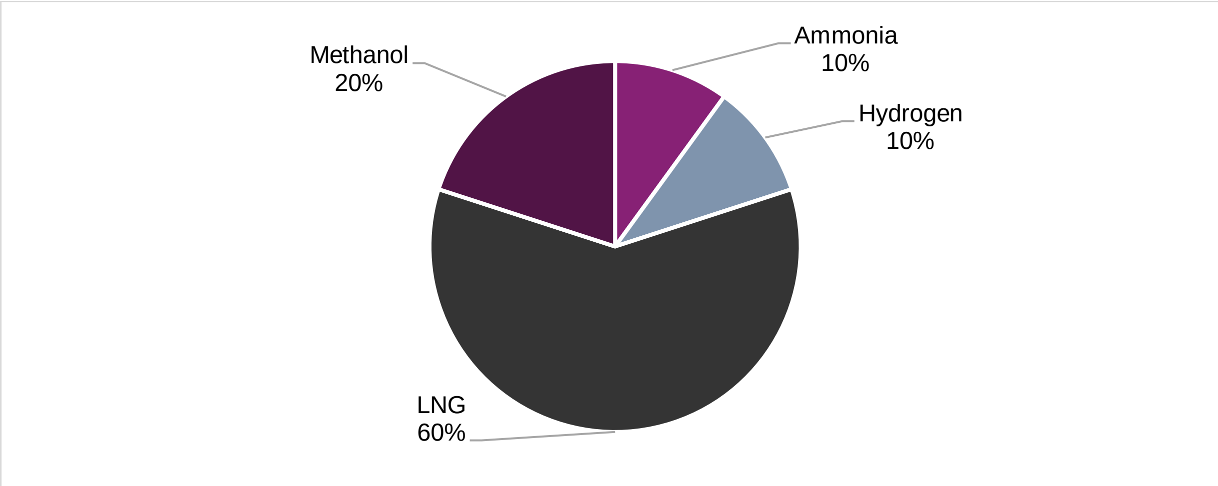
Source: Clarksons, Drewry (2024)

Figure 4.3 Global tugboat orderbook alternative fuel uptake



Source: Clarksons, Drewry (2024)

Figure 4.4 Alternative fuel type orderbook of tugboat



Source: Clarksons, Drewry (2024)

It would be safe to conclude that opportunities to adopt new generation tugboats are increasing in ports that are committed to an emission reduction strategy. From the upcoming orderbook, LNG operated tugboats are most popular dual-fuel tugboats.

However, the uncertainty of green fuel availability for tugboats makes it difficult for ports to order green tugboats.

Other recent examples worth mentioning are:

.1 The methanol-powered Methatug was launched in the Port of Antwerp (Belgium) in May 2024. It is a conversion of the engines of an in-service tug and is described as the world's first methanol-powered tugboat.

.2 Japanese shipping company NYK took delivery of an ammonia-powered engine in February 2024, which will be installed on a tugboat and is set to become the world's first commercially operated ammonia-fuelled vessel of its kind.

.3 K Line Port Service Co., Ltd. conducted a demonstrative test voyage in June 2023 with the tugboat 'Aihomaru' operating in Nagoya Port using next-generation biodiesel fuel.

4.3 Onshore power availability at berth

Vessels need significant energy while berthed, e.g. containerships for powering their reefer units and cruise ships for managing their hotel load (crew and passengers). They are typically powered by auxiliary engines, using marine diesel. The possibility of plugging at berth existed in the past (with smaller-sized vessels and limited power needs), but since the cost of fossil fuels was quite low it was more convenient for shipowners to turn on the auxiliary engine. As fuel prices increased and environmental requirements became more demanding, these practices were reversed.

OPS by means of on-berth connection points and cable management systems, significantly reduces GHG emissions, since it is not necessary to have the auxiliary engines running. The key challenges to realising onshore power include:

.1 Demand: At present, only a limited number of oceangoing ships can receive onshore power. According to the European Maritime Safety Agency (EMSA), among the total ships that called at EU ports in 2020, the percentage of ships active with OPS included 9.6% of containerships (166 ships of the total 1,724 ships), 15% of cruise ships (23 of total 152) and 10% of Ro-Pax (34 of total 337). According to DNV, only 118 onshore power facilities are operational globally, including 107 in the EU. Out of these 107 ports, only 15 ports are EU TEN-T ports, according to an analysis done by ENGINE (Konica, B., 2024).

.2 Cost: The infrastructure costs can be high with operational costs also significantly higher than for diesel (at present rates), depending on local electricity prices. The costs associated with the installation of OPS facilities include primarily transformers that receive and distribute electrical power, voltage and frequency converters, distribution networks within the port and devices for attaching electrical cables to ships. In some cases, it is required to adapt quay structures to accommodate some of these devices. The Port of Antwerp (Belgium), Port of Bremen (Germany), Port of Hamburg (Germany), Port of Haropa (France) and Port of Rotterdam (Netherlands) signed a Memorandum of Understanding (MoU) announcing a joint commitment to implement onshore power technology and asking for equalisation of certain levies and taxes on electricity for onshore power use with those on marine fuels along with sufficient availability of public funds to implement these projects. The capex for OPS in the Port of Hamburg (Germany) is estimated at €85 million as infrastructure investments, which will be fully funded by the Federal Ministry for Economic Affairs and Energy (50%) and The Hamburg Ministry for Economics and Innovation (50%). Barcelona Europe South Terminal (BEST) in Barcelona is the first container terminal in the Mediterranean region to have OPS. It was built at a cost of about €5 million and was partly funded by an EU-funded Spanish Programme “the Sustainable and Digital Transport Support Programme under the Recovery, Transformation and Resilience Plan”. The Port of Antwerp-Bruges (Belgium) will receive a European grant of €3.2 million for an OPS (cold ironing) for cruise ships in Zeebrugge. This OPS is scheduled to be operational in 2026. In June 2024, EC approved, under EU state aid rules, a €570 million grant to incentivise ships to use OPS in Italy.

.3 Capex for OPS is quite high and needs grant assistance as can be seen in the Port of Hamburg (Germany), BEST in Port of Barcelona (Spain) and Port of Antwerp (Belgium). Since the cost is very variable, the World Ports Sustainability Program[2] (WPSP) has developed an OPS cost calculator model.

.4 Source of energy: It needs to be green, as if the ship receives conventional (fossil fuel-fired) power when moored, there would be no real reduction in GHG emissions.

.5 Peak power demand: According to a white paper (GE Vernova, 2023), peak power needs can exceed baseload demand by a significant factor of 10 to 20, when multiple ships use OPS. Therefore, the capacity of the electrical grid of the terminal should be increased by a factor between five and six.

[2] WPSP is managed by the International Association of Ports and Harbors (IAPH) and was established in 2017. It is used as a reference database for best practices in ports

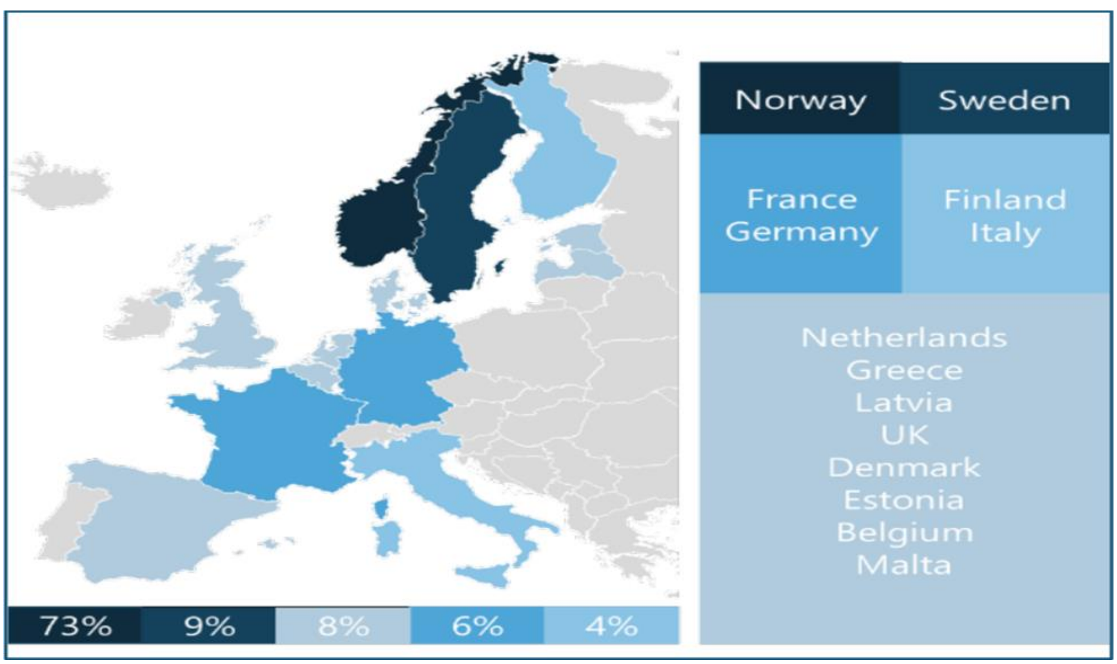
In general, OPS should be installed in terminals in collaboration with port authority. This poses problems for terminals as in many cases, concession agreements were signed many years prior to these systems coming into existence. Only in the most recent concessions, port authorities have included among their requirements the need to provide OPS. This is simplified when the scope includes the execution of berthing works, but when the port authority hands over the infrastructures to the operator, it is complex to attribute responsibilities and define who will be responsible for the corresponding investments. In many of the concessions granted in the past, the port authority retains full responsibility for the berthing works, and the operator is limited to using them within the terms of the agreements. In these cases, it is only through new agreements between the parties that the work necessary to implement an OPS can be carried out.

Another drawback is the existence of energy regulations in some countries that prevent the commercialisation of electricity to ports or terminals with energy being provided to them only by national energy distributors.

Although shipping lines have raised numerous objections against the implementation of this system, it should be noted that ferry operators have shown the most interest in OPS worldwide. Another sector moving in this direction is the cruise industry, which has adequate facilities in ports in northern Europe and on the USA Atlantic coast. There is also potential for growth in the berthing facilities for small crafts providing port services, such as tugboats.

Recent EU legislation includes objectives to reduce GHG emissions by at least 55% by 2030 and reach climate neutrality by 2050. The main objective of the FuelEU Maritime Regulation, as a key part of the EU Fit for 55 package, will involve investments in OPS in Europe. European authorities agreed in March 2024 to propose that passenger ships and container ships of at least 5,000 Gross Tonnage (GT) will be required to connect to OPS in major EU ports from 2030 and in all other ports from 2035. This would exclude ships that stay at berth for less than two hours and ships using zero-emission technology.

Figure 4.5 EU ports with OPS



Source: Power technology Research

According to European Parliamentary Research Service (2022), EC estimates that investment totalling €7.4 billion will be required in OPS facilities during the 2025-2050 period.

While Europe and California ports have strong regulations that help shippers meet their commitment to OPS, there are no such legal rules elsewhere even though some nations are exploring their potential. Ports in China, India, South Korea and Taiwan, for example, have already invested in the technology. Marseille Fos is the first French port to have installed electrical connections at quayside serving ferries to and from Corsica (La Méridionale in 2017 and Corsica Linea in 2019), which means that nearly 400 calls a year no longer contribute to air pollution.

Port of Kilini (Greece) became the first port in the Eastern Mediterranean region to offer OPS. 'Fior Di Levante' a Ro-Pax ferry was its first customer on 20 December 2018.

In Spain, Puertos del Estado (the state port coordination authority) initiated the deployment of OPS technology through the European project 'OPS Masterplan'. This action, co-financed by the EU, concluded in 2021 with the implementation of three pilot installations in Santa Cruz de Tenerife, Las Palmas de Gran Canaria and Palma de Mallorca.

After the operations were analysed and evaluated for the preparation of a master plan, Puertos del Estado selected 20 docks for electrification between 2023 and 2025, although the objective is to extend it to all docks by 2030.

Among the most advanced is the Port of Barcelona (Spain) with two pilot projects. The first is built at the BEST container terminal in July 2024, allowing to connect up to two medium-sized containerships simultaneously or a large containership with higher consumption. The second pilot will be implemented at the Barcelona Ferry Terminal (TFB).

Algeciras is preparing a Green Strategy to electrify 75% of the containership berths by 2030. The Port of Valencia (Spain) is investing in electrifying the berths of the MSC container terminal.

The last available data on OPS in ports of the Mediterranean coastal States is shown in the following table:

Table 4.1 OPS in ports of the Mediterranean coastal States

Country	Port	No. of berths	Vessel type	Operational
Belgium	Antwerp	1	Container	2024
France	Marseille	3	Ro-Pax	2015
Germany	Hamburg	3	Container and cruise	2024
Greece	Kilini	1	Ro-Pax	2018
Italy	Livorno	1	Cruise	2015
Italy	Ancona	2	Offshore Support Vessel (OSV)/Special Service	2016
Malta	Valletta	5	Cruise	2024
Malta	Marsaxlokk	1	LNG vessel	2016
Spain	Palma de Mallorca	1	Ro-Pax	2020
Spain	Barcelona	1	Cruise	2020
Spain	Barcelona	1	Cruise	2014
Spain	Barcelona	1	Container	2024
Spain	Motril	1	Ro-Pax	2018
Spain	Melila	1	Ro-Pax	2014
Spain	Palma de Mallorca	1	Ro-Pax	2021

Source: European Alternative Fuels Observatory, European Commission

In addition to Europe, these are installed in emerging economies, for example at Tanjung Priok, Tanjung Perak, Makassar and Semarang in Indonesia; Cai Mep International Terminal (CMIT) in Vietnam have OPS whilst Hai Phong Port Da Nang Ports, Long An International port are planning to install cold ironing facilities at its berths.

4.4 Cargo operations-related emission reduction by port

Until recently, diesel engines have been the main source of power for port handling equipment and vehicles. However, considerable progress has been made in improving the performance of fossil-fuel-driven equipment, as well as developing alternative power sources. The major current areas of focus include developments like hybrid technologies (principally diesel-electric); power management systems to conserve fuel when equipment is idling; energy storage and reuse technologies and techniques; and full electrification.

Some initiatives for using green energy for equipment handling are discussed below:

.1 Ship-to-shore (STS) cranes, which have been fully electrical for some years, are the main equipment used in ports for loading and unloading vessel cargo. The installed power of the drives consists of the hoist, boom, trolley and gantry. Many new STS gantry cranes include technology that allows braking energy (from both hoist and trolley) to be stored and reused in the same device or fed directly back into the main grid, transforming the lost energy into new working energy. The same technology is also used in other port equipment like rail-mounted gantries (RMG) that are quite popular at stacking yards and port-rail stations.

.2 Rubber-tyred gantry (RTG) cranes are used for handling containers at yards of terminals. There are several options of new generation equipment focused on reducing GHG emissions.

- eRTG (electrical RTG): The demand for this type of equipment has been surging as their emissions and maintenance costs are lower than those of traditional RTGs.

  PACECO Group and Mitsui E&S Machinery has released Near Zero Emission (NZE) RTG Transtainer® and Zero Emission (ZE) RTG Transtainer®. The NZE Transtainer features larger lithium-ion batteries and smaller engine gensets designed with a start/stop feature for recharging the battery pack. In parallel, it is currently developing a hydrogen fuel cell power module for ZE Transtainers. This will easily enable the conversion of NZE Transtainer to a ZE Transtainer by simply replacing the diesel generator with a hydrogen fuel cell power module without modifying other drive systems or mechanical parts.

- Hydrogen-powered RTGs: This is a new development pioneered by Japan’s Mitsui E&S and its U.S. subsidiary PACECO. Commercial operations of the “first of this kind”, H2-ZE Transtainer crane, at the Port of Los Angeles (USA) was announced in May 2024. The manufacturer claims that the same operational performance as the conventional diesel-powered RTG can be achieved while producing zero emissions without connecting to the electric grid, enabling the terminal operators to save on civil work investment by retaining the current operating procedures. The present diesel-powered RTGs can also be modified at the port.

- Japan's Kobe-Osaka International Port Corporation is launching a pilot project of hydrogen-fuelled cargo handling equipment, marking a global first in converting a RTG crane's diesel engine generator to a hydrogen engine generator.

.3 Straddle Carriers (SC) are handling equipment used extensively at yards of container terminals with the main manufacturers (Kalmar and Konecrane) developing hybrid models for reducing GHG emissions. The hybrid Kalmar straddle carrier uses 40% less fuel and emits less CO_2 than traditional machines. Fuel consumption is lower because the energy produced when braking or lowering containers is stored in special batteries on board. Innovative technology ensures an optimum balance between the diesel engine and battery power. Konecranes Noell Straddle Carrier NSC EHY is a diesel-battery-hybrid machine that provides better eco-efficiency, based on recent battery technology improvements.

.4 Terminal tractors are employed at ro-ro and container terminals for moving trailers. Terberg, a main supplier of such equipment, announced in October 2020, the start of extensive testing of its first concept hydrogen-powered terminal tractor. The tractor, developed in collaboration with ZEPP.SOLUTIONS, is in operation at United Waalhaven Terminals in Rotterdam. It will work among conventional diesel terminal tractors, pulling the same loads, while being remotely monitored to collect a wide range of data. The project is being supported by the DKTI-Transport regulation of the Dutch Ministry of Infrastructure and Water Management.

.5 Forklifts of various sizes are used at ports for operations, such as stuffing and unstuffing containers, handling and general cargoes. There are more than 10,000 fuel cell-powered forklift units in operation or on order globally for different industries, including ports, as their functionality is already proven through long-term use in real-time environments. Well-known manufacturers offer these types of equipment: Linde (T 20 pallet truck, provides indoor truck solutions under the use of PlugPowers GenDrive technology) and Hyster (Nuvera, fuel cell systems for electric lift trucks; PowerTap as supply equipment as well as PowerEdge as replacement for batteries).

4.5 LED lighting at port

Following the high share of reefer containers in the total energy consumption of ports, as well as the equal share of terminal equipment (mainly ship-to-shore cranes), lighting represents the third-largest energy consumer (12%) in a container terminal. Lighting is also among the top electric consumers for other types of terminals.

The development of lighting technologies in sectors, such as industrial lighting and urban transport infrastructures, has encouraged their implementation in ports which are increasingly replacing halogen lamps with light emitting diodes (LEDs). As a result, energy efficiency at ports has been improving and their carbon footprint has been reducing.

Valencia port reduced energy consumption by 73% after replacing 800 sodium vapor lights with LEDs at a cost of €346,000. This project was 50% financed by the European Regional Development Fund (ERDF), within the Operational Program for Sustainable Growth 2014-2020 "A way to build Europe".

More recently, at the Port of Monfalcone (Italy) the 80 discharge lamps have been replaced with 36 new LED efficient luminaires. The new lighting responded to the required regulatory requirements in force in some countries, ensuring the improvement in energy efficiency with a reduction in costs and light pollution.

Thanks to the LED technology it has become possible to develop projects for the deployment and testing of dynamic (smart) lighting systems covering different areas within the port, effectively meeting real-time operational needs.

The Noatum Container Terminal Valencia carried out a project in which, in addition to replacing the existing luminaires with LED luminaires, it developed a dynamic response system that adapts the lighting conditions of the terminals as per the type of operation in the facility at any given time. The system developed by Noatum identifies the location of the terminals where operations are being carried out and adapts the lighting level to the level required at that moment. When the operations are completed, the lighting level reduces. This combination of technologies resulted in energy savings of eight times the previous consumption of this terminal.

More specifically, a similar full-scale system was installed across the industrial park of the Port of Moerdijk (Netherlands) in 2017 wherein 1,100 LED lights were equipped with motion sensors managed by a centralised control system, with different light intensities being used according to the need. Operating costs are estimated to have reduced by 80%, while maintenance costs reduced by 50%.

Another system was implemented at the Port of Emden (Germany) (2018), within the context of the DUAL Ports project. The LED-based system covered a 10-hectare railway reloading point for rolling commodities. Based on European norms for work safety, different light scenarios were programmed within the system for ensuring that adequate light of different intensities is provided for supporting various activities (e.g., loading, unloading, shunting and siding). Sensors were also used to ensure that the scenarios were automated, while remote-control was enabled through an online application, allowing the manual on-and-off switching of the available scenarios. The associated energy and cost savings are expected to be important, derived from lower operating hours and maintenance, longer life span of lamps, as well as the absence of warm-up periods. Light pollution is also expected to be reduced considerably whereas working conditions, and thus, safety, will improve greatly.

