



Port Reform Toolkit

3rd Edition

Module 8

Environmental Sustainability

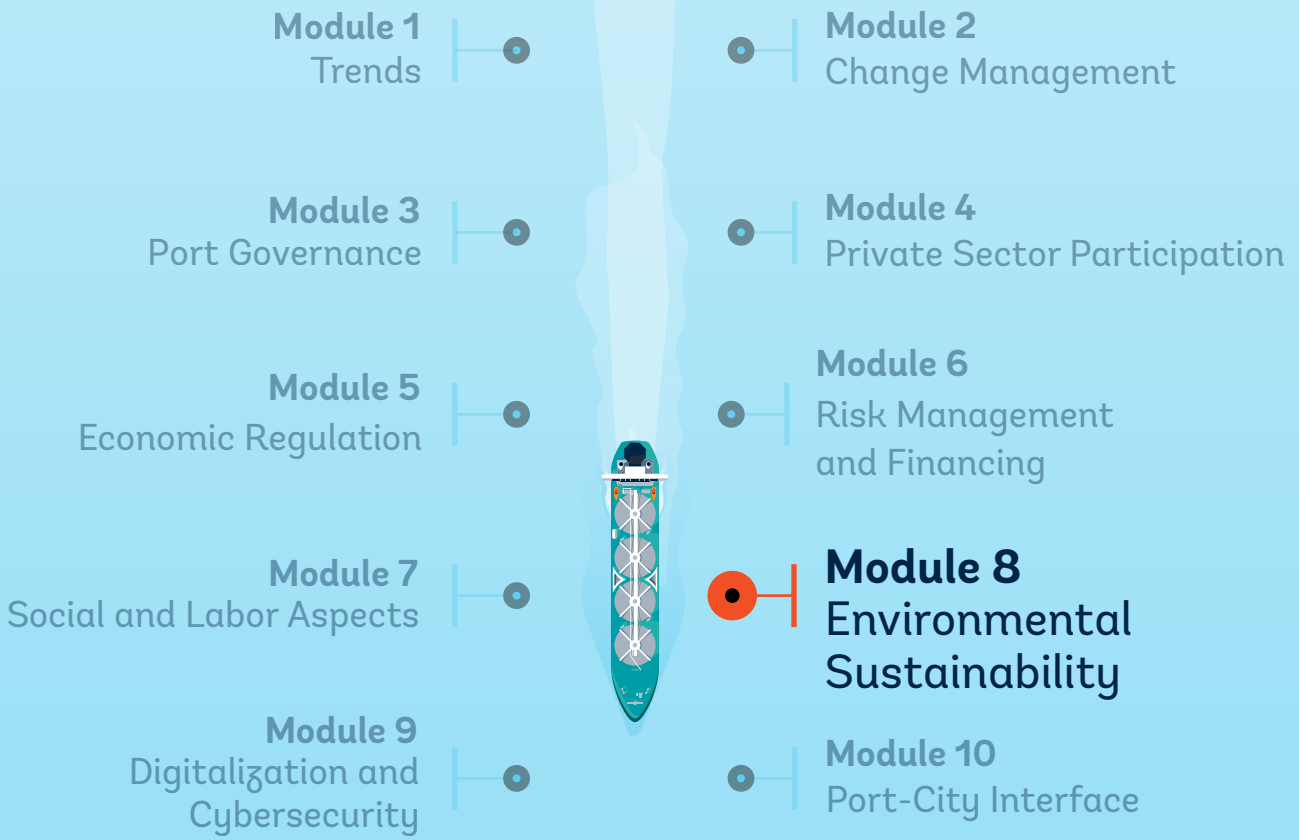


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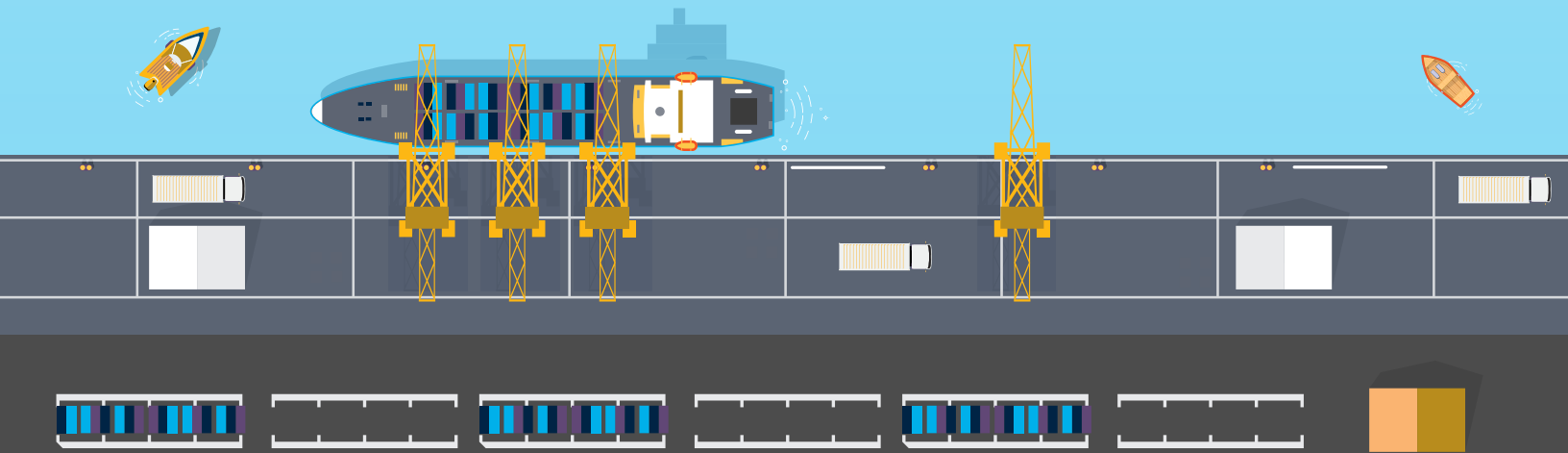
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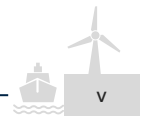


This module provides an overview of natural environment- and climate-related issues in ports to ensure environmental sustainability of port infrastructure and operations. It provides a roadmap to identify, measure, and implement a comprehensive, yet still non-exhaustive list of actions to improve the environmental and climate performance of ports.



Module 8

Environmental Sustainability



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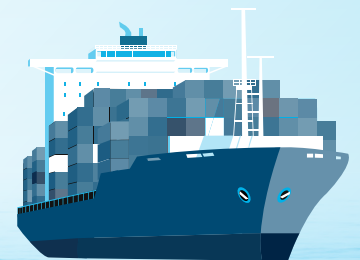
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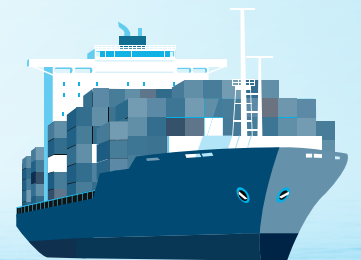
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Abbreviations

AAPA	American Association of Port Authorities
ANSI	American National Standards Institute
API	Application Programming Interface
AR6	Sixth Assessment Report
ASA	Acoustical Society of America
CCUS	Carbon Capture, Utilisation and Storage
CDP	Climate Disclosure Project
CICT	Colombo International Container Terminals
CII	Carbon Intensity Indicator
CIP	Inter-American Committee on Ports
CO	Carbon Monoxide
CO₂	Carbon Dioxide
CO₂e	Carbon Dioxide Equivalent
CSRD	Corporate Sustainability Reporting Directive
DP	Dry Ports
EC	European Commission
ECA	Emission Control Area
EEDI	Energy Efficiency Design Index
EEXI	Efficiency Existing Index
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management System
EnviCom	Environmental Commission
ESF	Environmental and Social Framework
ESG	Environmental, Social and Governance
ESI	Environmental Ship Index
ESPO	European Sea Ports Organisation



ESS6	Environmental and Social Standard 6
ETS	Emissions Trading System
EU	European Union
FAL Convention	Convention on Facilitation of International Maritime Traffic
FAO	Food and Agricultural Organization
FEMA	Federal Emergency Management Agency
GBIF	Global Biodiversity Information Facility
GHG	Greenhouse Gas
GLEC	Global Logistics Emissions Council
GP	Green Procurement Strategies
GRI	Global Reporting Initiative
GWP	Global Warming Potential
IAPH	International Association of Ports and Harbours
ICS	International Chamber of Shipping
IFC	International Finance Corporation
IMO	International Maritime Organization
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KPI	Key Performance Indicator
KPIZ	Khalifa Port and Industrial Zone Project
LCA	Life Cycle Assessment
LED	Light Emitting Diode
LNG	Liquefied Natural Gas
MARPOL	International Convention for The Prevention of Pollution from Ships
MMGS	Measure, Monitor and Goals Setting
N₂O	Nitrous Oxide

NDCs	National Determined Contributions
NGO	Non-Governmental Organization
NO_x	Nitrogen Oxide
OAS	Organization of American States
OPS	Onshore Power Supply
PA	Port Authority
PAF	Provide/Procure Alternative Fuels for Port Users
PAH	Polycyclic Aromatic Hydrocarbons
PE	Produce Electricity
PERS	Port Environmental Review System
PGPD	Pricing Green Port Dues
PIANC	The World Association for Waterborne Transport Infrastructure
PM	Particulate Matter
PM10	Particulate matter with a diameter of 10 micrometers or less
POLA	Port of Los Angeles
POLB	Port of Long Beach
POWERS	Port Opportunities with Energy, Resilience, and Sustainability
PRI	Principles of Responsible Investing
PSC	Port State Control
PSM	Promote Sustainable Mobility and Community Awareness
PTGCC	Permanent Task Group on Climate Change
RPDFF	Review Port Development of Fossil Fuel Specialized Terminals
RTG	Rubber-Tired Gantry
SASB	Sustainability Accounting Standards Board
SDG	Sustainable Development Goal
SDM	Self-Diagnosis Methodology
SEEMP	Ship Energy Efficiency Management Plan
SIDS	Small Island Developing State

SLCPs	Short-Lived Climate Precursors
SLTO	Social Legitimacy or Social License to Operate
SO₂	Sulphur Dioxide
SO_x	Sulphur Oxide
SS	Slow Steaming in Port Area
SWPPP	Stormwater Pollution Prevention Plan
TAG	Technical Advisory Group
TasPorts	Tasmanian Ports Corporation
TCFD	Task Force on Climate-Related Financial Disclosures
TRL	Technology Readiness Level
TTBT	Technological Transition Barges and Trains (Electric)
TTT	Technological Transition Trucks (Hydrogen)
TTTEE	Technological Transition Terminal Equipment (Electric)
TTTEH	Technological Transition Technical Equipment (Hydrogen or Other Energy Fuel)
TTW	Tank-To-Wake
UN	United Nations
UNCTAD	UN Trade and Development
UNGC	UN Global Compact
UV	Ultraviolet Radiation
VOCs	Volatile Organic Compounds
WHO	World Health Organization
WPCAP	World Port Climate Action Plan
WPSP	World Ports Sustainability Program
WTT	Well-To-Tank

Objective

The primary objective of this module is to provide comprehensive summary of the environmental issues in ports to ensure environmental sustainability of port operations. The second objective is to provide a roadmap to identify, measure, and implement a comprehensive, but non-exhaustive list of actions to improve the environmental performance of ports.

Abstract

The increasing threat of climate change and awareness of other environmental challenges, such as air pollution, water contamination, waste management, or ecosystems damages, has put additional pressure on port stakeholders to mitigate negative environmental externalities. They are increasingly expected to balance traditional objectives such as trade and traffic growth with the rising demand for greener ports.

In decarbonization, ports will play a role in three areas: decarbonizing their own port operations, facilitating the decarbonization of the shipping industry by providing the necessary storage and supply infrastructure to provide green bunkering fuel and onshore power to ships, and in supporting the national energy transition by importing, exporting, and/or supplying such green fuels to other industries.

At the same time, ports will also have to adapt to climate change, requiring both physical risk reduction solutions (hard solutions) and efforts to coordinate between actors, political will, and the presence of adequate institutional structures (soft solutions).

A schema is presented for port actors (for example, port authorities, ministries, environmental authorities, harbour masters, shipping companies and terminal operators) to start or continue developing an environmental sustainability strategy. The schema starts with an assessment of whether a port has an up-to-date environmental strategy and takes port actors through the different phases from establishing, monitoring, and reporting a baseline to prioritizing actions and programs and evaluating these against targets.

Key Recommendations

1. Optimize energy efficiency, promote electrification advancements, shift to less carbon intensive modes of transportation, and facilitate the transition to zero or near-zero GHG energy sources to meet climate change mitigation objectives.
2. Use decision matrices for assessing mitigation and adaptation risks and solutions in different implementation scenarios. In the adaptation context, for instance, each project should be assessed against the reduction of climate risk exposure, cost to reduce climate risk exposure, and the time to implementation.
3. Take advantage of a seven-phase roadmap to establish and implement an environmental program in ports. As ports operate in varying economic and social contexts, governance frameworks, and environmental settings (for example, exposure to climate change), strategies and outcomes will differ from port to port.

Introduction

The port sector is vital for a country's integration into and competitiveness within international trade networks. Ports are essential for developing economies, which handle a significant volume of global trade. They are also integral for low-income countries and Small Island Developing States (SIDS), which often depend disproportionately on maritime transport for international trade. As such, ports are key to the development agenda (World Bank 2023).

Traditional factors of port and trade competitiveness are the quality of services, infrastructure, and efficient hinterland integration. These factors are complemented by contemporary factors such as readiness for digitalization, decarbonization of port-related GHG emissions and maritime shipping, resilience to climate change, and environmental performance of operations.

Ports are a major growth sector in the world economy, given the growing levels of economic activity and investments. The port sector generates substantial revenues, employment and local value-added, and plays a significant role in shaping the performance of other industries and the wider economies that they serve. Ports must be adequately resourced in a physical sense, given their critical importance to economic development and social welfare. They should also be prepared to respond to the emerging changes in their environment.

At the same time, ports contribute to negative health impacts resulting from environmental externalities (Vega-Muñoz 2021) such as pollution and greenhouse gas emissions. Port authorities and terminal operators are becoming aware of these externalities and are starting to consider the mitigation of environmental issues as a competitive advantage for their terminals (Acciaro and Wilmsmeier 2015). In addition, issues such as transparency of the supply chain and strong awareness of the surrounding communities demand a new approach to sustainable development of port activities (Vega-Muñoz 2021).

Trade and traffic growth has posed significant challenges to port and governments across the globe in terms of infrastructure development, institutional frameworks, and policy strategies; the increasing threat of climate change; and other environmental challenges such as air pollution, emissions, noise, water contamination or ecosystems damages.

These factors create additional pressures for action to ensure the sector's medium and long-term sustainability and functioning. This pressure comes from environmental regulation at the International Maritime Organization (IMO) and the European Commission, port stakeholders, and port community concerns over the health impacts of port operations. A port's sustainability and social legitimacy or social license to operate (SLTO) can also be at stake if the bargaining power of local communities and the social dimension of the ports' activities is neglected (see Dooms (2010) and Module 10: Port-City Interface). Ports are increasingly differentiated by their ability to handle the latest generation of ships, the productivity levels achieved, and their institutional efficiency and effectiveness to respond to environmental challenges.

Given these increasing challenges and threats, port authorities and governments would benefit from external guidance. This support can help them develop and carry out strategies that keep ports running effectively while minimizing their environmental impact. The instruments and practices included in this module are relevant to various economic contexts and their connections to both current and emerging standards in the transport and logistics industry.

Environmental issues and their connection to sustainable development goals

This section provides an overview of the environmental issues in ports and their connection to the United Nations' Sustainable Development Goals (SDGs). The issues are drawn from surveys on the importance of various environmental sustainability issues in European and South Asian ports (ESPO 2024; Gupta and Prakash 2023) as described in Table 8.1.

Environmental issues include climate change, air quality, water quality, waste, light pollution, noise pollution, land use, and biodiversity. Environmental issues are affected by both landside and water-side port activities (that is, port operations and port development). For example, dredging is considered a water-side activity, as it removes sediment and debris from the bottom of the ocean. Land-side activities include projects like brownfield port development sites and land reclamation. Apart from land use, ships and onshore port activities contribute to all environmental issues.

The objective of environmental sustainability actions taken by ports should be to drive global sustainability. The 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly in 2015, provides a framework to measure the progress and efforts towards global sustainability across sectors and sustainability pillars (United Nations 2015). The UN SDGs aim at “eradicating poverty in all its forms and dimensions, combating inequality within and among countries, preserving the planet, creating sustained, inclusive and sustainable economic growth and fostering social inclusion” (United Nations 2015).

Table 8.1 Definition of environmental issues

Environmental issues	Description
Climate change	Ports can be affected by climate change through the rise of sea levels, changing wave patterns, and extreme weather events. Ports also contribute to climate change through emissions from land and waterside port activities (for example, shipping).
Air quality	Port operations relying on fossil fuels generate emissions that negatively impact air quality and pose risks to human health and the environment. Air pollution from port activities particularly impacts the port city because air pollutants have the most negative impact near the source.
Water quality	Port operations can cause significant damage to water quality, and subsequently to marine life and ecosystems, as well as human health. Major water quality issues include wastewater and leaking of toxic substances from ships, stormwater runoff, and dredging.

Environmental issues	Description
Waste	Ship and port waste is the waste produced by ships that arrive at port and the waste generated by port operations. Ship waste includes garbage, sewage, oil residues, and other operational waste. Port waste includes solid waste, hazardous materials, oily waste, and wastewater.
Light pollution	Artificial light alters the natural patterns of light and darkness in ecosystems. This light pollution comprises direct glare, chronically increased illumination, and temporary, unexpected fluctuations in lighting. It is caused by illuminated terminal areas, equipment, vessels, security lights, and lights on vehicles. This has harmful effects on plants, humans, and animals, especially nocturnal, migratory, and animals in flight.
Noise pollution	Ambient noise (from port equipment and trucks) and underwater noise (from the running of ships' auxiliary engines) impacts human health (for example, hearing impairments, high blood pressure) and adversely affects critical functions of marine life.
Land use	Land use management is an essential component of port and sustainability planning during the development or expansion of a port. It helps avoid detrimental impacts on the local community and habitats. Port development focuses on managing land use to optimize site utilization, minimize project footprints, redevelop urban and brownfield sites, and mitigate environmental impacts.
Biodiversity	Ports interact with sensitive marine and terrestrial ecosystems. If these ecosystems degrade, it can lead to a loss of critical habitats, reduced ecosystem services, and long-term negative impacts on local communities and port operations. Biodiversity is crucial for ports because it supports ecosystem resilience, enhances natural water purification, and maintains the ecological balance necessary for sustainable port operations.

Source: World Bank.

Ports play a key role in providing strategic infrastructure for development, and therefore, play an important role in attaining UN SDGs. They also create negative environmental externalities. The World Ports Sustainability Program (WPSP), managed by the International Association of Ports and Harbours (IAPH), is guided by all 17 UN SDGs; they are all considered important for the sustainable development of ports and their relation to society. This module focuses on the SDGs that are most directly linked to the issue.

It is crucial to recognize that port actions can simultaneously benefit multiple SDGs, as seen in Table 8.2. For example, ports can take mitigation and adaptation actions that improve infrastructure and thus contribute to SDG 13 – Climate Action. This also delivers towards SDG 9 – Industry, Innovation and Infrastructure and SDG 11 – Sustainable Cities, given the proximity of many ports to urban areas. Another example is the effort being taken to improve energy efficiency (via the climate change priority) and consumption (both energy and water), which directly contribute to SDG 12 – Responsible Consumption and Production. This might also align with SDG 7 – Affordable and Clean Energy; SDG 9 – Industry, Innovation and Infrastructure; and SDG 13 - Climate Action. These actions also contribute to the reduction of GHG emissions through electrification and the promotion of onshore power supply (instead of relying on auxiliary engines). Reducing the congestion in and around a port and improving the movement of cargo and people can boost city and community sustainability (SDG 11). This can also improve health by reducing accidents, noise pollution, and ambient air pollutants (SDG 3).

Table 8.2 SDGs and their relation to environmental issues

Environmental priorities and SDGs								
Air quality	✓			✓		✓		
Climate change			✓	✓	✓	✓		
Water quality	✓	✓		✓			✓	
Waste	✓	✓		✓	✓	✓	✓	✓
Light pollution	✓			✓				
Noise pollution	✓			✓				
Land use				✓	✓			
Biodiversity		✓					✓	✓

Source: World Bank, based on [UNSDGs](#).

Motivation and objectives

International organizations and countries have made big strides towards implementing new legislation and regulatory frameworks around environment and sustainability. This, coupled with the changing expectations of society, has created an environmental framework for ports to operate in. Many ports have been proactive with setting and addressing environment priorities, with some even initiating activities that go beyond environmental and climate regulations. The majority of ports, however, are lagging behind the current top-down requirements.

Transforming the sector requires ports to comply with existing global best practices and standards, and foster innovation, investment, and digitalization. These environmental priorities are now more important than ever to ensure ports remain operational and competitive in the long term.

Decision-makers must take into account that the port sector is highly diverse, encompassing various types of cargoes, geographical locations, ownership and management structures, and proximity to local populations, among other factors. Although the shipping sector responds to a global regulatory framework, ports operate and plan within national, regional, or even local regulatory environments. Thus, ports differ in their modes of operation, rates of evolution, and development pathways, as well as in their financial, organizational, and governance structures. To reduce environmental impacts and improve sustainable practices, organizations must use strategies that consider the local context.