LED lighting becomes the optimal solution in handling equipment. Due to vibrations and harsh weather conditions, crane lighting has more stringent requirements than lighting in ports and terminals. As a result, ports require lamps with the highest performance and durability, manufactured to resist the harshest environments.

One example is the lighting replacement for an RMG crane at a container terminal in Italy. Heavy-duty LED floodlights built to resist the harshest environments and capable of high performance and high durability were adopted.

A low weight design and compact size allows for an easy to install solution. Lamps designed with a wide range of optics were installed to provide a solution that maximises safety across all areas and allows for the provision of a tailor-made crane lighting layout, using the optimum choice of optics to reduce glare, increase uniformity and avoid any dark spots on the ground.

LED lamps were also successful in the fully underground new Galataport Istanbul cruise terminal. The lighting requirements for this huge area without daylight were to create a pleasant atmosphere; meet the high functional requirements of ticket sales, passport control and other key areas; and provide orientation and security for up to 15,000 travellers each day.

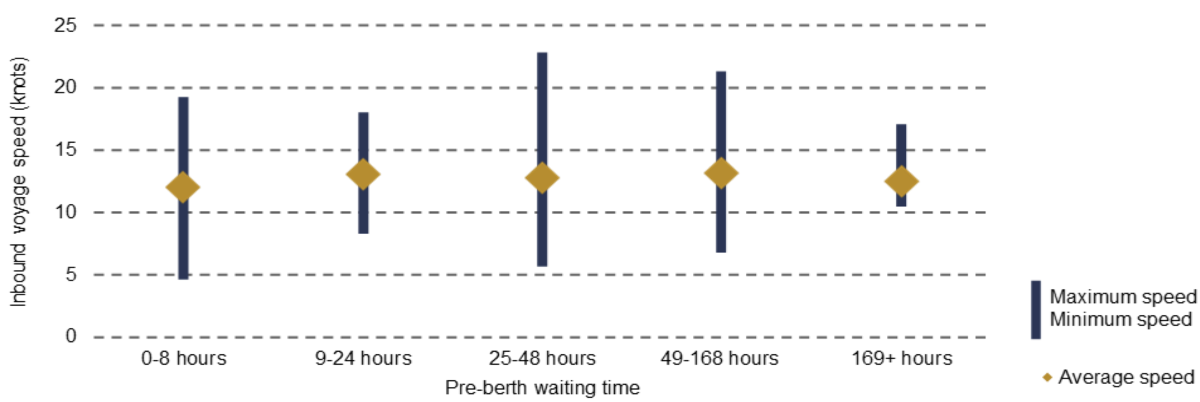
4.6 Just-In-Time (JIT) berthing

Just-In-time (JIT) arrival system ensures seamless communication among the vessel, pilot, tugboats and the port so that the vessel only arrives when the berth is ready. This requires various stakeholders to work together, including terminal operators, pilots, tugboat operators, vessel captains, etc.

As mentioned in the report 'Global Environment Facility (GEF)-United Nations Development Programme (UNDP)-International Maritime Organization (IMO) GloMEEP Project and the Global Industry Alliance (GIA), 2020: Just-In-Time Arrival Guide – Barriers and Potential Solutions', vessels at ports, at anchorage as well as those that operate at very slow speeds account for 15% of the global bunker consumption. On average, vessels (depending on the type) spend up to 9% of their time waiting at anchorage which can be reduced if ports implement JIT ship arrival systems. By adopting JIT, vessels can adjust their speeds and arrive when the availability of berth, navigation channel, pilots and tugboats is ensured, and consequently reduce GHG emissions.

According to an analysis (Drewry, 2024), vessels departing from the Port of Norfolk (USA) with the next Port of call Savannah (USA), which is located 450 nautical miles to the south, suggests that a selective speed reduction to achieve a 10-knot average speed (as a proxy for JIT) during congested periods could have reduced pre-berth waiting at Savannah by 24%, equating to a saving of almost 7,250 tonnes CO_2eq. A 12-knot threshold would have generated waiting time savings of 6% or 1,800 tonnes CO_2eq.

Figure 4.6 Port of Savannah (USA) arrivals from Port of Norfolk (USA), 2023 – comparison of inbound voyage speed to length of pre-berth waiting



Source: Drewry (2024)

Shipping companies are interested in developing JIT as it encourages them to invest in low-/zero-carbon fuelled vessels and thereby reduce GHG emissions. While port authorities coordinate amongst all stakeholders of a ship's call, including terminals, they have limited control over berth planning which comes under the preview of terminals. Since it is essential to receive accurate information from terminals to make JIT arrivals a success, it is important to implement a system based on available digital tools for port calls or to develop one specifically for a port.

Collaboration through data sharing among competing parties is essential for JIT, but there are several inhibitors to data sharing. While some are technical and are better thought of as stubborn obstacles, others are based on legitimate concerns for good governance and stewardship in protecting the interests of a business. For example, coastal States have regulations on issues such as free competition or data protection which should be taken into account. Some of the key barriers to data sharing and collaboration are:

.1 Competition law and antitrust concerns

.2 Data storage and control concerns

.3 Culture and behaviour resistance

.4 Contractual relationship concerns between the shipowner and the charterer

.5 Cost concerns

There are several cooperative platforms available for the interchange of data to facilitate port call optimisation, but the key is to guarantee that none of the factors has full control over what the others do. Smaller shipping companies fear that the system manager will favour the interests of large shipping companies, which are also the terminal operators. That is why it is important to ensure that the manager of the cooperative system is independent and acts fairly.

All solutions to implement JIT systems for ship arrivals at ports either from the port's perspective or from the shipping lines' perspective are discussed below.

.1 The MPA has implemented digitalOCEANS (Open/Common Exchange and Network Standardisation) initiative, which aims to harmonise application programming interface (API)/data standards and achieve the ship-port data exchange interoperability along the maritime transport chain process.

.2 The Port of Rotterdam (Netherlands) developed Pronto, a digital application, which is accessible to shipping lines, agents, terminal operators and other service providers. It helps to optimally plan, execute and monitor all activities during a port call based on standardised data exchange.

.3 Port of Tangier Med (Morocco) is co-developing a Port Management Information System (PMIS) including implementing JIT solutions. The new PMIS aims at addressing the needs of maritime liners and alliances calling at Egi Med Port Complex to optimise their vessel calls and to use standardised master and event data.

From a different perspective there are providers of JIT-related services, like:

.1 The Blue Visby Solution is a system designed to address the 'systematic operational inefficiency' of the 'sail fast, then wait' model in some shipping sectors. It provides the solution to reduce the anchoring time globally and is expected to achieve GHG emission reductions of between 9 and 14%. Recent prototype trials resulted in CO_2 savings of 28.2% for M/V Gerdt Oldendorff and 12.9% for M/V Begonia, meaning on average 17.3%, measured with the vessels' respective service speeds of 14 knots.

.2 Digital Container Shipping Association (DCSA), founded in 2019 by MSC, Maersk, CMA CGM, Hapag-Lloyd, ONE, Evergreen, Yang Ming, HMM and ZIM, aims to establish IT standards that would enable interoperability of technology solutions across the industry to facilitate digital interconnectivity and seamless data communication that anyone can leverage. DCSA JIT standards provide visibility to port call activities by allowing stakeholders to automatically share real-time event data.

.3 Portchain, Teqplay and Awake.ai are other platforms, software providers and JIT-related services. These are all private technology providers offering platforms that allow cooperation between parties and require a subscription fee. Each of them has a menu of applications that is tailored to the needs of users and relies primarily on AIS data.

.4 Multiple stakeholders are involved in the berthing process, including vessels, pilots, tug operators, ports, ship owners, surveyors, agents, ship chandlers and bunker barge companies, which necessitates information flow among these parties. A digital port call platform could provide the required information to them which is kept updated on a regular basis. The updated information provides an opportunity for efficient resource planning and facilitates JIT arrival and reduces emissions associated with earlier arrival or late arrival. The "Digital Port Call" is being implemented at the Port of Gothenburg (Sweden) as part of the major initiative towards "Green Connection".

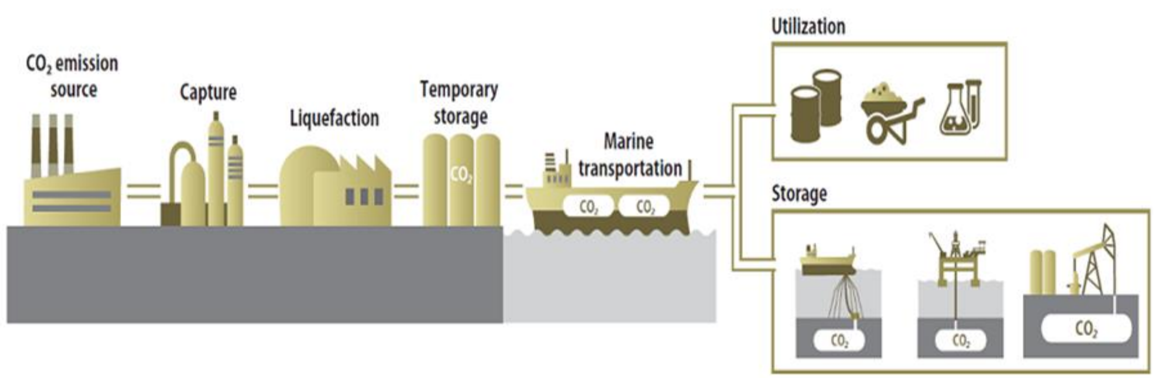
However, JIT is still work in progress with some way to go. It is not clear whether different systems and platforms will coexist over time or whether one will prevail over the others. In this sense, it is useful to compare what is being proposed for ships and ports with the system implemented in air transport, which has been in place for several decades.

4.7 Carbon Capture, Utilisation, and Storage (CCUS) value chain

Carbon Capture, Utilisation, and Storage (CCUS) value chain is a process that captures CO_2 released from thermal power plants, factories, etc. and either uses it in production processes for crops, chemicals and construction materials or stores it in a stable underground geological formation. These facilities may include shore terminals, floating CO_2 storage units, or Liquid Carbon Dioxide (LCO_2) receiving vessels.

The CCUS value chain is crucial in reducing greenhouse gas emissions and addressing climate change. Therefore, in recent years, its demand has surged, leading to a considerable amount of investment and development in the CCUS sector.

Figure 4.7 CCUS value chain



Source: NYK

4.7.1 Industrial usage for carbon

CO_2 is used for various uses across industries, ranging from oil & gas, food and beverages to agriculture.

Table 4.2 CO_2 usage across industries and its utilisation

Industry	Examples of utilisation
Oil and gas industry	Carbon dioxide can be used in oil recovery through Enhanced Oil Recovery (EOR), wherein carbon dioxide is injected into oil reservoirs to help increase oil production. This process of using CO_2 in oil recovery is considered to be an environmentally friendly method, as it helps to reduce emissions by storing carbon dioxide underground and also improves oil production.
Food and Beverages industry	Used for carbonating beverages like beer, soft drinks, and wine. Used for de-caffeinating coffee. Used to keep food products cold during transportation, as well as quick-freezing and cold sterilising food. Used to provide an inert blanket that protects food items during their production.
Metals industry	CO_2 is used in the manufacture of casting moulds to enhance their hardness.
Manufacturing and Construction	Used as a shield gas in Metal Inert Gas (MIG) / Metal Active Gas (MAG) welding and helps to protect the weld against oxidation (a mixture of argon and carbon dioxide is commonly used). Dry ice pellets are used to replace sandblasting when removing paint from surfaces, helping to reduce the cost of disposal and cleanup.
Chemicals, Pharmaceuticals and Petroleum industry	Used in methanol and urea production. Used in oil wells for extraction and to maintain pressure within a formation.
Healthcare industry	Used as an additive to oxygen for medical use as a respiration stimulant.
Environmental uses	Used as a propellant in aerosol cans.
Agriculture industry	Used as gases to kill insects and protect the products in the silos. Used in the manufacturing of fertilisers.
Multi-industry uses	Used for refrigeration and cooling. Used for the manufacturing of fire extinguishers.
Miscellaneous uses	Used as gases to increase the yields of plant products in greenhouses.

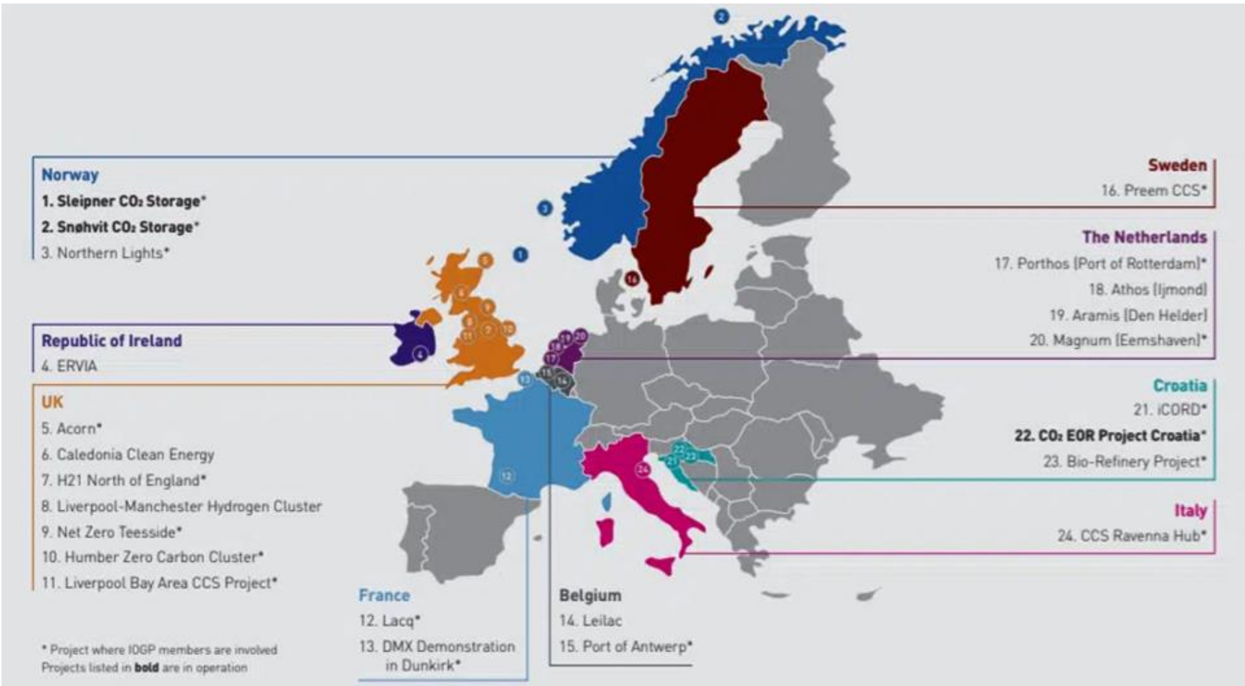
Source: Universal Industrial Gases Website, Drewry (2024)

CO_2 has been shipped by sea since the late 1980s, initially on converted dry cargo vessels. The existing fleet of CO_2 vessels has mostly been trading within Europe on short-haul routes, supplying CO_2 to the food and drink industries.

4.7.2 CCS facilities

CCS facilities are classified into two categories -commercial facilities and pilot and demonstration facilities. Commercial facilities are the main contributors, driving the carbon markets, while pilot and demonstration facilities are mainly for testing new technologies or demonstrating new processes.

Figure 4.8 Overview of existing and planned CCUS facilities in Europe



Source: The European Files

Examples of global CCS projects:

Northern Lights: This is a cross-border project linking CO_2 capture initiatives in several EU Member States with a future storage site at sea on the Norwegian continental shelf. Currently, the Northern Lights project is under construction and will capture CO_2 from industrial sources in the Oslo fjord region and ship it in liquid form to an onshore terminal on the Norwegian West Coast, before being transported by pipeline for safe and permanent storage in a reservoir 2,600 meters under the seabed in the North Sea. The Northern Light project is owned in equal shares by Total Energies, Equinor and Shell. Under this project, a few LCO_2 vessels are also being constructed. Around €131 million is being granted for this project through the Connecting Europe Facility (CEF) to support the expansion of the CO_2 import terminal in Øygarden in Norway and the construction of a 100 km offshore pipeline to the storage site.

Stella Maris: This project develops and manages the entire CCS value chain. From loading at the port, ship transport to the field and continuous injection of up to 10 million tonnes of CO_2 per year into offshore reservoirs. Partial funds from Gassnova, a Norwegian state enterprise. It plans for its first injection in 2027. This project is partially funded by Gassnova SF. More funds will be allocated from the EU Innovation Fund which is part of the EU Emissions Trading System (EU ETS), once feasibility of the project is confirmed.

DMX Demonstration in Dunkirk: The project aims to demonstrate a novel CO_2 capture solvent for industrial CCS, with a long-term objective of developing an industrial CCS cluster at Dunkirk in France. The project aims to have a full-scale 1.5MtCO_2 per year CCS plant operational by 2025. In the DMX process, the specifically designed solvent separates into two phases when CO_2 is absorbed, only the CO_2-rich phase needs regeneration leading to reduced operational energy and costs. The process has been successfully demonstrated at a mini-pilot scale. The new '3D' pilot plant at Dunkirk began operations in March 2022. A €189 million grant from CEF will support the construction of a collecting pipeline and an export terminal to provide industrial sites in the port and its hinterland with a route to export their captured CO_2 to storage sites abroad.

This project has also received European funding as part of the H2020 programme, as well as funding from ADEME as part of the Avenir investment programme.

CO_2next project: The CO_2next project has achieved a major milestone by entering a new project phase. CO_2next aims to build a liquid CO_2 terminal at the Maasvlakte in the Port of Rotterdam (Netherlands), which can be used by customers not connected to a CO_2 pipeline to ship liquid CO_2. Therefore, the terminal will be a critical piece of CO_2 infrastructure that can be leveraged as part of the CCS chain. Its commercial activity will commence in 2028. €33 million will be awarded for the CO_2 infrastructure in the Port of Rotterdam (Netherlands) in the Netherlands, consisting of an import terminal for the reception of CO_2 from carbon capture sites for CO_2 next project under the CEF grant.

Examples of CCS projects in the Mediterranean region

CCS projects have been increasingly prevalent as many countries aim to reduce carbon emissions. Ports of Mediterranean coastal States should closely monitor the development of LCO_2 trade and can consider entering the carbon value chain business, such as operating CO_2 terminals or providing CO_2 storage facilities.