This module addresses these factors by presenting a set of strategic elements to guide port actors — such as port authorities, ministries, environmental agencies, harbour masters, shipping companies, and terminal operators — as they begin or advance their environmental sustainability strategies.

The primary objective of this module is to provide a comprehensive summary of the environmental issues in ports to ensure environmental sustainability of port operations. It defines what each issue is and the existing tools, standards, and programs that have been implemented to address them.

This module also aims to provide a roadmap to identify, measure, and implement a non-exhaustive list of actions to improve the environmental performance of the port. This is complemented by examples from existing port initiatives that illustrate how each strategy could be applied in practice. This module is relevant for stakeholders inside and outside the port, such as port authorities, ministries, environmental authorities, harbour masters, shipping companies, and terminal operators, as well as other port related actors.



8.1 Environmental Sustainability Issues

This module discusses nine issues for the environmental sustainability of port operations in the following order: climate change, air quality, water quality, noise pollution, light pollution, waste, land use, and biodiversity. A detailed description of the environmental governance of these issues is not discussed in this module. Section 8.2 provides an overview of international shipping regulations that relate to some of these issues and the role of different stakeholder groups in influencing environmental governance of ports.

8.1.1 Climate change

Greenhouse gas emissions in ports

Ports are an interface between ships and hinterland transport or serve primarily as transshipment hubs. They are part of complex logistics chains that facilitate international or national trade, as well as passenger transport. To be well functioning, ports need to be connected to other modes (road, rail, inland shipping) of transport infrastructure to guarantee connectivity and accessibility to their hinterlands (especially for ports which are not transshipment hubs). The logistical role of ports and their interconnectivity creates greenhouse gas (GHG) emissions, primarily through the movement and operations of ships, trucks, and other transportation modes that facilitate the transfer of goods.

Box 8.1

General sources of greenhouse gas emissions

Carbon dioxide (CO₂) is a major source of greenhouse gas emissions. Non-CO₂ emissions that result in a radiative forcing (thus causing climate change) include Short-lived Climate Precursors (SLCPs) – methane, some fluorinated gases, ozone precursors, aerosols or aerosol precursors, such as black carbon and sulfur oxide – and long-lived greenhouse gases, such as nitrous oxide or some fluorinated gases (IPCC 2019).

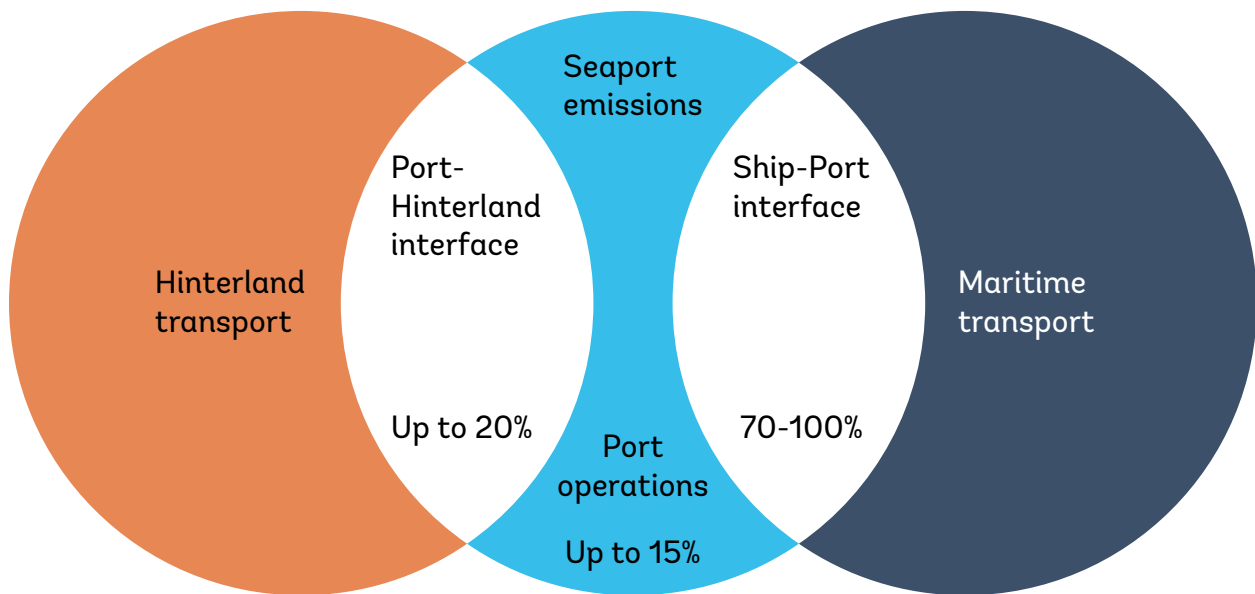
CO₂e (equivalent) is a unit of measurement designed to compare and aggregate the impact of all GHGs on global warming. It measures the 100-year Global Warming Potential (GWP) of GHGs and calculates the heat absorbed by any greenhouse gas for 100 years in the atmosphere as a multiple of the heat that would be absorbed by the same mass of CO₂ (IPCC 2019).

The shipping sector's total CO₂e emissions reached 1,076 million tons in 2018 (including methane [CH₄], nitrous oxide [N₂O], and CO₂), which represents almost 3 percent of global anthropogenic emissions (IMO 2021). GHG emission forecasts indicate that, by 2050, emissions will be between 90 percent and 130 percent of 2008 emissions (IMO 2021). Shipping emissions in ports represent around 2 to 6 percent of all shipping emissions (Merk 2014; European Commission 2021). While this represents a small share of the sector's emissions, ships contribute the highest share of emissions in ports. Reducing emissions from ships, therefore, is crucial (see Climate change mitigation solutions under Section 8.1.1).

Figure 8.1 shows that there are three components that contribute to GHGs in ports, namely, ships in the port area; trucks and other locomotives at the port-hinterland interface; and port equipment used for port operations.

Based on a literature review of academic studies on emissions in developed country ports compiled by Merk (2014), emissions from ships in port comprise 70 to 100 percent of total seaport emissions,¹ trucks and locomotives represent up to 20 percent, and port operations rarely exceed 15 percent. The composition is different in developing countries, however, where regulations on truck fuels are less strict and a larger share of the total emissions in ports is taken up by trucks and locomotives. For example, in the port of Mumbai, the NO_x emissions from port trucks are almost 20 percent higher than those from ships and PM10 emissions from trucks are 26 times higher than from ships (Joseph, Patil, and Gupta 2009).

Figure 8.1 Port emissions components for developed countries



Source: Adapted from Masodzadeh, et al. (2024), based on Merk (2014).

In most ports, road freight vehicles cause the largest share of emissions in port hinterland activities. Trains (diesel or electric) and barges usually have lower shares of emissions per unit transported (for example, containers or in tons) in these operations. The distribution of emissions from hinterland-related traffic depends on the modal split and technological advances of the available infrastructure and vehicles. Today, most heavy-duty road freight vehicles are operating with fossil fuel combustion engines.

Port congestion increased in 2021 due to the pandemic, which caused disruptions to supply chains and port operations, alongside increased ton-mile trade and higher steaming speeds in some shipping segments (UNCTAD 2022). Consequently, the functioning and performance of maritime logistics and value chains requires attention beyond the direct emissions from port operations.

¹ Emissions include non-CO₂ pollutants such as NO_x and PM, which by volume represent a small percentage of emissions compared to CO₂ for shipping emissions.

Allocating port emissions by scope

GHG emissions can also be categorized into three groups (or ‘Scopes’) within the Greenhouse Gas Protocol, the most widely used international accounting tool. In the port context, GHG emissions are categorized according to the IMO GHG Protocol as shown in Table 8.3.

Table 8.3 Emission scopes

Scope 1 (Direct emissions)	Scope 2 (Indirect emissions)	Scope 3
Direct GHG emissions from owned or controlled emissions sources of the port (such as terminal equipment, stationary engines), buildings associated with logistics sites (such as warehouses and port’s internal vehicles).	Indirect GHG emissions from generation of purchased energy for the port, that is, energy use for port logistics sites, owned assets or port operations.	Indirect GHG emissions that occur along the port value chain, for example, emissions from port users (ships, trains, trucks) or from third party contracted services and activities (for example, tug boats, pilotage vessels, dredgers), as well as the production and distribution of fuels associated with Scope 1 emissions.

Source: World Bank, based on Global Logistics Emissions Council (GLEC).

Direct emissions (Scope 1) are those generated from owned or controlled emission sources. For example, a terminal operator’s equipment and machinery used for handling and storing cargo or passengers within a terminal requires energy. The main energy sources used today by terminal operators are diesel, petrol, natural gas, and electricity. The GHG emissions from these activities that are under direct control of the port correspond to Scope 1 emissions.

Indirect emissions (Scope 2) are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling by a port entity, for example, a terminal operator or port authority. Although Scope 2 emissions physically occur at the facility where they are generated, they are accounted for in a port’s GHG inventory because they are a result of the port’s energy use.

Scope 1 and 2 emissions from port and port-related activities vary according to the type of cargo handled, the equipment used, and the productivity of port operations. To illustrate, handling refrigerated cargo is much more energy intensive than handling iron ore since the former requires cooled storage spaces or installations to connect refrigerated containers to the electricity grid (that is, using so-called reefer outlets).

The handling of a single dry container within a port can consume between five and 30 liters of equivalent diesel,² while a fully refrigerated container will consume two to three times more energy. Other factors, such as the terminal layout, the type of activity (for example, import, export, or transshipment), and operational factors such as vehicle maintenance and driver training, affect the specific energy consumption per unit handled.

As such, port-related GHG emissions can vary significantly from port to port, requiring detailed port-level GHG emissions accounting. The responsibility to address the reduction of Scope 1 and 2 emissions lies with the port authority and the terminal operators.

Indirect emissions from port users and third-party service providers (Scope 3) are also indirect emissions, but those not produced by the port itself. They differ from Scope 2 as they cover those emissions produced by third parties (for example, trucking companies) using the port or suppliers of services in the port (for example, pilotage services, dredging activities).

These GHG emissions are generated from port users in the maritime foreland³ (waterside operations of vessels); the port hinterland⁴ (landside transport operations to and from the port); port authority activities using third party services in their operations (for example, commuter services, air travel); and embodied emissions from construction activities (for example, physical upgrade, rehabilitation, or new construction).

Berthed ships often represent the largest source of greenhouse gas emissions at ports by running onboard diesel auxiliary engines for power while at dock. For a port with many tenants, Scope 3 emissions will likely be the largest source of emissions.

Tank-To-Wake (TTW) emissions are included in the Scope 3 calculations. However, TTW emissions derived from the fuels used in combustion are reported as Scope 1 emissions. Emissions for electricity used in the port's direct operations are reported as Scope 2 emissions. Well-to-Tank (WTT) emissions from fuel production are also accounted under Scope 3 (BIMCO 2025). Box 8.2 provides general formulas to calculate Scope 1 and Scope 2 emissions.

² See: https://repositorio.cepal.org/bitstream/handle/11362/40928/S1601301_en.pdf.

³ Maritime Foreland is defined as the areas that are under the jurisdiction of the port, for example, maritime access channels.

⁴ Port hinterland is defined as the direct transport activities to the port. For details, see <https://ghgprotocol.org/scope-3-calculation-guidance-2>.



Box 8.2

General formulas for calculating scope 1 and 2 emissions

Scope 1

$$CO_2e = \sum_1^n \left(fuel \text{ (kg)} \times fuel \text{ emission factor } \left(\frac{kg \text{ CO}_2e}{kg \text{ fuel}} \right) \right)$$

Scope 2

$$CO_2e = \sum_1^n \left(electricity \text{ (kWh)} \times electricity \text{ emission factor } \left(\frac{kg \text{ CO}_2e}{kWh \text{ electricity}} \right) \right)$$

The GHG Protocol defines 15 distinct reporting categories for indirect emissions. They are purchased goods and services; capital goods; fuel- and energy related activities (not included in Scope 1 or Scope 2); upstream transport and distribution; waste generated in operations; business travel; employee commuting; emissions from employee teleworking; upstream leased assets; downstream transportation and distribution; processing of sold products; end-of-life treatment of sold products; downstream leased assets; franchises, and investments.

These categories provide a systematic framework to measure, manage, and reduce emissions across a port's value chain and are intended to avoid double counting emissions.

It should be noted that the relevance of these categories will vary according to a port's business. For a detailed description, minimum boundaries, and examples, please refer to the Technical Guidance for Calculating Scope 3 Emissions (World Resources Institute and World Business Council for Sustainable Development 2013).

In theory, the boundary of Scope 3 emissions can be global (for example, including the ocean voyages of ships), or limited to the port's administrative boundary (IMO 2019). The EU and some other ports (for example, in North America) have extended the port's administrative boundary to address port-related emissions control policies and to track progress.

The Port of Los Angeles (POLA) and Port of Long Beach (POLB) have incorporated the South Coast Air Basin air quality modelling geographic domain. This allows both ports and regulatory communities to use their emissions inventories to develop port-related emissions control policies and track their progress. For example, for ocean-going vessels, the area outside the Port of Los Angeles' administrative boundary extends approximately 70 nm westward, forming a four-sided zone that reaches the edge of California's water boundary (The Port of Los Angeles 2021).

Climate change mitigation solutions

Solutions to mitigate GHG emissions under Scope 1 include the transition of terminal equipment towards zero or near-zero emissions technology (for example, the technological change from fossil fuels to zero emission energy sources). Another solution is the eco-driving of yard transport equipment (for example, forklift trucks, straddle carriers, RTG crane), which require behavior training for drivers or qualification programs. This results in reduced fuel consumption, increased efficiency, and a reduction of GHG emissions.

Solutions to mitigate GHG emissions under Scope 2 include more energy efficient terminal equipment that use electricity or synthetic e-fuels. Further, low or zero electricity procurement needs to be in place to ensure that the terminal's demand for electricity is met. Alternatively, ports can use their facilities to produce their own clean energy.

Solutions to mitigate GHG emissions under Scope 3 involve hinterland and foreland connections, and options for a modal shift to low-carbon inland transportation such as rail or inland waterways. A technological transition towards hydrogen or electric vehicles is underway, but a general rollout of these technologies is expected to take place over the next two decades.

Inland waterway transport consists almost entirely of barges that are diesel-fueled. Decarbonization initiatives that use technology to transition barge operations towards hydrogen or electric propulsion are advancing. These are starting to appear on the global market and in emerging economies.⁵ Electrification has been made available and implemented widely in rail passenger transport for decades but has been lagging in rail freight operations in many countries.

Shifting port hinterland transport from road freight towards barge and rail operations — particularly long-distance transport — still holds strong potential to reduce emissions. This potential depends, however, on how each mode can develop and how quickly zero or near-zero GHG emissions technologies are adopted across all transport modes in a given country.

Technological upgrades, operational measures, fleet maintenance, and optimization can be adopted to reduce Scope 3 emissions. Introducing slow steaming, operational measures (for example, optimized vessel traffic management systems) and technical measures (for example, alternative fuels, onshore power supply) can reduce GHG emissions from vessels entering and leaving the port.

The ongoing digital transformation of ports and the shipping industry presents a powerful opportunity to enhance emissions reduction strategies. Digitalization enables better coordination and collaboration between port stakeholders by leveraging real-time data, predictive analytics, and automation. This leads to greater efficiency, improved planning, and lower emissions (for a detailed analysis on the topic please refer to Module 9: Digitalization and Cybersecurity). Box 8.3 includes an overview of port call optimization that aims to reduce emissions through better coordination between ships and port managers.

⁵ For an analysis of the fuel substitution of the river transportation system of Paraguay, see: https://biblioteca.olade.org/cgi-bin/koha/opac-detail.pl?biblionumber=14771&query_desc=au%3A%22Wilmsmeier%2C%20Gordon%22.

Box 8.3**FAL Convention and port call optimization**

The Convention on Facilitation of International Maritime Traffic (FAL), established by the IMO, aims to prevent delays in maritime traffic, promote government cooperation, and ensure uniformity in formalities and procedures for international shipping. It defines internationally agreed initiatives to facilitate maritime trade and recommends measures for implementation. A key requirement of the FAL Convention is that national governments adopt electronic information exchange between ships and ports. It also mandates the use of a Maritime Single Window (MSW) — a single digital portal for submitting information on ship arrivals, stays, and departures to reduce duplication and enhance efficiency.

An important application of the FAL Convention is port call optimization, a strategy gaining attention due to its potential to reduce emissions and lower costs. Currently, most ports do not optimize port calls, leading to the “sail fast, then wait” practice — where ships travel at high speeds only to wait at anchor before entering port. Studies show that ships spend up to 9 percent of their time in anchorage (IMO 2022). For example, a study by Marine Traffic (2022) showed that containerships can reduce fuel consumption and resulting carbon emissions by up to 14% on a per voyage basis using Just-in-Time arrival, a key port call optimization strategy.

To address this inefficiency, all stakeholders (for example, ship masters, terminals, and port authorities) must electronically exchange information to report standardized timestamps for ship activities within ports. The IMO’s Global Industry Alliance (GIA) recommends using digital reporting to synchronize operations and enhance coordination by incorporating these timestamps into the FAL Convention. The MSW further streamlines this process by simplifying data exchange between all parties.

Energy efficiency

The measurement of energy consumption in port terminals has intensified due to fluctuating costs and direct links to GHG emissions. Consequently, port authorities, terminal operators, shipping lines, and shippers are striving to reduce their energy footprint. This effort is crucial for enhancing sustainability, efficiency, competitiveness, and revenue.

Energy security is a top issue on the political agenda of various countries. There is an emerging awareness of energy efficiency for reducing energy consumption. Port authorities and terminal operators are also aware of the challenges associated with improving energy efficiency, as they are increasingly concerned with their emission profiles (Wilmsmeier and Spengler 2016). Some worldwide terminals periodically report energy consumption and GHG emissions (see Section 8.3.3 on emissions reporting). There is a lack of global Key Performance Indicators (KPIs) that allow benchmarking of different terminals across countries. This is urgently needed, given that the emissions of this sector are expected to rise in the future as freight transport is anticipated to expand further over the following decades (Acciaro and Wilmsmeier 2015).

Authorities have adopted strict environmental regulations to limit pollutants and GHG emissions arising from energy consumption. Lawmakers have also designed strict environmental rules to control pollutants and GHG emissions from energy consumption to transition from a carbon-intensive port model to a low-carbon port industry.

There has been growing interest in measuring, tracking, and controlling energy consumption and GHG emissions in different industries. This has led to the development of various instruments and methodologies for calculating energy consumption and estimating associated GHG emissions. In the port industry, methodologies and tools must be specially designed for the context in which ports operate. This requires detailed data on energy consumption in ports, as well as a breakdown of that data according to different activity clusters, equipment, and operational activities.

Measuring the impact of the energy efficiency methods introduced in ports and terminals becomes a challenge due to the sheer number of terminals and the complexity of the problem. There is a consistent information gap on energy consumption associated with the handling of goods that flow through the world's ports. This results in an unclear picture of the current total GHG emissions and carbon footprint (Iris and Lam 2019). Collecting, analyzing, and updating this information is critical for decision-makers when deciding how to make ports and terminals more energy efficient and accountable without undermining their competitiveness and cost-efficiency.

The role of ports in contributing to decarbonization

In its Sixth Assessment Report (AR6), the Intergovernmental Panel on Climate Change (IPCC) (2022) highlighted that GHG emissions have reached the highest levels in human history. Despite ongoing efforts, the world is still falling short of the targets set in the Paris Agreement. Current progress is not on track to limit global warming to well below 2.0°, or to aim for 1.5°C by 2050.

Ship and cargo operations in ports are still predominantly based on fossil fuels. Ports, like all other sectors, need to strengthen and ramp up initiatives to reduce GHG emissions to reach carbon neutrality by 2050, as decided in the Paris Agreement.

In 2023, the IMO unanimously adopted the 2023 IMO Greenhouse Gas Strategy. Member states agreed to reach net-zero GHG emissions from international shipping by around 2050, with interim checkpoints in 2030 and 2040 to steadily reduce emissions. In addition, they agreed to make zero- or near-zero GHG energy, fuels, and technologies amount to 5 to 10 percent of shipping's energy mix by 2030. In 2025, member States agreed to combine a technical measure – a pair of Greenhouse Gas Fuel Intensity (GFI) targets determined so far until 2035– with an economic measure – a charge on each ton of emissions above the target GFI each year. Ports will play a vital role in decarbonization in three key areas:

- Port emissions: Facilitate the decarbonization of port operations
- Maritime transport emissions: Facilitate decarbonization of the shipping industry by providing storage and supply infrastructure to offer green bunkering fuel to ships
- National energy transition: Facilitate the decarbonization of the national energy system by importing, exporting, or storing green energy sources, and/or having industries clustered in the vicinity of ports that help facilitate the energy transition. Furthermore, ports can also facilitate renewable power generation

The first area requires a technological transformation in the equipment operated by the port and its users. The second area will require changes in the energy sources that ports provide to ships (for example, the production of electricity, green hydrogen, green ammonia, and green methanol). Shifting from fossil fuels to green energy sources will make fossil fuel-related infrastructure derelict. New port infrastructure will be required to support the trade of alternative fuels, leading to redevelopment and new development needs.

Port infrastructure plays a crucial role in supporting the national energy transition by serving as the entry point for importing and storing green energy sources, thereby aiding in the decarbonization of on-land industries. The transition of global economies towards zero or near-zero GHG economies and the related decoupling of economic growth from fossil fuel consumption will necessitate changes in the energy handling needs of ports. This includes producing, procuring, storing, and/or providing energy.

Ports play a significant role in national and international energy value chains as receivers or senders of energy-carrying vessels. Currently, this may refer to fossil fuels, but in the future, it could be hydrogen, ammonia, or methanol. Ports also store and provide energy sources and as fuels to the maritime transport sector. The highly embedded role of ports in the energy sector and its transformation will directly and indirectly impact the climate change mitigation efforts in ports and the related shipping and logistics sectors.

The key role of ports as emitters of GHGs and facilitators of global energy trade put them at the heart of the climate action agenda. Yet, few countries have specific port-related targets as part of their National Determined Contributions (NDCs) under the Paris Agreement. In most cases, the port sector is grouped together within the transport sector as a whole. Nevertheless, some port authorities, such as Belfast Harbour, have set net-zero targets by 2030 for emissions of assets directly controlled by the port. It is expected to reach net-zero well before its target (Belfast Harbour 2024). At a national level, India developed a new Green Port Policy motivated by its NDC. That policy sets out targets for ports to “green” their operations (less GHGs and environmental impacts).

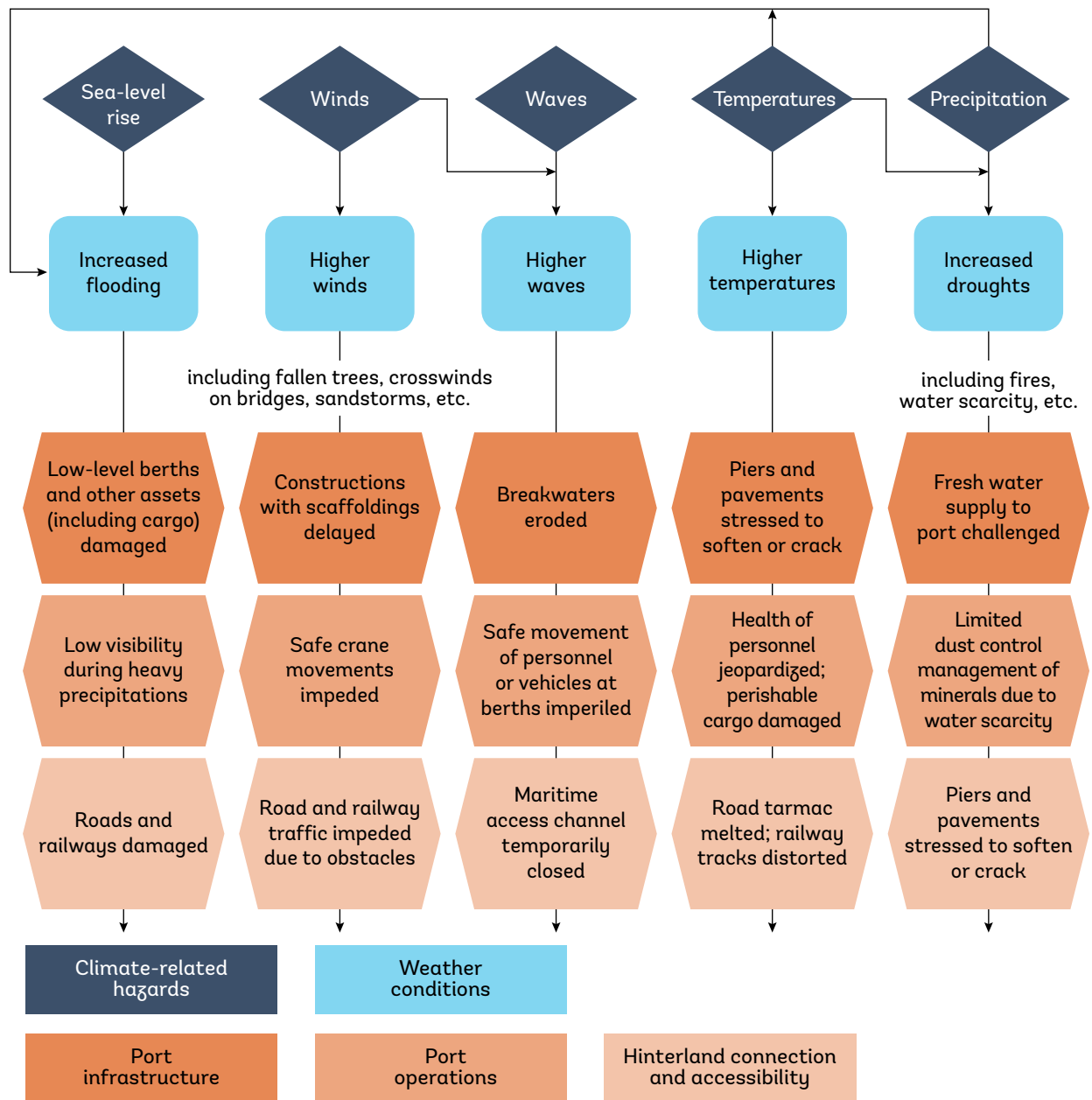
Adaptation

Ports are facing challenges and impacts as a result of climate change. Seaports are vulnerable to extreme weather events and natural disasters due to their coastal and riverine location. Sea level rise can cause permanent inundation of low-lying port areas. An increase in the frequency and intensity of extreme events, such as storm surges, extreme precipitation, heatwaves, and tropical storms, disrupt operations and damage infrastructure. Sedimentation, salinization, and acidification due to increasing CO₂ emissions pose a threat to biodiversity in and around ports.

Five climate-related hazards that particularly impact ports are sea-level rise, temperature, precipitation, waves, and wind. These hazards can affect ports through both infrastructure damage and operational disruption, which may have different expected impacts over the decades to come. Figure 8.2 provides an overview of these hazards, the weather conditions they cause, and examples of impacted ports. It illustrates the impact of reduced precipitation; however, increased precipitation is also a climate-related hazard, causing fog and limiting visibility within the port.⁶

⁶ For an overview of climate risks, see: <https://www.preventionweb.net/understanding-disaster-risk/risk-drivers/climate-change>.

Figure 8.2 Effects of natural hazards on ports



Examples of specific impacts on ports

Source: World Bank.

Sea level rise

Human-caused global warming is responsible for the ongoing rise in global sea levels. This poses a significant threat to low-lying port areas as it can lead to permanent inundation of low-lying terminals. The rise in sea levels contributes to the higher occurrence and greater intensity of storm surges, which can cause extensive damage and force ports to remain closed for extended periods of time (Asariotis 2021).

The consequences of these phenomena include the destruction of port terminals, equipment, cargo, and storage areas due to coastal inundation. This incurs a surge in expenses towards the protection of infrastructure, operational delays, and a rise in insurance premiums. Coastal roads and railways suffer structural damage, rendering them inoperable and disrupting truck and train operations in the port's surrounding area.

Extreme temperature and droughts

Higher mean temperatures, heat waves, and fluctuations in temperature extremes present significant obstacles to coastal transport infrastructure and operations. High temperatures can melt the tarmac, which affects the functionality of port infrastructure and impacts working conditions in ports. The increased occurrence and prolonged duration of droughts, attributed to decreased seasonal rainfall and high temperatures, can have adverse effects on water levels in inland waterways, canals, and ports. Insufficient rainfall reduces water levels to below the minimum depth necessary for safe navigation. This either leads to the non-navigability of inland waterways or necessitates the reduction of vessel loads to ensure safe passage (Christodoulou, Christidis, and Bisselink 2020).

Extreme precipitation

Extreme rainfall poses a significant risk of flooding. It subsequently damages ports in two distinct ways. Firstly, when the intensity of rainfall surpasses the capacity of infiltration, it leads to pluvial flooding. Secondly, high water levels in river channels can exceed the heights of riverbanks or even result in dike breaches, resulting in fluvial flooding (Tanaka, Kiyohara, and Tachikawa 2020). Both forms of flooding harms port infrastructure and operations. Floods, whether from coastal or inland sources, hinder safe access to ports and result in damage or loss of goods. Flash floods pose a particular threat as they can cause structural damage and disrupt port, rail, and road operations by washing away roads, bridges, and rail embankments (UNCTAD 2020). This negatively impacts the efficiency and reliability of railroads and leads to equipment failures in port terminals. Inefficiently designed drainage systems are prone to overflowing during extreme precipitation events, causing issues with tunnels and damaging earthworks and culverts.

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Winds and waves

The rising sea levels are occurring concurrently with an escalation in the severity of hurricanes, typhoons, and tropical cyclones. These extreme weather events exhibit heightened energy levels, slower movement, and greater precipitation, thereby amplifying the strength of storm surges. This surge in intense coastal storms poses a considerable risk to the infrastructure of ports.

Table 8.4 Safe operating thresholds in ports during selected weather conditions exacerbated by climate change

Weather conditions exacerbated by climate change	Impact examples	Safe operating threshold
Increased flooding	<ul style="list-style-type: none"> Inundates terminals 	Depends on berth height of the terminal, which can vary considerably. Most of the time, the berth height is 0.5 to 1 m above the highest observed wave crest in the port
Higher winds	<ul style="list-style-type: none"> Limits crane operations Limits the maneuverability and berthing of ships 	Up to 15-20 m/s depending on type of cranes and vessel
Higher waves	<ul style="list-style-type: none"> Limits approaching, maneuvering, and berthing Limits movements of tugboats/piloting vessels 	<p>At berth: Between 0.5 to 3 m, depending on vessel type and size</p> <p>Outside breakwater: Up to 1.5 to 2.5 m, depending on tugboats and piloting vessels</p>
Higher waves and water levels	<ul style="list-style-type: none"> Overtops breakwater or terminal decks because of storm surges 	Up to 0.1 – to 1 low/medium/severe
Higher temperatures	<ul style="list-style-type: none"> Melts tarmac Limits outdoor safety conditions 	Up to 35 degrees Celsius
Heavier precipitation	<ul style="list-style-type: none"> Limits visibility and inhibits crane operations 	Up for debate. Some say 20 mm/day, others say it can be up to 100 mm/day
More fog	<ul style="list-style-type: none"> Limits visibility 	Generally, visibility of more than 1,000 m

Source: Verschuur, Koks, and Hall (2023); Izaguirre, et al. (2021); Thoresen (2018).

The increased destructiveness and intensity of storm surges result in operational delays and significant damage to the infrastructural and superstructural components of ports (Becker, et al. 2018). This includes the potential for substantial harm to port facilities, resulting in disruptions and impairment of port operations. Wave heights and directions may change due to climate change, which causes more wave penetration within the basin (affecting berthing conditions) or affect the functionality of breakwaters (that were designed for different wave conditions). Further, where waves are locally limited by water depth, extreme wave heights may change because of increased water depths resulting from climate change.

Ports have a safe operating threshold for different weather conditions. Although operational thresholds vary from port to port, Table 8.4 provides some generic operational thresholds that are valid across ports.

Climate change adaptation solutions

Ports need to develop strategic adaptation plans to prepare for and respond to climate-related damage and disruptions and to increase the resilience of infrastructure and operations. These actions are responses to climate change related impacts and should be implemented at a local, regional, or national level. Solutions usually come in three main forms: risk assessment, hard measures, and soft measures.

Ports can respond to extreme weather events and natural disasters with physical risk reduction solutions. Such physical solutions can be categorized as hard measures and typically include engineering works that require high capital investments. Hard (green and grey) solutions include asset elevation, nature-based and grey infrastructure for coastal protection, water management, and general infrastructure improvements. More information specifically on nature-based solutions in ports can be found in World Bank and EcoShape (2025).

Soft solutions require effective regulatory responses that integrate and adapt existing policy and regulatory frameworks beyond common practices. Main solutions include risk reduction instruments, adaptation plans, land use management, resiliency through redundancy of infrastructure, technical knowledge, and collaboration.

8.1.2 Air quality

Air quality relates to the concentration of harmful substances (air pollutants) present in the atmosphere. Air pollution is caused by the emission of pollutants from a wide variety of anthropogenic and natural sources. Air pollutants that are considered harmful to humans include particulate matter (PM); oxides of nitrogen (NO_x); sulfur dioxide (SO_2); volatile organic compounds (VOCs); carbon monoxide (CO); ground level ozone (O_3); polycyclic aromatic hydrocarbons (PAH); and lead (Pb) (Manisalidis, et al. 2020).

Pollutants are categorized as either primary pollutants,⁷ which are directly emitted to the atmosphere, or secondary pollutants,⁸ which are formed in the atmosphere from a reaction between primary pollutants. Particulate matter (PM), which is a solid particle defined by its size, can be both a primary and a secondary pollutant depending on the source of pollution. For instance, dust from the handling of large amounts of bulk materials is considered a primary PM pollutant, while sulfur dioxide (a gas emitted from burning, for example, bunker fuel) contributes to PM.

Ships, port activities, hinterland transport, raw-material processing and power plants strongly add to deteriorating air quality in port cities. Oxides of nitrogen (NO_x, associated with ground-level ozone), PM and sulfur dioxide (SO_x, which contributes to PM) are the most critical pollutants affecting air quality around port areas (IMO 2019).

The link between serious health effects (such as lung and cardiovascular disease) and the climate impacts of the combustion of fossil fuels in diesel and other engines of marine vessels and cargo handling equipment has been well-documented over the last decade (Mueller, Westerby, and Nieuwenhuijsen 2023). Ozone can damage vegetation by affecting the growth of plants and trees and therefore the ability to uptake CO₂ from the atmosphere.

Port activities that affect air quality can be divided into two sources:

- Stationary sources: Emissions from non-moving sources such as refineries, oil and gas storage facilities, power generation, storage of open piles of coal or other minerals, and bulk cargoes.
- Mobile sources: Emissions produced during movement in the port area including trucks, marine vessels, locomotives, cargo handling equipment, diesel powered machinery, straddle carriers, reach lifters, and terminal tractors.

Box 8.4

The connection between air pollution and climate change

Research shows that air quality can impact climate change. Conversely, climate change can influence air quality. Namely, the climate is warmed by ozone in the atmosphere, and it can be warmed or cooled by various PM constituents (Von Schneidmesser, et al. 2015). Air pollution and climate change are interlinked because the emissions driving both problems come from the same sources.

SLCPs are both air pollutants and climate warmers. The primary SLCPs are methane, black carbon, and hydrofluorocarbons. Methane is one of the main precursors to ground level ozone, which is a major cause of premature death. SLCPs have a relatively short lifetime in the atmosphere (less than 15 years), so reductions in these emissions is the most effective way to combat warming in the short-term (Fuller, et al. 2022).

⁷ Primary pollutants include PM, SO_x, NO_x, CO, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAH) and methane (CH₄).

⁸ Secondary pollutants include ground ozone O₃ and secondary PM, SO₂, NO₂ (formed as NO combines with oxygen in the air).

Air quality solutions

Air quality monitoring and management programs⁹ are essential for quantifying the problem and assessing how pollutant sources, characteristics, topography, and meteorological conditions contribute to local air quality (also recognized by World Health Organization (WHO)). The impact of port-related emissions can be studied using real-time air quality monitoring in port areas. Combining meteorological parameters with real-time pollution data helps identify the most affected areas. Historical air pollution trends can be tracked and combined with port emissions to measure pollution reduction effectiveness. Further, local air quality can be compared with state, national or international air quality standards.

Many governments and port authorities are attempting to improve air quality and reduce air pollution from ships and port operations. The WHO published global air quality guidelines in 2021. These guidelines give recommendations on how to address air quality and provide an evidence-informed decision support tool. These guidelines provide a solid framework for ports that plan to work on air quality and where no specific national or local regulations exist.¹⁰

8.1.3 Water quality

Port operations can substantially degrade water quality, leading to adverse effects on marine life, ecosystems, and human health. These effects may include bacterial and viral contamination of commercial fish and shellfish, depletion of oxygen in water, and bioaccumulation of certain toxins in fish. Water pollution harms nature and poses a serious health hazard for coastal populations. It tarnishes the public's view of the port, leads to financial losses due to the decline of marine life, and adversely affects tourism in the region.

Water pollution from port operations can be associated with, but not limited to, wastewater, stormwater runoffs, oil spillages, eutrophication, dredging, ship paint, cleaning of the hulls of vessels, and invasive species. A brief overview is provided per category.

Wastewater

Ships periodically release sewage, wastewater, and bilge water (that is, wastewater that is often contaminated with oil). Wastewater includes both blackwater and greywater.

Blackwater: Used to describe toilet waste and is defined either as treated or untreated. Blackwater contains disease-causing bacteria and viruses that can result in human illness from direct contact or the consumption of affected fish and shellfish.

Greywater: Refers to wastewater that comes from kitchens, sinks, showers, or laundry. It contains fats, oils, harmful chemicals, bleaches, and germs that have impacts on water quality and public health. Greywater can turn septic in less than 24 hours if left untreated, and can harm the receiving environment, for example, marinas, mooring locations, and sheltered bays.

⁹ See EC. Air Quality Assessment Tools: A Guide for Public Health Practitioners. 2011.

¹⁰ Guidelines available here: <https://apps.who.int/iris/bitstream/handle/10665/345329/9789240034228-eng.pdf>.

Discharges are regulated by federal, state, and local governments, including port authorities. However, international regulations for the prevention of pollution by sewage from ships only apply to certain types of vessels¹¹ and types of voyages.¹² A key difference exists between the IMO's MARPOL Annex IV definition of "sewage" and "wastewater" in on-land regulations, which is used synonymously for "sewage". MARPOL specifically focuses on wastewater generated by ships, including from toilets, medical premises, animal spaces, and other wastewaters. These, when mixed with the other drainage categories while on-land, covers all water polluted by human life, including all greywater streams as per normative standard EN 16323.¹³

Wastewater solutions

Wastewater should be treated and reused to limit water pollution, conserve water, and minimize the impact on water quality. Vessel operators must undertake an assessment of their vessel and their operations to carry out the most reasonable and practical measures to manage greywater.¹⁴ They can use structural devices on board, such as fixed, fitted holding tanks, the introduction of treatment systems, or simpler filtration components.

Stormwater runoff

Port terminals have large impervious areas where a range of industrial chemicals and pollutants are used. Critical pollutants within ports include deposits of automotive fluids, sediments, pesticides, and metals. When stormwater travels across these paved areas, it can accumulate deposits of these pollutants and cause significant environmental degradation. Further, it can lead to changes in hydrology and water quality, as well as habitat loss and reduced diversity of aquatic life. Ports are subject to stormwater requirements to manage water runoff from their facilities.

Stormwater runoff solutions

A Stormwater Pollution Prevention Plan (SWPPP) should be prepared and implemented for all terminals. This includes the documentation and analysis of water quality and best practices for the prevention, control, and treatment of stormwater runoff. Additionally, stormwater runoff should be managed as a valuable water resource and used as an alternative source of water supply if possible.¹⁵

¹¹ For instance, MARPOL Annex IV applies for ships of 400 gross tonnage and above or ships of less than 400 gross tonnage which are certified to carry more than 15 persons, etc.

¹² Ships engaged in international voyages.

¹³ Glossary of wastewater engineering terms.

¹⁴ Annex IV of MARPOL prohibits the discharge of sewage into the sea within a specified distance from the nearest land and requires ships must be fitted with a sewage holding tank, a sewage treatment plant, a sewage comminuting, and disinfection system, or all three. However, it does not specify requirements for the management of greywater.

¹⁵ For guidance on Stormwater Pollution Prevention Plan (SWPPP) please see: <https://www.epa.gov/npdes/developing-stormwater-pollution-prevention-plan-swppp>.

Oil spillages

Oil spills around ports and in open waters are a large marine pollution problem, as they can harm human health and coastal ecosystems. A large share of oil contamination is the result of pollution from the removal of bilge water, loading and unloading of oil tankers, and port water runoff. Construction works can also directly or indirectly result in oil spillages from machinery. Oil can stick to animal fur or bird feathers, reducing their insulation; inhaling or ingesting it can poison animals. These toxins also cause long-term damage to their lungs, liver, and kidneys, as well as to the digestive, reproductive, and central nervous systems. Spills can destroy sensitive habitats like mangroves and coral reefs. Cleanup costs for oil waste are high for ports, and affected fisheries and tourism industries suffer financial losses.

Some of the most disastrous pollution events occur when ships are subject to accidents. While accidents can happen in the open sea, the risk for collisions or grounding is higher in shallow and confined waters with dense traffic. There is also a trade-off about whether to let a ship in distress sink into open waters or offer shelter in a port, which risks serious local contamination.

In 2002, the disaster from the MV Prestige (an oil tanker) created a debate after it released some 75,000 tons of heavy fuel oil off the Spanish coast. Following that, French, Spanish, and Portuguese governments disallowed the ship to dock in their ports. Large bulk and container ships carry a significant amount of bunker fuel on board. A collision in a port's confined water can lead to dire consequences.

Oil spillage solutions

Many laws and regulations were introduced to tackle oil spill accidents of tankers (Chen, et al. 2019). MARPOL Annex 1 regulates the discharge of oil and oily substances and requires that oil tankers be fitted with a double hull. MARPOL also introduced regulation on operational oil pollution on allowable discharges of bilge water through the oily water separator or oily waters from the cargo tanks, through the oil discharge and monitoring system (IMO n.d.). The IMO found that these regulations contributed to a noticeable decrease in the pollution of the world's seas. Non-compliance with MARPOL Annex I for oil waste management can also lead to fines and reputational damage, though greater enforcement is needed.

Ship paint

Toxic paint additives, meant to prevent barnacles¹⁶ from clinging to ships, can leach and impact the health of marine life. As a result, their use is banned and regulated in multiple countries to prevent the use of harmful substances in antifouling systems (Cresswell, Glegg, and Readman 2006).

Invasive species

Maritime transport serves as the main pathway for the spread of invasive aquatic species. Shipping-related mechanisms such as ballast water and biofouling are responsible for most of these transfers. Another identified source is hull fouling, where invasive species can still survive.