Table 4.3 CCS projects in the Mediterranean region

Project Name	Status	Location	Operational target
CIUDEN: CO_2 Storage Technology Development Plant	Operational	Spain	2015
Geothermal Plant with CO_2 Re-injection	Operational	Croatia	2018
DMX™ Demonstration in Dunkirk	Operational	France	2022
Air Liquide Normandy	Early Development	France	2025
Energean Prinos Sigma plant	Early Development	Greece	2025
Energean Prinos Transport and Storage	Early Development	Greece	2025
Holcim Milaki Plant	Early Development	Greece	2025
ENI Structures A&E	Early Development	Libya	2026
ENI Ravenna Hub[3]	Early Development	Italy	2027
D'Artagnan Dunkirk CO_2 Hub	Early Development	France	2028
ECO$_2$Normandy	Early Development	France	2028
Air Liquide CalCC	Early Development	France	2028
EQIOM K6	Early Development	France	2028
Holcim KOdeCO Koromačno Plant	Early Development	Croatia	2028
Motor Oil Hellas IRIS	Early Development	Greece	2028
CO$_2$NTESSA	Early Development	Croatia	2029
Gonfreville Raffinerie	Early Development	France	2030
Grand Ouest CO_2	Early Development	France	2030
Airvault GOCO$_2$ CCUS	Early Development	France	2030
Colleferro Cement	Early Development	Italy	Under Evaluation
Kutina Petrokemija ammonia	Early Development	Croatia	Under Evaluation
Zutica and Ivanic grad Storage	Early Development	Croatia	Under Evaluation
Waste-to-energy Aker CC	Early Development	France	Under Evaluation
Aluminium Dunkerque CO_2 Transport	Early Development	France	Under Evaluation
Idku Egypt	Early Development	Egypt	Under Evaluation
Titan Cement IFESTOS	Early Development	Greece	Under Evaluation
Tarragona CO_2 Hub	Early Development	Spain	Under Evaluation

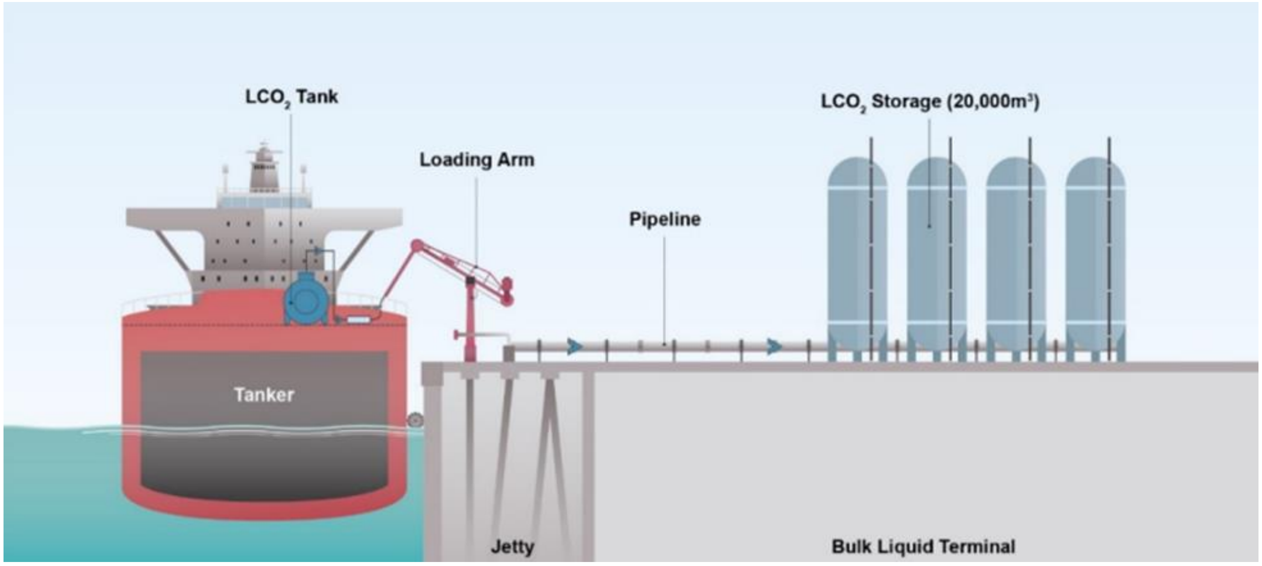
Source: Global CCS Institute and Inspenet

[3] CCS projects near the Port Area

4.8 Liquid CO_2 terminals

A liquid CO_2 terminal is required for two purposes. One for the purpose of liquid CO_2 trade and the second for the discharge of liquid CO_2 captured by vessels which have OCCS on board.

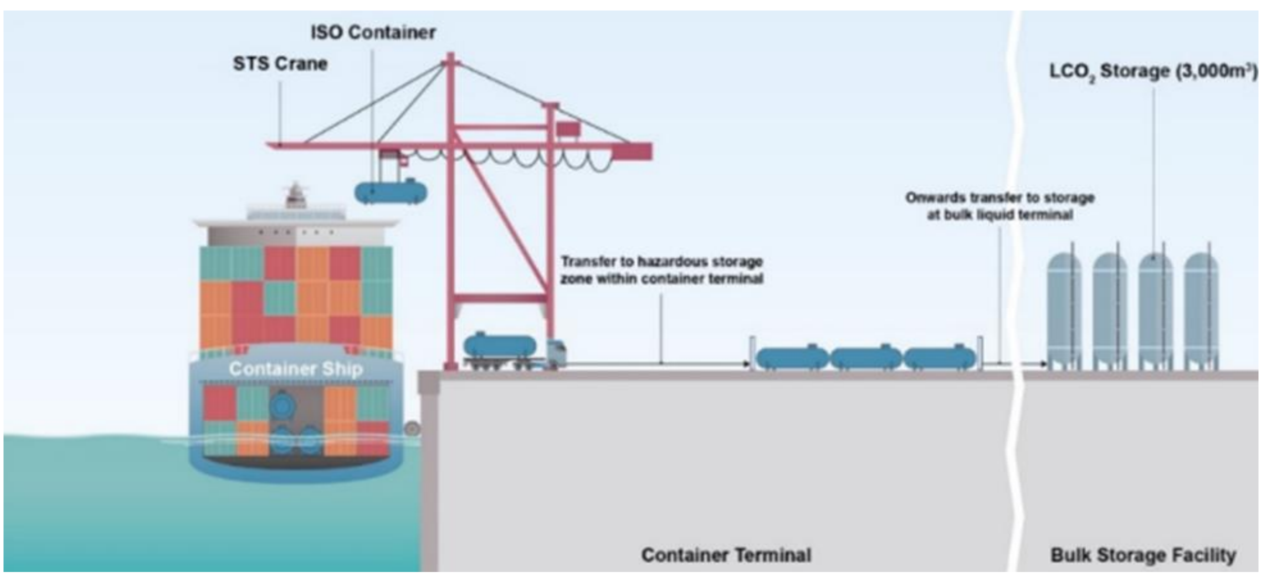
Figure 4.9 Liquid CO_2 handling at the port through pipelines



Source: Global Centre for Maritime Decarbonisation

Vessels that have OCCS and store liquid CO_2 in tanks can discharge the liquid CO_2 via pipeline. The same method is used for loading and discharging liquid CO_2 for trade. Recently, DNV awarded Wärtsilä Gas Solutions for Approval in Principle suitable for LCO_2 applications. They developed a cargo tank design for large quantities of LCO_2 transport as it is an important link in the value chain.

Figure 4.10 CO_2 container discharging at port



Source: Global Centre for Maritime Decarbonisation

4.9 Others

Besides these, there are other emission reduction measures, which are briefly covered in this section.

4.9.1 Measures by port for efficient vessel turnaround at berth

Several measures can be adopted by the port to ensure efficient vessel turnaround at berth, which can lead to lesser emissions from vessels at berth. Below are some examples of such measures:

.1 Well-maintained port equipment using tools such as predictive maintenance.

.2 Using gears and tools saves time in cargo operations; for example, quick connecting hooks, auto hooks, efficient hold cleaning equipment, etc.

.3 The usage of big data enables faster decision-making and enables higher efficiency.

.4 An Automatic Mooring System helps in mooring the vessels using a vacuum or a magnetic-based system which completes the mooring of vessels within 2-3 minutes as opposed to 15-20 minutes in traditional mooring methods using ropes. These advanced systems help reduce the vessel's and port's carbon footprint whilst also providing a safer working environment. However, such systems are expensive but could be very useful in terminals with vessels having short port stays and/or many vessel' calls in a day.

4.9.2 Digital solutions to reduce delays in pilot arrivals

The movement of pilots to vessels involves a combination of road and boat transportation as well as coordination with ports and vessels.

PSA Marine is a leader in providing pilotage service to about 500 vessels on a daily basis in Singapore. It leverages smart technology to ensure safer waterways and provide reliable and efficient marine services to customers. With a customised Marine Resource Management System, the Mission Command Centre captures real-time data for efficient scheduling and deployment of harbour craft, harbour pilots and marine crew, on a JIT basis.

4.9.3 Solar power generation at ports

Generating electricity at the port using renewable sources can lower carbon emissions when compared with buying electricity from the local grid, especially in the short-to-medium term. Some ports are well-located for installing solar panels (they have big areas like warehouses, parking spaces, reefer stacks and buildings for installing solar photovoltaic systems). The main features of solar photovoltaic panels are as follows:

.1 <u>Easily scalable and implementable</u>: Suitable roof structures on buildings can allow smaller-scale implementation of solar power despite port land constraints.

.2 <u>Flexible operations</u>: Suitable for ports that have limited landside space and also to save on land space. Floating solar power plants provide an alternative solution, although they are not technologically mature. Suitable wind, wave and surface conditions are also required, with salinity potentially impacting the durability of panel components.

The number of sunny days per year in the Mediterranean region is an advantage for photovoltaic electricity generation in the ports. Some examples of ports of the Mediterranean coastal States where solar panels are being installed:

.1 The Port of Valencia (Spain) will have installed solar panels generating 22% of the energy it consumes. The solar installation at Muelle Príncipe Felipe, which is already operational, will generate 2,297 MWh/year, which is 3.5% of the electrical energy consumed by Valencian docks. The installation comprises 2,290 photovoltaic modules that occupy a surface area of 6,420 square metres distributed over 850 metres of structure. These solar panels can be walked and driven on. A total of 24 passable solar tiles have been installed on the north dock that will generate power of more than 1 kWp in just six square metres of surface area. The solar floor is 100% walkable with a design that guarantees anti-slip, with regenerative properties and greater resistance than concrete to loads, impacts and scratches.

.2 Another solar park will soon be added on the roof of the Valencia Terminal Europa vehicle warehouse, which will generate 18.5% of the consumption.

.3 The Port of Gandía (Spain) will soon start the installation of a solar energy plant in shed 4 (which depends on Port of Valencia (Spain)). Once completed, this port will become the first European port to be self-sufficient in energy.

.4 BEST, a container terminal in the Spanish Mediterranean coast, has installed half a hectare of solar panels on the roofs of its buildings. The 1,832 panels can generate 1.18 GWh per year of electricity.

.5 Two offshore floating solar units in the Mediterranean Sea were deployed in March 2023 as part of a project that aims to supply clean electricity to the Port of Sete (France). The units are installed in the commercial port, located 1.5 kilometres from the coast, on the site of a former offshore oil unloading station. The project will expand to 25 units in its final stage for supplying 300 kWp on a surface area of half a hectare. The estimated production will then be 400 MWh/year and will be transported by a subsea cable.

.6 Marseille has already conducted feasibility studies in 2020 for the development of a 9 MW photovoltaic power plant to be installed on the roofs of six port sheds in eastern docks. Another photovoltaic project is underway in Fos ZIP.

.7 The largest photovoltaic system built by private individuals in port areas in Italy was installed in Genoa by a shipyard with an investment of about €1 million. The system is in operation and guarantees renewable energy to cover 53% of the annual needs of the plant and the new Waterfront Marina. It generates an overall maximum power of about 1 Mega Watt peak (MWp) through 1,782 solar panels that occupy an area of about 4,300 square metres on the roofs of sheds and structures.

.8 The Piraeus Port (Greece) first solar park that generates energy using photovoltaic panels was put into operation in 2016, generating up to 430 kWp. The installation in the Piraeus freight port is 1,080 metre in length and has been linked to the Public Power Corporation electricity grid. The installation will provide 635,000 'green' kWh/year to the electricity grid, corresponding to 635 tonnes of CO_2 emissions that are avoided.

.9 In 2023, Safiport (Türkiye) commissioned a solar panel project to meet the port's energy demand. The port is now generating power from 1 MW capacity solar panels installed on the roof of one of its closed warehouses. This is equivalent to 15% of the port's energy needs.

.10 In August 2023, the solar power plant with capacity of 500 kW was inaugurated in Egypt's Al-Hamra Port.

Newly developed solar cell based on the highest efficiency thin–film technology is now available and could be installed where rigid glass modules cannot function. This makes it possible to add solar energy generation to low-load capacity roofs, structures such as carports and storage facilities, curved surfaces, vehicles, floating reservoir covers, landfill membrane covers, amongst others.

4.9.4 Wind power

Wind power is a form of renewable energy that harnesses the power of the wind to generate electricity. It involves using wind turbines to convert the turning motion of blades, pushed by moving air (kinetic energy) into electrical energy (electricity). Ports are hubs for the development of offshore wind. They are key players in the local supply chain, logistics, and supporting infrastructure. This will be used in the generation of renewable hydrogen by locating electrolysers in ports. Hywind Tampen is the world's first floating wind farm that can supply power to offshore oil and gas installations. Similarly, Winfloat Atlantic is installed off the coast of Portugal.

4.9.5 Heavy-duty vehicles

Landside transport is a relevant source of GHG emissions for ports and the regions where they are located. Emissions can be reduced by using green fuel in trucks, and incentivising rail and inland waterways when possible.

In order to reduce emissions from trucks, ports reduce queuing and also use of cleaner sources of fuel. For large goods vehicles, a mix of hydrogen and electric recharging for batteries is among the alternatives. However, this requires infrastructure provision.

Automated gate/vehicle booking system (VBS) allows pre-booked and automated entrance and exit of ports by visiting heavy vehicles, reducing congestion of vehicles waiting outside the port gate. Reduced congestion from pre-planned journeys can reduce carbon emissions. This intervention would however require work outside the project boundary, which may be a limitation.

For example, the Port of Los Angeles and the Port of Long Beach introduced the PierPASS programme that applied peak hour fares to incentivise transit on evenings and weekends, thereby reducing congestion on access roads during peak hours. They focused on the use of differentiated port charges to incentivise a more environmentally friendly hinterland transport system.

Heavy-duty trucks powered by fuel cells are otherwise conventional multi-tonne trucks using compressed hydrogen gas as fuel to generate electric power via a polymer electrolyte membrane (PEM) fuel cell as an energy converter – which in turn fuels an electric engine. For projects, several prototypes have been and will be developed like H2Share (EU), ASKO distribution logistics trucks (Norway), Waterstofregio 2.0/HydrogenRegion 2.0 (The Netherlands), COOP distribution logistics trucks (Switzerland), Project Portal (Japan) and US Hybrid FC drayage truck (USA).

The Alabama Port Authority has applied for a federal grant of $69 million from the U.S. Environmental Protection Agency (EPA)'s Clean Ports initiative to launch a major emissions reduction effort at port facilities. Funds will be deployed for port equipment such as electric locomotives, terminal trucks, material handling cranes and forklifts along with the installation of three OPS units.

4.9.6 Railroad locomotives

Many railroad freight operators are investing in diesel-electric models that are more fuel-efficient, as well as exploring alternative ways to power locomotives, homing in on three main technologies: batteries, biodiesel and hydrogen.

Battery-electric locomotives reduce emissions but their power storage capacity, and therefore their range, limit how they can be used—at least for now. Major freight railroads in the United States are using or plan to use battery locomotives in some of their port-unloading and rail-yard operations. This year, rail-equipment and technology provider Wabtec plans to deliver locomotives with battery capacity ranging from 7 MWh to 8 MWh.

Another option is regenerative braking, which captures kinetic energy when a train decelerates or goes downhill and converts it into electrical energy that can be stored in the battery. This has been used for a long time. For example, Vale has been using this technology since the 1960s in railways connecting one of its iron ore mines in Brazil to the loading port.

In recent years, several operators have tested or started using various blends of biodiesel and renewable diesel. Since current locomotives can be modified to burn both low-/zero-carbon fuels and regular diesel, this option has the potential to reduce carriers' carbon emissions by as much as 60%.

At least two freight railroads in North America (Canadian Pacific Kansas City and CSX) are testing hydrogen fuel-cell locomotives. With this technology, hydrogen gas is fed into the fuel cell to generate electricity, which powers the locomotive's motors. Hydrogen fuel-cell locomotives emit only water vapor, and they have more energy capacity than battery locomotives, although not as much as diesel locomotives.

4.9.7 Power consumption of reefers

Reefers account for a very high percentage of electricity consumption at container terminals that cater to them and in some cases, they consume the largest percentage at the terminal. As the demand for perishable products increases, so does the demand for reefer and in turn the importance of conserving port energy. Currently, automated temperature management, box positioning and advanced insulation materials are being used to develop more efficient refrigeration systems.

Innovative technologies and solutions that could help include energy-efficient refrigeration systems powered by advanced microprocessor controllers, vacuum insulation panels to reduce heat transfer and improve thermal efficiency, and natural refrigerants like CO_2 and ammonia.

4.9.8 Green construction of ports

Port expansions often require new infrastructure or modification of the existing infrastructure. Civil works linked to those projects, sometimes including land reclamation and dredging, could have a major capital carbon impact. There may be opportunities to reduce carbon through:

.1 Use of low-carbon cement in concrete design.

.2 Use of circular economy principles through design, construction and decommissioning.

.3 Low carbon construction equipment (including floating equipment like dredgers).

.4 Use of green materials in place of concrete or steel, where appropriate.

.5 Use of recycled plastic and tyres where possible.

Jurong Port (Singapore) constructed the first green berth in the world and sustainable methods were used for the upgradation of the existing berths.

.1 Concrete from the existing berths and yards is cut up, crushed and recycled for use in the upgrading.

.2 The pre-casting of slabs and beams was done on-site to minimise the need for their transportation from off-site, thus reducing carbon emissions.

.3 Certified green construction materials such as green, green steel mesh and green reinforcement bars were used for the construction.

4.9.9 Dynamic Under Keel Clearance (DUKC)

Dynamic Under Keel Clearance (DUKC) systems enable the docking of vessels of a greater draft, which increases the effective berth capacity in tidal ports at a low cost and/or by reducing the dredging requirement. DUKC allows ships to carry more cargo, thereby boosting port productivity and lowering emissions at berth per tonne of cargo. Since fewer vessels will be required annually to carry the same quantity of cargo, emissions will be reduced further. For example, the Port of Melbourne (Australia) was able to berth vessels of 14.5 metres draft in comparison to 14.0 metres previously. Also, the capacity of Port Headland in Australia increased by 16% per annum (from 495 million tonnes per annum to 577 million tonnes).

4.9.10 Main engine maintenance at berth

Sometimes vessels need to carry out main engine maintenance, which requires the main engine to be immobilised. Only a few ports allow this at berth and at other ports, vessels have to go to anchorage for such maintenance. Even if ports disallow main engine maintenance at berth, emissions of the port area will still increase as the maintenance is carried out at anchorage.

4.9.11 Allowing bunkering and provision supply at berth

Some ports disallow bunkering or provision supply with ongoing cargo operations. This results in a longer port stay for the vessel, thereby increasing emissions.

4.9.12 Low-/zero-carbon fuel production and bunkering hubs

Low-/zero-carbon fuels are alternative fuels, such as hydrogen, ammonia, as well as synthetic carbon-based fuels, that produce low or zero GHG emissions during their production, distribution and use.

In recent years, the shipping industry has been focussing on the development and application of low-/zero-carbon fuels to reduce emissions.

While low-/zero-carbon fuels and their combustion technologies in ships as well as some of the new clean power technologies are all work in progress, significant developments have already been made.

At present, the available low-/zero-carbon fuels are fossil-based which will transition to blue fuels (in which CO_2 emissions are captured during the production process) and finally to e-fuels that use hydrogen either from electrolysis and CO_2 from the atmosphere or captured CO_2 or nitrogen from the atmosphere. The production of e-fuels is limited due to the high cost of generating renewable electricity, but it is gradually increasing.

The usual methods of bunkering such as STS bunkering, shore-to-ship bunkering and truck-to-ship bunkering would need to be re-visited for low-/zero-carbon fuels. While sustainable biofuels can use the existing bunkering infrastructure, new infrastructure would be required for low-/zero-carbon fuels such as LNG, methanol, hydrogen and ammonia. Of these, LNG bunkering infrastructure is fairly developed, but that for methanol is evolving, and that for hydrogen and ammonia still under development.

Low-/zero-carbon fuel bunkering is presently available at a few locations. For example:

.1 In Singapore, LNG, sustainable biofuels and methanol are available.

.2 In Rotterdam, LNG, sustainable biofuels, methanol and swappable batteries are available.

.3 In some Chinese ports, LNG and methanol are available.

.4 The H2V Marseille Fos project in France will generate 84,000 tonnes of green hydrogen per year and 140,000 tonnes of e-methanol per year. The first phase is scheduled to be commissioned in 2028, with the second phase to follow in 2030.

Life Cycle Assessment (LCA) of bunkers is gradually gaining momentum and will lead to regionalisation of bunker procurement. In addition, higher space requirements for low-/zero-carbon fuels on vessels may lead to more frequent bunkering. Therefore, bunkering hubs are expected to shift to new locations. This also offers opportunities for Mediterranean coastal States to establish themselves as bunkering hubs.

The availability of CCS technology, long-term storage of compressed CO_2, low cost of renewable energy, and availability of gas reserves will be prominent factors for the development of green fuels and bunkering hubs in the near term. The Mediterranean region has good potential to develop these low-/zero-carbon fuels as depicted in the table below.

Table 4.4 Projection for various Mediterranean coastal States and potential for future

Country	Type of zero carbon fuel	Potential
Spain	Green/Blue ammonia/hydrogen from natural gas with CCS	High potential
	Green/Blue ammonia/hydrogen from renewable energy	High potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	High potential
France	Green/Blue ammonia/hydrogen from natural gas with CCS	High potential
	Green/Blue ammonia/hydrogen from renewable energy	High potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	High potential

Italy	Green/Blue ammonia/hydrogen from natural gas with CCS	High potential
	Green/Blue ammonia/hydrogen from renewable energy	High potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	High potential
Morocco	Green/Blue ammonia/hydrogen from natural gas with CCS	High potential
	Green/Blue ammonia/hydrogen from renewable energy	High potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	High potential
Türkiye	Green/Blue ammonia/hydrogen from natural gas with CCS	High potential
	Green/Blue ammonia/hydrogen from renewable energy	High potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	High potential
Greece	Green/Blue ammonia/hydrogen from natural gas with CCS	Promising potential
	Green/Blue ammonia/hydrogen from renewable energy	High potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	High potential
Croatia	Green/Blue ammonia/hydrogen from natural gas with CCS	Promising potential
	Green/Blue ammonia/hydrogen from renewable energy	Promising potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	Promising potential
Slovenia	Green/Blue ammonia/hydrogen from natural gas with CCS	Promising potential
	Green/Blue ammonia/hydrogen from renewable energy	High potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	High potential
Algeria	Green/Blue ammonia/hydrogen from natural gas with CCS	Promising potential
	Green/Blue ammonia/hydrogen from renewable energy	Promising potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	Promising potential
Egypt	Green/Blue ammonia/hydrogen from natural gas with CCS	Promising potential
	Green/Blue ammonia/hydrogen from renewable energy	High potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	High potential
Gibraltar (United Kingdom of Great Britain and Northern Ireland (UK))	Green/Blue ammonia/hydrogen from natural gas with CCS	No relevant data is available
	Green/Blue ammonia/hydrogen from renewable energy	High potential
	Green/Blue ammonia/hydrogen from natural gas with CCS and later move to renewable energy	High potential
Note: Mediterranean coastal States in the first quintile of the scenario assessment are labelled “high potential” while those in the second quintile are “promising potential”. The composite score takes into consideration various factors such as natural gas with CCS, renewable energy, shipping volume, geographical location, regulatory framework and existing infrastructure.		

Source: The Potential of Zero-Carbon Bunker Fuels in Developing Countries by World Bank

Development of low-/zero-carbon fuels has been undertaken and is ongoing at various ports of the Mediterranean coastal States. Some of them are listed below:

.1 The Port of Gibraltar (UK) is among the top 10 bunkering hubs in the world and is already supplying biofuels in addition to conventional fuels.

.2 In the Port of Barcelona (Spain), an IMO type II tanker has been deployed to supply biofuels to vessels, which means that it has the capability of supplying 100% biofuels to vessels, compared to the traditional bunker barges, which can only supply less than 25% biofuel mix.

.3 In July 2023, Trasmapi, a leading ferry company on the Ibiza-Formentera route, partnered with Repsol, a leading energy company, to conduct Spain's first-ever maritime trial of 100% renewable fuel derived from organic waste materials, such as used cooking oil and agro-industrial by-products.

.4 An Italian company is building a new methanol bunkering vessel with advanced propulsion and steering system. The bunkering vessel is expected to be ready by 2025 and will sail among few ports in the Mediterranean region.

.5 Egypt Ports: In recent events AP Moller-Maersk's new methanol-powered container vessel stopped at East Port Said in August 2023, taking on about 500 tonnes of bio-methanol.

.6 Port of Algeciras (Spain), Port of Barcelona (Spain), Port of Marseilles-Fos (France), and Port of La Spezia (Italy) are a few ports of the Mediterranean coastal States carrying out LNG bunkering.

Due to substantial efforts by industry first movers, we can see the deployment of low-/zero-carbon fuels such as LNG and methanol. The progress in the development and deployment of ammonia is also visible with the order of the first ammonia-fuelled container vessel Yara Eyde for sailing between Norway and Germany. Collaboration and partnership among shipowners, ship managers, charterers and fuel producers have been key factors in the progress thus far.

Major challenges include establishing and scaling supply chains, revising fuel standards, accelerating the pace of infrastructure deployment, and adoption of modern, fuel-efficient ships.

4.10 Section summary

Ports play an important role in reducing the overall GHG. Various ports are in a phase of developing sustainable strategies to reduce emissions in ports and ships. This includes, among many other actions, incorporating within the terminal concession specifications some clauses favouring those proposing initiatives aligned with this strategy. Renewable energy, reduction of consumption and transition towards sustainable sources are a few initiatives for reducing emissions.

A few ports manage their own energy demand using offshore wind, solar and tidal energy, but there can be a conflict of interest for energy companies with their local legislation.

.1 <u>Emission reduction from tugboats</u>

Tugboats involved in assisting vessels to berth usually have powerful engines; therefore, their contribution to GHG emissions should be considered. In many ports, tugboats are connected to onshore power while they are berthed and await the next job.

Switching to low-/zero-carbon fuels, such as methanol, ammonia and hydrogen, is a good option to decarbonise this sector in addition to using systems based on electric charging with onboard battery storage. Hydrogen fuel cells and battery electric are particularly appealing for tugs due to their unique load-following characteristics. There are many such applications at ports which can be used to analyse the benefit of operating green tugboats in port areas.

From the upcoming orderbook, LNG-operated tugboats are the most popular dual-fuel tugboats. However, the uncertainty of green fuel availability for tugboats makes it difficult for ports to order green tugboats.

.2 Onshore power availability at berth

OPS by means of on-berth connection points and cable management systems, significantly reduces GHG emissions from vessels, since auxiliary engines are no longer required to run on vessels.

The key challenge with OPS is the current demand, with only a limited number of oceangoing ships that can receive onshore power, high infrastructure costs, the requirement for clean energy sources and peak power demand when multiple ships use OPS. The electrical grid of the terminal should increase its capacity by a factor between five to six to cater to the peak power demand when multiple ships use OPS.

Although shipowners have raised numerous objections to the implementation of the system, ferry and cruise operators are more accepting of OPS. There is potential for growth in berthing facilities for small crafts providing port services, such as tugboats.

Legislation such as the FuelEU Maritime Regulation is making it mandatory for vessels to use OPS in ports and will drive the promotion of OPS. However, there will be exceptions for stays of less than two hours and for ships that use zero-emission technology at berth.

In general, OPS should be installed in terminals in collaboration with port authorities. This poses problems for terminals as, in many cases, concession agreements were signed many years prior to these systems coming into existence. In these cases, it is only through new agreements between the relevant parties that OPS implementation can be carried out. However, in the most recent concessions, port authorities have among their requirements the need to include OPS in their provided framework.

Besides uncertainty about who should invest and own the OPS infrastructure, another issue is the existence of energy regulations in some countries that prevent the commercialisation of electricity to ports or terminals, with energy being provided to them only by national energy distributors.

In addition, the cost of installation of OPS is variable and can be high; therefore, it should be supported by government grants.

.3 Cargo operations-related emission reduction by port

In recent years, considerable progress has been made in improving the performance of fossil fuel-driven equipment, as well as developing alternative power sources. The major areas of focus include developments like hybrid technologies (principally diesel-electric); power management systems to conserve fuel when equipment is idling; energy storage and reuse technologies and techniques; and full electrification.

There are several initiatives for applying green technologies to all kinds of handling equipment like ship-to-shore cranes, RTG, SC, terminal tractors and forklifts.

.4 LED lighting at port

Lighting is the third-largest energy consumer (12%) in a container terminal and also a major consumer in other types of terminals. The development of lighting technologies such as LED has made it possible to replace energy guzzlers like halogen lamps in ports, improving energy efficiency and reducing the carbon footprint.

It has now become possible to develop projects for the deployment and testing of dynamic (smart) lighting systems covering different areas within the port, effectively meeting real-time operational needs.

.5 JIT

JIT arrival system ensures seamless communication between the vessel, pilot, tugboats and the port so that the vessel only arrives when the berth is ready. This requires various stakeholders to work together, including terminal operators, pilots, tugboat operators, vessel captains etc.

JIT aims to reduce the waiting time of a vessel outside ports. By adopting JIT, vessels can adjust their speed during the voyage to arrive when the availability of berth, navigation channel, pilots and tugboats is ensured, consequently reducing GHG emissions.

A few challenges with implementing JIT are antitrust concerns (JIT operators might give preference to large companies), cultural resistance to data sharing as well as issues due to the contractual relationship between the shipowner and the charterer.

Some ports have implemented similar systems to ensure better coordination between ports and vessels which reduced emissions by 4% to 7%.

There are various JIT-related services and platforms available. The "Digital Port Call" is being implemented at the Port of Gothenburg (Sweden) which will provide updated information flow and opportunities among stakeholders to improve the efficient utilisation of resources, thereby reducing emissions.

However, JIT is still a work in progress with some way to go. It is not clear whether different systems and platforms will coexist over time or whether one will prevail over the others.

.6 CCUS value chain

CCUS is a process that captures CO_2 released from thermal power plants, factories, etc. and either use it in production processes for crops, chemicals, construction materials, etc. or stores it in a stable underground geological formation. These facilities may include shore terminals, floating CO_2 storage units, or liquid CO_2 receiving vessels.

The inclination towards combatting climate change, switching to low-/zero-carbon fuel, reducing GHG emissions and a cleaner environment with zero carbon footprint requires the CCUS value chain to be developed. Industrial usage of CO_2 and its importance as a key member in attaining zero emissions make CCS, OCCS and Liquid CO_2 infrastructure, including terminals, an important requirement in the future. Such facilities should be encouraged and given financial assistance.

.7 Others

Several measures can be adopted by the port to increase efficiency and therefore reduce emissions. Some examples of such measures include dynamic under-keel clearance, auto mooring, etc.

Auto mooring system reduces the vessel’s and port’s carbon footprint. Such systems could be very useful in terminals where vessels have short port stays and/or many vessel calls in a single day. DUKC helps in reducing emissions per tonne of cargo by enabling the docking of vessels of a greater draft.

Pilotage providers in ports with large numbers of pilotage movements could leverage smart technologies to provide reliable and efficient services that will reduce delays in the arrival of pilots and therefore reduce emissions.

The inclusion of ports in green corridors would help the surrounding region’s transition towards a green future. Newly developed solar cells with higher efficiencies can be installed on low-load capacity roofs, structures such as carports and storage facilities, curved surfaces, vehicles, floating reservoir covers and landfill membrane covers, amongst others. Similarly, wind power can be used in the generation of renewable hydrogen by locating electrolysers in ports.

Emissions can be reduced by using green fuel in trucks and incentivising rail and inland waterways when possible. Innovative technologies can be applied to lower the power consumption of reefers, which have a high percentage of electricity consumption at container terminals. The Port of Alabama (USA) has applied for government grants for the electrification of port equipment as well as OPS.

Port expansions require new infrastructure or modification of existing infrastructure. These civil works have a major carbon footprint, which can be reduced by using low-carbon cement, green materials, recycled plastic and tyres where possible.

Some main engine maintenance requires the main engine to be immobilised. However, only a few ports allow this at berth. If ports disallow bunkering or provision supply while cargo operations are going on, emissions from vessels increase due to longer port stays.

Low-/zero-carbon fuels are alternative fuels that produce low or zero GHG emissions. While the production of e-fuels is limited due to the high cost of generating renewable electricity, it is increasing gradually.

LCA of bunkers is gradually gaining momentum and will lead to regionalisation of bunker procurement. In addition, higher space requirements for low-/zero-carbon fuels on vessels may lead to more frequent bunkering. Therefore, bunkering hubs are expected to shift to new locations, and this offers opportunities for ports to establish themselves as bunkering hubs.

The availability of CCS technology, long-term storage of compressed CO_2, low cost of renewable energy and availability of gas reserves will be key to deciding the perception and feasibility of upcoming bunkering hubs.

While sustainable biofuels can use the existing bunkering infrastructure, new infrastructure will be required for low-/zero-carbon fuels such as LNG, methanol and ammonia. Of these fuels, LNG bunkering infrastructure is fairly developed, that for methanol is evolving, and that for hydrogen and ammonia are under development.

Major challenges include establishing and scaling supply chains, revising fuel standards, accelerating the pace of infrastructure deployment, and adopting modern fuel-efficient ships.

5 Policies and regulatory measures to reduce emissions during the ship-port interface

This section covers policies and regulatory measures to reduce emissions. It also includes green corridors and best practices at various ports, including speed reductions to lower vessels' emissions and discounts on port dues to promote green shipping.

5.1 Regulations affecting the ship-port interface

The 2023 IMO Strategy on Reduction of GHG Emissions from Ships (2023 IMO GHG Strategy) envisages ambitious targets, and IMO has come up with short, mid and long-term measures, which include the revision of Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) and the inclusion of regulations like the Carbon Intensity Indicator (CII) and Energy Efficiency Design Index (EEDI) / Energy Efficiency Index for existing vessels (EEXI). Additionally, several countries are implementing local regulations such as the EU ETS Directive, the FuelEU Maritime Regulation and the UK ETS to become net-zero by 2050 or earlier. For example, Türkiye is taking the initiative to establish its own carbon pricing scheme comparable with the EU ETS.

The maritime sector has taken initiatives to reduce emissions as material change has only been achieved where regulations have been introduced. Unlike shipping, there is no global organisation regulating the ports sector. If ports are to achieve net zero emissions, local or regional regulations and facilitative policies will be required, for example, government grants to support decarbonisation.

To analyse the effect of these regulations on the ship-port interface, we need to examine them separately, as they differ from each other.

5.1.1 EEDI/EEXI

EEDI and EEXI are design-based measures to ensure that a vessel is designed in an efficient manner, while CII deals with the operation of a vessel. These regulations apply to all vessels above 400 GT engaged in international voyages and will include vessels operating near port areas like feeder vessels, ferries, etc. All such vessels need to have an EEXI technical file, which would allow the vessel to be granted a one-time International Energy Efficiency (IEE) Certificate, which should be present onboard during inspections and surveys. For new ships, the IEE Certificate is issued during the initial survey before the ship begins operating. However, for existing vessels, the certificate should have been issued following the first annual, intermediate or renewal survey after 1 January 2023.

EEXI depends on the rating and design of the engines, the type of fuel used, energy-efficient technologies, shaft generator specifications, the type of vessel and the ship's speed in a fully loaded condition (V_{ref}).

If a vessel does not comply with the regulation, it has to undergo necessary changes in its design to obtain the Internal Energy Efficiency Certificate. One of the most accepted methods is installing an EPL on the engine, limiting the Maximum Continuous Rating (MCR), thus making it compliant with the EEXI regulation. This does not affect vessels involved in near coastal voyages as they usually operate at speed below the derived speed after installing EPL.

5.1.2 CII regulation

CII regulation depends on the operation of the vessel during the last year and applies to vessels above 5,000 GT engaged in international voyages. Every vessel's CII rating is calculated (A, B, C, D and E) and it needs to attain at least a C rating to be compliant with the regulation. The regulation is planned to get stricter year by year, due to which vessels would be required to constantly reduce their carbon emissions to remain compliant with the regulation. The 'CII required' value (which is used as a reference to determine the CII rating of the vessel) will be reduced by 5% in 2023, 7% in 2024, 9% in 2025 and 11% in 2026. Reduction after 2026 is yet to be declared by the IMO.

The CII rating of a vessel depends on fuel consumption, a carbon correction factor of the fuel used, deadweight (DWT) and distance covered during a particular year. Vessels involved in coastal voyages cover less distance and, as a result, get a low rating.

Below are a few methods to improve the CII rating:

.1 Reduce vessel speed to decrease fuel consumption.

.2 Use low-/zero-carbon fuels to reduce emissions.

.3 Use ESDs and PIDs to lower fuel consumption.

Fuel consumption at ports is also accounted for, implying that vessels may prefer Onshore power at ports to reduce fuel consumption while at berth.

The CII regulation will push shipowners to opt for energy efficiency measures.

5.1.3 The EU ETS Directive

EU has introduced a cap-and-trade system to reduce carbon emissions from vessels entering European ports. This fee/levy is applicable to vessels above 5,000 GT, and ship operators will have to pay the price per tonne of CO_2 emitted (by buying and submitting EU Allowances during their voyage to and from an EU port, including the emissions at berth). Vessels have to report their fuel consumption data on EU Monitoring, Registration and Verification (MRV)-Thetis after getting it verified by a certified verifier. Vessels will try to lower their emissions to reduce the number of European Union Allowances (EUAs) they have to purchase.

5.1.4 The FuelEU Maritime Regulation

The EU is also introducing the FuelEU Maritime Regulation under its Fit for 55 package to broaden the scope of emissions, which have to be controlled. The FuelEU Maritime Regulation includes Well to Wake (WtW) GHG emissions of a vessel greater than 5,000 GT. The regulations set requirements on the annual average GHG intensity of energy used by ships trading in the EU or European Economic Area (EEA), measured as GHG emissions per energy unit (gCO_2e/MJ).

Under this regulation, a vessel has to submit fuel consumption information, CO_2 emissions and distance travelled during voyages to and from EU ports.

5.1.5 Alternative Fuel Infrastructure Regulation (AFIR)

The Alternative Fuel Infrastructure Regulation (AFIR) under the EU Fit for 55 package requires zero-emission requirements for ships at berth and requires the main ports of EU Member States to provide Onshore power for container vessels and passenger ships by 2030. This will mitigate GHG emissions in ports, which are often close to densely populated areas.

It also requires the main ports of EU Member States to provide liquid methane refuelling by January 2025. Moreover, ports are required to provide refuelling facilities for other low-/zero-carbon fuels, which will increase the use of green fuel in ports and reduce emissions from ships while at berth. This will create demand for low-/zero-carbon fuel bunker facilities in the EU.

5.1.6 Other Market Based Measures (MBM)

Green marine fuels have low GHG emissions and are mainly obtained from renewable sources. These fuels are expensive than conventional marine fossil fuels such as Very Low Sulphur Fuel Oil (VLSFO). By 2025, IMO is likely to decide whether to penalise the use of fossil fuels or how to incentivise the use of greener fuels to bridge the cost gap and ensure a level playing field between conventional fossil fuels and expensive new greener fuels. These measures are called Market-based Measures (MBM), and some examples of these measures are International Chamber of Shipping (ICS)'s Zero Emission Shipping Fund and World Shipping Council's Green Balance Mechanism.

EU is the global climate leader in reducing GHG emissions, and the EU ETS Directive is a form of levy to lower emissions via a carbon market. Many governments and non-government organisations have come up with proposals, which IMO might consider. All proposals aim to impose penalty for high-emitting vessels and may also provide incentives for shipping lines to use low GHG fuels by balancing the cost of these fuels over high GHG emission fuels. In addition, several proposals have a 'feebate' system where there is a levy on the emission of GHG emission fuels, with funds being allocated to reward those shipowners using eligible low/zero GHG fuels and providing funds to support projects designed to assist in the GHG reduction in the maritime sector.