¹⁶ Ships travel faster if their hulls are clean and smooth from fouling organisms such as barnacles.

Invasive species solutions

Horizon scanning is used to manage invasive species by prioritizing the hazards posed by possible invasive species. This process can be made easier by an understanding of maritime routes (Costello, et al. 2022), as marine animals can be transported across the world to new habitats where they may become invasive species. This can threaten the balance of natural ecosystems (De Castro, Fileman, and Hall-Spencer 2017).

The IMO regulates ballast water discharge through the International Convention for the Control and Management of Ship's Ballast Water and Sediments. Also known as the Ballast Water Management Convention, it aims to prevent the spread of harmful aquatic organisms from one region to another by establishing standards and procedures for the management and control of ships' ballast water and sediments.

Dredging operations

Dredging activities play a vital role in rivers, streams, waterways, and shorelines to overcome the threat of sedimentation and deposition along the port's channels. To provide and retain the depth and improve conveyance of certain fairways, capital or maintenance dredging can be increased or expanded.

The process of dredging produces underwater noise and disturbances which adversely affect marine ecosystems. Dredging operations lead to the loss of fishery resources due to alterations in underwater depth, tidal flow, currents, velocity, and waves. Dredging also involves the re-suspension of contaminants and sediments, increased turbidity, and changes in light availability. Removing sediment to deepen ship channels increases the cloudiness of water and disturbs contaminated bottom sediment, harms or permanently destroys critical wildlife habitats, and disturbs or eradicates threatened and endangered species.

Dredging impact mitigation and material reuse

Dredging contractors should be briefed on the environmental risks of dredging works. The method should be agreed upon with the port before the work takes place. This includes consulting with local conservation agencies on the marine features of the site and sensitive areas and times of the year and considering the hydrodynamic conditions (ABP Research 1999). During the works, sediment disturbance and dispersion should be limited (for example, using silt curtains¹⁷), the time of operations should be set to minimize environmental impact, suitable dredging equipment should be used to minimize sediment suspension, and ways to reduce and reuse dredged material should be investigated.

¹⁷ For more information, see <https://semspub.epa.gov/work/01/466658.pdf>.

Dredged materials, such as bunds, breakwater, or diked bay lands, can be reused. CEDA (2019) defines five functions for dredged material:

1. **Raw material:** To substitute virgin manufactured soil or building materials, such as tiles or aggregates.
2. **Remediation:** To assist clean-up of contaminated sites, brownfields or closure of landfills and mines.
3. **Reclamation:** To create new or expanding existing land for human/commercial development activities.
4. **Restoration:** To create habitat to support aquatic organisms and wetlands to improve natural value.
5. **Resilience:** To contribute towards shoreline nourishment and (dyke) reinforcement for defense against floods and extreme climatic events.

Box 8.5 provides an example of how dredging material was used to protect several coastal communities in the UK and industrial facilities from erosion and flood risk.

Box 8.5

Dredging material as a resource in climate change adaptation

The Bacton Sandscaping scheme in the UK is a large-scale beach nourishment designed to protect the Bacton Gas Terminal from cliff and beach erosion while also reducing flood and erosion risk to the communities of Bacton and Walcott. It buys the time needed for adaptation to coastal change. The sand was extracted by a dredging vessel which transported the sand to the coast.

Source: Terra et Aqua (2020).

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, is commonly called the “London Convention”. Its updated version is the London Protocol (1996). Both establish regulations governing the disposal of dredged material at sea. The London Protocol follows a precautionary approach, which prohibits the dumping of hazardous materials, and mandates a permit system for the ocean disposal of dredged sediments. To comply with these regulations, sediment testing must be conducted to ensure that contaminants stay within safe environmental limits before any offshore disposal is approved (IADC 2019).

Guidelines on options and constraints to use dredged materials have been developed by PIANC (2009), OSPAR (2024), and in several countries such as Ireland (Cork Institute of Technology 2013). PIANC also recommends actions to make valuable use of the dredged material (see Section 8.3.6).

Water footprint measuring

Understanding water consumption and footprints helps ports to quantify water use patterns. A water footprint assessment shows the water used in the various port processes and accounts for the amount of water used and the contamination with health risk levels during these processes.¹⁸ Ports use water as part of their operations, for example equipment and surface cleaning, consumption from port employees or sold water to vessels.

A manual to measure water footprints was developed by Hoekstra et al (2011). The ISO 14046 standard specifies principles, requirements and guidelines related to the water footprint assessment of products, processes and organizations based on a life cycle assessment (LCA). It helps in conducting and reporting a water footprint assessment as a stand-alone assessment, or as part of a more comprehensive environmental assessment. Such standards allow ports to constantly monitor the water consumption associated with products and services of an individual port, identify improvement strategies by identifying the most critical elements in terms of water consumption, and improve the image and the environmental profile of ports (see Box 8.6 for an example of water footprint measuring that followed the ISO standard).

Box 8.6

Example of water footprint measuring, Puerto Ventanas, Chile

In 2022 Puerto Ventanas, Chile completed the verification of its water footprint calculation, which allows it to obtain the APL Blue Certificate, a public-private initiative that promotes the sustainable management of Chile's water resources and is promoted by Corfo's Sustainability and Climate Change Agency and Fundación Chile. The calculation allows the port to generate an action plan to reduce the water footprint.

As part of the quantification of the footprint, the company defined its scopes and indicators, measuring and verifying its direct footprint and identifying critical points for its reduction. This is a first step towards the overall water footprint measuring and certification ISO 14046.¹⁹

Source: (PVSA n.d.).

8.1.4 Waste

Waste in ports can be classified into two main categories: ship waste and port/garbage waste (ESPO 2024). Ship waste refers to oil, sewage, and garbage waste and international regulation from the IMO covers all three types (see Section 8.2 for details).

Garbage waste from ships consists of various types of packaging materials like paper, cardboard, plastic, wood, light metal, glass, as well as absorbents, filter materials, batteries, and other waste types (Deja, Weichbtoth, and Ślącżka 2023).

¹⁸ For details see: <https://www.waterfootprint.org/en/water-footprint/business-water-footprint/>.

¹⁹ For ISO 14046 see: <https://www.iso.org/obp/ui#iso:std:iso:14046:ed-1:v1:es>.

Port/garbage waste refers to solid waste generated from port companies involved in ship handling services. This type of waste mainly consists of packaging materials, including wood, plastic, and cardboard, some of which may be classified as hazardous due to contamination with hazardous substances. Such contamination requires a specialized management process distinct from that of uncontaminated packaging. Additionally, port companies generate large volumes of iron and steel waste. Port/garbage waste can only be separated and temporarily stored at the port. Most of waste management is carried outside port premises in designated areas by specialists (Deja, Weichbtoth, and Ślącżka 2023).

Waste management solutions

Waste management has remained a consistent priority for ports, indicating ongoing efforts to address waste generated by vessels and port facilities. There is a significant reduction in pollution from all types of shipping, despite an increase in world waterborne trade. Global improvements in waste management are largely attributed to the measures required by environmental legislation and international conventions (UKMPA 2001).

Garbage waste from ships is transferred to licensed entities for downstream management. Port/garbage waste is stored in sealed drums, big-bags, metal containers, or waste bins at designated temporary storage facilities, fenced areas, or specially prepared locations within ports. Some of port waste is kept separately in warehouses or storage yards. Hazardous materials are placed in properly adapted containers to ensure safe handling and compliance with regulations (Deja, Weichbtoth, and Ślącżka 2023).

Through the partnership GloLitter²⁰, the Government of Norway, the IMO, and the Food and Agricultural Organization (FAO) developed a Guidance Document on Developing Port Waste Management Plans in 2022 for waste generated on ships. The guidance document only refers to the collection and treatment of ship waste. The treatment of port-generated waste is often part of local and national regulations. Best practices for port waste management refer to recycling and use of plastics strategies (ESPO 2021). Ports and terminals may also have to meet national, regional, or local regulations on waste management and treatment.

The concept of the circular economy presents a significant opportunity for ports to go beyond traditional waste management by shifting from a linear “end-of-life” model to one focused on reducing, reusing, recycling, and recovering materials. It operates at the micro-level (products, companies, consumers), meso-level (eco-industrial parks or geographical areas such as ports) and macro-level (city, region, nation and beyond), with the aim of accomplishing sustainable development. It is enabled by novel business models and responsible consumers (Kirchherr, Reike, and Hekkert 2017, 229). Box 8.7 provides more information on what the circular economy means for ports, as well as a couple of examples of initiatives which have been set up to stimulate the circular transition in ports.

²⁰ For details see: [https://wwwcdn.imo.org/localresources/en/OurWork/PartnershipsProjects/Documents/GloLitter/GloLitter%20PWMP%20\(ENG\)%20-%20Guidance%20Document%20on%20Developing%20a%20Port%20Waste%20Management.pdf](https://wwwcdn.imo.org/localresources/en/OurWork/PartnershipsProjects/Documents/GloLitter/GloLitter%20PWMP%20(ENG)%20-%20Guidance%20Document%20on%20Developing%20a%20Port%20Waste%20Management.pdf).

Box 8.7

The circular economy in ports

The circular economy provides a significant opportunity for ports, as it creates new business models and value streams by, amongst others, bringing port and recycling industries together, with ports acting as hubs for import and export of waste or bio-based materials. Ports can also become material hubs where waste materials are consolidated, processed, and shipped as secondary materials (Carpenter, et al. 2018). On the other hand, the circular transition will result in less extraction for some non-renewable resources (for example, oil, coal), and in more local or regional supply chains, leading to decreases in port traffic (De Langen and Sornn-Friese 2018).

Ports can serve as “matchmakers and crossing-points” in the circular economy, excelling in this role due to their position as cluster managers. This role gives them the possibility of bringing different port actors together in stimulating industrial symbiosis. It also facilitates the emergence of innovation circles amongst companies in the port cluster (Ballini 2017). The implementation of the circular economy in ports is still nascent and often limited to established recycling plants and the valorization and reuse of dredging sediment.

A recent example of efforts in ports at project levels is the LOOP Ports Project. The main goal of this project was to facilitate the transition to a more circular economy in the port sector, where products, materials, and resources are kept in the economy for as long as possible to minimize waste generation. The two-year project comprises various activities, ranging from the establishment of a database of EU ports and their circular activities, to the identification of best practices worldwide. The project published six case studies in Europe and shows that some ports do include the circular economy concept in their strategies, for example, Port of Rotterdam (Port of Rotterdam 2022) and Port of Antwerp-Bruges (Port of Antwerp-Bruges 2022).

Another example of an initiative which helps to stimulate the circular transition in ports was the 2024 ESPO award. The award honored the port projects and strategies that actively engage the port in the circular economy. Shortlisted projects ranged from marine cleanups and Carbon Capture, Utilisation and Storage (CCUS) projects, to the reuse of dredging materials (ESPO 2024).

Source: <https://www.loop-ports.eu/downloads/>.

Despite the increased attention to the circular economy given by the port sector and its stakeholders, the complexity of the transition means that it stays a work-in-progress. Some of the challenges that often need to be addressed include regulatory and budgetary constraints, as well as emerging forms of collaboration.

As is the case with other transitions, stakeholder dynamics may shift as new stakeholders emerge, or previously unimportant stakeholders gain importance. However, collaboration is especially crucial in the circular transition, as sectors that previously may not have been relevant to each other suddenly become partners through cross-sectoral collaboration (World Economic Forum 2022).

For example, industrial symbiosis can occur between two production facilities located in a port area, where the waste from one production process serves as an input for the other's production process. The heightened need for collaboration introduces its own challenges and represents an area where port authorities can act as matchmakers.

8.1.5 Noise pollution

Port operations produce sound that are perceived as a serious environmental “pollution”, which can be above or underwater sound. Sound may reduce the quality of life, provide a health hazard, and have ecological impacts. There are several parameters for measuring noise including intensity, frequency, and duration. The intensity of the sound is measured in decibels, while the frequency is measured in Hertz and indicates the pitch of the sound.

Different marine animals are sensitive to different frequency ranges (El-Dairi, Outinen, and Kankaanpää 2024). The noise pollution from port activities can also have serious negative health effects. It is linked to hearing impairment, high blood pressure, sleep deprivation, reduced performance, and even aggressive behavior (Schenone, et al. 2016). Additionally, noise from ship engines may disturb the hearing and behavior patterns of marine animals, as well as bird feeding and nesting sites. Human-generated underwater sound levels may induce adverse effects on marine life (Murphy and King 2014).

The control of sound is an important component of long-term port planning. This is because chronic sound disturbances related to cargo handling, road, and rail transport are perceived as more disturbing than temporary sounds such as construction and dredging. Noise sources in ports come from road, railway, ships, port terminals, and industrial area sources.

Noise pollution solutions

For those countries where no national or local noise regulation is in place, general guidance is available, such as WHO Environmental Noise Guidelines for the European Region (WHO 2018), which provide noise indicators and guidelines for different noise sources.²¹

The sources of sound and their noise level should be identified when assessing above and underwater sound requirements. Additionally, the frequencies, levels, and intervals of sound that have the most significant impact on health should be studied before determining mitigation measures.

Noise mapping is a common methodology to understand the level of noise pollution. The ‘Good Practice Guide on Port Area Noise Mapping and Management’ was developed by the NoMEPorts (Noise Management in European Ports) Project for noise mapping. While this guidance was developed for European ports, the principles can be applied across all countries. It provides guidance and examples of best practices on noise management in ports. The guidance consists of various steps, including liability, responsibility, and stakeholder frameworks; area and noise sources boundaries; noise predicting and mapping; noise map analyses; noise action planning; and integrated noise management systems.

²¹ For guidance see: https://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf.

8.1.6 Light pollution

Ports often operate 24 hours per day and seven days per week. During night activity, ports require artificial lighting which causes light pollution. Light pollution from port operations comes from several sources. These include stationary lighting used for safety and efficiency within the port and surrounding waters, lighting from vessel operations and maritime safety systems, and temporary lighting for specific projects, events, or emergencies (Interreg North Sea, n.d.). The first two categories are associated with daily port operations, while the third is used only for short-term needs.

Light pollution may result in loss of night sky, energy waste, ecological impacts, and adverse impacts to human health. At ports bordering residential neighborhoods, bright night-time lights and the flashing lights of straddle carriers and forklifts can affect nearby residents, disrupt biological rhythms and cause stress and annoyance.

In addition, artificial lights negatively affect wildlife: they can cause disorientation, confusion of biological day/night rhythms, and a general degradation of habitat quality. This type of pollution causes high mortality in animal populations, particularly to birds attracted to brightly lit buildings and towers.

Light pollution solutions

Ports should aim to minimize light pollution, for instance, by avoiding expanding into near residential areas. Where existing terminals are already close to residences, ports must make efforts to minimize light pollution. For example, bright lights used at night should be minimized to the extent possible to avoid creating glare in the local community. Where light is needed, LED lights should be used with shielding, adaptive lighting systems that adjust based on activity levels, and motion-sensitive lighting.

While general standards for light pollution do not exist, a good example of how to define and address light pollution is in TasPorts, Tasmania. In 2021, TasPorts adopted an environmental standard on light pollution, which defines light pollution in several forms, including:

- Glare from undue brightness of a light source
- Over-illumination from lighting areas at levels beyond those at which human vision is able to differentiate
- Light clutter from excessive grouping of light sources
- Light trespass from the unwanted direct lighting of an area
- High energy, short wavelength UV/violet/blue light that is strongly detected by wildlife
- Skyglow from increased night sky brightness produced by upwardly emitted and reflected artificial light

The TasPorts standard provides an example framework to address light pollution at ports.²² Light pollution action needs to be aligned with respective work health and safety regulations as well as possible light pollution guidelines for wildlife and cities.

8.1.7 Land use

Land use management is an essential component of port and sustainability planning during the development or expansion of a port. The focus on land use management in port development aims to optimize site utilization (for example, increase efficiency of land use at existing terminals), minimize project footprints, redevelop urban and brownfield sites, and mitigate environmental impacts. The spatial planning of a port has become more complex due to the need to incorporate renewable energy production, such as hydrogen production (ESPO 2024).

Port development and land reclamation can have adverse effects on the environment. The sources of these effects relate to the location of the port, construction,²³ and ship-related port operations. The first challenge for constructing a new port is to determine if the chosen site allows for a viable long-term operability of the port when considering the overall social (workforce, hinterland), ecological (nature areas), and environmental (sedimentation/erosion, wave/flooding, river discharges) situation (PIANC 2018).

There is a spectrum of land options for port development, ranging from greenfield sites (green, pristine land) to blackfield (former industrial or commercial site that is heavily contaminated). Bluefields are waterfront sites that have flooding and stormwater issues and are subject to strict ecological regulations.

Brownfields and blackfields are tracts of land developed for industrial or commercial purposes and are contaminated (known or perceived to be) and then abandoned. Blackfields are the most contaminated. The potential costs of cleaning up these sites make them unappealing to companies looking to locate or expand. As a result, new industrial operations are often situated on pristine, undeveloped greenfield land, often impacting biodiversity, for example, loss of habitat and wildlife, alteration of ecosystem functions, and fragmentation or degradation of biological resources. It also affects air and water pollution and leads to urbanization of open spaces with recreational and aesthetic qualities.

Land reclamation

Another form of land use management for new infrastructure development is land reclamation, which requires creating new pieces of land above the existing water levels, often using large amounts of dredged materials. Land reclamation involves the removal of marine habitat and therefore requires compensatory measures (see Section 8.1.8 for more information on biodiversity impacts). Appropriate measures and mitigation to protect the environment and legitimate uses of the sea are negotiated through licensing processes.

²² For details on the standard see: <https://static1.squarespace.com/static/5b67d139365f0223c5ae13d0/t/60d97bf1a89f05766aa7971f1624865779038/ENVIRONMENTAL-STANDARD-Light-Pollution-19-Apr-21.pdf>.

²³ Construction activities in the sea and on land include dredging, disposal of dredged materials, and transport of construction materials.

Land reclamation is widely practiced for port development around the globe, and is especially prominent in East Asia, the Middle East (West Asia), and Southeast Asia, followed by Western Europe and West Africa. Regions in Asia (East, West, and Southeast) have the highest number of port land reclamation projects. Examples of coastal land reclamation for port development or expansion include Khalifa Port and Industrial Zone Project (KPIZ) in Abu Dhabi; Hong Kong's container terminals; Singapore; Tianjin (China); Mombasa (Kenya);²⁴ Alexandria (Egypt); and Tangier (Morocco).

Land use management solutions

An environmental impact assessment should be carried out to consider the impact of port development on environmental facets including water quality, coastal hydrology, bottom contamination, marine and coastal ecology, air quality, noise and vibration pollution, waste management, visual quality, and social-cultural impacts (UN ESCAP 1992).

Greenfield port development

Regional authorities should improve efforts to protect marine habitats from further infill associated with port development. An active, structured engagement between regional authorities and all stakeholders, including locals, environmental groups, and indigenous communities, is needed to ensure sustainable and socially responsible land use planning.

Brownfields

(Re)developing brownfield sites offers many advantages to business, communities, and the environment. While cleaning up contamination that poses a danger to both the community and the environment, businesses benefit from locating onsites near existing transportation infrastructure and with utility infrastructures like energy, water, and waste already in place. Several ports have demonstrated the feasibility of brownfield redevelopment on their properties.²⁵

²⁴ For further information see: https://boskalis.com/media/n5y3ma3bg/kenya_-_port_of_mombasa.pdf, <https://www.eib.org/attachments/registers/79951022.pdf> and current challenges and questioning of the land reclamation see: <https://nation.africa/kenya/counties/mombasa/environment-case-puts-dongo-kundu-project-in-jeopardy--4088656>. Problems emerging from dredging and land reclamation with examples from Africa can be found in this report <https://www.wiomsa.org/wp-content/uploads/2020/08/Regional-Overview-of-Physical-Alteration-and-Destruction-of-Habitats.pdf>.

²⁵ For guidance on Brownfield redevelopment see: <https://documents1.worldbank.org/curated/en/754171468295822120/pdf/550090WP0P118011PUBLIC10brownfields.pdf>.

Box 8.8**Examples of brownfield ports redevelopment**

Cape Town, South Africa: In a rapidly expanding urban region, South African authorities decided to sell an old portion of Cape Town port precinct in 2006. The aim was to improve conditions using land use management and spatial planning. The Port of Cape Town has a successful project with the redevelopment of the Victoria and Alfred Waterfront. The project attracted both domestic visitors and international tourists along with businesses and infrastructure investment, including real estate development.

Buenos Aires, Argentina: The development of the Puerto Madero project was crucial to the conversion of Buenos Aires' business district. The Puerto Madero land was acquired using funds from the sale of the land, which covered all project costs, including administrative and infrastructure costs. This was made possible by the recently established Administrative Emergency and Economic Emergency Laws. The examples from Barcelona and the Canary Wharf Project in London served as important models for the execution of the Puerto Madero Project. Results suggest that the project is a success given that the initial goals (to revitalize the Buenos Aires CBD and spur investment) were surpassed. It brought employment, investment in surrounding areas, and revitalized a previously abandoned area.

Source: Ferreira and Visser (2007); Amirtahmasebi, et al. (2016).

Land reclamation

Appropriate measures and mitigation strategies to protect the environment and legitimize sea use are negotiated through licensing processes. Sustainable alternatives to traditional land reclamation and port expansion methods are green infrastructure, eco-engineering approaches, or integrated land use planning that prioritizes environmental conservation alongside development. These should be analyzed in detail before engaging in projects (see Section 8.1.8 for more information on solutions to minimize habitat loss). The country should also review if the regulatory framework in place meets the expectations and standards of environmental protection.