5.2 Green corridors

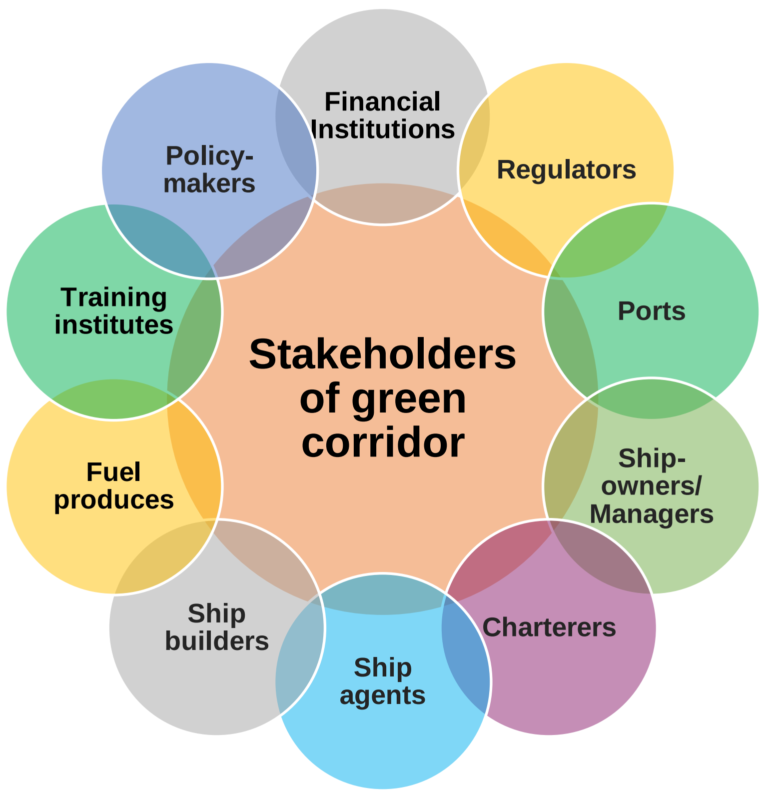
The use of 'clean fuels' is the principal strategy implemented in the maritime sector to reduce emissions. However, for this to be possible, there should be enough bunkering hubs for such fuels, to adequately spread throughout routes.

In 2021, the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) saw the establishment of partnerships among key stakeholders in the maritime sector to facilitate decarbonisation on maritime routes. The declaration, known as the 'Clyde Bank Declaration', led to the formation of Green Shipping Corridors. Around 26 countries have signed this declaration so far, which aims to establish at least six green shipping corridors by the middle of this decade.

According to the Global Maritime Forum and Getting to Zero Coalition, a maritime green corridor is defined as the specific shipping routes where public and private actions catalyse the technological, economic, and regulatory feasibility of operating zero-emission ships. In short, it is a route between two or more ports where low-emission shipping solutions are demonstrated and operated.

The use of low-emission fuels is the principal strategy, which is implemented in maritime transport to reduce emissions. However, for this to be possible, there should be enough fuelling points, and they should be adequately spread throughout the routes. Often, a detailed risk analysis is necessary for ports involved in the creation of green shipping corridors due to the risks commonly associated with the adoption of low-emission fuels (e.g. methanol, ammonia, hydrogen, etc.). Hence, the existing maritime shipping ecosystem of low-/zero-carbon fuel production and supply capability makes the possibility of establishing green shipping corridors imperative. Green shipping corridors are set to leverage set standards in terms of regulatory measures, financial incentives and safety regulations to facilitate the expansion of the green shipping corridor network.

Figure 5.1 Stakeholders of green corridor



Source: Drewry (2024)

Establishing green shipping corridors will require not only individual efforts from numerous stakeholders involved but also collaborative action from the entire maritime shipping ecosystem. Furthermore, collective actions by stakeholders are vital in developing a green corridor consortium by amplifying potential synergies and minimising trade-offs between each stakeholder. Stakeholders such as ports and fuel producers can leverage socio-economic synergies by integrating low-/zero-carbon fuel production plants within green corridor port infrastructures to improve efficiency in the green corridors.

Therefore, the initial selection of green corridors is crucial for decarbonisation to become successful. Four critical building blocks are required for a potential green corridor which are highlighted by the Global Maritime Forum and are stated below:

.1 Stakeholders who are committed to decarbonisation and are willing to collaborate across the value chain;

.2 A viable fuel pathway and readily available supply infrastructure;

.3 Customer demand for green shipping; and

.4 Policy and regulation that can aid in narrowing cost gaps and expedite the adoption of such corridors.

Green corridors in the Mediterranean region

According to DNV, as of February 2024, 57 green corridor initiatives have been identified worldwide. The only one for the Mediterranean was Rotterdam-Singapore, which crosses the Mediterranean Sea but does not include any of its ports as a refuelling point. Some publications also mention the 'Spanish corridors', which include connections between Valencia and the USA East Coast, and the 'Suez Canal corridor', both of which seem to be at a nascent stage.

Spain, due to its strategic position, is likely to kickstart the development of green shipping corridors – with the UK, Italy and the USA identified as promising partners. A study by the Global Maritime Forum (Elena, T., Jesse, F., et al., 2023), has identified eight green corridors from Spain. These include deep-sea opportunities to further regions and short-sea and ro-ro opportunities within the Mediterranean region. This shortlisting is derived based on the scale of trade, energy demand, dominant trade segments and policy environment.

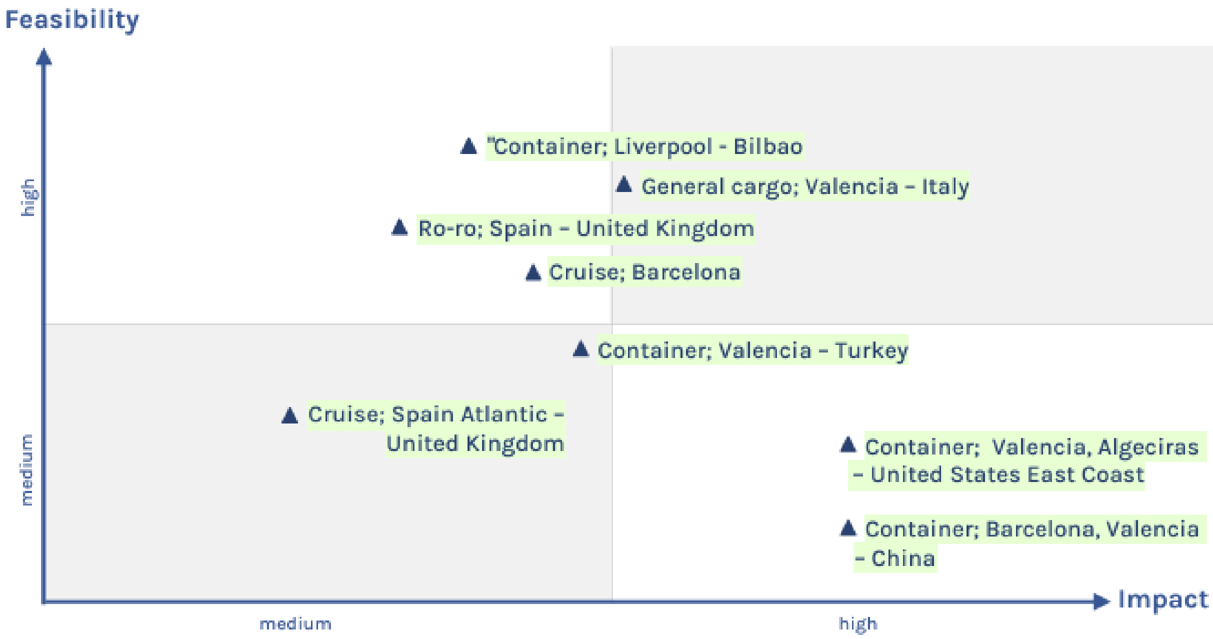
Figure 5.2 Eight most promising green corridor routes (Spanish ports)

Source: Global Maritime Forum

Focusing on the Mediterranean region, studies have identified opportunities in the container segment on the routes, Valencia - Algeciras - USA East Coast, Valencia -Türkiye – Barcelona and Valencia - China. Notable liners servicing these routes include MSC, Maersk, Hamburg Sud, ONE, Hapag Lloyd and CMA-CGM.

Another route worth mentioning is the general cargo (containerised and non-containerised) route between Valencia and Italy, and the latter covers a significant share of the former's total volumes.

Figure 5.3 Assessment of the relative impact and feasibility of the eight promising routes

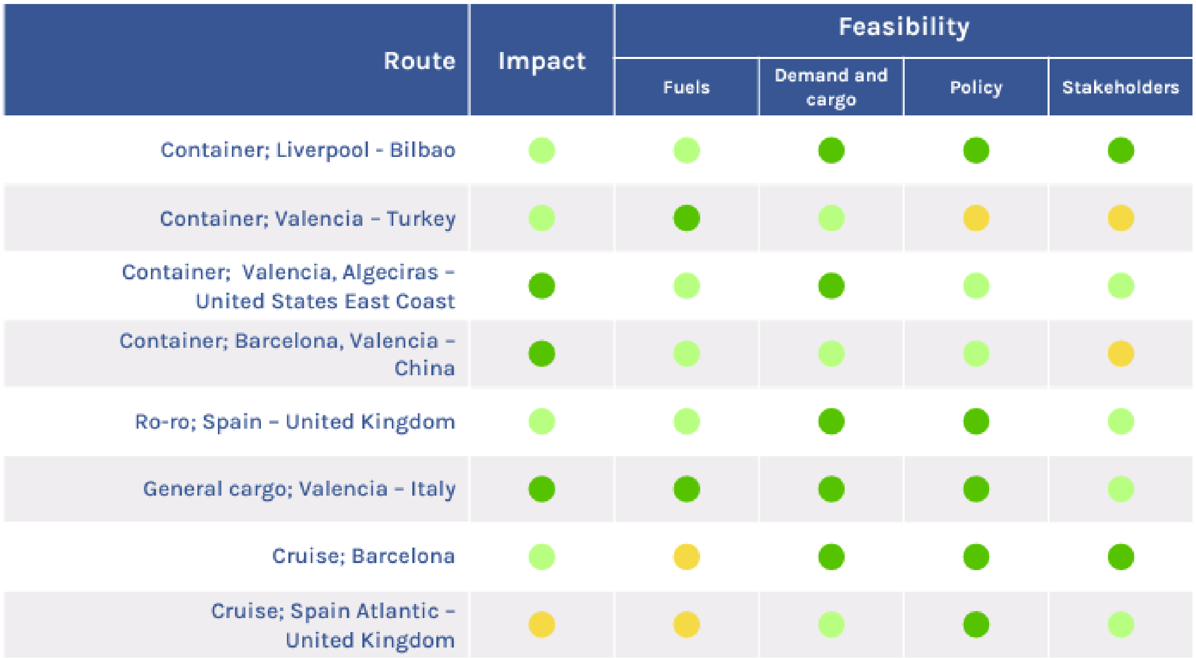


Source: Global Maritime Forum

High-impact approaches, such as routes from Spain to the USA and China, are positioned lower in terms of feasibility – this is likely due to the challenges in meeting timelines and coordinating stakeholders across different regions.

However, trades within the Mediterranean region from Spain to Italy and Türkiye are ranked higher in terms of feasibility. Interestingly, general cargo trade from Valencia to Italy is the only route ranked high-feasibility and high-impact, adding to the likeliness of this green corridor materialising first within the Mediterranean region.

Figure 5.4 Multicriteria assessment of the selected routes



Source: Global Maritime Forum

As seen from the assessment above, the container trade route involving Türkiye poses some hurdles when it comes to policy and stakeholders' feasibility. Demand and cargo are positive as this has been a popular short-sea container trade route. In terms of fuel, the Valencia Port has access to a well-established local supply of low/zero-carbon emission fuels; since the distance between the two ports is not large, one bunkering stop in Valencia Port should be sufficient.

General cargo trade between Valencia and Italy scored positively across all matrices – specifically in terms of traffic volumes in relation to travelled distance. Stakeholders' interests need to be studied to solidify the feasibility of developing this corridor. Furthermore, various shipping segments- including container and ro-ro trade- serve this route, adding to the intricacy of establishing a potential green shipping corridor.

In conclusion, a corridor-specific feasibility study should be conducted to delve deeper into understanding the needs and requirements of infrastructure, policy and finance to build a more solid political case for the green corridor. A key consideration before finalising a green corridor is the availability and feasibility of bunkering low/zero-carbon emission fuels at these ports.

5.3 Examples of best practices

With stricter regulations, few ports have taken the lead in emission reduction initiatives and become the first movers in this process. Taking such strict decisions has an impact on the trade of the country. Incentivising vessels with green technology and lower emissions is an easy way to kickstart the decarbonisation goals. This sub-section shows examples of such ports as mentioned below:

5.3.1 Port of Los Angeles (USA) and Port of Long Beach (USA)

.1 Speed limits

The Port of Los Angeles (USA) and the Port of Long Beach (USA) took the initiative of incentivising vessels to enter port waters at a low speed and are giving discounts of 15% - 30%. This helps the port achieve two goals simultaneously. First, vessels running at low speeds consume less fuel and thus lower GHG emissions. Second, it helps ensure the safety of vessels during manoeuvring. Ships are incentivised according to the Vessel Speed Reduction Incentive Programme (VSRIP) mentioned in Table 5.1.

.2 Discounts

The index for identifying low-emission vessels is used to benchmark vessels entering these ports. Environmental Ship Index (ESI) scores of 40 and above and 25 and above are incentivised in the form of discounts by the Port of Los Angeles and Long Beach, respectively, as per Table 5.2.

These discounts help shipowners get a Return on Investment (ROI) on expensive efficiency measures or low-/zero-carbon fuel technologies. With more vessels using green technology and using these ports, the port becomes more capable of handling such vessels and completing the prerequisites of becoming a part of green corridors.

.3 OPS

The California Air Resources Board (CARB) introduced a regulation in 2007 to reduce emissions from vessels at berth by using OPS. In 2023, CARB adopted a new regulation to further lower emissions from vessels at berth by adding more categories of vessels to the list of mandatory OPS requirements. By 2025, the authority plans to include car carriers and liquid bulk vessels on the list.

.4 Low-/zero-carbon fuel supply

Presently, low-/zero-carbon fuel bunkering is not as prominent as in other major ports like Singapore. However, being a part of a green corridor between Los Angeles/Long Beach and Singapore, these ports plan to expand their supply of low-/zero-carbon fuel, mainly focussing on methanol, as most shipowners operating in the Los Angeles-Singapore green corridor are adopting methanol as their fuel of choice. The authority wants to increase its focus on green corridors with Shanghai and Singapore, increasing the availability of low-/zero-carbon fuels in the port.

.5 Air quality monitoring

Both ports have a complex air monitoring network that collects air samples and analyses air quality in real time. This helps them monitor and maintain the air quality around the port below the standards set by state and federal agencies.

.6 Heavy-duty vehicles operating in port

Port of Los Angeles and Long Beach launched the Clean Trucks Programme (CTP) to implement a progressive ban on older heavy polluting diesel trucks. As a result, the fleet of trucks operating are running on the latest emission-efficient technology in the market. Apart from that, a Clean Truck Fund (CTF) rate was introduced, which established a rate of $10 per 20-foot equivalent unit to encourage the trucking industry to invest in cleaner vehicles and reach zero emissions.

.7 Renewable energy

The Port of Los Angeles has solar power installation of around 3MW output. The port has also tried out power generation through waves recently. Eco-wave Power has partnered with a major energy company in the USA to install the plant, which would be a first-of-its-kind power plant in the USA.

.8 Green tugboats

The Los Angeles Harbor Commission has approved the shared trial of the hybrid electric tugboat in the port areas of Los Angeles and Long Beach. The battery plug-in hybrid vessel is under construction.

The new tug will be powered by dual batteries, which will be rapidly recharged via a capable charging system. While it will include diesel engines, the tugboats are designed to use those only as backup and for emergencies.

.9 Initiatives

The Port of Los Angeles (USA) and the Port of Long Beach (USA) are a part of the World Ports Climate Action Programme (WPCAP) that focuses on taking action to combat climate change in the maritime sector.

5.3.2 Port of Singapore

.1 Speed limits

For safety reasons, the Port of Singapore has made a mandatory speed limit of 12 knots or less in the port waters. Apart from safety, it also reduces emissions by these vessels due to their low speed. Table 5.1 shows additional details about this topic.

.2 Discounts

As mentioned in Table 5.2, under the Green Port Programme (GPP), the port authority gives 25-30% port dues reduction to vessels that are more fuel efficient with either low or zero emission.

.3 Alternate fuel supply

With Singapore being the world's largest bunkering hub, the port has started several initiatives to be multi-fuel future ready. Currently, the port has been engaging relevant stakeholders to ensure ample supply of low-/zero-carbon fuels such as sustainable biofuel, green methanol etc. According to the MPA, sustainable biofuel sales in Singapore reached 520,000 tonnes in 2023, compared to 140,000 tonnes in 2022.

Singapore is ready for methanol bunkering for container vessels at Tuas Port, with the first successful simultaneous methanol bunkering and cargo operation in July 2023 for Maersk's first delivered methanol vessel and an STS operation of 1,340 metric tonnes of blended methanol on 24th May 2024.

Earlier in 2024, Air Liquide and Vopak signed a MoU to develop and collaborate on infrastructure for ammonia import, cracking and hydrogen distribution infrastructure in Singapore.

In addition, the Port of Singapore along with Unitrove plans to set up the world's first hydrogen bunkering facility.

.4 Electrification

The Maritime and Port Authority of Singapore selected various companies for their vessel charging concepts to be piloted in Singapore. The pilot is planned from March 2024 to March 2026. From 2030, all new harbour crafts operating in the Port of Singapore should be fully electric and be capable of using B100 sustainable biofuel or be compatible with net zero fuels such as hydrogen. MPA plans to progressively roll out the charging infrastructure for e-HC (electric Harbour Crafts) operations in Singapore from 2025. MPA will continue to monitor technology trends and develop pilots to support the development of electrification charging standards for domestic maritime activities.

.5 Renewable energy

In 2016, Jurong Port built Singapore's largest single-site solar energy facility, with a peak capacity of 9.65 MW and the power produced by the port is also sold to the grid. This renewable energy power plant has been used as an example to make similar plans and efforts for big industries. The 25-year lease agreement did not cost anything to the port, and it also reduced its power bills, with all capital expenditures from installation to maintenance borne by local solar leasing company Sunseap.

.6 Green tugboats

The Coastal Sustainability Alliance (CSA) has announced the start of construction of its fully electric PXO-series tug (e-tug). The zero-emissions vessels are among the pioneering and largest electric harbour craft designed for operation in Singapore's coastal waters. They are planned for deployment in 2025, aligning with the country's target for all new coastal vessels to be fully electric or utilise low-carbon energy solutions by 2030.

.7 Initiatives

The Castor Initiative

This is a joint development project formed in February 2021 to develop an ammonia-fuelled tanker, with representation from all areas of the maritime shipping ecosystem. The key roles of the six members are:

- MAN (engine manufacturer): Identifying the engineering parameters to be adapted to use ammonia as a fuel in an internal combustion (IC) engine.
- SHI (ship manufacturer): Designing and construction of the vessel.
- Yara (ammonia manufacturer): Giving expertise by one of the world's largest ammonia producers and a pioneer in the development of green ammonia.
- MISC (Malaysian shipowner): Investing in an ammonia-fuelled vessel and operate it.
- Lloyds Register (class): Reviewing safety appraisals and research into the development of suitable fuel storage and supply systems, along with the required risk assessments.
- MPA (port authority and bunkering hub): Adding expertise to safety regulations relating to ammonia infrastructure and bunkering operations.

Global Centre for Maritime Decarbonisation (Public Private Partnership initiative) was established in 2021 with six founding partners: BW, BHP, DNV Foundation, Eastern Pacific Shipping, Sembcorp Marine and Ocean Network Express. GCMD aims to assist in shaping standards, deploying solutions, financing projects and fostering collaboration across sectors.

Overstay dockage policy

Jurong Port (Singapore) has an overstay dockage policy to discourage vessels from staying at berth beyond a certain time. As a result, all stakeholders work together to ensure that the vessel departs within the stipulated time to avoid the penalty, which increases in a stepped manner over time. This policy has been developed and thereafter revised based on feedback from various stakeholders. It has certain exceptions as well as mechanisms to appeal for lowering/waiving of charges.

Such practices ensure that vessels vacate the berth in a timely manner which not only increases the availability of berth but also leads to emission reductions from the vessels at berth.