8.1.8 Biodiversity

Maintaining biodiversity in ports is crucial because it supports ecosystem resilience, enhances natural water purification, and maintains the ecological balance necessary for sustainable port operations. A diverse array of species contributes to ecosystem stability, enabling recovery from disturbances and adaptation to environmental changes.

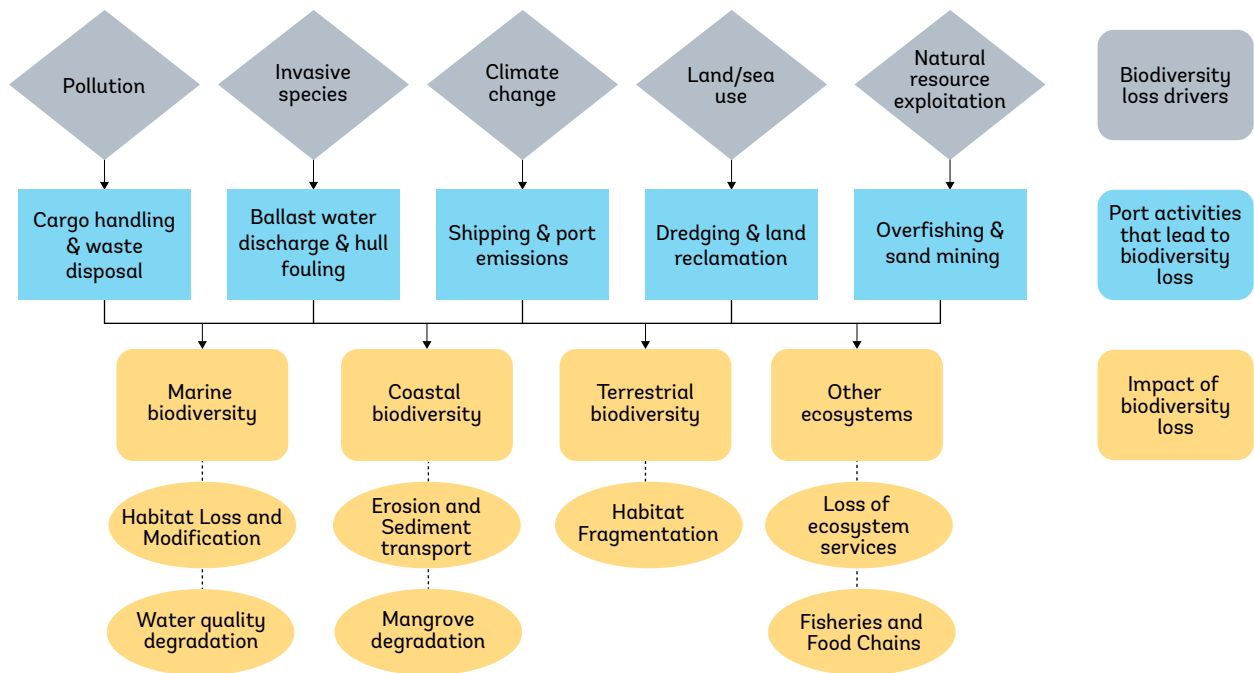
The Port of Rotterdam, which supports over 200 unique plant and animal species, exemplifies how industrial areas can coexist with rich biodiversity, leading to a more resilient ecosystem. Additionally, natural habitats within ports, such as mangroves and seagrass beds, play a crucial role in filtering pollutants and sediments, thereby improving water quality (Madon, et al. 2023).

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has identified certain direct drivers for biodiversity loss: pollution; invasive species; climate change; land and sea use change; and natural resource use and exploitation.

Pollution that is the result of oil spills, ballast water discharge, and chemical runoff contaminates the marine and coastal ecosystems and impacts biodiversity. Invasive species are introduced through ballast water and hull fouling, outcompeting native species and altering food chains. Climate change is exacerbated by port emissions from shipping, cargo handling, and industrial activities, contributing to rising sea levels, ocean acidification, and temperature changes that disrupt marine habitats (Acciaro 2023; Asari, et al. 2021).

Changes in land and sea use results from port expansions, dredging, and coastal infrastructure development. This destroys critical habitats such as wetlands, mangroves, and coral reefs. Finally, natural resource use and exploitation through overfishing, sand mining, and excessive freshwater extraction for port operations can deplete ecosystems, further reducing biodiversity.

Figure 8.3 Overview of drivers and impacts of biodiversity loss for ports



Source: World Bank.

Ports often interact with sensitive marine, coastal and terrestrial ecosystems that, if degraded, can lead to a loss of critical habitats, reduced ecosystem services, and long-term negative impacts on local communities and port operations.

Figure 8.3 provides an overview of the biodiversity loss drivers as defined by IPBES, the port activities that can lead to biodiversity loss along with specific impacts on ports. Importantly, the diagram suggests that multiple port activities can contribute to the same impact and does not illustrate a one-to-one correlation, demonstrating the interconnected nature of these environmental stressors. Examples of impacts shown in Figure 8.3 are described in this section.

Marine biodiversity

Habitat loss and modification: Habitats such as mangroves, seagrass beds, coral reefs, and intertidal zones are destroyed. Dredging and land reclamation can alter seabed structures, impacting benthic ecosystems.²⁶ Coral reefs are also degraded, resulting in the loss of biodiversity hotspots.

Water quality degradation: Benthic habitats are smothered by dredging. Discharges of ballast water and bilge water may introduce pollutants (for example, oil, heavy metals) and alter water chemistry. Coastal protection structures alter the hydrodynamic patterns of sea waves and currents. They change water current circulation, resulting in either strong currents or water stagnation (Agarwala and Saengsupavanich 2023).

Coastal biodiversity

Erosion and sediment transport: Natural water flow patterns altered by port infrastructure can impact coastal erosion and disrupt sediment transport.

Mangrove degradation: Mangrove forests act as habitats for diverse species and natural barriers against erosion.

Terrestrial biodiversity

Habitat fragmentation: Terrestrial habitats are fragmented, impacting local species.

Other ecosystems

Loss of ecosystem service: Carbon sequestration (for example, by mangroves and seagrasses).

Fisheries and food chains: Fish stocks are depleted, with cascading effects on food chains.

Biodiversity solutions

Ports should conduct a comprehensive baseline assessment of the local biodiversity²⁷ to gain a thorough understanding of the existing ecological conditions surrounding the port. A baseline can highlight areas of importance for biodiversity, identify threats to species and habitats and help understand how local communities use and value resources (Fauna & Flora International 2023).

Ports should include specific biodiversity protection and restoration measures as part of their environmental strategies and sustainability plans. This includes incorporating conservation into port development plans to meet legal requirements (where applicable) and enhance ecological resilience.

²⁶ A benthic ecosystem refers to the ecological region at the lowest level of a body of water such as an ocean, lake, or river, including the sediment surface and some sub-surface layers. Organisms living in this zone are called benthos, and they include various species of bacteria, fungi, algae, plants, and animals. These ecosystems are crucial for nutrient cycling, energy flow, and providing habitat for various aquatic species.

²⁷ For detailed guidance on conducting biodiversity baseline assessments, the International Council on Mining and Metals (ICMM) provides a resource titled "[Good Practices for the Collection of Biodiversity Baseline Data](#)." Although tailored to the mining sector, the principles and methodologies outlined are applicable to port operations.

For example, the EU Birds and Habitats Directives establishes conservation requirements for coastal and marine habitats, which ports must comply with to ensure there are no significant adverse effects on biodiversity.

Proactive restoration, such as creating or rehabilitating wetlands, mudflats, and tidal marshes, is essential in ports to mitigate the ecological degradation caused by past and current activities.²⁸ Restored habitats enhance climate resilience by buffering storm surges, reducing erosion, and supporting ecosystem services critical for sustainable port operations.

Following the implementation of a baseline assessment, protection, and restoration measures, ports should conduct biodiversity monitoring and reporting, utilizing KPIs that reflect changes in species diversity and habitat quality. Establishing clear, measurable, and robust targets is critical for creating an effective biodiversity policy and safeguarding biodiversity within port operations. These targets, along with their associated KPIs, have both direct and indirect implications on port management practices.

Ports can utilize various frameworks and metrics to measure and set biodiversity targets that reflect changes in species diversity and habitat quality. However, the vast number of potential targets, combined with the complexity of the issue, makes it challenging to identify the most robust, quantitative, and easily measurable options (UNEP FI and UNEP-WCMC 2021).

Protecting biodiversity during port development

During port development or expansion, ports should address policies and practices that minimize disruption to habitats, such as creating green infrastructure (Sharma and Kharbanda 2023) and implementing buffer zones.²⁹

Green infrastructure involves designing and constructing port facilities that integrate natural and engineered systems to manage stormwater, enhance biodiversity, and reduce air and water pollution. For example, the Galveston Bay Park in Houston is a successful case of green infrastructure that promises to be the largest of its kind in the US (World Economic Forum 2022). It was developed in response to increasing hurricane threats and storm surges. Instead of dumping dredged material from the Houston Channel at environmental cost, the project will use it to build barrier islands and develop them into a massive public amenity (a 10,000-acre park, restored wetlands, and new oyster reefs) while protecting the surrounding ecosystem.

Buffer zones can be part of green infrastructure when they incorporate natural elements like wetlands or forests to manage environmental impacts. Buffer zones serve as natural barriers, shielding sensitive ecosystems within and around port areas from potential contamination and disruptions caused by port operations. For example, the presence of wetlands, dune fields, and other intertidal or marine ecosystems in and around ports helps to maintain water quality, filter pollutants, and provide habitat for a wide range of species (Borja and Perez 2000; Acciaro 2023).

²⁸ For more information on the benefits of “Restoration and management of coastal wetlands” under Climate ADAPT visit <https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/restoration-and-management-of-coastal-wetlands>.

²⁹ Buffer Guidelines established by Fremantle Ports provide guidance for land use planning around the Inner Harbour. The aim is to ensure compatibility between the operational needs of the working port and surrounding uses. https://www.fremantleports.com.au/docs/default-source/planning-and-development/buffer-guidelines-fact-sheet.pdf?sfvrsn=9dc39c43_2. <https://www.icmm.com/en-gb/guidance/environmental-stewardship/2015/biodiversity-baseline-data>.

8.2 The Role of Environmental Governance in Ports

Port organizations tend to be complex and involve different configurations of public and private sector stakeholders at various levels of geographic scope, ranging from local to global. The present-day governance structures are the result of major reforms that took place in the 1980s and 1990s, which devolved responsibilities from the public sector to the private sector (Baltazar and Brooks 2001) to respond to challenges (principally) related to a lack of port infrastructure and technological investment (Brooks and Cullinane 2007). See Module 3: Port Governance and Module 4: Private Sector Participation for more details.

During these reforms, environmental issues were not prioritized, for example, concession contracts did not include climate change risks, adaptation and mitigation issues and responsibilities. Over the past several decades, many ports have addressed environmental issues by modifying their governance structures to incorporate environmental considerations. Module 10: Port-City Interface provides a case study of how the San Pedro Bay Complex adapted its governance structure to deal with air quality issues from increased traffic in the port. Nevertheless, the climate crisis will put pressure on ports to further evolve their governance structures.

Environmental governance refers to the specific systems, policies, and practices that guide how ports manage their environmental responsibilities and interactions with ecosystems, local communities, and regulatory bodies. Port governance structure is critical for improving environmental sustainability for several reasons. Effective port governance ensures that environmental policies are enforced (Monios 2020), leading to efficient port operations (reducing port congestion) (World Bank 2024). This facilitates better coordination and engagement with stakeholders (including local communities, businesses, and environmental groups) to ensure that environmental impacts are considered in port activities and development.

This section conceptualizes a framework for port governance using climate change governance as an example based on Monios, et al (2024) (more details can be found in Module 3: Port Governance). It describes the role of each stakeholder group and their interactions in influencing environmental governance of ports. Although the focus is on ports, shipping is intrinsic to ports, and therefore, the environmental governance of shipping is also discussed. Recommendations are provided for how ports can be actively engaged in furthering the decarbonization agenda.

8.2.1 Dynamic conception of port governance for environmental sustainability

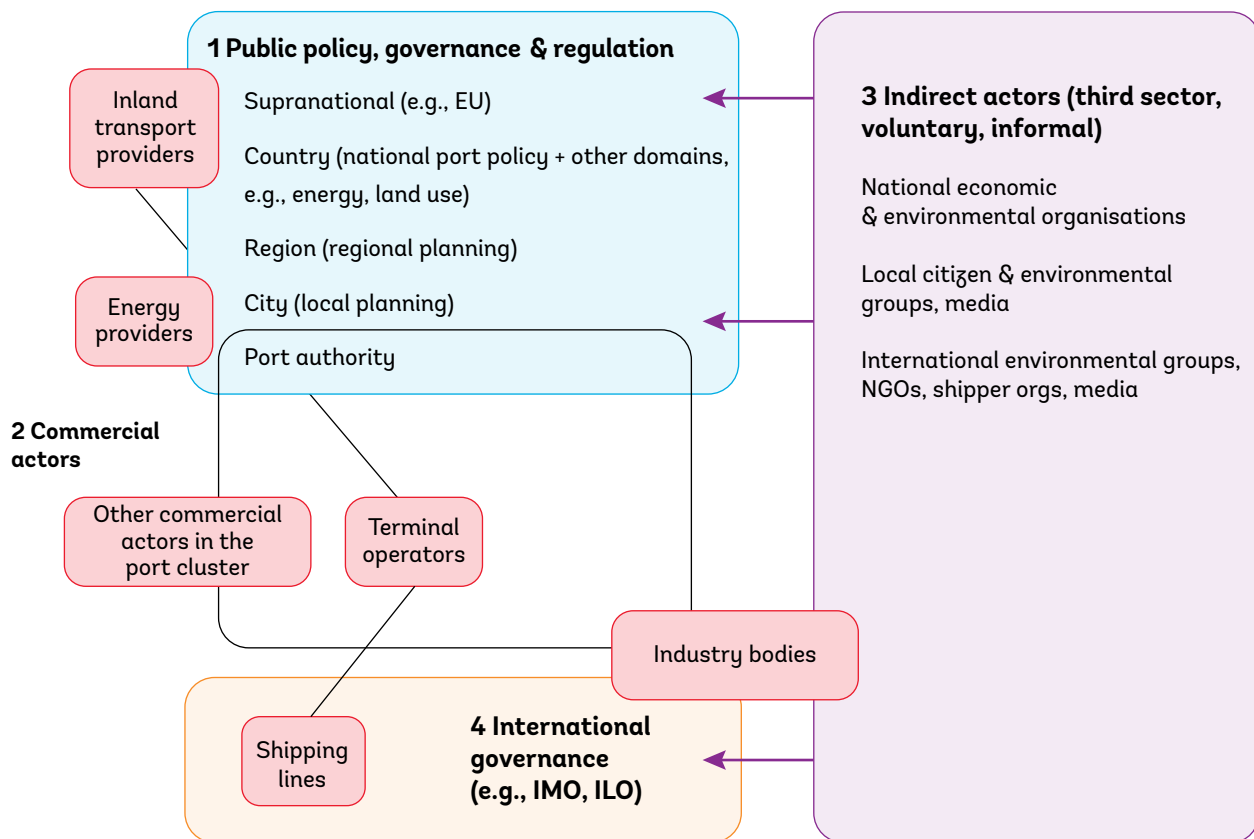
Port governance resembles a variety of interlinked systems (Lee and Lam 2017) as many stakeholders are involved. These stakeholders may not be evolving in the same trajectory or at the same pace (Sánchez and Wilmsmeier 2010). Environmental challenges remain under-addressed due to the fragmented responsibility that weakens the mandate of public actors. It also hinders their ability to manage the distribution of costs and benefits and delegate actions to achieve environmental sustainability.

For instance, the uptake of adaptation measures is impeded by a lack of incentives for stakeholders in the port. Ports are reluctant to invest because port users do not want to pay charges, ultimately leaving the burden on governments to pay themselves or impose an unpopular mandate on ports to make investments.

Recognizing this polycentric³⁰ reality is important for understanding environmental issues and requires an understanding of the roles played by informal organizations (for example, citizen and environmental groups) and external actors (for example, carriers, shipping regulators) (Monios 2019). Figure 8.4 conceptualizes a port governance framework, which is based on Monios, et al (2024). This section describes each group using the governance of climate change to illustrate the relationships between and across the groups. For a more general discussion of this subject, see Module 3: Port Governance.

While the framework specifically focuses on port governance under climate change, the same classification of stakeholder groups is used for other environmental issues. However, the prominence of some of the individual actors would differ. For example, some commercial actors — such as energy providers that play a key role in addressing climate change — have little or no involvement in other environmental issues like noise and light pollution.

Figure 8.4 The four stakeholder groups of port governance under climate change



Source: Monios, et al. (2024).

³⁰ Polycentric governance emphasizes decentralization, local embedding, and responsiveness to specific contextual conditions, along with the potential to mobilize entrepreneurial initiatives, also against incumbent powers and rigid institutions. The concept of polycentric governance includes a combination of differential and uniform centers of authority to accommodate the complex relationships between the stakeholders of the port sector.

Public policy and governance in ports

Ports operate and plan within national, regional, or even local regulatory environments, which therefore also have an influence on port governance in the context of climate change. The public port sector encompasses the port authority, city, region, national and supranational levels as shown in the box on public policy and governance.

National level

The IMO establishes the rules regarding environmental performance at an international level. The national level, however, is responsible for enforcing the IMO's shipping regulations through the port state. A port state is a nation that extends its jurisdiction to include foreign vessels for the purpose of enforcing internationally accepted standards and safety codes. This concept is part of the Port State Control (PSC) regime, which allows a state to inspect foreign ships in its ports to ensure they follow international regulations.

The IMO's global sulfur cap on marine bunker fuel in 2020 serves as an example of how ports play a role in enforcing a lower emissions fuel standard. PSC inspections of foreign-flagged vessels are carried out to ensure that ships comply with the regulation. Although ports are not directly regulated by IMO, international shipping governance influences decisions made by flag, port and coastal states. This indirectly affects ports in terms of influencing the type and quantity of cargoes, services, and energy sources requested (for example, future requirements for zero-emission fuels on ships such as hydrogen and ammonia).

The climate change crisis will also require a new level of interinstitutional collaboration between the national government and the port and city level. One example is in Chile, where the Ministry for Energy introduced a national law on energy efficiency, which requires all sectors to report advances in energy efficiency measures including ports.³¹ As extreme weather events become more frequent, ports will face greater damage. This will require national governments to invest in affected ports and, in some cases, consider closing others (Monios, et al. 2024).

Port authority

The Port Authority (PA) is the focal point of port governance and acts as a community builder, interfacing with commercial actors and with the city and national level. The port and its land and water areas sit within local, regional, and national policy and planning regulations, both in terms of its development and resource management obligations. Such requirements include traditional transport policy, energy and land management, and the added responsibilities for both climate change mitigation and adaptation.

As community builders, port authorities create or facilitate the creation of new, zero or near-zero GHG sustainable value chains and phase out fossil-based value chains. This requires involvement and alignment with energy producers, shipping companies, government agencies at different

³¹ The law can be found here: <https://energia.gob.cl/ley-y-plan-de-eficiencia-energetica>.

levels, financiers, and societal stakeholders, such as environmental NGOs and local communities. A relationship of mutual trust between industries, governments, and the general public is especially relevant for a successful transition towards climate neutrality and circularity (Hendriks and De Gooyert 2023).

Active energy management can offer substantial efficiency gains, contribute to the development of alternative revenue sources, and improve the competitiveness of the port (Acciaro, et al. 2014). A port's nodal position between transport and energy systems makes port authorities a crucial intermediary in transitioning the many different sectors that intersect in ports (Bjerkan, Hansen, and Steen 2021). The complexity of ports, including the heterogeneity of port actors, represents tremendous potential for aligning compatible sets of energy transition pathways that could lead to deep and sector-wide transitions (Bjerkan and Ryghaug 2021).

There are, however, limitations on the agency of port authorities in the energy transition. Notteboom and Haralambides (2023) point out that while ports unmistakably have a role to play in facilitating interaction among market players, a port authority-centric approach to the energy transition might not always be the right choice and needs to be contextual. For example, the port authority can be an investor/entrepreneur in some aspects of the energy transition but remain 'the usual' onlooker in others.

The power of the port authority to enforce its own policies is contingent upon the structure of national policy. For example, the Hamburg Port Authority has the responsibility for ensuring the waters within the port area are safe and there is ease of vessel traffic. Arrival planning can improve efficiency and reduce congestion and emissions. It requires communicating with shipping companies and terminals and is outside the port authority's jurisdiction under the federal regulation of waterways in Hamburg. As such, the Port Authority works with a separate entity to organize arrivals more efficiently. In contrast, other ports have the authority to set their own measures such as just-in-time arrival, which allows ships to save fuel and reduce emissions by slow steaming when there is congestion in port.

Port authorities need a convincing business plan. Stakeholder resistance may arise when a public port authority develops a strong entrepreneurial role in energy transition. Given that many ports operating under a landlord governance model depend significantly on port dues and concession fees from oil tankers, bulk carriers, fossil fuel-related terminals, and industrial activities, it seems inevitable that port authorities will need to explore alternative revenue streams (Notteboom and Haralambides 2023).

Commercial actors

The Port Authority is responsible for ensuring that the infrastructure used by terminal operators stays in good condition throughout the concession period. These concessions typically last 20 to 30 years but can extend up to 99 years for major terminals (for example, in Hambantota Port, Sri Lanka or other ports in Australia) (Monios, et al. 2024). As the climate crisis increases the impacts of sea-level rise and adverse weather conditions, the port can no longer guarantee that the port infrastructure will be intact for the life of the concession (Monios, et al. 2024). They will likely face a higher insurance premium for port buildings and infrastructure. These challenges imply that a new relationship will be needed between terminal operators and the PA to negotiate investments and revenues (Monios, et al. 2024).

Proactively working with the PA to foresee these infrastructure challenges will ensure that ports are resilient to the potential disruptions caused by climate change. Beyond reconfiguring existing relationships, commercial actors such as energy providers will also need to interface with the PA to supply the low- and zero-emission fuels and energy in ports. Module 3: Port Governance discusses the expansion of the PA as a facilitator and entrepreneur.

Indirect actors

Citizen and environmental groups are separate but often overlap with the public chains of policy and planning regulations. They play an active role in managing the environment, as one cannot separate the port space from the neighboring area when dealing with challenges such as emissions, water quality and noise (see Module 10: Port-City Interface). In most cases, such groups do not have sufficient power to block port developments on their own, but they can delay or influence the proposals.

The Interstate 710 (I-710)³² expansion in Los Angeles County is a relevant example of how local communities and community groups can affect port-related development (see Module 10: Port-City Interface). The project faced nearly two decades of opposition from communities next to the I-710 Freeway. They advocated against the project since its approval in 2003 (Schoch 2003) due to environmental as well as health and safety concerns. They engaged with both government and transport officials to oppose the project. The US Environmental Protection Agency found that the project violated the federal Clean Air Act in the proposed expansion area, citing the area as having “the worst air quality in the United States”. Following this, the Los Angeles County Metropolitan Transportation Authority Board voted to suspend the project in May 2021 (Jones 2021).

Another area of indirect influence are universities, research organizations, development banks, and global NGOs who perform studies on environmental issues on behalf of port stakeholders and governments as well as independently and establish guidelines and standards for environmental management of ports (see Section 8.3.6 for examples of guidelines and standards). Some development banks and global NGOs are also member states of the IMO which enables them to advocate for environmental policies at the IMO.

There are several national and international port organizations that share the best practices and have established voluntary incentive schemes. For example, the IAPH established the Environmental Ship Index (ESI) in 2011 to measure the environmental footprint of ships so that ports can provide a financial incentive to mitigate GHG emissions. The most common financial incentive used is the environmentally differentiated port fee. However, GHG reductions from voluntary port schemes is low (Sköld 2019). This suggests that efforts to reduce emissions in ports should focus on how public policy can be positively influenced to enact environmental regulations.

Industry groups have played a proactive role in implementing environmental policies, often incentivized by the synergy between economic and environmental sustainability. Many container ships anchored outside major Californian ports during the pandemic in 2021,

³² An interstate freeway is a federally funded, constructed, and operated national roadway that crosses state lines in the United States. Interstate freeways like the I-710 have directional travel lanes that are usually separated by a physical barrier. Its access and egress points are limited to on- and off-ramp locations or a very limited number of at-grade intersections.

posing risks to maritime safety and air quality. In response to this an industry working group formed to implement a new vessel queuing system. The group comprised the Pacific Maritime Association, the Pacific Merchant Shipping Association, and the Maritime Exchange of Southern California.

The system was designed to reduce the number of vessels at anchorage and allow vessels to optimize their speed to the ports of Long Beach, Los Angeles, and Oakland. The system pushed vessels to drift 50 to 150 miles off the shore of California, reducing the local impact of air pollution. The ports have seen a significant drop in emissions (measured NO_x and PM levels) since the introduction of the system.

On the other hand, industry groups can have the opposite effect when the economic interests are threatened by environmental action. An InfluenceMap report showed how powerful shipping trade associations can stall progress at the IMO, with the International Chamber of Shipping (ICS), alongside BIMCO and the World Shipping Council, collectively lobbying to delay implementation of any climate regulations until 2023 (InfluenceMap 2017).

International shipping governance

Shipping contributes to seven of the eight environmental issues (apart from land use in ports) identified in Section 8.1.1. Regulation of shipping is therefore essential to address climate change, pollution (air, water, waste), and biodiversity protection. The IMO is a specialized agency of the UN responsible for the safety and security of shipping and the prevention of maritime pollution by ships and acts as a global regulatory framework for the shipping sector. A detailed description of the environmental regulations of ships and ports pertaining to each issue is outside the scope of this module. This section starts by providing an overview of international environmental regulations from the IMO followed by discussing the role of EU regulation to propel international decarbonization policy.

IMO regulation

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention of environmental management of ships. It entered into force in 1983 and now contains six annexes which cover pollution and waste in the sea (Annexes I-V) and air pollution (Annex VI). Table 8.5 describes each Annex.

Annex VI addresses air pollution from ships by limiting NO_x, SO_x, and PM emissions. It was revised over the years to establish Emission Control Areas (ECAs) in the North Sea, Baltic Sea, North America, and United States Caribbean Area. ECAs limit SO_x and PM emissions by limiting the amount of sulfur content in bunker fuel which was gradually reduced from 1.5 percent prior to 2010 to 0.10 percent (m/m) in 2015. Outside of ECAs, the IMO set a global cap on sulfur fuel content to 0.50 percent (m/m) in 2020.

While MARPOL regulates the release of harmful substances by ships into the water (relating to Water Quality and Waste) and air (relating to Air Quality), noise³³ and light pollution are not covered.

³³ The IMO issued a set of underwater noise guidelines in 2014 that provide an overview of approaches applicable to designers, shipbuilders, and ship operators to reduce the underwater radiated noise of any given ship (further revised in 2024) but these are on a voluntary basis.

Table 8.5 International regulation covering maritime pollution

The International Convention for the Prevention of Pollution from Ships (MARPOL) contains six annexes:	
<p>Oil</p> <p>Annex I</p> <p>Prevention of Pollution by Oil (entered into force October 2, 1983)</p>	<p>Sewage</p> <p>Annex IV</p> <p>Prevention of Pollution by Sewage from Ships (entered into force September 27, 2003)</p>
<p>Noxious Liquid Substances</p> <p>Annex II</p> <p>Control of Pollution by Noxious Liquid Substances in Bulk (entered into force October 2, 1983)</p>	<p>Garbage</p> <p>Annex V</p> <p>Prevention of Pollution by Garbage from Ships (entered into force December 31, 1988)</p>
<p>Harmful Substances</p> <p>Annex III</p> <p>Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form (entered into force July 1, 1992)</p>	<p>Air</p> <p>Annex VI</p> <p>Prevention of Air Pollution from Ships (entered into force May 19, 2005)</p>

Source: IMO (n.d.).³⁴

The IMO is also responsible for regulating the GHGs of ships at berth. The IMO agreed to unanimously adopt the 2023 IMO Greenhouse Gas Strategy, in which IMO member states agreed to reach net-zero GHG emissions from international shipping by around 2050 (with interim reduction targets by 2030 and 2040). The full set of GHG regulations needed to achieve these targets, however, has not yet been agreed. Currently, the IMO has introduced performance standards to improve the energy efficiency and carbon intensity of ships. MARPOL was amended to include an Energy Efficiency Design Index (EEDI) and a Ship Energy Efficiency Management Plan (SEEMP) for all new ships in 2011.

In 2022, MARPOL was amended to include energy efficiency reductions for existing ships through the Energy Efficiency Existing Index (EEXI) and Carbon Intensity Reductions (known as the Carbon Intensity Indicator or CII). Unlike the EEDI and EEXI, which does not allow a vessel to sail without a valid certificate showing it follows the regulation, there is no such penalty for noncompliance with the CII.

The IMO has also been engaged in the prevention of invasive species from ballast water which causes ecosystem damage and reduces biodiversity. The IMO regulates ballast water discharge through the International Convention for the Control and Management of Ship’s Ballast Water and Sediments

³⁴ For more information see: [https://www.imo.org/en/about/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-\(MARPOL\).aspx](https://www.imo.org/en/about/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx).

(known as the Ballast Water Management Convention). It aims to prevent the spread of harmful aquatic organisms from one region to another by establishing standards and procedures for the management and control of ships' ballast water and sediments.

Supranational environmental shipping regulation from the EU

The transition from global environmental governance of shipping to a more fragmented approach, where individual countries, blocs, or even cities take the lead, is anticipated. This shift is expected if international shipping regulations are not aligned with the IMO decarbonization targets, potentially hindering timely achievement of these goals.

The EU has implemented a range of regulations which aim to reduce GHG emissions and promote sustainability across various sectors including maritime transport. Such measures are part of the wider EU Green Deal and the Fit for 55 package which aims to reduce all emissions by at least 55 percent by 2030 and achieve climate neutrality in 2050. Supporting measures include a fuel standard that incentivizes the production and uptake of sustainable low carbon and renewable fuels by requiring ships trading on European voyages to gradually decrease the GHG intensity of energy consumed, a requirement for containerships and passenger ships to connect to onshore power supply (OPS) while at berth in an EU port, and the inclusion of shipping in the EU's Emissions Trading System (ETS) which places a price on carbon emissions.³⁵

There has also been an institutional interplay between the IMO and EU in environmental policies. Regional regulations can also put pressure on the IMO to enact global policies. Van Leeuwen and Kern (2013) show that the EU has influenced IMO decision-making and improved the implementation and effectiveness of IMO conventions particularly on double hulls, PSC, and SO_x.

8.2.2 How port governance can manage environmental sustainability

Each of the four groups of environmental port governance needs to be actively engaged for successful sustainable practices:

Public policy and governance: In the absence of action from the IMO on greenhouse gas policies, stronger national — and, in the EU, supranational — policy is needed to enforce strict environmental regulations. Such policies are essential to drive the production of low- to zero-emission fuels and energy in ports. The first step for national policy makers is to map all the relevant stakeholders and their responsibility for potential environmental actions. All four groups need to be included in this mapping to identify potential conflicts or redundancies in decision making and responsibility.

Commercial actors: These actors exert influence over port investment decisions. They need to work more closely with port authorities on reducing Scope 3 emissions, addressing other environmental issues, and setting a timeline for full decarbonization. Commercial actors need to work with port authorities to ensure that ports make the appropriate investments and that both parties develop a suitable pricing mechanism, so that all stakeholders distribute the costs and benefits appropriately. For example, if a port authority plans to install cold ironing or a national port policy requires that

³⁵ For more information see: https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en.

they do so, the port needs to liaise with both terminal operators and shipping lines in order to determine the demand for onshore electricity and to provide economic incentives (for example, a fair price to charge for the electricity).

Indirect actors: These groups have increased their influence and media representation. They are now regularly included as stakeholders in port governance but lack agency to enforce action. They are important at the local level to ensure that the voice of citizens is heard and at the international level to provide a transversal link to global best standards and scientific knowledge. Port authorities and commercial actors need to consider the legitimate concerns of third sector actors.

International shipping governance: Regulations that match the IMO's emissions reduction goals remain a significant gap. Without clear and strict greenhouse gas regulations and a defined direction for decarbonization and greener shipping from international regulators, shipping lines will lack a clear path toward adopting low- and zero-emission fuels. As a result, there is a significant challenge for ports to adapt their businesses accordingly (for example, to provide appropriate fuel bunkering).

8.3 A Roadmap for Implementing Environmental Strategies

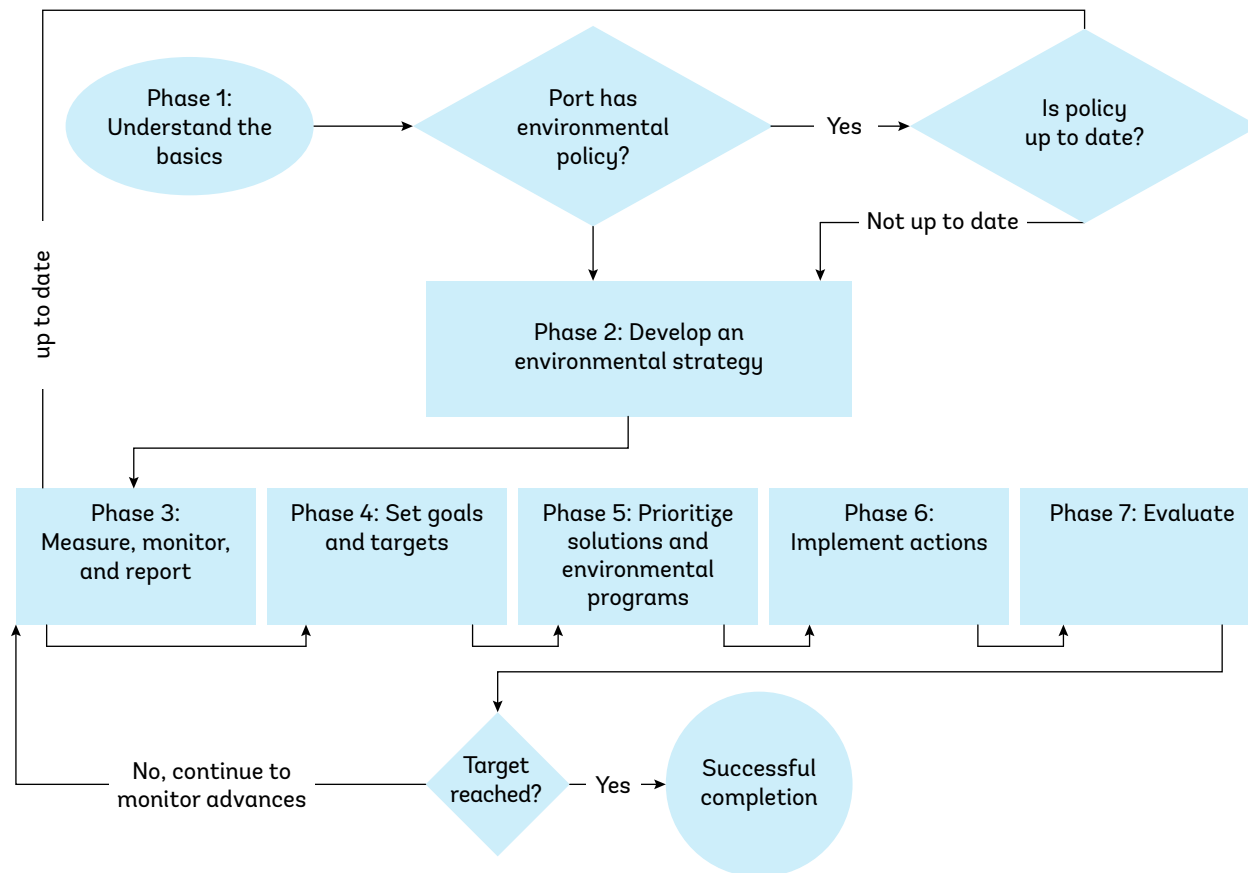
The conceptualization, implementation and evaluation of environmental management strategies and plans can take considerable time. As ports operate in varying economic and social contexts, governance frameworks, and environmental settings (that is, exposure to climate change), strategies will be different for specific ports. This also applies for ports within the same port system of a country. The framework proposes seven main steps (phases) to implement environmental programs in ports and describes the goal of each of the phases.

Figure 8.5 illustrates a flowchart that outlines a structured process for developing and implementing an environmental policy for ports. It is divided into different phases, starting from understanding the basics to setting goals, implementing actions, and evaluating progress.

The first phase asks whether the port has an existing environmental policy in place and whether the state of the policy is up to date. The response to this question determines the pathway of phases a port needs to take. If there is no policy or the policy is not up to date, Phase 2 in the roadmap requires that a baseline be created to develop environmental strategies.

The process then moves to Phase 3: Measure, Monitor, and Report, where a diagnostic assessment of the port's environmental status is conducted. This phase involves defining key performance indicators (KPIs) to establish a baseline for monitoring future progress. Phase 4 sets goals and targets for these KPIs both in the intermediate and long-term. Phase 5 prioritizes solutions and environmental programs based on evaluating measures across mitigation impact, cost, and time to implement dimensions. Phases 6 and 7 cover implementation and evaluation of measures and programs against the targets.

Figure 8.5 Generic framework for implementing environmental strategies



Source: World Bank.

8.3.1 Phase 1: Understand the basics

The first step in creating a roadmap for environmental strategies is to identify whether the port has an existing environmental policy and what the development and implementation state of that policy is. ESPO surveys ports to understand the state and level of an environmental policy in a port. The questions in Box 8.9 are based on the environmental management indicators that are reported by ports from the survey.

Box 8.9

Understanding the basics: The state and level of environmental policy

- Does the port have an environmental policy?
- Is the policy publicly available on the ports website?
- Does the policy include reference to improvement of environmental standards beyond those required under national and international legislation?
- Does the environmental policy refer to the implementation of specific environmental policy and guidance documentation?
- Does the port have an inventory of relevant environmental legislation and regulations related to its liabilities and responsibilities?
- Does the port have an inventory of Significant Environmental Aspects for the port area?
- Have objectives and targets for environmental improvement been defined?
- Does the port have a budget specifically for environmental management?

Source: Based on ESPO (2022).

8.3.2 Phase 2: Develop an environmental strategy

If the port does not already have an environmental strategy, it should define a team to develop the environmental strategy. This team should be undergoing a capacity building process to lead the process of developing the environmental strategies for the port.

The team should:

- Identify current national and international policies, plans, standards, and environmental sustainability objectives
- Identify and rank environmental issues and problems in the port. The matrices provided in Section 8.3.5 can help to define the ranking
- Identify the type of data necessary to create a diagnostic for establishing a baseline and monitoring each problem by evaluating available frameworks and standards
- Create a stakeholder map for the identified problems to understand the roles and responsibilities of each stakeholder when developing a solution. This stakeholder map should include internal and external actors and establishes who can take the leadership in addressing a specific environmental issue

The result of this phase should be a set of prioritized environmental problems for which strategies are to be developed.

Box 8.10 illustrates how the Port of Colombo (Sri Lanka) aligned its emissions reduction projects with the government's National Climate Change Policy.

Box 8.10

Port of Colombo, Sri Lanka

Following the Sri Lanka government's formulation of a National Climate Change Policy, the Sri Lanka Ports Authority, along with some terminal operators, have aligned their GHG emission reduction projects with this overarching national policy. Among others, the policy includes electrifying diesel-operated RTG cranes and the use of e-RTG cranes.

Colombo International Container Terminals (CICT) completed a conversion project to upgrade the terminal's diesel-operated RTG cranes to e-RTG cranes. This project involved extensive modifications, including installing electricity collector trolleys in the cranes and constructing a conductor bar system (Bus-Bar) in the terminal. Over \$10 million was invested, in which 40 zero-emission e-RTG cranes were acquired for the Colombo South container terminal. This achieved a 45 percent reduction in the terminal's overall CO₂ emissions and a reduction of more than 95 percent in diesel consumption.

Beyond emissions reductions, the equipment change led to a reduction of noise pollution as well as operating and maintenance costs.

Source: World Ports Sustainability Programme (2021); Sri Lanka Ports Authority (n.d.).

8.3.3 Phase 3: Measure, monitor, and report

To address the identified issues in Phase 2, a diagnostic of the situation needs to be developed, where key performance measures are defined. This will be used to establish a baseline for monitoring future progress and the impact of measures against the current situation, and to reveal information gaps which will need to be addressed to improve monitoring.

Existing KPIs for ports and the shipping industry have mainly focused on water and air pollution (Di Vaio, Varriale, and Alvino 2018). Several organizations have produced reports on key KPIs including ESPO and PORTOPIA. PORTOPIA provides a tool for environmental indicators in ports with an extensive list of indicators covering environmental management and indicators. Key indicator categories are air quality, water quality, emissions to soil, resource consumption (for example, water), waste production, noise, port development (for example, dredging), and effects on biodiversity (Portopia 2016).

Baselines should be developed using existing frameworks (for example, GLEC) or standards (for example, PERS) (see Section 8.3.6). International standards facilitate the development of environmental actions and the measurement of their impact. Monitoring environmental

sustainability factors and following international standards are an important step towards assuring port competitiveness. Applying these frameworks and standards provides a reference for the required information and data and allows benchmarking the port's situation against others. This section describes existing guidelines and standards that ports can utilize for establishing, monitoring, and reporting on environmental performance.

Existing guidelines and standards for monitoring and reporting environmental performance

As environmental regulations evolved, standards and guidelines were developed for the port sector. With increasing expectations for stricter environmental performance, applying these guidelines and standards is becoming more relevant for transparency and benchmarking ports' sustainability efforts.

The International Organization for Standardization (ISO) offers a family of ISO 14000 and ISO 50000 standards, which provides a framework of principles, guidelines and requirements for ports and terminals to address environmental challenges. The internationally known ISO 14001 (ISO 2015) defines the specifications for an environmental management system. A port or any company can use these specifications to improve, measure and track their environmental performance. Beyond this, there are several existing guidelines — specific to ports — on monitoring and reporting various environmental factors:

Emissions: The Global Logistics Emissions Council (GLEC) Framework is a standardized methodology to calculate and report GHG emissions from logistics along a multimodal supply chain for different stakeholders, including shippers, carriers, and logistics providers. This allows stakeholders to track their progress, evaluate the impact of certain measures and take informed decisions. This methodology includes, among others, guidelines and recommendations for measuring energy consumption in ports. The GLEC framework forms the basis for the development of a new ISO 14083³⁶ "Quantification and reporting of GHGs of transport operations". Box 8.11 provides an example of emissions reporting for the port of Cartagena.

Air pollutants: ISO 4225:2020 is a guideline to report air quality in terms of the presence of air pollutants or emissions. The concept of air quality could refer to indoor, ambient, or workplace air. The document was created to ensure that terms that are frequently used have accepted definitions, and to get rid of ambiguities and inconsistent usage. Stakeholders involved in air quality, sampling, and laboratory analysis will benefit from it.