5.3.3 Port of Rotterdam (Netherlands)

.1 Speed limits

The port has a mandatory speed limit of 13 kilometres per hour relative to the water as mentioned in Table 5.1. The measure is temporary and subject to change after 1 January 2025, depending on the air quality.

.2 Discounts

A score of 31 and above on the ESI is incentivised as per the table mentioned in Table 5.2. Additionally, if the vessel has an individual ESI-NO_X (Low Nitrogen oxide emissions) score of 31 and above, the discount will be doubled.

.3 Low-/zero-carbon fuel supply

The Port of Rotterdam (Netherlands) is one of the three largest hubs for bunkering conventional fuel in the world. With the rising demand for low-/zero-carbon fuels, the port is ready with fuel supply.

The first pilot for ammonia bunkering is planned for 2024 when the first ammonia engine joins the market. For sustainable biofuels, the Port of Rotterdam (Netherlands) has become the largest bunker port in Europe and is a major sustainable biofuel producer for the European market. Hydrogen is already being bunkered at the port on a small scale via hydrogen-powered water taxis, while LNG can be bunkered via trucks.

The Port of Rotterdam (Netherlands) is the largest methanol hub in Northwest Europe. Dutch company “GIDARA” and the Port of Rotterdam (Netherlands) will establish an advanced sustainable biofuel facility, aiming to produce 90,000 tonnes of green methanol per year from waste, starting in 2026.

.4 Renewable energy

With five energy plants, the combined power capacity stands at 3.9 GW. In combination with the expansion of solar and wind production, these energy plants will continue to play a vital role, in supplying electricity to the ports of the Netherlands and Europe.

.5 OPS

The Rotterdam Port Authority and Municipality of Rotterdam are working on a joint strategy and development programme to accelerate and scale up OPS. The authority plans to provide 35 MW of power for containerships, liquid bulk and cruise ships by 2025. At least 90% of the offshore, ferries, cruise, ro-ro ships and container ships in Rotterdam should use onshore power by 2030. This will reduce emissions of CO_2 and nitrogen by about 200,000 tonnes and 2,500 tonnes, respectively.

.6 Electrification

The port offers eight truck charging stations, of which two are fast chargers. By 2035, around 2,000 electric trucks are expected in the port area, which would need at least 50 charging bays.

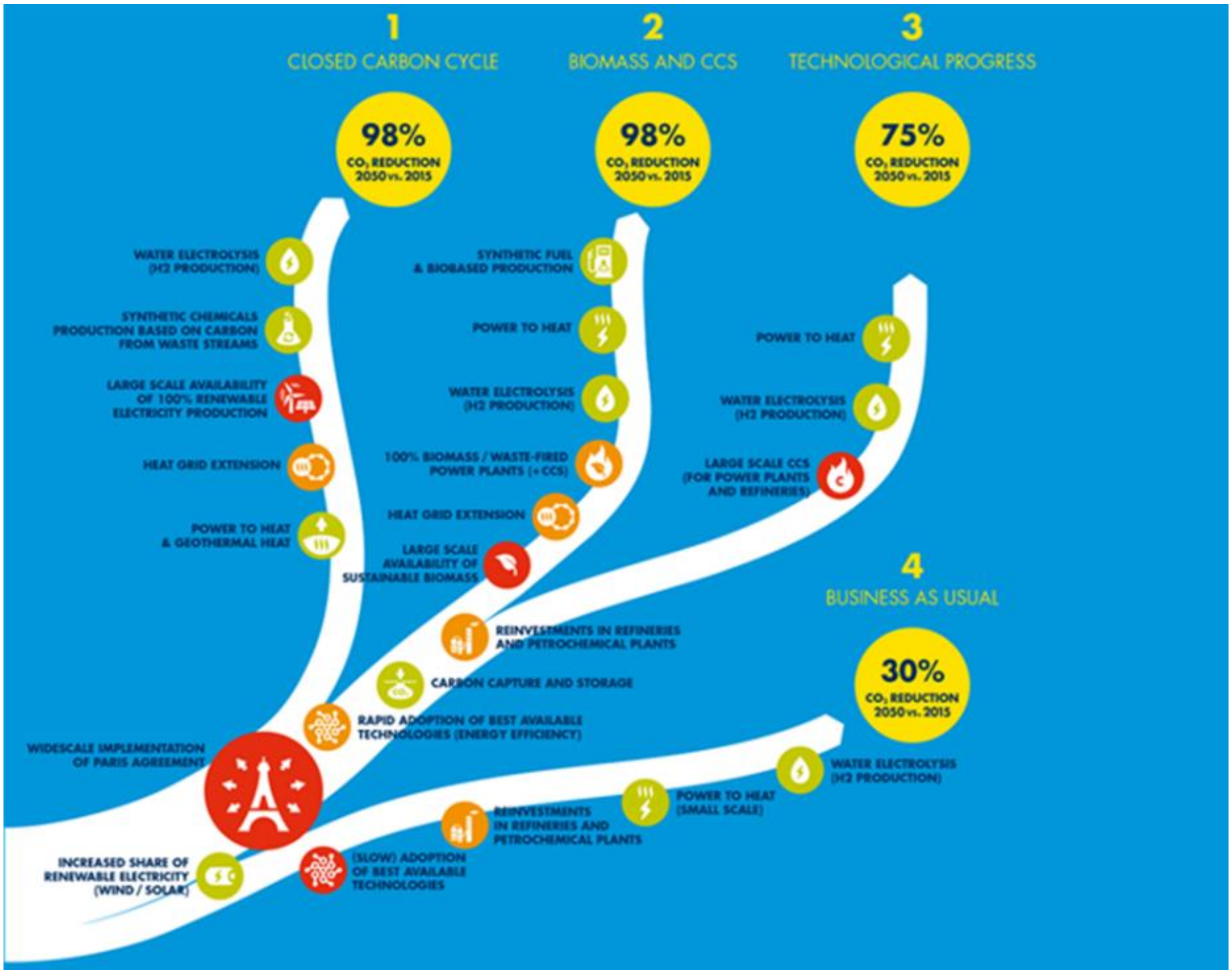
.7 Green tugboats

The Port of Rotterdam (Netherlands) is expanding its fleet of tugboats as a part of boosting its capacity. The new tugboats will be hybrid and be on stand-by or when very low power operations are there, electrical energy can be used.

.8 Initiatives

- The German Wuppertal Institute research on Decarbonisation Pathways for the Industrial Cluster of the Port of Rotterdam (Sascha, S., Stefan, L., et al., 2016) indicates that the port can achieve 98% CO_2 reduction by 2050.
- Four paths were explored in the study:
  - Closed Carbon Cycle (path 1) will achieve a 98% reduction.
  - Biomass and Carbon Capture and Storage (path 2) is also able to achieve a 98% reduction.
  - Technological Progress (path 3) offers a reduction of 75%.
  - Business as Usual (path 4) projects a reduction of 30%.
- The Port of Rotterdam (Netherlands) is also a part of the WPCAP, which focuses on taking action to combat climate change in the maritime sector.

Figure 5.5 Pathway to carbon emission reduction in the Port of Rotterdam (Netherlands)



Source: The Port of Rotterdam (Netherlands)

5.3.4 Example of ports in the Mediterranean region

.1 Low-/zero-carbon fuel supply

Japanese company Itochu Corporation and Peninsula Petroleum recently signed a MoU to develop an ammonia bunkering facility at the Port of Algeciras (Spain).

A new Flex LNG bunkering vessel with a capacity of 12,500 m3 is being built for the Port of Algeciras (Spain). It will be able to bunker large LNG-fuelled vessels at sea and feed barges for small-scale bunkering in the Port of Algeciras (Spain) at the south end of the Atlantic and Mediterranean Corridor.

Spanish marine fuel supplier, Cepsa, started delivering second-generation biofuels to the cruise industry at the Port of Barcelona (Spain) with Norwegian Escape, a cruise ship operated by Norwegian Cruise Line Holdings (NCLH), receiving the first supply in July 2024.

Cepsa will also supply second-generation sustainable biofuels for voyages of Naviera Armas Trans-Mediterranean from the Port of Algeciras (Spain), fulfilling its commitment to supply sustainable fuel for maritime transport in Spain. In addition, Cepsa expects to supply synthetic marine fuels, such as green ammonia and/or methanol, in the future. These fuels will be produced at Andalusian Green Hydrogen Valley in southern Spain, which, when developed, will be the largest green hydrogen project in Europe.

Meanwhile, for the first time in Spain, Repsol supplied bio-LNG to LNG-powered vessels of Brittany Ferries in September 2024. The bio-LNG used in this trial was produced at Spain’s first dedicated bio-LNG facility located in As Somozas, Galicia. This facility uses waste from agriculture and households as well as the agri-food industry in addition to sewage plant sludge to produce renewable fuel, showcasing how waste can be converted into sustainable energy solutions.

On 20 September 2024, an MoU was signed to develop port and logistics infrastructure in Port-La Nouvelle (France), dedicated to low-carbon fuels. These initiatives will connect the port of Port-La Nouvelle (France) to major hydrogen and CO_2 transport infrastructures.

The H2Ports project is an initiative of the Port of Valencia (Spain), in line with its strategy of port-logistics decarbonisation, reduction of port carbon footprint and adoption of low-/zero-carbon fuels, which facilitates the transition of ports towards zero-emission operations. H2Ports is the first European project focused on testing heavy-duty port equipment powered with hydrogen fuel cells, and also the first port in Europe to supply this low-/zero-carbon fuel by means of hydrogen supply infrastructures.

.2 Green corridors

The Port of Algeciras (Spain) is exploring all possible opportunities to form green corridors with other major global ports. Eight proposals are being reviewed to make green corridors, with ports trading the most with the Port of Algeciras (Spain).

.3 Renewable energy

Port Authority of Valencia has approved two photovoltaic installations, which will enable 14% of electricity consumption to be generated through solar energy.

.4 Electrification

Two electrical substations are being built so that ships docking in Valencia can be connected to the electricity grid.

.5 OPS

The Valencia port aims to prepare the port’s electrical network for OPS to container ships, ferries and cruise ships in the new terminals of the Port of Valencia (Spain) (new container terminal and new passenger terminal), with an initial capacity of 60 MW with plans to extend it to 90 MW in the future.

.6 Initiatives

The Port of Valencia (Spain) became the first port in the world to operate a 4x4 harbour truck powered by green hydrogen. This initiative is a part of the H2PORTS project, which makes it the first port to incorporate hydrogen technologies to reduce the environmental impact due to its operations.

The Port of Valencia (Spain) is also a part of the WPCAP, focusing on taking action to combat climate change in the maritime sector.

5.4 Speed limits and incentives in major ports

Various efforts are made for reduction of GHG emissions from vessels during manoeuvring in the port area. Many ports have either put speed restrictions for vessels entering/exiting the port or have given incentives to vessels operating at lower speeds. Some of these examples are shown below in this section.

Table 5.1 Speed limit and incentives in different ports

Port name	City, Country	Speed Limit	Incentives
Port of Los Angeles	San Pedro, USA	12 knots or less (40nm towards and from the port)	VSRIP: Rebate equivalent to **30% of the first-day dockage**, per vessel call.
Port of Long Beach	San Pedro, USA	12 knots or less (40nm towards and from the port);	Green Flag Programme: **25% reduction of dockage fees** if slowed from 40nm and **15% reduction of dockage fees** if slowed from 20nm.
Port of Rotterdam	Rotterdam, Netherlands	13 kilometres per hour relative to the water. The speed limit will change based on prevailing flow velocity and wind force.	No incentives; mandatory speed The measure is temporary (till 1 January 2025), assuming air quality will improve due to advancing technology.
Port of Singapore	Singapore, Singapore	12 knots or less (Between South of St John's Island to Raffles Lighthouse)	No incentives; mandatory speed The limits are not to reduce emissions but safety.

Source: Drewry (2024)

5.5 Discount on port dues for low-emission ships

In July 2023, a MoU for future cooperation, signed by the IMO and the International Association of Ports and Harbours (IAPH), established the ESI. This is a voluntary system designed and used by ports to incentivise shipowners to improve the environmental performance of their vessels. Applicable to any vessel exceeding the current IMO emission standards, ESI has become the established global standard for ports to incentivise the ongoing improvement of the sector's environmental performance. It has also been recognised by the IMO as the standard basis for port incentives for low- and zero-carbon ships.

There are also private firms, such as Envision, Sinay and Drewry, that provide services and tools to measure berthing performance.

The incentives provided by different ports are listed below.

Figure 5.6 Ports which have agreed to incentivise low-emission vessels based on their ESI score

Source: ESI Portal (environmentalshipindex.org)

Table 5.2 Examples of ports incentivising low-emission vessels

Port name	City, Country	Regulations	Incentives
Port of Los Angeles	San Pedro, USA	Vessels should achieve an ESI score of 40 and above.	ESI Score from 40 to 49: **$750 per call** ESI Score of 50 and above **$2,500 per call**
Port of Long Beach	San Pedro, USA	Vessels should achieve an ESI score of 25 and above.	ESI Score from 25 to 47: **$600 per call** ESI Score from 48 to 53: **$3,000 per call** ESI Score of 54 and above **$6,000 per call** Additionally, vessels with main engines meeting IMO Tier III standards will be eligible for an additional **$3,000 bonus.**
Port of Rotterdam	Rotterdam, Netherlands	Vessels should achieve an ESI score of 31 and above.	**10% discount** on the GT part of the port dues. Additionally, if the vessel has an individual ESI-NO_X (Low NO_X emissions) score of 31 and above, the discount will be **doubled (20%).** *Discounts apply to a maximum of 20 vessel calls per quarter.
Port of Antwerp	Antwerp, Belgium	Vessels should achieve an ESI score of 31 and above.	**10% discount** on the GT part of the port dues.

Port name	City, Country	Regulations	Incentives
Port of Singapore	Singapore, Singapore	Various criteria are based on the GPP.	Use of zero-carbon fuels (e.g. hydrogen synthetic non-carbon fuels, such as ammonia, derived from renewable-based electricity): **30% port dues reduction** Use of low-/zero-carbon fuels (e.g. LNG and 20% pure sustainable biofuels): **25% port dues reduction.** Vessels with main engines meeting IMO Tier III standards: **25% port dues reduction.** Additionally, qualifying GPP vessels serviced by low-/zero-carbon-fuel MPA licensed harbour crafts will be entitled to an **additional 10% port dues reduction.**
Port of Koper	Koper, Slovenia	Vessels should achieve an ESI score of 30 and above.	ESI Score from 30 to 49.9: **5% discount on port fee.** ESI Score above 50: **10% discount on port fee.**
Port of Gibraltar	Gibraltar, UK	Green Award certified vessels.	**A 5% discount** on tonnage dues will be awarded.

Source: Drewry (2024)

5.6 Section summary

IMO has implemented regulations related to GHG emission reduction measures such as EEDI/EEXI and CII. With every passing year, the CII regulation will get stricter, forcing vessels to improve their GHG emission reduction.

Several countries are implementing local regulations such as the EU ETS Directive, the FuelEU Maritime Regulation and the UK ETS to become net-zero by 2050 or earlier. For example, Türkiye is taking the initiative to establish its own carbon pricing scheme comparable with the EU ETS.

Unlike shipping, there is no global organisation regulating the ports sector. However, the emissions from vessels near the port area are also accounted for; hence, vessels operating in the ship-port interface will be directly affected by these regulations. The FuelEU Maritime Regulation and the AFIR specifically mandate vessels to use OPS while at berth in several European ports, while the AFIR requires ports to have LNG bunkering facilities.

In addition to the regulations, initiatives are required, which promote early movers in achieving the net-zero target. 'Green corridors' encourage all stakeholders involved to opt for low-carbon emission alternatives and is expected to create demand for low-/zero-carbon fuels.

The use of low-emission fuels is the principal strategy, which is implemented in maritime transport to reduce emissions. However, for this to be possible, there should be enough fuelling points that are adequately spread throughout the routes. Often, a detailed risk analysis is necessary for ports involved in creating green shipping corridors due to the risks commonly associated with the adoption of low-emission fuels (e.g. methanol, ammonia, hydrogen, etc.). For instance, the Port of Algeciras (Spain), due to its strategic location in the Mediterranean region, has a lot of potential to form green corridors with ports, with which it is involved in maximum trade.

The initial selection of green corridors is crucial, and it requires certain factors such as stakeholders that are committed to decarbonisation, viable fuel pathways with readily available supply infrastructure, customer demand as well as policies and regulations that can expedite the adoption of green corridors. Establishing a green corridor will require not only individual efforts from numerous stakeholders involved but also collaborative action from the entire maritime shipping ecosystem, such as ports and fuel producers. A green corridor-specific feasibility study should be conducted to delve deeper into understanding the needs and requirements of infrastructure, policy and finance to build a more solid political case for the green corridor. A key consideration before finalising a green corridor is the availability and feasibility of bunkering low/zero-carbon emission fuels at these ports.

Many ports are taking charge to reduce GHG emissions. Port authorities of countries such as Singapore is actively involved and facilitating multi-stakeholder initiatives for the development of green shipping. Major ports in North America, Europe, Asia and the Mediterranean region can be seen taking major steps in the following categories:

.1 Speed limits: Ports are incentivising vessels operating in the ship-port interface with a speed limit to reduce emissions. Some port authorities such as the Port of Los Angeles (USA) and the Port of Long Beach (USA) are giving discounts of 15-30% reduction in dockage fees to vessels following such recommendations.

.2 Discounts for low-emission vessels: Many ports have come up with an ESI and offer discounts to low-emission vessels while visiting their ports. These initiatives promote vessels to improve their energy efficiency and reduce carbon emissions.

.3 OPS and Electrification: Vessels can lower their emissions while at berth by using power supplied by ports called OPS. If the power is from renewable energy, carbon emissions can be reduced significantly. Similarly, promoting electrification of the port and providing charging stations for electric trucks help in curbing emissions.

.4 Low-/zero-carbon fuel supply: Many ports such as Rotterdam, Antwerp and Singapore have been supplying green and low-/zero-carbon fuels.

.5 Renewable energy: Many ports are investing in solar/wind energy to meet their power requirements. This will not only reduce overall carbon emissions but will also help ports to become self-sustainable for their power requirements. In a few cases, these solar panels are making excess power, which is sold to the city grid.

.6 Overstay Dockage: The overstay dockage policy contains clauses for imposing penalties on vessels that stay longer than the permissible time. This in turn reduces emissions from vessels at berth.

6 Stakeholder Analysis

Drewry engaged with the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (the “Barcelona Convention”) (CPs) to seek feedback on various issues related to the implementation of emission control and energy efficiency measures for ships in port areas in the Mediterranean region. The online copy of the questionnaire was shared with other stakeholders as well. In addition, a few interviews were also conducted.

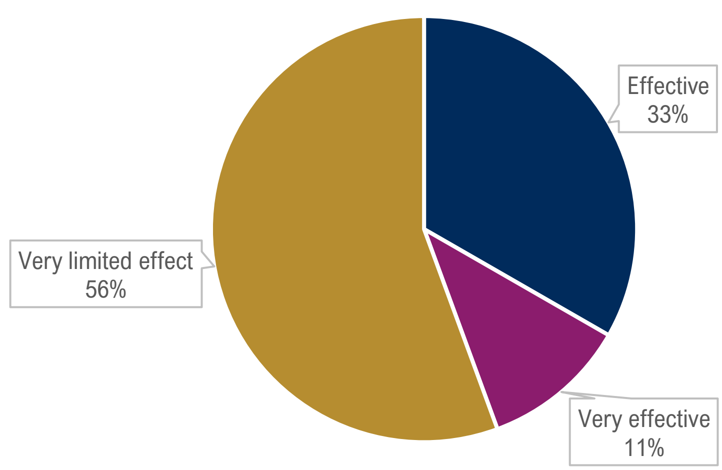
This section covers the feedback from these stakeholders. This feedback has further been considered in Section 7 (Challenges, opportunities and recommendations) and Section 8 (Roadmap and action).

Of all responses collected through this questionnaire, 87.5% of respondents are moderately or completely aware of the rising need to reduce GHG emissions from the ship-port interface.

6.1 Feedback related to emission reduction measures from vessels during ship-port interface

The overall responses to the questionnaire show that 56% of respondents think that GHG emission reduction measures for deep-sea voyages measures will have a limited effect on the ship-port interface. This implies that different measures and policies are required for port areas compared to deep-sea areas.