Noise: The European Union developed the 'NoMEPorts Good Practice Guide' for port areas to build noise mapping and implement action plans to reduce it. This project is intended to be part of the EU Environmental Noise Directive. In addition, any environment that satisfies certain qualification requirements, ISO 11204:2010 specifies a method for calculating the emission sound pressure levels of machinery or equipment at a workstation and at other specified nearby positions.

ISO 3740-2019 also offers recommendations for choosing one or more of these standards that are suitable for any specific kind of sound source, measurement setting, and desired accuracy. It can be used to create noise test codes (see ISO 12001) and to test noise emissions in cases where there

³⁶ Establishes a common methodology for the quantification and reporting of greenhouse gas (GHG) emissions arising from the operation of transport chains of passengers and freight. For details see: <https://www.iso.org/standard/78864.html>.

is no specific noise test code exists. Other relevant international standards include ISO 9613-1 and ISO 9613-2, which address the prediction of sound propagation outdoors. Finally, the WHO Environmental Noise Guidelines (WHO 2018), ANSI/ASA Standards, the Directive 2002/49/EC (Environmental Noise Directive) and BS 4142:2014+A1:2019 (British Standard) offer additional guidance on assessing, monitoring and reporting noise impacts in various environments.

Water quality: ISO 14046 is a guideline to report the water footprint of processes and organizations, using a life cycle assessment framework. Not all soil or air emissions are included — only those that impact water quality are considered, as they often lead to acidification and eutrophication of aquatic ecosystems.

Marine Water Quality Monitoring Programs also play a critical role in assessing and managing water quality in port and coastal environments. These programs help track pollution levels, sediment contamination, and ecological health. Additionally, Ballast Water Management Programs, in line with the IMO Ballast Water Management Convention, include the IMO G2 Guidelines for Ballast Water sampling, a framework for how and when ballast water should be sampled.

Biodiversity: The World Bank emphasizes the integration of biodiversity considerations into port development and operations. The World Bank’s Environmental and Social Framework (ESF) includes specific standards aimed at protecting and conserving biodiversity, ensuring that development projects, such as ports, do not adversely affect critical habitats. In August 2024, the World Bank introduced a comprehensive biodiversity database encompassing over 600,000 species, including arthropods, mollusks, plants, fungi, and traditionally represented vertebrates such as amphibians, birds, fish, reptiles, and mammals.

Ports can contribute biodiversity data to global databases such as the Global Biodiversity Information Facility (GBIF) that is also linked with the WB biodiversity database. By providing detailed insights into global species distributions, the World Bank’s initiative supports the Global 30x30 biodiversity conservation target (CBD 2022). It seeks to protect 30 percent of the world’s terrestrial and marine areas by 2030. This resource is expected to enhance conservation planning and inform environmental impact assessments. It is also meant to aid in implementing the World Bank’s Environmental and Social Standard 6 (ESS6) on biodiversity conservation during project preparation and execution.

Environmental strategies can be certified following the Eco-Management and Audit Scheme (EMAS)³⁷ or the Port Environmental Review System (PERS), which are the port sector’s own, independently verified, international standard, the only international Environmental Management System (EMS) dedicated to the port sector.³⁸

³⁷ For details see: https://green-forum.ec.europa.eu/emas_en.

³⁸ For details see: www.ecoport.com.

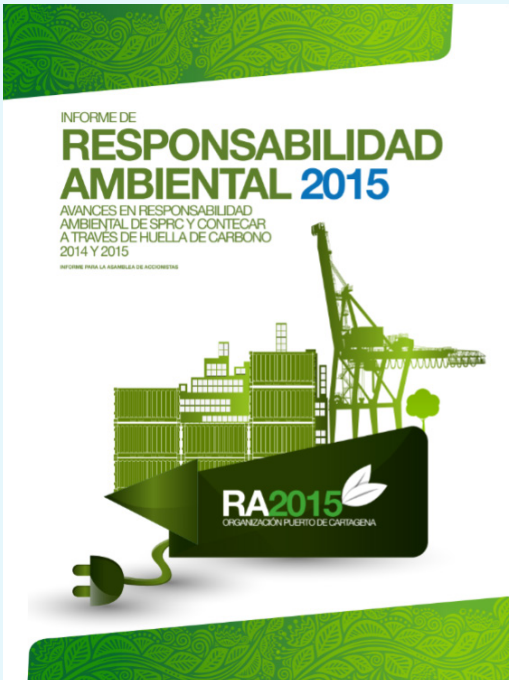
Box 8.11

Sample on emissions reporting and continuous improvement

The port of Cartagena started publishing its report on environmental responsibility since 2015 and thus has been collecting and reporting energy consumption data and calculating emissions since 2014. This has allowed the port to have solid baseline information for publicly reporting its progress in contributing to the goals of the Paris agreement.

The report provides energy consumption and emissions at equipment level that can be used to observe the technological transition in port operations and the efforts towards electrification.

The periodic publication shows that there has been an evolution in the presented data and detail in the report, while maintaining comparability over the years. While the first report focused on Scope 1 and 2 emissions, the port has advanced its methods to also include part of Scope 3 emissions in the latest reports. This is a great example of the efforts of continuous improvement in actions and reporting.



Environmental responsibility report 2015



Environmental responsibility report 2021

Reports across various years are available on the Puerto de Cartagena website.³⁹

Source: World Bank and Puerto de Cartagena.

³⁹ <https://www.puertocartagena.com/es/sala-de-prensa/publicaciones>.

ESG reporting practices

Corporate reporting practices that cover non-financial aspects known as Environmental, Social and Governance (ESG) are a vital component of the sustainability agenda and have become increasingly important in recent years (Milne and Gray 2013). In addition, environmental impacts from GHG emissions in seaports have received growing interest over the last three decades (Di Vaio and Varriale 2018). Firms in different industries are switching from giving priority to economic concerns in their corporate strategy to integrating sustainability goals into their management processes reflecting society's demands for environmental protection and guarantees (Laskar 2018).

Stakeholders' perceptions of a company may be influenced by its sustainability reporting practice. As a communication tool and resource for improving sustainability performance, sustainability reports can also tell its story, develop or test its strategy, and facilitate communication with internal and external stakeholders. Sustainability reporting should be seen as a strategic instrument to strengthen significant business ties and create new opportunities for corporate growth (Deloitte 2020).

Ports, like other organizations, should assess their performance in identifying, mitigating, and disclosing significant ESG threats or opportunities to their business model (KPMG 2022). Sustainable reporting should be adaptable and open to new disclosure requirements to address societal and environmental challenges that, if left unchecked, might have significant adverse effects on reputation and finance (Meath 2018).

Organizations are embracing sustainability reporting in response to pressures from stakeholders. This is shown by the development of tools like global goals, standards, frameworks, regulations, and rankings (Siew 2015).

The IFC ESG (IFC 2021); the Task Force on Climate-Related Financial Disclosures (TCFD) framework; the Global Reporting Initiative (GRI) standards; the Sustainability Accounting Standards Board (SASB); and the Climate Disclosure Project (CDP) framework have led the way in developing standards for sustainability reporting. The UN Global Compact (UNGC), The GHG Protocol, the Principles of Responsible Investing (PRI), the Science-based targets, and the UN Sustainable Development Goals (SDGs) are other principles that add to the wide landscape of sustainability reporting.

Reporting has become more important, and it is estimated that there are more than 600 ESG standards, guidelines, ratings, and reporting systems globally available (Mougenot and Doussoulin 2023). As more organizations are publishing sustainability reports and regulations come into place in some regions, a new industry of standards, frameworks and rankings emerged providing data to governments, investors, and other stakeholders. However, research and reports have shown that the consolidation and harmonization of reporting approach is necessary to reduce the complexity for firms, investors, and public authorities and at the same time increase the transparency for other stakeholders (Adams and Abhayawansa 2022; Atkins, et al. 2023; Subramaniam, et al. 2023).

By way of example, the IFC ESG defines a set of environmental, social, and governance factors considered by organizations when managing their operations, and by investors when making investments, in respect of the risks, impacts, and opportunities relating to but not limited to (IFC 2021):

- Environmental issues: Potential or actual changes to the physical or natural environment, for example, pollution, biodiversity impacts, carbon emissions, climate change, natural resource use;
- Social issues: Potential or actual changes on surrounding community and workers, for example, health and safety, supply chain, diversity, and inclusion; and
- Governance: Corporate governance structures and processes by which companies are directed and controlled, for example, board structure and diversity, ethical conduct, risk management, disclosure, and transparency. This includes the governance of key environmental and social policies and procedures.

IFC's ESG Standards comprise the Performance Standards, which define clients' responsibilities for managing their environmental and social risks, and the Corporate Governance Methodology, which sets out an approach to evaluate and improve the corporate governance of clients.

Some countries have begun to include mandatory requirements for GHG emissions in their regulations across sectors, stakeholders continue to urge for corporate action mandating the disclosure of sustainability performance even when sustainability reporting may not be required by law.

The view of sustainability reporting is complex and has grown due to inadequate coherence and integration and the need to adapt frameworks for internal and external stakeholders. The distinctions between standards, frameworks, rankings, ratings, and their aims and methodologies are complex and require good understanding to act strategically (GRI 2022).

The fact that environmental disclosure is still primarily voluntary and growing in importance has led to the proliferation of over 600 ESG standards worldwide. These range from globally recognized frameworks to industry-specific initiatives, making it difficult for ports to navigate the ESG landscape. This diversity must be strategically addressed through clear prioritization, a tiered implementation approach and a compliance approach.

Since each port is different, ESG reporting needs to be tailored to the port's characteristics and regulations. Some ESG reporting standards are voluntary while others may be compulsory depending on the country or region's regulations and the PA's size (for example, CSRD in EU is mandatory for the Port of Antwerp-Bruges).

Some ESG reporting standards are still dynamic and going through a "trial and error" process. Therefore, it is likely that until this is stabilized, ports too will have to go through some trial and error of choosing a standard which suits them best. Nevertheless, OSPAR should include some common ESG reporting topics, for example, social initiatives with local communities, energy transition, waste and resource management, and emissions.

8.3.4 Phase 4: Set goals and targets

Based on the identified policies and environmental objectives, quantifiable goals and targets need to be set. The specific targets in terms of results and timeline should be in line with national and international ones. Since some of these overall targets (for example, zero emissions) are medium and long-term, intermediate targets should be set, to indicate whether the developed strategies are allowing progress in the expected directions.

Scenario planning or foresight techniques are recommended to set achievable and realistic targets, as they facilitate strategic thinking and long-term focus. This is particularly relevant because responses to environmental issues are challenging traditional operational and governance paradigms. This process should be coordinated with the identified key stakeholders to address this problem.

Successfully reaching targets depends on institutionalized review mechanisms such as recurrent evaluation of adopted policies and sustainability strategies and reports of terminal operators to reflect upon the self-evaluation process.

8.3.5 Phase 5: Prioritize solutions and environmental programs

Environmental programs to address the identified problems and to reach the defined targets will face financial and time constraints. Thus, it is necessary to define which programs will be prioritized. The prioritized programs will depend on the local social and economic context of the port and its exposure to climate threats. This section provides a guidance matrix for climate change mitigation and adaptation to illustrate how solutions and environmental programs can be identified. This process should be coordinated with the identified key stakeholders to address this problem.

Guidance matrix for mitigation

The success of mitigation measures is to be assessed based on three metrics:

1. The impacts of any mitigation measure should be evaluated in terms of the tons of CO₂e reduced in comparison to the baseline year, and its contribution to the NDCs of the country and the overall global target of net-zero GHG emissions by 2050.
2. The efficiency of any mitigation effort should also be measured in terms of cost (investment) per ton of GHG emissions reduction. This should also account for the positive effects on the overall operation affected (for example, lower energy use and thereby lower operating costs), and the social cost of carbon.⁴⁰ By way of example, an IPCC report suggested limiting global warming to below 1.5 degrees requires marginal abatement costs of 135-5500 \$2010 CO₂e in 2030 and 245-13000 \$2010 CO₂e in 2050 to stay below the 1.5°C limit (IPCC 2018). Over the medium and long term, a positive result should be expected, particularly as the valuation of the social cost of carbon⁴¹ will increase as climate change progresses.
3. The efficiency of the mitigation action needs to be measured in terms of return on investment, which in most cases will determine the financial viability of the proposed solution.

Stakeholders, ministries, port authorities, and terminal operators must be cautious in interpreting results from one individual operational or technical measure in isolation. There can be positive or negative feedback effects between policies, fuels, and technologies in terms of the generated costs and observed GHG emissions reductions.

⁴⁰ The monetary value that society places on one ton of carbon dioxide equivalent.

⁴¹ For details on the social cost of carbon see: <https://www.brookings.edu/bpea-articles/the-social-cost-of-carbon/>.

Distinguishing between short- and long-term costs of the measures could be beneficial. For instance, some currently high-cost measures could become low-cost options in the long term due to expected progress in innovation (Gillingham 2019). The costs associated with implementing a specific measure can also vary according to the location, the type of main process it targets, and the technological readiness of a port.

To bring this all together, a system of three axes is proposed:

The first axis depicts how much climate mitigation impact the measures will have in terms of GHG emissions reduction. Reduction in terms of percentages, from different studies, proposes this classification. Any measure with a reduction of more than 20 percent (>20 percent) is high, between 10 and 20 percent (10-20 percent) is medium, and less than 10 percent (<10 percent) is low.

The second axis measures the cost to reduce one ton of CO₂e. This is based on the upfront capital expenditures and operating costs of the solution divided by the number of tons of CO₂e emissions reduced over the implementation period. The range of estimated cost/GHG emissions reduction is proposed as follows: low (less than 50 \$/ton CO₂); medium (50 -300 \$/ton CO₂); high (more than 300 \$/ton CO₂).⁴²

The third axis is the implementation time required from taking the decision to implementation, which will define the period until the impact becomes directly measurable. Three main categories are defined — short term is 1-2 years, medium term is 3-6 years, long term is more than 6 years.

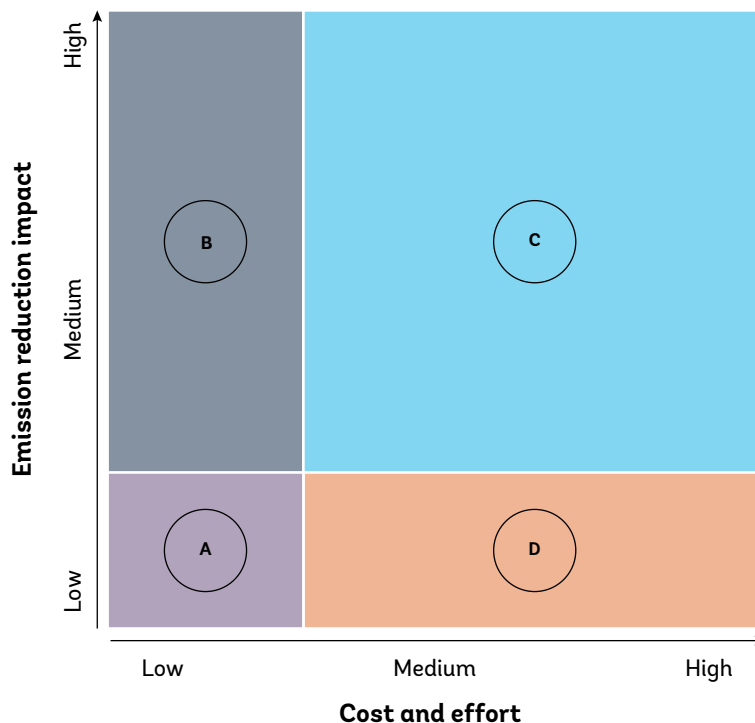
A conceptual example of this system is shown in Figure 8.6, where the first two axes are shown in the graph, and the time to impact is provided in the matrix.

Eventually, solutions fall into one of four categories, as shown in Figure 8.6. These are:

- A. Quick wins: Low cost with limited emission reduction impact.
- B. Priority projects: Yield the best return given relatively low costs and have a significant GHG emissions reduction impact.
- C. High-cost projects: Provide significant GHG emission reductions but may be more complex and expensive to execute.
- D. Hidden traps: Medium and high cost and effort-consuming activities with low impact that should be managed carefully.

⁴² For reference see: Gillingham, K. and Stock, J.H. (2018) The Cost of Reducing Greenhouse Gas Emissions, *Journal of Economic Perspectives*, 32 (4), pp. 53-72 and CER-ETH (Center of Economic Research at ETH Zurich). The Economic Cost of Carbon Abatement with Renewable Energy Policies., Working Paper 17/273.

Figure 8.6 Effort matrix and time to impact of mitigation measures in ports



Measure	Matrix cat.	Time to impact
MMGS: Measure, monitor, and goals setting	B	S
ECO: Eco-driving	B	S
FM: Fleet management	A	S
PGPD: Pricing green port dues	A	S
LEE: Low electricity lighting	A	S
SS: Slow steaming in port area	A	S
STD: program to implement international relevant standards	A/B	S
TTTEE: Technological transition terminal equipment (electric)	B	M
AG: Automate gates and appointment systems	D	M
OM: Operational measures (storage optimization in terminals)	D	M
GP: Green procurement strategies	A	M

Measure	Matrix cat.	Time to impact
PSM: Promote sustainable mobility and community awareness	B	M
RPDF: Review port development of fossil fuel specialized terminals	C	M
CI: Onshore power supply or cold ironing	C	M
TTTEH: Technological transition technical equipment (hydrogen or other energy fuel)	C	L
TTT: Technological transition trucks (hydrogen)	C	L
TTBT: Technological transition barges and trains (electric)	C	L
DP: Dry Ports	C	L
MS: Modal Split	C	L
PE: Produce electricity	D	L
PAF: Provide/procure alternative fuels for port users	C	L

Source: World Bank (each measure of this illustration is described in more detail in Appendix 1).

Notes: the categorization is indicative and will vary according to each port context. Time to impact is defined as: short (S), Medium (M), and long term (L).

The solutions should not be developed as standalone projects. Exploring different sequences and combinations of solutions allows finding one or several paths to achieve zero or near-zero GHG targets and reach effectiveness and efficiency gains.

Guidance matrix for adaptation

To implement solutions in adaptation, a simplified matrix is proposed and divided into four sections which will be explained in more detail. The success of adaptation measures is to be assessed based on three metrics:

1. Cost of inaction, which is the total economic cost of climate change in the absence of planned adaptation — with or without mitigation measures.
2. Cost of adaptation, which is the total expenditure dedicated to adaptation, or total investment needs to implement the measures defined in a given adaptation plan.
3. Additional benefits of adaptation, which is calculating avoided losses, that is, considering the avoided direct and indirect damage to infrastructure and assets.

Stakeholders, ministries, port authorities, and terminal operators must be cautious in interpreting results from one individual measure in isolation. The costs associated with implementing a specific measure will vary according to the location (Houtven, et al. 2022), the adaptation measure, and the technological readiness of a port. When developing adaptation efforts, port authorities are well advised to closely collaborate with the local, regional, and national administration and the community to correctly interpret responsibilities and policy developments.

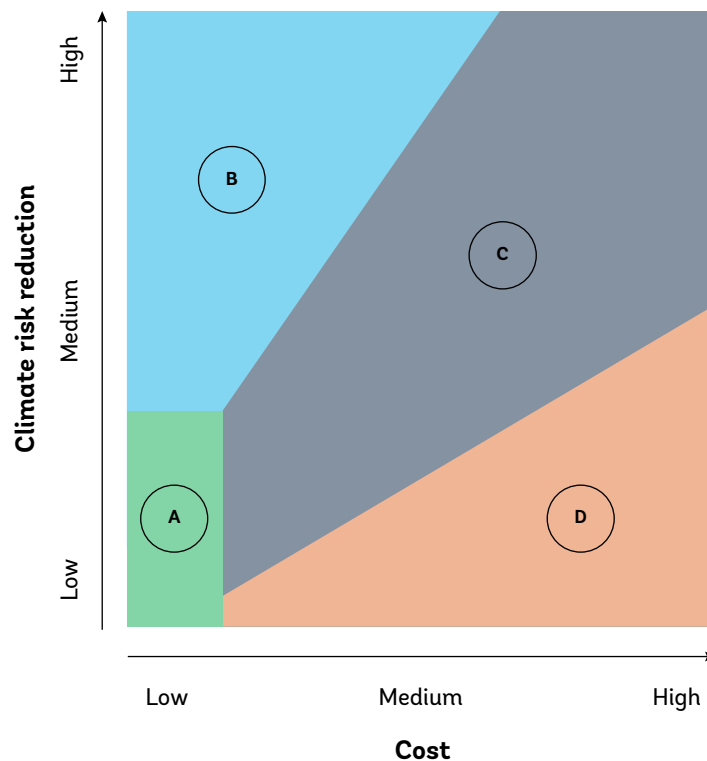
To bring this all together, a system of three axes is proposed. The first axis depicts how much climate adaptation measures will reduce climate risk exposure. Reduction in terms of percentages, from different studies, proposes this classification. The second axis measures the cost to reduce climate risk exposure. This is based on the investment requirements of the solution. The range of estimated cost/avoided losses. The third axis is the implementation time required from taking the decision to implementation, which will define the period until the impact becomes directly measurable. Three main categories are defined — short term (1 to 2 years), medium term (3 to 6 years), and long term (more than 6 years).

A conceptual example of this system is shown in Figure 8.7, where the first two axes are shown in the graph, and the time to impact is provided in the matrix.