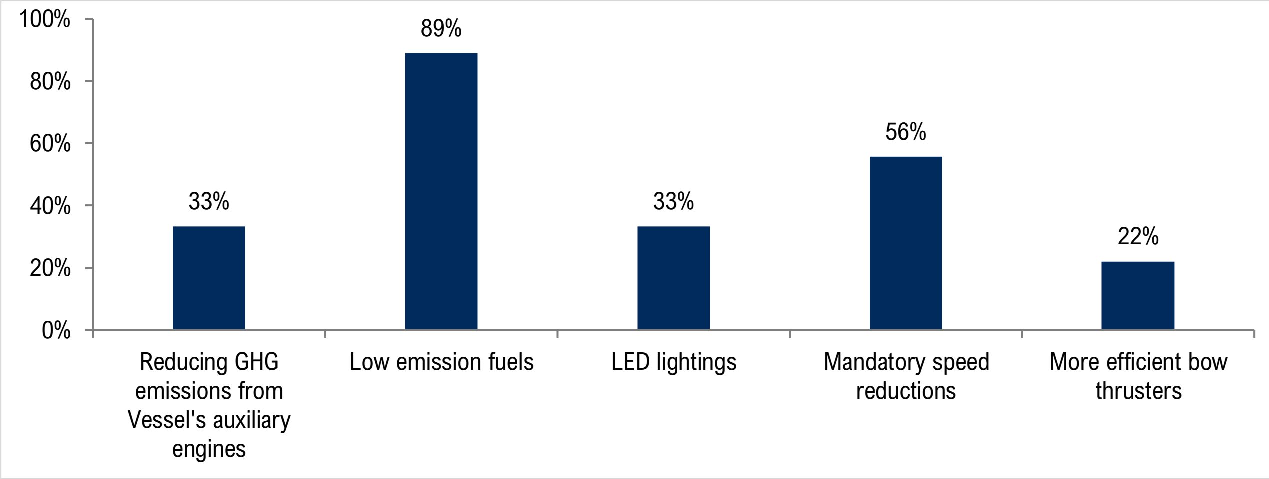
Figure 6.1 Respondents view on the effectiveness of deep-sea GHG emission reduction measures in ship-port interface



Source: Drewry (2024)

Most of the respondents favour using low-emission fuels as the primary method to reduce GHG emissions from vessels in the ship-port interface. Respondents also believe that mandating speed limits during ship navigation in port areas is also an effective measure.

Figure 6.2 Responders' primary choice to reduce GHG emissions during navigation of a vessel in the port area

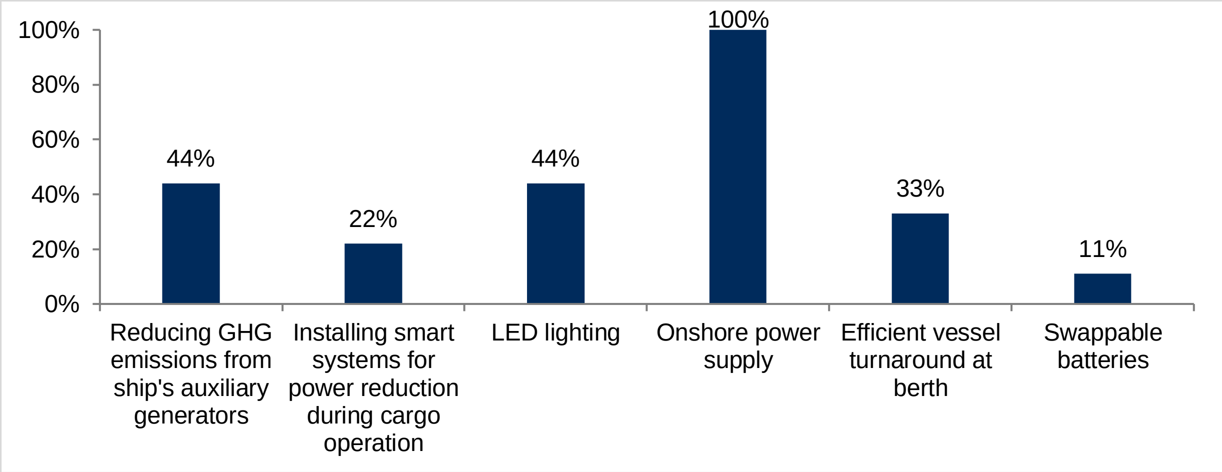


Source: Drewry (2024)

Most respondents want JIT to be accepted to reduce waiting time for pilot boarding the vessels, as it will ensure that vessels reach the pilot station on time at the required speed and enter the berth without any delay. This requires cooperation between ports and vessels. Respondents agree that the need for a third party (usually agents) should be removed from communications between the vessel and the pilot, and this communication should be possible at least 24 hours before arrival as, currently, it is only possible via Very High Frequency (VHF) radio around two hours before arrival. These measures will also help reduce emissions from tugboats as they may not be required to sail at full speed and then wait for the arrival of the vessel/pilot.

Emissions due to power generation from vessels can be easily minimised by using an OPS while at berth, and all respondents agree with this. Amongst other measures, such as using LED lighting onboard and ensuring efficient vessel turnaround at berth, responders also suggested having large batteries that are charged at sea and can be used for power requirements at berth.

Figure 6.3 Responses for GHG emission reduction methods for vessels at berth



Source: Drewry (2024)

Additional feedback

Below is the additional feedback received from stakeholders.

.1 Financial assistance should be given for retrofitting existing vessels to help in decarbonisation.

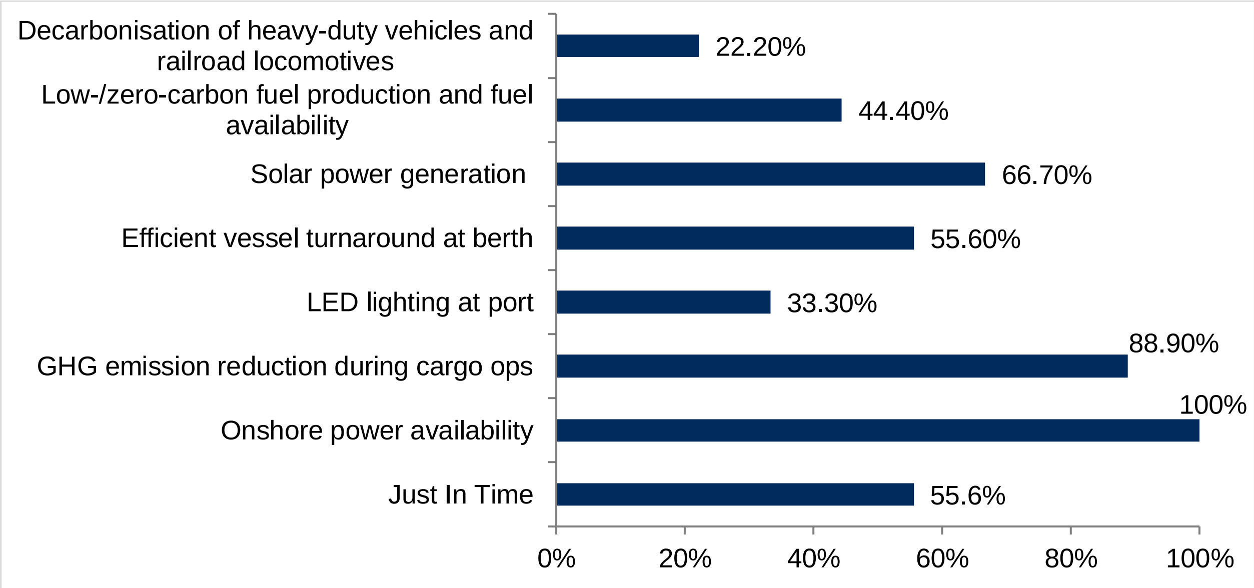
.2 Use of OCCS.

.3 Significant investment in vessels is required to overcome the barrier that hinders the reduction of GHG emissions from vessels in the ship-port interface (recommended by more than 50% of respondents).

6.2 Feedback related to emission reduction measures in ports during ship-port interface

Ports play a vital role in reducing GHG emissions. All respondents consider OPS availability at ports as the primary measure to reduce GHG emissions. Around 90% of the respondents feel that GHG emissions during cargo operations via port equipment need to be slashed. The use of solar power, JIT system and efficient vessel turnaround at berth were also recommended by more than 50% of respondents.

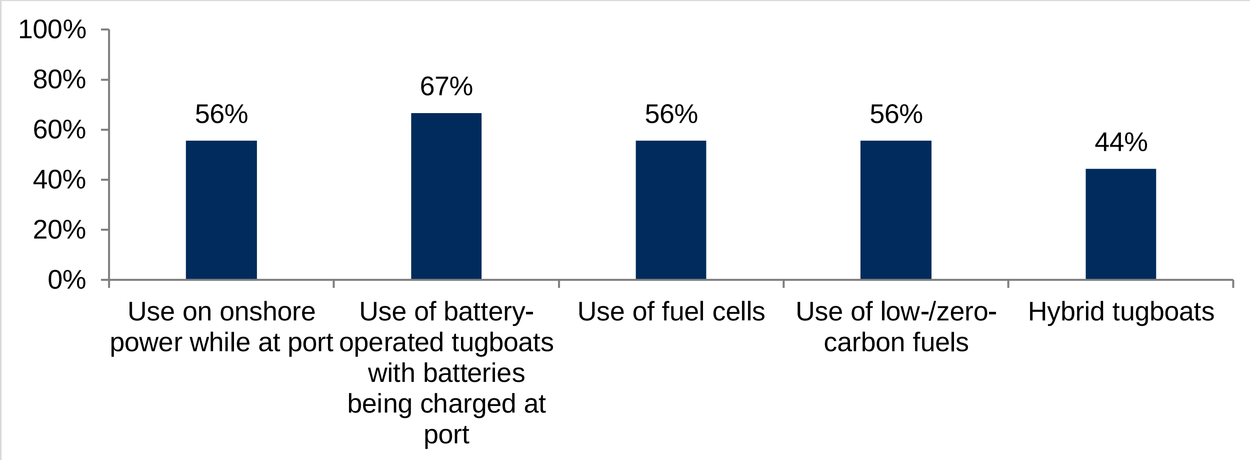
Figure 6.4 Stakeholder responses regarding the most effective measure to reduce GHG emissions in ports



Source: Drewry (2024)

One of the major sources of GHG emissions during navigation in the ship-port interface is tugboats. Due to their small size, electric propulsion and the use of fuel cells are considered preferred alternatives to reduce GHG emissions.

Figure 6.5 Stakeholder responses for reducing GHG emissions from tugboats



Source: Drewry (2024)

Additional feedback

Below is the additional feedback received from stakeholders.

.1 Auto-mooring system to reduce emissions in ports.

.2 A combination of discounts on port dues for green vessels, including those vessels that have OPS installed.

.3 Cargo operations to be done by port cranes (instead of ship cranes), thereby reducing emissions from vessels at port.

.4 Reduction in emissions from port equipment by electrifying it or operating it with green fuels.

.5 Development of carbon storage and pipelines.

.6 Promotion of equipment electrification and green port initiatives (e.g., green constructions, minimising wastes, etc.).

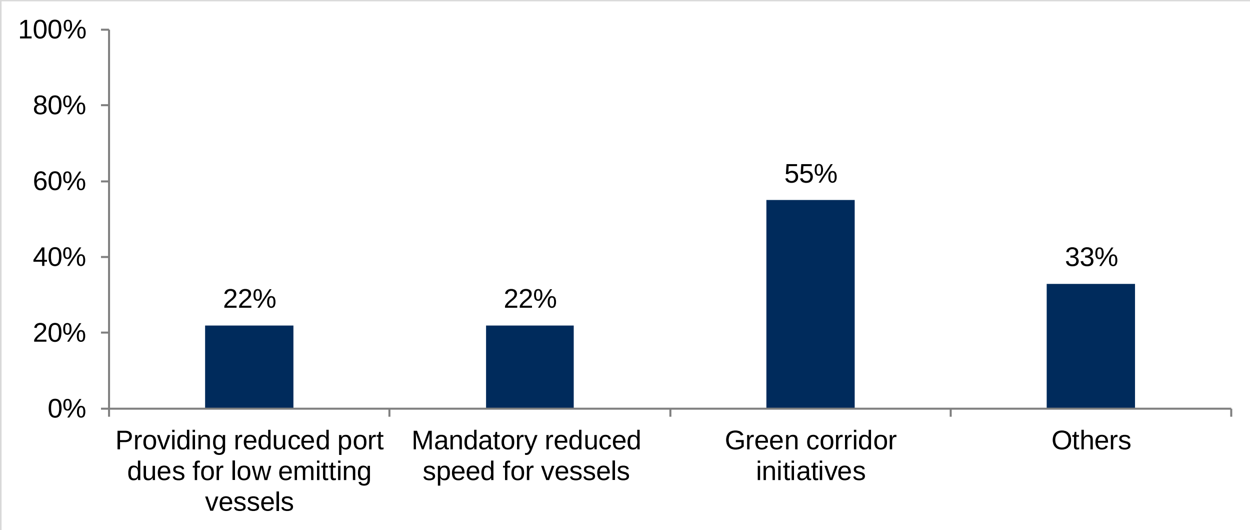
.7 Financial encouragement for the installation of solar power in ports and equipment electrification.

6.3 Feedback related to policies and regulatory measures to reduce emissions during ship-port interface

One of the stakeholders mentioned that a lack of appropriate, harmonised, robust and sufficient rules and regulations at the Mediterranean or international level to incentivise GHG emission reduction is a major barrier to reducing such emissions. The limited regional collaboration and cooperation is one of the challenges mentioned by a stakeholder. Moreover, there are multiple MoUs, leading to a lack of clarity for operators regarding which technology to invest in the Mediterranean region.

To contribute to the reduction of GHG emissions, ports have to come up with policies that will help achieving the targets. The most recommended policy in the responses was initiating green corridors. Other recommendations include reducing port dues for vessels connecting to OPS and port electrification.

Figure 6.6 Stakeholder responses for policies to be undertaken by ports in order to reduce GHG emissions from ship-port interface



Source: Drewry (2024)

Additional feedback

Below is the additional feedback received from stakeholders.

.1 There should be proper and strict local regulations that comply with international and regional regulations.

.2 The constraints to sustainable investments need to be removed as all ports face challenges due to a lack of funding.

.3 Making OPS mandatory for vessels.

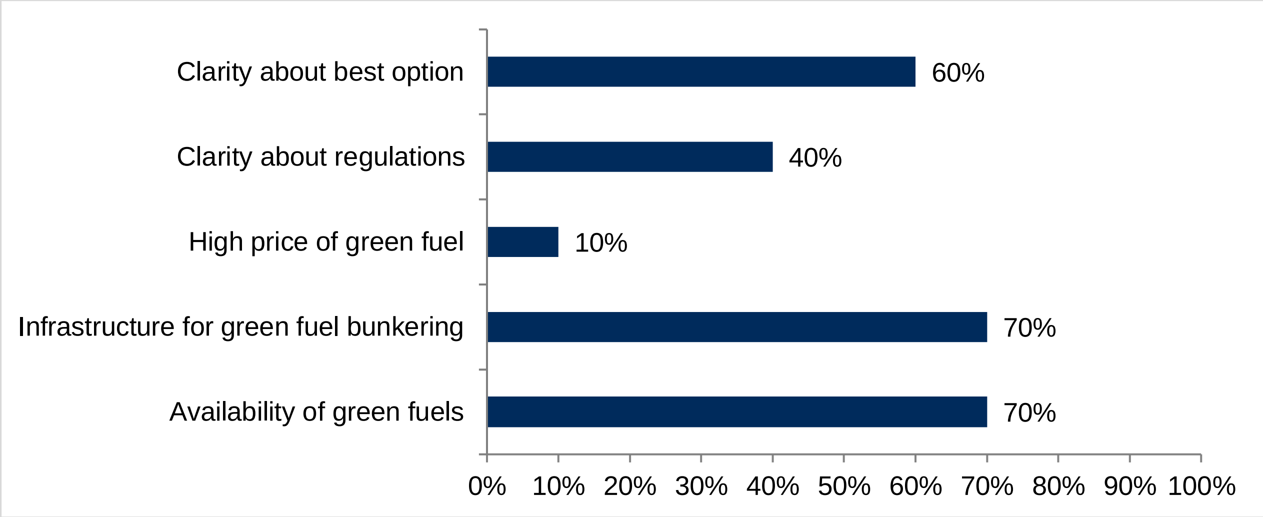
.4 Establishment of a provision for green fuel bunkering.

.5 Reducing port dues for vessels connecting to OPS and port electrification.

6.4 Other feedback from various stakeholders

Around 70% of respondents highlighted the lack of availability of green fuels and their bunkering infrastructure as one of the critical challenges. Uncertainty pertaining to new regulations and the availability of the best low-/zero-carbon fuels are also some of the challenges faced by the stakeholders. As a result, stakeholders are unable to make major decisions, as stated by one of them.

Figure 6.7 Responses regarding challenges faced by stakeholders



Source: Drewry (2024)

Responses show a need of investments in ports to make them capable of bringing a change to the industry and reduce GHG emissions from the ship-port interface.

Additional feedback

Below is the additional feedback received from stakeholders.

.1 Boosting the cooperation between different stakeholders (port authorities, shipping companies, charterers, and regulators) will aid emission reduction in the Mediterranean region.

.2 Various stakeholders need to be trained on environmental matters.

.3 The lack of proper/verified technologies for the decarbonisation of vessels using conventional fuel will lead to the scrapping of most of the existing vessels, which is not a practical approach.

6.5 Section summary

Drewry engaged with the CPs and collected feedback from various stakeholders in the Mediterranean region. Most respondents indicated they have a moderate to high level of awareness regarding the need to reduce GHG emissions from the ship-port interface. Most respondents think that the measures undertaken to reduce GHG emissions during deep-sea voyages of a vessel are not so effective in the ship-port interface. This indicates that there is a need for different measures to be adopted for reducing emission during ship-port interface areas. These measures have to be implemented on ships, ports, pilot operations and tugboats and will require coordination and mutual cooperation among these parties.

To reduce waiting time for pilot boarding the vessels, most respondents consider JIT to be the best option to ensure that vessels reach the pilot station on time at the required speed and berth without any delay. Another reason for waiting time is the involvement of third-party agents in communication between different parties. Respondents indicate the need for a platform to provide direct communication between the vessel and the port around 24 hours before arrival.

To reduce GHG emissions, around 89% of respondents prefer the use of low-/zero-emission during navigation in the port areas and 56% of respondents concur with reduced speed requirements. While at berth, all respondents show their support for OPS. The need for financial investments was highlighted by a few respondents to improve green technologies onboard a vessel.

All respondents recommend OPS as the best measure to reduce GHG from vessels at berth. The ports are recommended to electrify the equipment required for cargo operations by 89% of the respondents. Meanwhile, 67% of the respondents also proposed solar energy to be the source of this power requirement in ports.

Reducing GHG emissions from tugboats is another area, which port authorities should focus on, according to respondents. Use of low-/zero-emissions fuels, hybrid tugboats, fuel cells, swappable batteries, and OPS while at the port, are the options that received around or more than 50% of respondents' agreement. One stakeholder recommended auto-mooring systems, which can reduce the involvement of tugboats in the process.

Considering the uptake of onboard carbon capture technology, respondents recommended installing carbon storage and pipelines in the ports. About 55% of the respondents believe that ports should take green corridor initiatives, which will boost green technologies in the Mediterranean region. Other policy recommendations include reduced port dues for greener vessels, making the use of OPS mandatory for vessels, and establishing a provision for green fuel bunkering.

Many barriers which hinder the implementation of GHG emission reduction measures in the ship-port interface, were listed by the respondents. These include the lack of funding/investments faced by almost all ports. Almost 70% of respondents highlighted the lack of availability of green fuels and their bunkering infrastructure as one of the critical challenges. Lack of clarity regarding new regulations and the best alternative are also some of the challenges faced by stakeholders. One stakeholder highlighted the need for training of different stakeholders involved.

7 Challenges, opportunities and recommendations

During the ship-port interface, implementing emission control and energy efficiency measures results in some challenges, but also provides various opportunities. Both challenges and opportunities were considered to devise a set of recommendations for the Mediterranean region.

7.1 Challenges in the implementation of emission control and energy efficiency measures for ships in port areas

Some challenges will be faced while implementing emission control and efficiency measures both globally as well as in the Mediterranean region. These have been mentioned below:

.1 The use of sustainable biofuels along with conventional fuels on vessels can decrease emissions by reducing CO_2 emissions. However, the supply of sustainable biofuels for shipping is limited.

.2 The use of main and auxiliary engines driven by low-/zero-carbon fuels such as LNG, methanol, hydrogen, sustainable biofuels and ammonia will reduce or eliminate carbon emissions. However, each of them has its respective challenges. For example, hydrogen requires a lot of volumetric storage onboard, LNG has the problem of methane slip and methanol as well as ammonia are highly toxic and flammable.

.3 There is a lack of infrastructure to receive liquid CO_2 or CO_2 storage containers required for the OCCS in ports.

.4 Uncertainty of green fuel availability for tugboats makes it difficult for ports to order green tugboats. In addition, electric tugboats involve high upfront costs and require infrastructure for power supply at berth.

.5 Presently, only a limited number of oceangoing ships can receive OPS because of the low availability of onshore power in ports.

.6 The infrastructure cost associated with the installation of OPS facilities can be high.

.7 One of the challenges for the OPS is that the source of energy needs to be green or else there would be no real reduction in GHG emissions.

.8 OPS can be installed at the terminals in collaboration with the port authority. However, this could pose problems for terminals as the concession agreements may have been signed many years before these systems came into existence and there may be a lack of clarity on the party responsible for the installation of OPS. This, in turn, requires amendments to the agreement between the port authorities and the terminal operators.

.9 Energy regulations in some countries prevent the commercialisation of electricity to ports or terminals, with energy being provided to them only by national energy distributors.

.10 Few ports are becoming energy hubs, which includes managing their own energy sources (e.g. offshore wind, solar or tidal). However, this strategy, in some cases, conflicts with the interests of the energy companies and with local legislation. It may require changes in local legislation with regard to the right to distribute power and pricing mechanisms.

.11 Additionally, in some ports, the electricity costs are also significantly higher than the cost of producing electricity on vessels; therefore, vessels avoid shore power in such ports.

.12 Collaboration through data sharing among competing parties is essential for JIT, but there are several limitations in data sharing, such as competition law and antitrust concerns, data storage and control concerns, culture and behaviour resistance and contractual relationship concerns between the shipowner and the charterer.

.13 With the concern of JIT, smaller shipping companies fear that the system manager will favour the interests of large shipping companies, which may also be terminal operators. Hence, it is important to ensure that the manager of the system is independent and acts fairly.

.14 OCCS and CCS facilities as well as technologies are still in the development phase. These technologies are expensive and require major investments for infrastructure development.

.15 The production of green fuels is limited, while its cost is relatively high.

.16 Major challenges with low-/zero-carbon fuel include establishing and scaling supply chains, revising fuel standards, accelerating the pace of infrastructure deployment as well as adopting modern and fuel-efficient ships.

.17 While sustainable biofuels can use the existing bunkering infrastructure, new infrastructure would be required for low-/zero-carbon fuels such as methanol and ammonia.

.18 A feasible fuel pathway, consumer demand for sustainable shipping, supportive laws and regulations as well as cooperation across value chains are some of the challenges in forming a green corridor.

.19 The constraints to the availability of sustainable investments need to be removed.

7.2 Opportunities in the implementation of emission control and energy efficiency measures for ships in port areas

The implementation of emission control and energy efficiency measures during the ship-port interface will provide various opportunities, as mentioned below:

.1 While OCCS and CCS are increasingly becoming popular, ports need to build the infrastructure to receive liquid CO_2 or CO_2 storage containers facility. Once the supply chain develops for carbon capture technologies, there could be great potential for liquid CO_2 transportation. These will result in ports developing infrastructure for loading and discharging the cargo of liquid CO_2, which will give further impetus to the development of OCCS.

.2 The growth of CCS technologies offers opportunities to reduce emissions in hard-to-abate sectors. This will also encourage the development of liquid CO_2 terminals, which will also encourage OCCS.

.3 Many ports are developing sustainability strategies that consider the reduction of GHG emissions within their port boundaries. As a result, some ports are planning to become energy hubs, which includes managing their energy sources (e.g. offshore wind, solar or tidal) and becoming self-reliant.

.4 As per Clarksons, LNG-operated tugboats are the most popular dual-fuel tugboats in the orderbook. The opportunities to adopt new-generation tugboats are increasing in ports that are committed to an emission reduction strategy.

.5 Cruise and ferries have shown a keen/the highest interest in OPS worldwide, and there are opportunities for OPS, especially for cruise and ferry terminals across the globe.

.6 There are considerable opportunities for manufacturers of port equipment for modification of existing equipment to include energy-saving measures or to retrofit them to use green fuels. Moreover, a new market is also developing for equipment getting operated on green fuels.

.7 The associated energy and cost savings with LED-based systems, make LED lighting on vessels or in ports an easy and important measure to reduce emissions.

.8 JIT offers the potential to reduce emissions, especially in ports that face congestion for vessels.

.9 There are opportunities to reduce carbon footprint in the construction of ports using low-carbon cement in concrete design, the use of green materials in place of concrete or steel, where appropriate, as well as the use of recycled plastic and tyres where possible. These will, in turn, increase the demand for these technologies and reduce costs for them due to economies of scale.

.10 LCA of bunkers will lead to regionalisation of bunker procurement. In addition, higher space requirements for low-/zero-carbon fuels on vessels may lead to more frequent bunkering. Therefore, bunkering hubs are expected to shift to new locations. This also offers opportunities for various States to establish themselves as bunkering hubs.

.11 The availability of CCS technology, long-term storage of CO_2, low cost of renewable energy and availability of gas reserves will be the key to deciding the opportunities for bunkering hubs.

.12 The potential for the development of multiple green corridors represents a significant opportunity. These green corridors would support the surrounding region develop better infrastructure and improve the availability of green fuels.

.13 Shipowners can reduce their carbon footprint by using low-/zero-carbon fuels to comply with the regulations.

.14 There are opportunities for various equipment and component manufacturers. For example:

- Fuel cell manufacturers;
- Battery manufacturers;
- Other emission reduction equipment including PIDs and ESDs manufacturers;
- LED lighting manufacturers
- Provision of swappable batteries services;
- Shipyards for installation of various PIDs and ESDs; and
- Upgrading/modifications to run an engine on 100% sustainable biofuels.

7.3 Recommendations

Proposed recommendations have a wide scope and require actions from all stakeholders, including shipowners, port authorities and CPs. They have been categorised accordingly.

7.3.1 Recommendations related to emission reduction measures from vessels

The recommendations related to emission reduction measures from vessels are as follows:

.1 A vessel depends on tug and pilot assistance from the port for berthing/unberthing. Effective coordination among the ship crew, ship agent and port authorities can ensure that such assistance is made available to the vessel on time, ensuring quick turnaround. Since crew changes as well as delivery of essential supplies and spares are mainly done at port, efficient and advanced liaising with ship agents as well as other stakeholders can ensure that these activities cause no delay to the departure schedule of the vessel. Systems like the digital port connection may be considered for better coordination and efficiency in the Mediterranean region.

.2 When a vessel berths at a port, it can be subjected to several inspections from third parties such as customs, port State controls, flag States, classification societies, and various other service providers. Various port clearance portals and data platforms could help vessels to streamline these inspections, therefore, saving time and reducing emissions in ports of the Mediterranean coastal States.

.3 Vessels should consider having a riding team to carry out maintenance, when possible, which would result in reducing the time required at anchorage/repair berths causing less emissions in the Mediterranean region.

.4 Various emission reduction measures can be adopted by vessels and should be explored by shipowners operating in the Mediterranean region. These include:

- Efficient management of bow thrusters;
- For refrigerated cargo operations on board, measures such as automated temperature management and smart refrigerant systems help save energy;
- VFDs in ship crane motors for energy saving; and
- LED lighting on vessels.

7.3.2 Recommendations related to emission reduction measures in ports

The recommendations related to emission reduction measures in ports are as follows:

.1 While acquisition costs for electric and hybrid tugboats are high, there are savings in fuel and maintenance when considering it on a life cycle basis. Therefore, ports of the Mediterranean coastal States should consider investing in green tugboats.

.2 Ports of the Mediterranean coastal States should include advanced ship-to-shore cranes, new generation RTG, hybrid model SC, fuel-cell powered forklifts, low-emission locomotives, etc.

.3 Ports of the Mediterranean coastal States should opt for LED technology to improve energy efficiency.

.4 As shipping companies are interested in developing JIT, port authorities of the Mediterranean coastal States should coordinate amongst all stakeholders of a ship's call, including the terminal, to implement a system based on available digital tools to achieve JIT berthing.

.5 Ports of the Mediterranean coastal States should explore making use of platforms like the “Digital Port Call” that is being implemented at the Port of Gothenburg (Sweden).

.6 In ports, where vessels tend to stay longer than a reasonable time after the completion of cargo operations, an overstay dockage policy should be considered in ports of the Mediterranean coastal States, which will also reduce the emissions from vessels at berth.

.7 Ports of the Mediterranean coastal States with large numbers of pilotage movements could consider leveraging smart technologies to reduce delays in the arrival of pilots and therefore reduce emissions.

.8 DUKC is useful in tidal ports and helps in reducing the emissions per ton of cargo. Therefore, such ports of the Mediterranean coastal States should explore these types of systems to reduce emissions.

.9 Auto mooring system should be considered in the Mediterranean region for terminals with vessels having short port stays and many vessels calling the terminal.

.10 Risk assessments should be undertaken by ports of the Mediterranean coastal States for the following:

- Allowing main engine immobilisation at berth considering the weather conditions.
- Permitting bunkering, provision supply and other such activities to lower emissions during port stay.
- Analysing harmful impact on the marine life of the local area due to hull cleaning and propellor polishing, carried out preferably at berth or else at anchorage.

.11 Newly developed solar cells based on the highest efficiency thin–film technology are now available and could be installed where rigid glass modules cannot function efficiently. This makes it possible to add solar energy generation to low-load capacity roofs, structures such as carports and storage facilities, amongst others. Ports of the Mediterranean coastal States with a high projection of sunlight around the year should consider installing new-generation solar cells.

.12 Any port expansions in the Mediterranean region should be done, with sustainable construction methods to reduce carbon impact.

.13 The inclination towards combatting climate change, switching to low-/zero-carbon fuel, reducing GHG emissions as well as achieving a cleaner environment with zero carbon footprint requires the CCUS value chain to be developed. Industrial usage of CO_2 and its importance as a key member in attaining zero emissions make CCS, OCCS and Liquid CO_2 infrastructure, including terminals, important requirements in the future. Such facilities should be given financial assistance. Therefore, CCS projects have been increasingly prevalent as many countries aim to reduce carbon emissions. Ports in Mediterranean coastal States should closely monitor the development of LCO_2 trade and can consider entering the carbon value chain business, such as operating CO_2 terminals or providing CO_2 storage facilities.

7.3.3 Recommendations related to policy and regulatory measures

The recommendations related to policy and regulatory measures are as follows:

.1 Local emission regulations should be reviewed by Mediterranean coastal States that are not EU Member States and should be aligned with the EU ETS as far as possible.

.2 The use of low-emission fuels is the principal strategy, which is implemented in maritime transport to reduce emissions. However, for this to be possible, there should be enough bunkering facilities in the ports of the Mediterranean coastal States and they should be adequately spread throughout the routes. Often, a detailed risk analysis is necessary for ports involved in the creation of green shipping corridors due to the risks commonly associated with the adoption of low-emission fuels (e.g. methanol, ammonia, etc.).

.3 Establishing green corridors in the Mediterranean region will require not only individual efforts from numerous stakeholders involved but also collaborative action from the entire maritime shipping ecosystem. Stakeholders such as port authorities and fuel producers can integrate low-/zero-carbon fuel production plants within green corridor port infrastructures to improve efficiency in the green corridors.

.4 A feasibility study should be conducted for specific green corridors to dive deeper into understanding the needs and requirements of infrastructure, policy and finance to build a more solid political case for the green corridors in the Mediterranean region.

.5 The infrastructure cost associated with the installation of OPS facilities can be high. Therefore, grants from various organisations and national governments of Mediterranean coastal States should be given to the ports for their installation.

.6 The concession agreements between the port authorities and the terminals of the Mediterranean coastal States should be amended to include OPS.

.7 Existing energy legislations of some Mediterranean coastal States may need to be changed to allow the ports to manage their energy sources (e.g. offshore wind, solar or tidal) and its distribution.

.8 Port authorities of the Mediterranean coastal States should consider providing electricity to vessels at rates that are cheaper than the cost incurred by the vessels, till the time this becomes mandatory. This will not only encourage the usage of OPS facilities of the ports and reduce emissions but will also motivate the ship owners to fit OPS reception capabilities earlier than the time required by the regulations.

.9 In case multiple vessels use OPS, there is a potential for energy demand imbalance; therefore, the electric grid requirement of the terminals in ports of the Mediterranean coastal States should be increased by about five to six times to handle such loads.

.10 Port authorities of the Mediterranean region should give discounts to vessels having onshore power, even if the port does not have onshore power infrastructure. This may motivate ship owners to fit OPS reception capabilities earlier than the time required by the regulations.

.11 As data sharing is a big concern worldwide, countries are reluctant to share information. A neutral third party could work on bringing relevant stakeholders of the Mediterranean region on a common ground as a facilitator for a fast step towards decarbonisation.

.12 Mediterranean coastal States should review their laws related to data sharing and modify them as required so that information-sharing platforms can be developed and used.

.13 Port authorities of the Mediterranean region should give discounts in port dues to vessels running on low-/zero-carbon fuels. This will incentivise the efforts of first movers and motivate more ship owners to make the switch to low-/zero-carbon fuels.

.14 Ports of the Mediterranean coastal States should adopt speed reduction policies as done by some benchmarking ports.

7.3.4 Recommendations related to other measures

The recommendations related to other measures are as follows:

.1 Mediterranean coastal States should educate the various stakeholders and train the required staff to make them fully aware of green transition underway and take action accordingly.

.2 Access to grants and finance should be increased for green initiatives in the Mediterranean region.

8 Roadmap and action plan for the implementation of emission control and energy efficiency measures for ships in port areas in the Mediterranean region

Emission reduction in the ship-port interface raises certain challenges and opportunities. Mediterranean coastal States can collectively work towards a more sustainable and environment-friendly shipping industry by leveraging opportunities for regional cooperation, investment in cleaner technologies, and development of green infrastructure, in addition to enhanced monitoring and reporting, capacity-building, and international collaboration.

The recommended roadmap and action plan are presented in the table below.

Table 8.1 Recommended roadmap and action plan for the implementation of emission control and energy efficiency measures for ships in port areas in the Mediterranean region.

Timeline	Area / Type	Recommended action	Responsibility
Short-term	Vessels	Shipowners operating in the Mediterranean region should consider having a riding team to carry out maintenance when possible; this would reduce the time required at anchorage/repair berths, causing less emission.	Shipowners
	Ports	Port authorities of the Mediterranean coastal States should include an 'overstay dockage policy' for vessels staying longer than a reasonable time.	Port authorities
	Ports	Port authorities of the Mediterranean coastal States with large numbers of pilotage movements should consider leveraging smart technologies to reduce delays in pilot arrivals.	Port authorities
	Ports	Port authorities of the Mediterranean coastal States should conduct a risk assessment for hull cleaning and propellor polishing at berth or at anchorage.	Port authorities
	Ports	Port authorities of the Mediterranean coastal States should conduct a risk assessment of weather conditions to allow main engine immobilisation for maintenance jobs, bunkering, provision supply, etc.	Port authorities
	Policy and regulatory	Port authorities of the Mediterranean coastal States should give discounts to vessels running on low-/zero-carbon fuels and those fitted with OPS.	Port authorities

	Policy and regulatory	Port authorities of the Mediterranean coastal States should consider providing electricity to vessels at rates cheaper than the cost of energy incurred by the vessels.	Port authorities
	Others	CPs should take the initiative to educate the various stakeholders and train the required staff to make them fully aware of green transition underway and take action accordingly.	CPs

Timeline	Area / Type	Recommended action	Responsibility
Mid-term (till 2030)	Vessels	Shipowners operating in the Mediterranean region should consider emission reduction measures such as efficient management of bow thrusters and automated temperature management for refrigerant cargo operations, VFDs in the ship's crane and LED lighting.	Shipowners
	Vessels and Ports	Shipowners operating in the Mediterranean region (notably cruise and ferries) and port authorities of the Mediterranean coastal States should consider implementing OPS for all ports, as appropriate.	Shipowners and Port authorities
	Ports	Port operators of the Mediterranean coastal States should consider investing in green tugboats.	Port operators
	Ports	Port operators of the Mediterranean coastal States with a high projection of sunlight should consider carrying out solar power generation in ports.	Port operators
	Ports	Terminal operators of the Mediterranean coastal States should invest in new generation RTG, hybrid model SC, fuel-cell powered forklifts, low-emission locomotives, LED technology, etc.	Terminal operators
	Ports	Port authorities of the Mediterranean coastal States should consider systems like 'Digital port connection' for efficient port calls to facilitate effective coordination between stakeholders.	Port authorities
	Ports	Port authorities of the Mediterranean coastal States should coordinate with shipowners and other stakeholders to include JIT for efficient berthing.	Port authorities and Shipowners

	Ports	Port authorities of the Mediterranean coastal State should consider port clearance portals and data-sharing platforms for efficient port calls.	Port authorities
	Ports	Port authorities in tidal ports of the Mediterranean coastal States should explore the use of DUKC systems to reduce emissions.	Port authorities
	Ports	Terminal operators of the Mediterranean coastal States should explore auto mooring system for fast berthing/unberthing prospects.	Terminal operators
	Ports	Port authorities of the Mediterranean coastal States should take the lead in emission reduction.	Port authorities
	Ports	Port authorities of the Mediterranean coastal States should adopt speed-reduction policies to reduce emissions.	Port authorities
	Policy and regulatory	Local emission regulations should be reviewed by Mediterranean coastal States that are not EU Member States and should be aligned with the EU ETS as far as possible.	CPs
	Policy and regulatory	The infrastructure cost associated with the installation of OPS facilities can be high. Therefore, grants from various organisations and national governments of Mediterranean coastal States should be given to the ports for their installation.	CPs
	Policy and regulatory	Mediterranean coastal States should review their laws related to data sharing and modify them as required so that information-sharing platforms can be developed and used.	CPs
	Policy and regulatory	A neutral third party could work on bringing those stakeholders of the Mediterranean region on a common ground as a facilitator for a fast step towards decarbonisation.	CPs

Timeline	Area / Type	Recommended action	Responsibility
Long term (beyond 2030)	Vessels and Ports	Industrial usage of CO_2 and its importance as a key member in attaining zero emissions make CCS, OCCS and liquid CO_2 infrastructure, including terminals, an essential requirement in the future. Such facilities should be adopted in the Mediterranean region by all relevant stakeholders.	Shipowners, Port authorities and CPs
	Policy and regulatory	Green corridors require supporting policies and collaboration amongst all stakeholders. All stakeholders should work together to make green corridors in the Mediterranean region while CPs should take the initiative.	CPs, in cooperation with relevant stakeholders
	Policy and regulatory	The concession agreements between the port authorities and the terminals of the Mediterranean coastal States should be amended to incorporate OPS.	Port authorities

Timeline	Area / Type	Recommended action	Responsibility
Ongoing	Others	Efforts should continue to increase the demand and supply of green fuels and reduce their costs in the Mediterranean region.	All stakeholders
	Others	Access to grants and finance should be increased for green initiatives in the Mediterranean coastal States.	CPs, port authorities, national and international financial institutions
	Others	Cooperation and collaboration between relevant stakeholders are continuously required to help reduce emissions in the Mediterranean region.	All stakeholders

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