Eventually, solutions fall into one of four categories as shown in Figure 8.7. These are:

- A. Quick wins: Low cost, realizable in a short time with limited climate risk reductions impact.
- B. Priority projects: Yield the best return given relatively low costs and have a significant climate risk reduction impact implementation time is medium to long-term.
- C. High-cost projects: Provide significant climate risk reduction but may be more complex and expensive to execute.
- D. Hidden traps: Medium and high cost and effort-consuming activities with low impact that should be managed carefully, require in-depth analysis to ensure good decision-making.



Figure 8.7 Benefit effort matrix and time to impact of adaptation measures in ports


Measure	Matrix cat.	Time to impact
Asset elevation	D	M/L
Grey infrastructure	B	M/L
Drainage systems	A	M
Dredging	D	S/M/L
Equipment improvements	A	S
Early-warning systems	A	S
Emergency preparedness and response	A/B	S
Land use management	B	M
Strategic national port planning	D	M
Technical know-how and collaboration	A	S

Source: World Bank (each measure of this illustration is described in more detail in Appendix 1).

Notes: the categorization is indicative and will vary according to each port context. Time to impact is defined as: short (S), medium (M), and long term (L).

The solutions should not be developed as standalone projects. Exploring different sequences and combinations of solutions allows finding one or several paths to achieve climate resilience.

8.3.6 Phase 6: Implement actions

Developing comprehensive environmental strategies is a complex task and will take significant time (up to several years) and has short to long-term orientation and goals. Furthermore, each environmental program contains concrete actions. These actions will vary in time, financial and resource needs, and have to be developed based on well-developed planning. Thus, it requires continuous commitment from the port and its stakeholders.

Given these complexities, it is important to have a dedicated team to lead the process; ensure efficient decision-making processes; initiatives to continuously improve timelines of programs; and monitoring of guidance, policies, and targets.

A key mechanism for advancing environmental strategies and the implementation of programs and actions is engaging the port stakeholders. These should be involved from the early stages to assist in identifying areas of interest within their roles.

International programs and working groups to reach environmental sustainability in ports

Several international organizations have implemented programs and working groups to support ports in their efforts to improve environmental sustainability by providing valuable examples of projects and progress in the sector. As a result of these initiatives, the stocktaking and visibility of efforts in this field has significantly increased. The majority of the best practice examples are, however, in developed economies and limited to a small number of ports, even though efforts in emerging economies have gained significant traction over the last years. A brief overview of the different programs is provided in this section.

American Association of Port Authorities (AAPA) POWERS Program⁴³

The Port Opportunities with Energy, Resilience, and Sustainability (POWERS) program was implemented by the American Association of Port Authorities (AAPA) in July 2022. It advocated for federal policies supporting energy provision, pragmatic decarbonization, technologies for renewables, and environmental sustainability. The scope is to make the most of the crucial funding and direct investments in sustainability in ports of the future. The main aim of the program is to support the construction of green, resilient, and carbon-neutral infrastructure projects. The program establishes five lines of work between the port industry and the Federal Government:

- Export of American energy: This relates to strengthening the energy availability and export capacity of Liquefied Natural Gas (LNG) and other alternative fuels, for instance ethanol and biodiesel, by planning and funding construction projects to expand export capacity. Other areas include developing and implementing carbon capture technologies to advance sustainability

⁴³ For details see: AAPA (2022). <https://aapapowers.com/>.

- Alternative maritime fuel use and production: Ports can reduce their emissions from vessels and port operations and simultaneously increase energy security by utilizing alternative fuels, for instance, hydrogen, methanol, ammonia, propane, and LNG. This requires investment strategies outlining technology and fuel infrastructure needs, done by both port authorities and national government. A third aspect aims at establishing green shipping corridors between ports around the world
- Port electrification: Developing grants for electrification of port operations, including microgrid technology, local power generation, onshore power supply and electric vehicles. Further, the program includes ports in the transformative National Electric Vehicle Charging Plan
- Strengthened energy and coastal resilience at ports: The program works to ensure assistance for ports to receive substantial assistance from the government for infrastructure and supply chain resilience through the Department of Energy and through FEMA's 'BRIC' program
- Physical and human infrastructure for wind energy: Ports are the manufacturing and marshaling space for wind turbines and related equipment and are key elements to develop the full potential of wind energy production. The program works to continue funding for offshore wind marshaling infrastructure and to support current and future wind energy job creation, which is supported by AAPA's ACCErerate Apprenticeship Program⁴⁴. Further, wind energy has the potential to provide power for the country and facilitate provision of renewable energy for alternative fuel production for zero-emission vessels

ESPO EcoPorts

EcoPorts was initiated by several ports in 1997 and has been fully integrated into the European Sea Ports Organisation (ESPO) since 2011. It has become the main environmental initiative of the European port sector. The aim of EcoPorts is to increase awareness about environmental challenges, deliver compliance with legislation and demonstrate a high standard of environmental management.

EcoPorts published the 'ESPO Green Guide: A Manual for European Ports Towards a Green Future' in 2021.⁴⁵ The guide aims to share knowledge and experiences and guide port authorities in the development and improvement of their environmental strategies and performance. The guide is divided into three parts. The first outlines the role, competences and responsibilities of port authorities and port stakeholders when constructing environmental strategies. It also highlights the roles of policymakers to set legislative conditions for greening the port. The second part presents a port-specific roadmap for 2050. Further, it identifies a series of tools for port authorities.

⁴⁴ For details see: <https://www.aapa-ports.org/unifying/content.aspx?ItemNumber=22733>.

⁴⁵ For details see: <https://www.ecoport.com/publications/espo-green-guide-2021-a-manual-for-european-ports-towards-a-green-future>.

A database of good green practices covers five categories of tools, including:⁴⁶

- Energy & Fuels concerns the various initiatives taken by ports as hubs of clean energy and alternative fuels through the supply, production, export and import of energy
- Climate & Air captures long-standing efforts by European ports to address the challenge posed by climate change and air pollution through emission reduction commitments, cooperation, innovative projects, and continuous monitoring efforts
- Port & City includes good practices for port-city interaction and relations in urban ports, showing how ports can successfully engage with wider communities and encourage greening the city
- Waste & Circular shows that many European ports actively reduce waste and encourage circularity through innovative green practices and projects
- Environment & Biodiversity illustrates that port authorities are committed to preserving their local environment and precious habitats through protection and conservation efforts

The final part provides mitigation strategies to reduce negative externalities and explores how ports can contribute more widely to the transition of the economy towards environmental sustainability.

EcoPorts also offers two tools:

1. The EcoPorts Port Environmental Review System (PERS),⁴⁷ which is a port sector specific environmental management standard, and
2. The EcoPorts Self Diagnosis Methodology (SDM),⁴⁸ which provides a framework for ports to self-evaluate their environmental management and allows them to compare their performance against the sector's benchmark.

The PERS standard was developed by ports themselves, and combines the main general requirements of recognized environmental management standards (for example, ISO 14001) with the specific context that ports are embedded in. The SDM tool is a checklist that allows a port to identify and reflect on its environmental risks. Aggregated and anonymized data provided by EcoPorts members are used to build and update the sector's benchmark of performance in environmental management.

PIANC – Sustainable ports guide

The World Association for Waterborne Transport Infrastructure (PIANC) has one commission (out of six) on environmental issues. This Environmental Commission (EnviCom) has four strategic initiatives on EU Water Framework Directive Navigation Permanent Task Group on Climate Change (PTGCC), Working with Nature, and Dredging and the Environment.

⁴⁶ Please visit: www.espo.be/practices.

⁴⁷ For details see: <https://www.ecoport.com/pers>.

⁴⁸ For details see: <https://www.ecoport.com/sdm>.

The current working groups in EnviCom⁴⁹, which are relevant to environmental management in ports, are:

- EnviCom WG 174: ‘Sustainability Reporting for Ports PIANC- IAPH’.⁵⁰ The objectives of the group are to:
 - provide an overview of the trends driving sustainability reporting and the benefits of the reporting process for ports and their stakeholders,
 - develop guidance for the process to define objectives and goals for sustainability reporting for ports,
 - develop guidance for the stakeholder process that should be fulfilled to be able to address all relevant issues for the specific port,
 - define port specific indicators to report on corporate socially responsible performance for ports, and
 - develop a reference that can be used for dealing with internal monitoring and external benchmarking port specific indicators.
- EnviCom WG 226: ‘A Guide for Assessing and Managing Effects of Underwater Sounds from Navigation Infrastructure Activities’. Underwater sounds are produced during the building, running, and maintenance of waterborne transport infrastructure. To assess their possible ecological concerns, an assessment of the biological consequences of underwater sound from such operations in comparison to other anthropogenic sources is required. It is necessary to have a deeper understanding of the noises produced by operations involving waterborne transport infrastructure, the potential consequences they could have, and how those sounds compare to the hearing frequency ranges of different fish and marine mammal species
- EnviCom WG 227: ‘A Guide for Assessing and Managing Environmental Restrictions on Dredging and Disposal Operations’. The proposed working group’s goal is to provide a wide range of management practices for lowering environmental risks related to dredging activities. The method will provide decision-makers with information about environmental concerns related to dredging activities and related to navigation infrastructure projects
- EnviCom WG 230: ‘How to Attract Green Funding for Nature-Based Navigation Infrastructure’.⁵¹ Its objective is to describe options and practical steps for infrastructure managers and developers to attract funding from institutional investors for their nature-based infrastructure projects

In 2020, PIANC published the ‘Climate Change Adaptation Planning for Ports and Inland Waterways Report’.⁵² This three-part guidance document introduces the potential consequences and challenges of climate change for ports and waterways. Second, it presents a four-stage methodological framework to help port and waterway owners and operators plan for improved resilience.

⁴⁹ For details see: <https://www.pianc.org/upcoming-publications>. A full list of publications from the Working groups can be found here: <https://www.pianc.org/publications/envicom/p2>.

⁵⁰ For details see: <https://www.pianc.org/uploads/files/EnviCom/ToR-new/ToR-EnviCom-WG-174-Sustainability-Reporting-for-Ports-PIANC-IAPH.pdf>.

⁵¹ For details on the group work see: <https://www.pianc.org/uploads/files/EnviCom/ToR/ToR-EnviCom-WG-230-How-to-Attract-Green-Funding-for-Nature-Based-Navigation-Infrastructure.pdf>.

⁵² Report available here: <https://www.pianc.org/publications/envicom/wg178>.

Stage 1 facilitates understanding of how assets, operations and systems could be impacted and who should be involved in identifying climate change adaptation requirements.

Stage 2 identifies the type of climate-related information needed to prepare an adaptation strategy and explains how reference to climate change ‘scenarios can assist in understanding the range of possible future changes.

Stage 3 describes how the vulnerability of waterborne transport infrastructure assets, operations and systems can be assessed and a risk analysis undertaken.

Stage 4 presents a ‘portfolio’ of potential adaptation options (structural, operational, and institutional) to be considered when developing an adaptation pathway.

The third part presents good international practice case studies, along with various templates that could be used for data collection and record keeping.

In 2014, PIANC published the Sustainable Ports – A Guide for Port Authorities report.⁵³ The report focuses on the sustainable development and green growth of ports and its related logistics chains and added-value activities and addresses 13 environmental and sustainability topics in ports.⁵⁴ The PIANC report provides tools and guidance that show how proactive environmental measures and strategies can contribute to obtaining consent for future operations and developments, how opportunities can be created through own initiatives and how green growth can be realized. The report advocates the shift of thinking towards a proactive “ports and natural environment” approach, starting with a long-term vision.

Key elements in the introduced “green port” concept are:

- Long-term vision which strives towards an acceptable footprint on the environment and nature
- Transparent stakeholder participation and stakeholder approved strategies to operate and grow
- Shift from sustainability as a legal obligation to sustainability as an economic driver (economic development and sustainable development as complementary factors)
- Active sharing of knowledge with other ports and stakeholders
- Continuous striving towards innovation in process and technology

World Ports Sustainability Program (WPSP)

The World Ports Sustainability Program (WPSP) is led by the IAPH and aims to “demonstrate global leadership of ports in contributing to the Sustainable Development Goals of the United

⁵³ For details see: <https://sustainableworldports.org/wp-content/uploads/EnviCom-WG-150-FINAL-VERSION.pdf>.

⁵⁴ Topics cover: Land Use Planning, Modalities and Connectivity, Air Quality, Surface Water and Sediment Quality, Soil and Groundwater Quality, Dredging Impacts, Sound/Noise Impacts, Energy and Climate Change Mitigation, Climate Adaptation, Habitat and Species Management Health, Landscape Management and Quality of Life, Ship Related Waste Management, Sustainable Resource Management.

Nations”. The program intends to “empower port community actors worldwide to engage with business, governmental and societal stakeholders in creating sustainable added value for the local communities and wider regions in which ports are embedded”.

In 2020 WSPSP published its first World Ports Sustainability Report, which includes focused projects in five dimensions related to the SDGs: Resilient Infrastructure, Climate and Energy, Community Outreach and Port City Dialogue, Safety and Security, Governance and Ethics. The relevant dimensions in the context of this module are:

- **Climate and energy:** This work focuses on facilitating the energy transition in ports and collects project output that shows the results in terms of achieving a CO₂-neutral port. Experience and good practice are related to topics such as energy efficiency; circular economy; bio-based economy; renewable energy; CO₂ reduction initiatives; clean ship incentives; deployment of alternative transport fuels; zero or near-zero GHG bunkering infrastructure
- **Environmental care:** This work relates to the environmental impact of port operations on air, water, soil, sediment, and natural habitats. Experience and good practices are related to topics such as addressing air pollution, dust, noise, and water pollution; protecting freshwater resources; addressing water consumption; waste collection; re-use and recycling initiatives; targeted marine litter initiatives; addressing soil and sediment contamination; protecting habitats and enhancing biodiversity

WSPSP offers an extensive database of projects from WSPSP members and other ports, which can be used as reference to current best practices and efforts in the sector.⁵⁵ The projects are categorized by the five SDG-related dimensions they address. A range of projects from developing countries are available in this database, as it covers over 120 projects covering 38 countries and five continents.

Inter-American committee on ports

The Inter-American Committee on Ports (CIP) is part of the Organization of American States (OAS). CIP has created a Technical Advisory Group (TAG) on ‘Sustainable Port Management and Environmental Protection’. The objective of the group is to promote projects, through cooperation and exchange of information, which help to protect the environment, contribute to economic development and promote good practices of social responsibility for the benefit of the Americas.

In 2020 CIP published a ‘Guide to Environmental Certification and Sustainability Reporting for Ports of the Americas’, a reference tool for Latin American ports and terminals. The document provides guidelines for developing environmental management strategies, summarizes environmental impacts of ports, and highlights some experiences from Latin American ports. The guide further elaborates on internationally recognized environmental certifications (that is, ISO 14001 and EcoPort) and the Global Reporting Initiative (GRI).⁵⁶

⁵⁵ To access the database, see: <https://sustainableworldports.org/portfolio/>.

⁵⁶ Available here. <https://portalcip.org/guide-for-environmental-certification-and-for-the-preparation-of-sustainability-reports-for-ports-of-the-americas/>.

CIP also has a collection of best practice cases from Mexico.⁵⁷ The project includes fourteen out of sixteen local port administrations, called API at that time,⁵⁸ and describes the process of involvement of local port authorities into the national environmental audit program and their results including best practices.

IAPH and the World Port Climate Action Plan (WPCAP)'s port readiness level for marine fuels assessment tool

IAPH and the World Port Climate Action Plan (WPCAP) – a coalition of front runner ports – have designed a framework⁵⁹ to allow port communities to self-assess their preparedness, develop systems to address gaps and align stakeholder commitments and expectations for new marine fuels in preparation for zero- or near-zero GHG fuels to be used in ports. The tool has a checklist that is a goal-based framework which creates a practical roadmap to evaluate the port ambitions over time with the intention to make the current level of TRL and future ambitions publicly available, so that stakeholders can make informed decisions when investing in fuel production, ships, equipment, planning, routes, green corridors etc.

The assessment tool is developed to assess the port readiness for a call of vessels sailing on a marine fuel that is still new to the port. It also assesses port readiness for the bunkering of a marine fuel that is still new to the port.

The first three levels concern the research phase, the next three levels the development phase, and the last three levels the deployment phase. Every level within the checklist has an objective that can be fulfilled by meeting specific goals across four different domains – governance, safety, infrastructure, and market and supply/demand. Tasks within the levels can be fulfilled by a port authority and by port stakeholders or by national authorities. For example, a risk assessment can be performed by a stakeholder in the port, a national authority can develop a safety framework, and a port authority can initiate local regulations.

8.3.7 Phase 7: Evaluate

All programs need to undergo periodic monitoring to measure the actual impact and advances towards the set goals and targets. For example, the monitoring of emissions in the port will reveal if the progress is in line with the Paris Agreement targets or the national NDCs.

Based on the overall change management process explored in Module 2: Change Management, Phase 7 is the final step in implementation and evaluation of an environmental strategy, but what remains to be done from a change management perspective is to report results to stakeholders (examined in Module 2: Change Management, as well as Section 8.3.2). The best approach for this is to make it part of the discussion with commercial and non-commercial stakeholders.

⁵⁷ Available here: <https://portalcip.org/tags/sustainable-port-management-and-environmental-protection-tag/documents/best-practices-compilation/>.

⁵⁸ Nowadays Mexico is in the middle of a reform to its port system and a distinction was made between federal and local port administrations.

⁵⁹ <https://sustainableworldports.org/wp-content/uploads/Port-Readiness-Level-for-Marine-Fuels-assessment-tool-July-2024.pdf>.

8.4 Summary and Conclusions

The port sector is critical for a country's economic development, competitiveness, and growth in national, regional, and international trade. Trade and traffic growth continue to pose significant challenges to ports and governments across the globe in terms of infrastructure development, institutional frameworks and policy strategies. At the same time, the increasing threat of climate change and other environmental challenges, such as air pollution, emissions, noise, water contamination or ecosystems damages, are creating additional pressures for action to assure the medium and long-term sustainability and functioning of the sector.

Given these environmental challenges, ports are increasingly differentiated by their ability to handle the latest generation of ships, the productivity levels achieved, and by their institutional efficiency and effectiveness to respond to environmental challenges.

The transition from fossil fuels to green energy over the coming decades will lead to an evolution in terms of trade facilitation at ports and a diversification of their energy handling capacities. While this shift presents new opportunities, ports will also need to address the potential early obsolescence of existing terminals. This could be due to changes in trade composition or the increasing vulnerability of assets to climate change impacts, rendering continued operations economically unviable in the medium to long term.

In the current volatile economic and political environment, many actors might be hesitant to commit to the investment risks associated with technological transition and long-term climate change infrastructure projects, especially when the benefits of certain measures may not be immediately apparent. For example, in the case of constructing new infrastructure to protect the port from extreme waves, the measurable impact might only be visible when a port can continue operations during high waves or extreme weather events.

Environmental management and investment in environmental projects are hindered by the multitude of stakeholders. The resulting fragmented responsibility weakens the mandate of public actors, limits the ability to manage the distribution of costs and benefits, and delegation of actions to achieve environmental sustainability.

Addressing Scope 1 impacts (such as emissions within the port area, water quality, and noise that affect the local environment) are exacerbated by the lack of a clear mandate between the Port Authority, local groups, and government. The stakeholders involved in environmental management have different priorities. An example is climate adaptation investments in port infrastructure, which are often excluded from existing concession agreements and, therefore, may not be prioritized.

A roadmap can be used to establish and implement an environmental program in ports. Section 8.6 provides a framework which proposes seven main phases to implement solutions and environmental programs in ports and provides some examples. As ports operate in varying economic and social contexts, governance frameworks, and environmental settings (that is, exposure to climate change), strategies will be different for specific ports. The examples serve only to illustrate some outcomes of each phase for specific priorities.

The ESPO 2022 Sustainability Report shows that climate change is the top environmental priority for European ports. While having a European focus, it represents a longer-term trend that has been attracting attention in policy discussions beyond the EU as the international climate change policy agenda has been ratcheting up. In maritime transport, the IMO adopted the 2023 IMO Greenhouse Gas Strategy in July 2023, replacing the 2018 Initial Strategy and significantly strengthening shipping's greenhouse gas reduction targets.

Climate change continues to increase the frequency and magnitude of extreme weather events and disasters, indicating that it is no longer just a future problem for ports, but one that needs to be addressed now. These climate events increase the risk of physical asset damage and operational disruptions at ports.

The physical toll of extreme weather on ports is apparent. The damage to the US ports of New York and New Jersey due to Hurricane Sandy caused a temporary shut-down. Containers were diverted to neighboring ports for a week, as the storm surge inundated coastal infrastructure. It resulted in a total revenue loss of \$170 million and physical damage costs in billions of dollars.

While each environmental priority represents a different challenge, approaches to climate change interact with other key environmental issues. Specifically, failure to take effective mitigation action across all sectors will amplify issues related to air pollution, community engagement, and water management.

Neglecting to address critical environmental issues such as climate change and air pollution will have negative impacts on the competitiveness of a port, terminal, or port system. This is because climate change can be expected to drive and exacerbate major risks to successful port operations. It is also due to an inability to implement important mitigation solutions that will eventually move cargo flows away from “climate-laggard” ports towards “climate-smart” ports.

These “climate-smart” ports proactively address climate mitigation by reducing their reliance on fossil fuels; building significant capacity to provide clients with zero or near-zero GHG fuels and electricity from renewable resources; and supporting transport and logistics activities with zero or near-zero GHG technologies. In these cases, port operations are rarely interrupted — only during exceptional extreme weather and climate-related events — and are resilient to climate change.

This is because of increasing awareness among port users to consider, report, and minimize the carbon footprint and climate impacts of their own operations. The trend toward digitalization in ports will further support data collection, sharing, and management, enhancing insights into resource consumption and facilitating coordinated vehicle usage to minimize idle time.

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